सत्यमेव जयते

Government of India

NATIONAL REPORT
to

THE CONVENTION ON NUCLEAR SAFETY

Eighth Review Meeting of Contracting Parties, March 2020

August 2019

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Foreword

The Government of India ratified the Convention on Nuclear Safety on March 31, 2005. India started presenting its national reports from the 4th Review Meeting of the Contracting Parties of the CNS in 2008. The present national report for the 8th Review Meeting is the fifth one being submitted by India. The Report updates how Government of India continues to fulfil its obligations under Articles 6 through 19 of the Convention.

The National Report was prepared in line with the guidelines contained in information circular INFCIRC/572/Rev.6 on "Guidelines regarding National Reports under the Convention on Nuclear Safety", summary report of the 7th Review Meeting, country review report of India for the 7th Review Meeting, and the letter written by President of 8th Review Meeting of CNS to the Contracting Parties in December 2018. All land-based Nuclear Power Plants (NPPs) including storage, handling and treatment facilities for radioactive materials attached to the NPP and directly related to the operation of NPPs are covered in the national report.

This report also addresses the national position with regard to the Vienna Declaration on Nuclear Safety for the implementation of the objectives of the CNS.

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List of Acronyms

ACNRS	Advisory Committee on Nuclear and Radiation Safety
ACPSR	Advisory Committee on Project Safety Review
ACROSS	Apex Committee for Review of Operating Station Safety
ACS	Advisory Committee for Security
AEC	Atomic Energy Commission
AERB	Atomic Energy Regulatory Board
AGFS	AERB Graduate Fellowship Scheme
AGMS	Annulus Gas Monitoring System
AHWR	Advanced Heavy Water Reactor
ALARA	As Low As Reasonably Achievable
AMD	Atomic Minerals Directorate for Exploration and Research
AMG	Accident Management Guidelines
AOO	Anticipated Operational Occurrences
APIO	Assistant Public Information Officer
ASCE	Assistant Shift Charge Engineer
ASN	French Nuclear Safety Authority
ATTF	AHWR Thermal-hydraulic Test Facility
ATWS	Anticipated Transient Without SCRAM
BAERA	Bangladesh Atomic Energy Regulatory Authority
BARC	Bhabha Atomic Research Centre
BARCIS	BARC Channel Inspection System
BHAVINI	Bharatiya Nabhikiya Vidyut Nigam Limited
BOA	Basis of Acceptance
BRIT	Board of Radiation & Isotope Technology
BRNS	Board of Research in Nuclear Sciences
BSD	Biennial Shutdown
BWR	Boiling Water Reactor
CAG	Comptroller & Auditor General
CCC	Construction Completion Certificate
CCF	Common Cause Failure
CDF	Core Damage Frequency
CEA	Central Electricity Authority
CESC	Civil Engineering Safety Committee
CFD	Computational Fluid Dynamics
CFVS	Containment Filtered Venting System
CLND	Civil Liability for Nuclear Damage
CMD	Chairman and Managing Director
CMG-DAE	Crisis Management Group-Department of Atomic Energy
CNCAN	National Commission for Nuclear Activities Control, Romania
CNRA	Committee on Nuclear Regulatory Activities
CNS	Convention on Nuclear Safety
CNSC	Canadian Nuclear Safety Commission
COG	Candu Owners Group
ConvEx	Convention Exercises
CPIO	Central Public Information Officer

CPR	Corporate Peer Review
CRZ	Coastal Regulation Zone
CS	Chief Superintendent
CSIR	Council for Scientific & Industrial Research
CSNI	Committee on Safety of Nuclear Installations
CSRP	Committee for Safety Research Programmes
CSWG	Code and Standards Working Group
DAE	Department of Atomic Energy
DAE-SRC	DAE Science Research Council
DC	District Collector
DDMA	District Disaster Management Authority
DDMP	District Disaster Management Plan
DG	Diesel Generator
DHC	Delayed Hydride Cracking
DICWG	Digital Instrumentation and Control Working Group
DID	Defence In Depth
DRA&C	Directorate of Regulatory Affairs & Communication
DRI	Directorate of Regulatory Inspection
DRP&E	Directorate of Radiation Protection & Environment
DSS	Decision Support System
EAC	Expert Appraisal Committee
EAL	Emergency Action Level
ECC	Emergency Control Centre
ECCS	Emergency Core Cooling System
ECIL	Electronics Corporation of India Limited
ECNR	Event Closing Notification Report
ECR	Emergency Communication Room
EIA	Environment Impact Assessment
EMCCR	En-Masse Coolant Channel Replacement
EOP	Emergency Operating Procedure
EPA	Early Protective Action
EPD	Extended Planning Distance
EPR	Emergency Preparedness & Response
EPZ	Emergency Planning Zone
ERD	Emergency Response Director
ERM	Environmental Radiation Monitors
ERRC	Eastern Regional Regulatory Centre
ERT	Emergency Response Team
ESL	Environmental Survey Laboratory
FAC	Flow Assisted Corrosion
FBR	Fast Breeder Reactor
FH	Fuel Handling
FINAS	Fuel Incident Notification and Analysis System
FOAK	First Of A Kind
FRCS	Fuel Rod Cluster Simulator
FSAR	Final Safety Analysis Report
GC	Generic Criteria
GCNEP	Global Centre for Nuclear Energy Partnership

GDF	Geological Disposal Facility
GDP	Gross Domestic Product
GHAVP	Gorakhpur Haryana Anu Vidyut Pariyojana
GIS	Geographical Information System
HBNI	Homi Bhabha National Institute
HLLW	High Level Liquid Waste
HPU	Health Physics Unit
HQ	Headquarters
HQI	Head Quarters Instruction
HS&E	Health, Safety & Environment
HUREC	Human Performance Review & Enhancement Committee
HWB	Heavy Water Board
IAEA	International Atomic Energy Agency
IAEA - OSMIR	IAEA- OSART Mission Results
IAEA PRIS	IAEA Power Reactor Information System
IAEA-CRP	IAEA Coordinated Research Programme
IAEA-IRS	IAEA - Incident Reporting System
IC	Initiating Condition
I&C	Instrumentation & Control
ICPD	Ingestion and Commodities Planning Distance
ICRP	International Commission on Radiological Protection
ID	Internal Diameter
IERMON	Indian Environmental Radiation Monitoring Network
IGCAR	Indira Gandhi Centre for Atomic Research
IIT	Indian Institute of Technology
IMS	Integrated Management System
INES	International Nuclear and Radiological Event Scale
IPR	Institute for Plasma Research
IPWR	Indian Pressurized Water Reactor
IREL	Indian Rare Earths Limited
IRRS	Integrated Regulatory Review Service
ISI	In-Service Inspection
ISO	International Organisation for Standardization
IV&V	Independent Verification & Validation
IVR	In-Vessel Retention
KAMINI	Kalpakkam MINI Reactor
KAPP	Kakrapar Atomic Power Project
KAPS	Kakrapar Atomic Power Station
KGS	Kaiga Generating Station
KKNPP	Kudankulam Nuclear Power Plant
LAN	Local Area Network
LASER	Light Amplification by Stimulated Emission of Radiation
LBB	Leak Before Break
LCO	Limiting Conditions of Operation
LILW	Low and Intermediate Level Waste
LLE	Low Level Event
LOCA	Loss of Coolant Accident
LSSS	Limiting Safety System Settings

LWR	Light Water Reactor
MAPS	Madras Atomic Power Station
MDEP	Multinational Design Evaluation Programme
MDL	Minimum Detectable Limit
MFCI	Molten Fuel Coolant Interaction
MoEFCC	Ministry of Environment, Forests and Climate Change
MoU	Memorandum of Understanding
MS	Maintenance Superintendent
NAPS	Narora Atomic Power Station
NBHM	National Board for Higher Mathematics
NCMC	National Crisis Management Committee
NCRI	National Conference on Regulatory Interface
NDMA	National Disaster Management Authority
NDRF	National Disaster Response Force
NEA	Nuclear Energy Agency
NFC	Nuclear Fuel Complex
NFRG	Nuclear Facilities Regulation Group
NODRS	National Occupational Dose Registry System
NPCIL	Nuclear Power Corporation of India Limited
NPP	Nuclear Power Plant
NPSD	Nuclear Projects Safety Division
NREMC	Nuclear and Radiological Emergency Monitoring Centre
NRRC	Northern Regional Regulatory Centre
NSAD	Nuclear Safety Analysis Division
NSARG	Nuclear Safety Analysis & Research Group
NSDF	Near Surface Disposal Facility
NSRA	Nuclear Safety Regulatory Authority
NTC	Nuclear Training Centre
O&M	Operation and Maintenance
OBE	Operating Basis Earthquake
OE	Operating Experience
OECD	Organisation for Economic Co-operation and Development
OED	Off-site Emergency Director
OERC	Operating Experience Review Committee
OERG	Operating Experience Review Group
OESC	On-Site Emergency Support Centre
OIL	Operational Interventional Level
OL&Cs	Operating Limits & Conditions
ONERS	Online Nuclear Emergency Response Decision Support System
ONR	Office for Nuclear Regulation of Great Britain
OPCC	Operating Procedures Cum Checklist
OPSD	Operating Plants Safety Division
OS	Operation Superintendent
OSART	Operational Safety Review Team
OSEF	Operating Safety Experience Feedback
PAHMS	Post Accident Hydrogen Management System
PAR	Passive Autocatalytic Recombiner
PAZ	Precautionary Action Zone

PCB	Pollution Control Board
PCRD	Passive Catalytic Recombiner Device
PDSC	Project Design Safety Committee
PESO	Petroleum and Explosives Safety Organisation
PFBR	Prototype Fast Breeder Reactor
PHWR	Pressurized Heavy Water Reactor
PI	Performance Indicators
PIE	Postulated Initiating Event
PSA	Probabilistic Safety Analysis
PSAR	Preliminary Safety Analysis Report
PSI	Pre-Service Inspection
PSR	Periodic Safety Review
PUA	Precautionary Urgent protective Action
PWR	Pressurized Water Reactor
QA	Quality Assurance
QBIS	Quick Boron Injection System
QC	Quality Control
QMS	Quality Management System
R&DD	Resources and Documentation Division
R&M	Renovation and Modernization
RABITS	Rupture And Ballooning In TubeS
RADAS	Radiation Data Acquisition System
RAPP	Rajasthan Atomic Power Project
RAPPCOF	Rajasthan Atomic Power Project Cobalt Facility
RAPS	Rajasthan Atomic Power Station
RB	Reactor Building
RIA	Radiological Impact Assessment
RPV	Reactor Pressure Vessel
RRC	Regional Regulatory Centres
RRCAT	Raja Ramanna Centre for Advanced Technology
RSD	Radiological Safety Division
RSD	Refueling Shutdown
RSO	Radiological Safety Officer
RSZ	Radiological Surveillance Zone
RTI	Right to Information
SARCAR	Safety Review Committee for Application of Radiation
SARCOP	Safety Review Committee for Operating Plants
SAS	Sweep Arm Scanner
SAT	Systematic Approach to Training
SCAP	Safety Culture Assessment Panel
SCE	Shift Charge Engineer
SCR	Supplementary Control Room
SCRC	Station Commissioning Review Committee
SD	Station Director
SDDP	Safety Document Development Proposal
SDMA	State Disaster Management Authority
SDV	Screening Distance Value
SEB	State Electricity Board

SEC	State Executive Committee
SECC	Site Emergency Control Centre
SECRC	Significant Event/Change Reporting Criteria
SED	Site Emergency Director
SER	Significant Event Report
SERC	Site Emergency Response Committee
SFR	Sodium Cooled Fast Reactor
SINP	Saha Institute of Nuclear Physics
SNRIU	State Nuclear Regulatory Inspectorate of Ukraine
SOP	Standard Operating Procedure
SORC	Station Operation Review Committee
SOT	Site Observer Team
SPC	Station Protection Code
SRC(O)	Safety Review Committee for Operating Plants
SRC(P&D)	Safety Review Committee for Projects & Design
SRI	Safety Research Institute
SRRC	Southern Regional Regulatory Centre
SSCs	Structures, Systems and Components
SSE	Safe Shutdown Earthquake
SSSC	Standing Site Selection Committee
STD	System Transfer Document
STUK	Nuclear Safety Authority of Finland
TAPS	Tarapur Atomic Power Station
THAI	Thermal-hydraulics, Hydrogen, Aerosols and Iodine (THAI)
TIFR	Tata Institute of Fundamental Research
TLD	Thermo Luminescence Dosimeter
TS	Training Superintendent
TSMS	Temperature Sensitive Magnetic Switch
TSO	Technical Support Organisation
TSS	Technical Services Superintendent
UCIL	Uranium Corporation of India Limited
UPA	Urgent Protective Action
UPZ	Urgent Protective Action Planning Zone
USC	Unit Safety Committee
USNRC	United States Nuclear Regulatory Commission
USUSS	Under Sodium Ultrasonic Scanner
VECC	Variable Energy Cyclotron Centre
VVER	Voda Voda Energo Reactor (Water cooled, Water moderated Energy Reactor)
WANO	World Association of Nuclear Operators
WGAMA	Working Group on Analysis and Management of Accident
WGFS	Working Group on Fuel Safety
WGIAGE	Working Group on Integrity and Ageing of Components and Structures
WGOE	Working Group on Operation Experience
WGPC	Working Group on Public Communication of Nuclear Regulatory Organisations
WGRisk	Working Group on Risk Assessment
WGRNR	Working Group on the Regulation of New Reactors
WIM	Weld Inspection Manipulator
WMP	Waste Management Plant

INTRODUCTION

1.0 GENERAL

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

Nuclear facilities in India are sited, designed, constructed, commissioned and operated in accordance with strict quality and safety standards. The primary responsibility for the safety of the facility lies with the licensee. These licensees have a system of independent review and scrutiny of safety as an integral part of the management control. Atomic Energy Regulatory Board (AERB), the national regulatory body of India, oversees the safety and has been mandated to frame safety policies, lay down safety standards and requirements. AERB has power to monitor & enforce safety and regulatory provisions of the Atomic Energy Act, 1962 and the rules thereunder, in nuclear and radiation installations and practices.

1.1 NATIONAL NUCLEAR POWER PROGRAMME

Atomic Energy Programme in India is governed by Atomic Energy Act of 1962 and the rules framed thereunder. Atomic Energy Commission (AEC) is the apex body which lays down the policies for the national nuclear programme. The Department of Atomic Energy (DAE) is responsible for execution of policies laid down by the AEC. DAE is engaged in research, technology development and commercial operations in the areas of nuclear energy, related high-end technologies and also supports basic research in nuclear science and technology. As per provisions of the Atomic Energy Act, 1962, NPPs in India can be established and operated only by the Central Government or any authority or corporation established by it or a Government Company. The Nuclear Power Corporation of India Limited (NPCIL) is a Government owned company for design, construction and operation of the nuclear power plants in India (other than Fast Breeder Reactor based NPPs) and is currently operating all NPPs. The Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI) is another Government company established for construction, commissioning and operation of the first 500 MWe Prototype Fast Breeder Reactor (PFBR) and future Fast Breeder Reactors. The Bhabha Atomic Research Centre (BARC) is the premier multi-disciplinary nuclear research centre of India having infrastructure for advanced research and development, with expertise covering the entire spectrum of nuclear science & engineering and related areas. The Indira Gandhi Centre for Atomic Research (IGCAR) is another national institution engaged in broad-based multi-disciplinary programme of scientific research and advanced engineering directed towards the Fast Breeder Reactor technology.

The organisational structure for Atomic Energy in India is shown in Annex 1-1.

Presently, there are 22 NPP units in operation in India, with an installed capacity of 6780 MWe as indicated in Table 1. Eleven more units with a capacity of 8700 MWe are under construction / commissioning as indicated in Table 2. In addition, administrative approval and financial sanctions of the Government of India are accorded for 10 more nuclear power reactors with a total capacity of 7000 MWe as indicated in Table 3. Various pre-project/preparatory activities are in progress at these sites towards progressive launching of construction of these reactors.

In addition, a number of light water reactor based NPPs are planned to be set up with international cooperation for which various techno-commercial discussions and pre-project activities are in progress.

The first NPP in the country, TAPS-1&2, based on BWR, supplied by General Electric, USA, became operational in the year 1969. After completion of 30 years of operation, during the years 2000 to 2006, these plants underwent safety assessments for continued long term operation. Based on that review, a number of safety upgrades were implemented during the refueling outages of individual units and in a simultaneous long shutdown of both the units during November 2005 to January 2006. These safety upgrades were described in the Indian National Reports submitted to the 4th and 5th Review Meetings of the CNS.

The mainstay of India's nuclear power programme has been the PHWR. Two units of 200 MWe each (RAPS-1&2) were established in the 1970s, at Rawatbhata in Rajasthan, with the technical cooperation of AECL (Canada). Subsequently, in 1980s, two units of 220 MWe PHWRs (MAPS-1&2) were constructed at Kalpakkam in Tamil Nadu, with indigenous efforts. Among these, presently RAPS-2 and MAPS-1&2 have undergone extensive safety upgrades, which were described in the National Reports to earlier review meetings of CNS.

Subsequently, India developed a standardised design of 220 MWe PHWRs. This design incorporated state of the art features viz. integral calandria & end shields, two independent fast acting shut down systems, high pressure Emergency Core Cooling System (ECCS), water filled calandria vault and provision of double containment with passive vapour suppression pool. Four units of this standardised design were built, two each at Narora in Uttar Pradesh (NAPS-1&2) and Kakrapar in Gujarat (KAPS-1&2). These plants became operational in the 1990s. In later years, eight more units of standardised 220 MWe PHWRs were built, four each at Kaiga in Karnataka (KGS-1 to 4) and Rawatbhata in Rajasthan (RAPS-3 to 6). Over and above the basic standardised 220 MWe PHWR, these plant designs have a more compact site layout and incorporated further improvements in safety features and containment.

Kakrapar Site
KAPS-1&2 , 220 MWe PHWR units (left) and KAPP-3&4, 700 MWe PHWR units (right)

In the 1990s, India undertook the design and development of 540 MWe PHWR. Two units based on this design became operational in 2005-2006 at Tarapur (TAPS-3&4). Evolving on the 540 MWe PHWR design, India has developed 700 MWe PHWR design, with limited boiling in the coolant channels. Six such units are being set up at Kakrapar, Rawatbhata and Gorakhpur-Haryana sites (KAPP-3&4, RAPP-7&8 and GHAVP-1&2). Of these, KAPP-3 is under commissioning and other units in Kakrapar & Rawatbhata are in advanced stage of construction. Site excavation for construction of GHAVP-1&2 is in progress.

In addition, India has setup two units of 1000 MWe LWRs (VVER based design), at Kudankulam (KKNPP-1&2) in Tamil Nadu, with the co-operation of Russian Federation. Further, construction of four more units of similar design at Kudankulam (KKNPP-3&4 and KKNPP-5&6) is in progress.

KKNPP-1&2 1000 MWe units

Construction of 500 MWe PFBR has been completed and pre-commissioning activities are in progress.

India continued the technology development programmes for utilisation of thorium in the nuclear power programme. Use of U-233 derived from irradiated thorium as nuclear fuel has been demonstrated successfully in a neutron source research reactor 'Kalpakkam MINI' reactor (KAMINI). India has developed the design of Advanced Heavy Water Reactor (AHWR) of 300 MWe capacity for direct utilisation of thorium. The design of AHWR incorporates state of the art advanced passive safety features. Pre-consenting safety review of the design of AHWR has been completed by AERB and review findings have been communicated with respect to FOAKs. A number of R&D activities have been taken up in BARC in connection with these FOAKs and for the development and detailing of AHWR systems and equipment. BARC has also set up a critical facility to validate the physics design of the AHWR.

BARC is working for the design of Indian Pressurised Water Reactor (IPWR). IPWR is an indigenous PWR design with a power rating of 900 MWe, incorporating advanced safety features, including passive safety systems similar to the ones developed for the AHWR. AERB has carried out pre-consenting review of the conceptual design of IPWR.

1.2 EMERGING SCENARIO

The government of India ratified the Paris Agreement of the United Nations Framework Convention on Climate Change on October 2, 2016. Under the agreement, India is committed to reduce the carbon emissions intensity of its GDP by 33 – 35% by 2030 from the 2005 level. Towards this, it is intended that about 40% of the installed electric power capacity in the country will be from non-fossil fuel based energy resources by 2030. Towards this, India identifies nuclear power as a safe, environmentally benign and economically viable source to meet the increasing electricity needs of the country.

The current installed electricity generating capacity in India as of March 2019 is 356 GW. With this capacity, India is among the top five producers of electricity globally. The annual per capita electricity consumption for 2017-18 was 1149 kWh (Source: CEA, India). The contribution from nuclear energy to the overall installed capacity is currently about 2%. To enhance the power generation capacity, India is in the process of setting up Light Water Reactors with foreign collaboration, while continuing its own programme of PHWR based NPPs and pursuing the design & development of light water reactor based NPPs.

Recognizing the need for developing indigenous capability to support this growth, setting up / augmentation of facilities to manufacture major components by the leading industry partners has also been taken up.

1.3 NUCLEAR FUEL CYCLE

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

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

India has developed necessary technologies for safe management of the radioactive wastes arising out of the nuclear fuel cycle. This includes the vitrification technology for conditioning and fixation of the high-level waste produced during spent fuel reprocessing in a glass matrix. The vitrified high-level nuclear waste is stored in exclusive interim storage and surveillance facilities, prior to its final disposal in a Geological Disposal Facility (GDF) later. The vitrification plants and storage & surveillance facilities for the vitrified waste packages are in operation. The volumes of vitrified high-level waste currently stored in Vitrified Waste Storage Facility are too small to call for setting up of a GDF. R&D work is in progress in the field of natural barrier characterization, numerical modelling and conceptual design pertaining to GDF. The timing of setting up of GDF in India is also linked to achieving the projected growth in the nuclear power programme. India has developed the necessary processes and technologies for partitioning of actinides from High Level Liquid Waste (HLLW), resulting in further reduction of vitrified high-level waste volume. A pilot plant employing this process is currently in operation. With the planned power profile and deploying the technology of vitrification without resorting to partitioning of HLLW, the need for GDF is seen to be much later in time frame. Based on our future policy of deploying "Actinide Partitioning" for the HLLW, the setting up of a GDF will also get modified accordingly.

India is using the Cesium-137 separated from the HLLW using in-house developed novel extractants, for medical applications. The recovered Cesium-137 from High level radioactive waste is converted into non-dispersive vitrified glass form, which is further encapsulated in stainless steel pencils to be used as sources for medical applications such as blood irradiators. This technology is currently deployed in the commercial domain. Use of these technologies will simultaneously help in effectively addressing the objectives of minimisation of the radioactive waste generation as well as the radiotoxicity of the high-level wastes in the nuclear power programme.

1.4 REGULATION OF NUCLEAR FACILITIES

Atomic Energy Regulatory Board (AERB) was established in 1983 under the provisions of the Atomic Energy Act, 1962, and was provided with the necessary powers and mandate to frame safety policies, lay down safety standards and requirements for monitoring and enforcing the provisions under the Act and Rules thereof. AERB follows multi-tier systems for its review and carries out safety assessment, safety monitoring, surveillance and enforcement.

AERB issues regulatory consents for various stages during the life cycle of NPPs viz. Siting, Construction, Commissioning, Operation and Decommissioning. These consents are issued based on requisite safety reviews and assessments including site evaluation and the design of NPP. Compliance to the regulatory requirements is ensured through regulatory inspection, reporting obligations of utility and enforcement actions. Periodic Safety Review (PSR) of NPPs is carried out once in ten years, as part of the process for renewal of licence for operation.

AERB gets its technical support mainly from BARC and also from IGCAR, national laboratories, and industrial and academic institutions in the country. AERB has access to the outcome of the safety research performed by these organisations. Further, as and when required, AERB commissions their services to perform research, analysis and studies in specialized areas of its interest. AERB also utilises their expertise to conduct its safety review and assessment function. Safety Research Institute (SRI) of AERB conducts independent safety studies in certain specific areas to supplement the regulatory review and assessment activities. AERB has also developed the capabilities for conducting independent verification of selected aspects of the safety analyses submitted by the applicants, which is one of its strengths in fulfilling its mandate. AERB also has a strong programme for international co-operation with the regulatory bodies of other countries as well as IAEA. AERB experts participates in many safety standards committees of IAEA.

In March, 2015, AERB hosted the Integrated Regulatory Review Service (IRRS) Mission of IAEA. The Government of India has made the report of the IRRS Mission publicly available through the website of AERB. Actions have been taken to address the recommendations and suggestions of the IRRS Mission. India is in the preparatory phase for hosting IRRS follow-up mission.

1.5 INDUSTRIAL INFRASTRUCTURE FOR NUCLEAR POWER

Towards developing various technologies for the envisaged nuclear power programme in the country, a number of facilities were established by DAE in the early years of the nuclear power programme. These included uranium and thorium extraction plants, fuel fabrication plant, heavy water production facilities, research reactors, a fuel reprocessing plant, waste treatment facilities and several radiological laboratories for radioisotope production, radiochemistry research and radio-metallurgy studies. Significant up-gradation and developmental efforts were undertaken in initial days for manufacturing and precision machining jobs to meet the quality standards of nuclear industry. Today almost all ferrous and non-ferrous materials, components and equipment required for nuclear power plants are manufactured indigenously.

India has heavy engineering and manufacturing facilities in both public and private sectors. It is capable of manufacturing equipment / components like coolant tubes, calandria tubes, calandria and end shields for PHWRs; large components of PFBRs viz. main vessel, safety vessel, etc.; steam generators, turbines, electrical equipment, heat exchangers, pumps, pressure vessels, fueling machines etc. for both PHWR and FBR based NPPs. The developments in manufacturing of electrical machines, electrical & electronic accessories and Control & Instrumentation items such as large size motors, high quality conductors, sophisticated control panels and computer based control systems progressed in line with requirements of nuclear power projects. In recent times, a joint venture of NPCIL and another public limited company was established to manufacture critical heavy forgings for major primary components of NPP such as Steam Generators, End Shields and Pressurizers. These forgings for 700 MWe PHWR have been successfully developed and delivered. Development of forgings for Reactor Pressure Vessel (RPV) for IPWR has also been initiated. Concurrently with the manufacturing technologies, non-destructive examination methods and related equipment such as optical and laser based instruments, etc. have been developed. Maturity of the industry and its capability to take up mega package contracts have enabled reduction of gestation time of nuclear power projects in India.

India has a large synchronous grid with capacity of over 350 GWe. The grid is operated based on the 'Indian Electricity Grid Code', enabling high reliability of off-site power.

1.6 HUMAN RESOURCE DEVELOPMENT

In order to create a competent pool of well-trained scientists and engineers, a specialised training school at BARC was established in 1957 for training of graduates and post graduates. The Homi Bhabha National Institute (HBNI) established under DAE conducts post-graduation and doctoral programmes in areas of nuclear science and technology. With the growth of nuclear power, NPCIL set up its own Nuclear Training Centres (NTCs) to meet its demand. Training schools have also been set up at the Raja Ramanna Centre for Advanced Technology, Indore (2000), Nuclear Fuel Complex, Hyderabad (2001) and IGCAR, Kalpakkam (2006) to meet the expanding needs. The core of the human resource for the nuclear power programme comes through these training centres. In addition, experienced manpower from conventional power sector and industry is also inducted to meet the demand.

The Indian universities, science and engineering institutes, polytechnics, and industrial training institutes form the basic educational infrastructure from which engineers/scientists, technicians and skilled tradesmen are recruited and subsequently trained to suit the job needs.

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

NPCIL's technical manpower includes freshly recruited engineers who go through one year of training in DAE/BARC Training School or in Nuclear Training Centres of NPCIL. It also hires experienced manpower available in the country through open advertisement. NPCIL provides challenging work environment, attractive remunerations and promotional avenues to its employees for motivating them to continue their career with NPCIL. It also provides excellent quality of life at its residential colonies by adequately taking care of their health, education, transportation and recreational needs.

The initial manpower of BHAVINI for construction, commissioning and operation of the PFBR has been inducted from NPCIL and IGCAR. BHAVINI has also undertaken recruitment of graduate engineers and personnel at various grades. IGCAR training school caters to training needs for Fast Reactors. Qualification and licensing of the staff will be in line with the norms established by AERB. Details are covered in Article-11.

AERB is continuously augmenting its human resources to meet the demand arising from the expanding nuclear power programme and increasing number of radiation facilities in the country. AERB inducts fresh technical and scientific staff from the training schools and nuclear training centres. It also hires graduate engineers and sponsors them for Masters programmes in the Indian Institutes of

Technology through the AERB Graduate Fellowship Scheme (AGFS), who later serve as AERB staff. Experienced professionals are also recruited through open advertisements. AERB imparts intensive in-house orientation training to the newly recruited staff. In addition, refresher courses are regularly conducted on various topics of regulatory and safety importance to enhance the competence of staff. AERB colloquia are organised on topics of current interest and on new developments in the areas of safety & regulation. Details are covered in Article-8.

1.7 COMMITMENT TO THE CONVENTION ON NUCLEAR SAFETY

India is committed to implement the provisions of the Convention on Nuclear Safety. This National Report demonstrates how these provisions are implemented and the same is described under the respective Articles.

After ratification of the Convention in 2005, India submitted National Reports as well as answers to the questions raised on the Reports in a comprehensive and timely manner in all the Review Meetings as well as the Extraordinary Meetings of the Convention. The National Reports from India to CNS review meetings are publicly available on the website of AERB. India has actively participated in the Review Process of the Convention and engaged a large number of experts for review of national reports of other Contracting Parties. India provided services of its experts as officers in all the Review Meetings of CNS after ratifying the Convention. India actively contributed in the review process subsequent to the accident at Fukushima Daiichi NPPs, to enhance the effectiveness of the Convention. During the Diplomatic Conference held on February 9, 2015, India actively supported the adoption of the Vienna Declaration on Nuclear Safety by consensus. Soon after the second Extraordinary meeting of CNS in August 2012, India had taken steps to incorporate the lessons learned from the accident at Fukushima Daiichi NPPs into its regulatory requirements with respect to siting and design of NPPs. These requirements are in line with the latest IAEA standards. Safety upgrades in line with these have also been implemented in the existing NPPs (refer section 6.5 of Article-6). India follows the Periodic Safety Review system as part of the basis for renewal of operating licences of NPPs, which enables evaluation of safety of operating NPPs vis-à-vis the latest requirements / practices as well as timely implementation of the identified safety enhancements. This approach demonstrates India’s commitment to the CNS as well as the Vienna Declaration on Nuclear Safety.

1.8 NATIONAL REPORT TO THE 8th REVIEW MEETING OF CNS

The national report of India to the 8th review meeting of the Convention is prepared in line with the guidelines contained in information circular INFCIRC/572/Rev.6 on “Guidelines regarding National Reports under the Convention on Nuclear Safety”, the summary report of the 7th review meeting, the country review report of India for the 7th Review Meeting and the letter written by the President of 8th Review Meeting of CNS to the Contracting Parties in December, 2018.

In the 7th Review Meeting of CNS, certain challenges were identified for India to further improve safety. Current status on these are detailed in the relevant Articles of the report. An account of the actions taken with respect to the common issues highlighted during the 7th Review Meeting of CNS has also been included.

Further the report brings out the aspects related to the Vienna Declaration on Nuclear Safety in the Summary as well as under Articles 6, 14, 17, 18 and 19.

Table 1 NPPs in Operation as of August 2019

Unit	Type	Gross Capacity (MWe)	Licensee / Owner	Reactor Supplier	Commencement of Operation
KGS-1	PHWR	220	NPCIL	NPCIL	Nov-2000
KGS-2	PHWR	220			Mar-2000
KGS-3	PHWR	220			May-2007
KGS-4	PHWR	220			Jan- 2011
KAPS-1	PHWR	220			May-1993
KAPS-2	PHWR	220			Sep-1995
MAPS-1	PHWR	220			Jan-1984
MAPS-2	PHWR	220			Mar-1986
NAPS-1	PHWR	220			Jan-1991
NAPS-2	PHWR	220			Jul-1992
RAPS-1#	PHWR	100	NPCIL / DAE	AECL, CANADA	Dec-1973
RAPS-2	PHWR	200	NPCIL	AECL/ DAE	Apr-1981
RAPS-3	PHWR	220		NPCIL	Jun-2000
RAPS-4	PHWR	220			Dec-2000
RAPS-5	PHWR	220			Feb-2010
RAPS-6	PHWR	220			Mar- 2010
TAPS-1	BWR	160		GE, USA	Oct-1969
TAPS-2	BWR	160			Oct-1969
TAPS-3	PHWR	540		NPCIL	Aug-2006
TAPS-4	PHWR	540			Sep-2005
KKNPP-1	PWR	1000		ASE, RUSSIA	Dec-2014
KKNPP-2	PWR	1000			Mar- 2017

 # Unit under shutdown since 2004.

Table 2 NPPs under Siting, Construction and Commissioning as of August, 2019

Project	Type	Gross Capacity (MWe)	Licensee/ Owner	Reactor Supplier	Start of Construction
PFBR	SFR	500	BHAVINI	BHAVINI	Oct-2004
KAPP 3&4	PHWR	700 each	NPCIL	NPCIL	Nov-2010
RAPP 7&8	PHWR	700 each		NPCIL	Jul-2011
KKNPP 3&4	PWR	1000 each		ASE, RUSSIA	Jun-2017
GHAVP 1&2	PHWR	700 each		NPCIL	Mar-2018
KKNPP-5&6	PWR	1000 each		ASE, RUSSIA	Dec-2018

Table 3 NPPs accorded Administrative Approval and Financial Sanction from Government of India as of August 2019

Project	Type	Gross Capacity (MWe)	Licensee/ Owner	Reactor Supplier
GHAVP-3&4	PHWR	700 each	NPCIL	NPCIL
Kaiga-5&6	PHWR	700 each		
Chutka-1&2	PHWR	700 each		
Mahi Banswara -1 to 4	PHWR	700 each		

Annex 1-1 Organisational Structure for Atomic Energy in India

Atomic Energy Commission

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

Atomic Energy Regulatory Board

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

Department of Atomic Energy

Development and implementation of nuclear power and related nuclear fuel cycle activities and research & development activities are carried out in various units under the DAE. The DAE organisation is divided into four major sectors, viz. Research & Development sector, Industrial sector, Public Sector Undertakings and Services & Support sector. The DAE also provides for the interaction needed between the production and R&D units. The organisations engaged in the area of Atomic Energy in different sectors are as given below and the organisation structure is shown in Figure 1.

i. Research and Development sector includes Bhabha Atomic Research Centre (BARC), Indira Gandhi Centre for Atomic Research (IGCAR), Atomic Minerals Directorate for Exploration and Research (AMD), Raja Ramanna Centre for Advanced Technology (RRCAT), Variable Energy Cyclotron Centre (VECC) and Global Centre for Nuclear Energy Partnership (GCNEP). Board of Research in Nuclear Sciences (BRNS) and National Board for Higher Mathematics (NBHM) provide funding to universities and other national laboratories.

ii. There are 11 grant-in-aid institutes like Tata Institute of Fundamental Research (TIFR), Institute for Plasma Research (IPR) and Saha Institute of Nuclear Physics (SINP) and Homi Bhabha National Institute (HBNI) under DAE.

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

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

- Nuclear Power Corporation of India Limited (NPCIL) engaged in the design, construction, commissioning and operation of the nuclear power plants;
- Uranium Corporation of India Limited (UCIL) engaged in mining, milling and processing of uranium ore;
- Indian Rare Earths Limited (IREL) engaged in mining and separation of beach sand minerals to produce ilmenite, rutile, monazite, leucoxene, zircon, sillimanite 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 control and instrumentation equipment related to atomic energy and also to other sectors;
- Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI) for setting up fast reactor based nuclear power plants.

DAE Science Research Council (DAE-SRC)

DAE Science Research Council (DAE-SRC) is a body consisting of eminent scientists and is involved in advanced research in the frontier areas of science and engineering of interest to DAE to meet the future challenges.

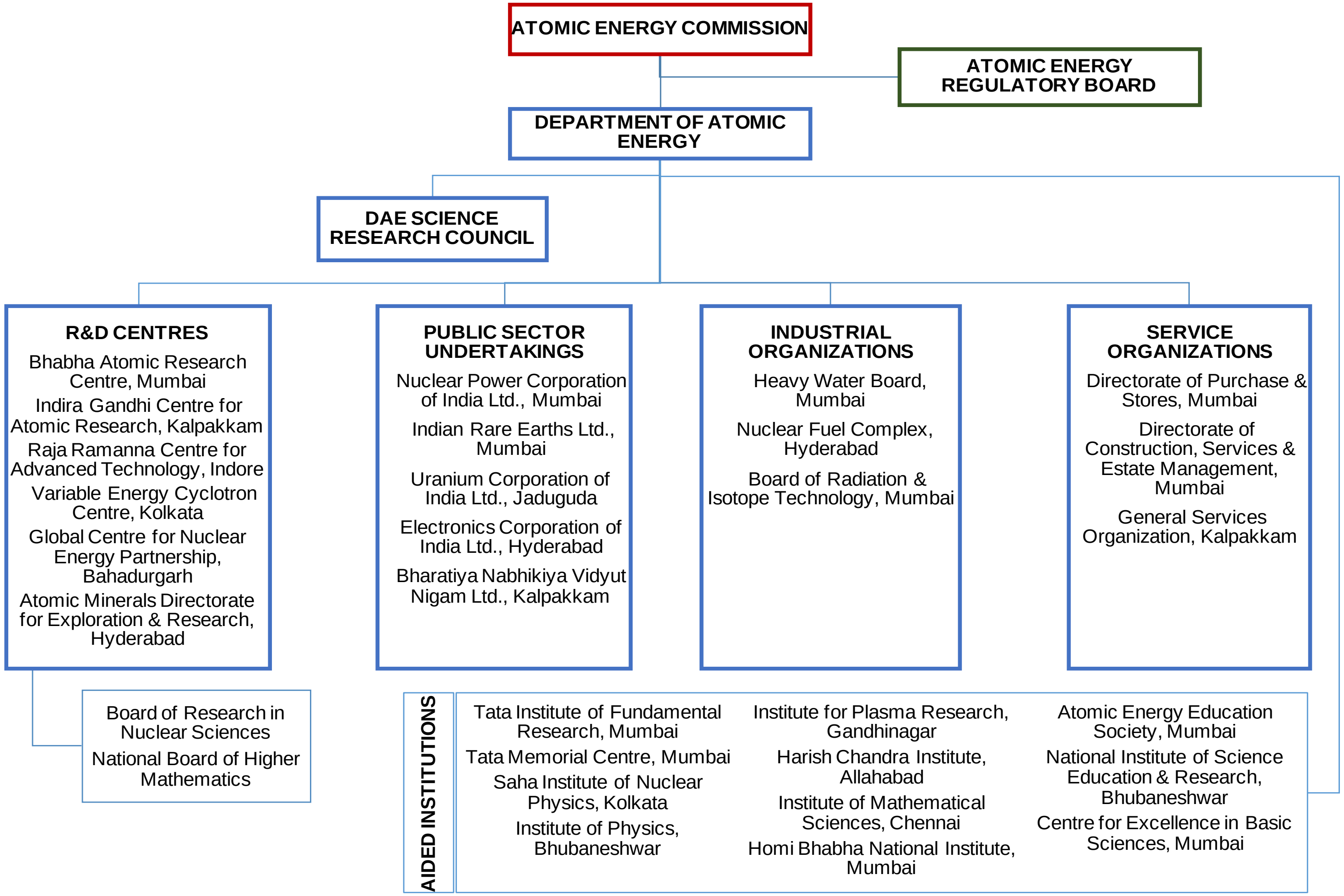

Figure 1 Organisational Structure for Atomic Energy in India

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SUMMARY

Nuclear energy is an important element in India's energy mix for sustaining rapid economic growth. India remains firmly committed to its indigenous nuclear power programme and is carrying out major expansion of installed nuclear capacity. To facilitate speedy enhancement of the nuclear power generation capacity, India has standardised the design of Indian PHWR based NPPs. Further, capacity addition through setting up Light Water Reactor based NPPs with foreign collaboration is also being pursued. These are being done with full regard to safety of people and environment. Considering the major expansion of nuclear power programme, the regulatory body of India, Atomic Energy Regulatory Board (AERB) has taken up initiatives for further enhancement of effectiveness & efficiency of the related regulatory processes. Another area of focus was the implementation of safety enhancements in the existing NPPs as well as incorporating them in the regulatory requirements for new NPPs, particularly in the area of severe accident management.

The 7th review meeting of CNS had identified three challenges for India viz. (1) prepare for the planned rapid expansion of nuclear power in the coming years, including the buildup of the needed competence for many different types of new reactors, (2) completion of the identified long term measures after accident at Fukushima Daichii NPPs and (3) identification of root cause of the events of pressure tube leak at KAPS-1&2.

PREPARATION FOR PLANNED RAPID EXPANSION OF NUCLEAR POWER PROGRAMME

India is in the process of setting up four units of PWR (VVER) design and six units of indigenous 700 MWe PHWRs. In addition, the Government of India has accorded administrative approval and financial sanction for taking up construction of ten 700 MWe PHWR units in fleet mode as a planned rapid expansion of nuclear power programme.

The challenges on the regulatory front for the planned expansion have been addressed by establishing state-of-the-art requirements, strengthening the human resources & competence of regulatory body and reinforcing its knowledge management processes. Further, the management systems of the regulatory body have also been reinforced with an Integrated Management System (IMS).

The requirements for site evaluation and design of NPPs have been updated incorporating the lessons learned from the nuclear accident at the Fukushima Daiichi NPP and are in line with the current IAEA safety standards. Thus, the requirements are in place for all the reactor technologies which India intends to deploy. Details are covered under Article-17 & 18.

The integrated management system of the regulatory body takes account of the aspects related to the planned rapid expansion of nuclear power programme, in particular enhancement of its human resources, competence development as well as knowledge management, with respect to safety aspects of different reactor technologies which are being regulated or expected to be regulated by it. Details are covered in Article-8.

The utility, NPCIL, is following a large recruitment plan to meet the manpower requirements for planned rapid expansion of nuclear power programme. Key competences for the projects under construction and projects being pursued are developed and maintained through elaborate training programme. The details of this training programme are given in section 11.2 of the Article-11. The manpower is optimised taking account of the requirements for projects under construction, operating NPPs, design & engineering also considering the requirements of multi-unit sites.

For the 700 MWe PHWRs in fleet mode, NPCIL is striving for faster completion of pre-project activities (including land acquisition, design, procurement, obtaining regulatory and statutory clearances, setting up site infrastructure and so on) with due emphasis on quality assurance aspects. The quality assurance programme for all stages of NPPs is elaborated in Article-13 of the report. The procurement of long delivery equipment for reactors in fleet mode has already commenced as the industrial infrastructure is in place. The industrial capabilities for supporting the nuclear power programme of India are described in section 1.5 of 'Introduction'.

SAFETY ENHANCEMENTS SUBSEQUENT TO THE ACCIDENT AT FUKUSHIMA DAIICHI NPPs

The safety enhancements identified for Indian NPPs subsequent to the accident at Fukushima Daiichi NPPs were classified as short term, medium term and long term. Implementation of the short term and medium term safety enhancements have been completed as reported during the 7th review meeting of CNS. The long term enhancements identified were (a) enhancing severe accident management programme, (b) strengthening hydrogen management provisions, (c) provision of containment filtered venting and (d) creation of on-site emergency support centre. These required research & development efforts, analysis, detailed engineering and testing/qualification. The severe accident management guidelines for different NPP designs (PHWR, BWR & PWR) were developed based on technical bases reviewed & accepted by AERB and are now in place at all NPPs. The activities related to R&D, engineering, testing & qualification related to the rest of the long term enhancements have been completed and their on-site implementation is now in progress. Complete implementation of these safety enhancements is no longer a challenge. Details are covered in Article-6.

ESTABLISHMENT OF ROOT CAUSE OF EVENTS OF PRESSURE TUBE LEAK IN KAPS-1&2

The investigations for establishing the root cause of the pressure tube leak events in KAPS-1&2 on March 11, 2016 & July 01, 2015 respectively have been completed. Based on the investigation, it was concluded that the event occurred due to a small amount of unlisted impurity of hydrocarbons in carbon dioxide gas used for 'Annulus Gas Monitoring System' (AGMS) for detection of leak from pressure tubes. The underlying causal factors were latent deficiency in the specifications of carbon-di-oxide gas used for AGMS. Limit on hydrocarbon impurities in carbon dioxide gas was not specified.

AGMS gas mixture in combination with these hydrocarbons under reactor conditions resulted in formation of reactive chemical species causing localized corrosion on the outer surface of pressure tubes, which in turn led to enhanced hydrogen pickup. High hydrogen content in the affected pressure tubes eventually led to crack initiation and its propagation through Delayed Hydride Cracking (DHC). In the case of KAPS-1, the degradation in material properties was higher due to longer period of operation with contaminated carbon dioxide gas as compared to KAPS-2 and therefore the crack grew to critical size in the affected pressure tube and resulted in a small LOCA event. However, in KAPS-2, the material properties of the affected pressure tube remained adequate enough to allow for the crack to grow in a stable manner following leak before break (LBB).

Based on the lessons from these events, corrective measures were implemented at all PHWRs which include strengthening of AGMS specifications & quality checks, enhancing the surveillance & monitoring of AGMS, enhancing the scope of in-service inspection programme of pressure tubes. The capability of AGMS was also analyzed and confirmed to meet the design requirements in all PHWRs.

Details of the investigations for establishing the root cause of the pressure tube leaks and the corrective actions taken are given in Articles-6 & 14.

Both the KAPS reactors have undergone En-masse Coolant Channel Replacement (EMCCR). After completion of EMCCR activities and necessary regulatory review & clearance, KAPS-1&2 are now operational.

ADDRESSING THE VIENNA DECLARATION ON NUCLEAR SAFETY

The practices in India with respect to design, operation and regulation of NPPs integrate the benefits from the principles of learning from experience, research and development, periodic safety assessments, safety enhancements and international engagement. The safety regulations in India are kept updated in line with the IAEA safety standards and other international benchmarks in the relevant area, thus ensuring that the new constructions follow the latest requirements. The programme for periodic renewal of operating licences for the Indian NPPs facilitate regular safety evaluations against the current requirements and timely implementation of practicable safety enhancements. These aspects in relation to the Vienna Declaration on Nuclear Safety are described in detail under Articles 6, 14, 17, 18 and 19. These have been consolidated and summarized below.

India has been following an active nuclear power programme, with units being added more or less at a regular pace. With India pursuing an indigenous nuclear power programme, the NPP designs have been seeing enhancements over time, particularly in respect of safety, in tune with the prevailing international benchmarks and best practices. This has facilitated the design approach for the Indian NPPs to stay up to date with the state of the art.

From the early phase of the nuclear power programme, India has been following a proactive approach towards safety enhancements in the NPPs. The regulatory processes, which evolved over a period of time have adopted many of the best practices with respect to safety and regulation. Indian regulatory system always placed strong emphasis on learning from experience and using it to enhance safety. This character has helped the nuclear industry, the regulator and the R&D community to evolve with the times to achieve and maintain high level of safety in accordance with the societal expectations. In line with this, the regulatory system incorporates a system of 'special safety reviews', undertaken following major events, wherein the implications of such experience and lessons are reviewed for identifying and implementing safety enhancements. Indian NPPs have undergone many such reviews, examples of which include the Three Mile Island accident of 1979, the Chernobyl accident of 1986, the fire incident at unit-1 of Narora Atomic Power Station (NAPS) in 1993, the flood incident at the Kakrapar Atomic Power Station (KAPS) in 1994, the tsunami at the Madras Atomic Power Station (MAPS) in 2004, the accident at Fukushima Daiichi NPPs in 2011, and pressure tube leaks at KAPS in 2015-16. All these post-event reviews have resulted in enhancements in the safety features and/or regulatory requirements.

The regulatory system in India has adopted the Periodic Safety Review (PSR), which incorporates addressing the cumulative effects of ageing and comparison with the current safety requirements / practices, to identify the need for safety enhancements in the existing NPPs. In the regulatory system in India, licence for operation of NPP has a maximum validity period of five years. Renewal of the licences is based on a limited scope safety review once in 5 years and conduct of PSR, once in 10 years. Linking of the PSRs and renewal of operating licences helps in ensuring that the identified safety enhancements are implemented timely.

Article-6 of the National Report brings out a detailed account of the safety enhancements carried out in the NPPs. The PSR along with operational experience feedback programme and the special safety reviews of Indian NPPs conducted in the past have led to substantial safety upgrades in older NPPs and the design of NPPs built later. The safety reviews carried out following the accident at Fukushima Daiichi NPPs have shown the inherent strengths in the design, operational and regulatory practices and requirements associated with the Indian NPPs. The strengthening measures identified and being implemented for the Indian NPPs are associated mainly with enhancing the resilience of the plants to cope with extreme external events exceeding the design bases and to strengthen the provisions for mitigation of severe accidents.

The Atomic Energy Regulatory Board (AERB) is mandated to formulate the necessary regulations and requirements with respect to safety of nuclear and radiation facilities. AERB has well-established systems and process for development of regulatory documents which consider in detail the requirements of relevant IAEA documents, feedback from operating experience as well as the current best practices. These regulatory requirements are reviewed from time to time and updated taking account of the latest IAEA requirements in the relevant area. AERB has issued the safety code on site evaluation of nuclear facilities (2014) and design of light water reactor based NPPs (2015), which are in line with the latest requirements specified in the IAEA documents and incorporate the lessons learned from the accident at Fukushima Daiichi NPP. The details of siting and design requirements as brought out in these codes are described in Articles-17 & 18. AERB has also taken up the revision of the existing requirements for design of PHWR based NPPs and development of a Code on Design of Sodium Cooled Fast Reactor based NPPs. These requirement documents are in advanced stage of publication.

As brought out in the National Reports to the 2nd Extraordinary Meeting and 6th & 7th Review Meetings of the CNS, certain safety enhancements were identified for Indian NPPs based on the review conducted post the accident at Fukushima Daiichi NPPs. All the NPPs that were in operation and under construction were directed to implement the identified safety enhancements in a timely manner. In parallel, AERB carried out review of its existing regulatory documents with regard to the lessons learned from the accident at Fukushima Daiichi NPPs. These aspects were also brought out in the national report of India for the 6th & 7th Review Meetings of CNS. Based on this review, AERB is progressively revising the identified documents, as per its established process, for incorporating the lessons learned from the accident at Fukushima Daiichi NPPs, as well as to take account of the aspects in the latest IAEA documents.

The safety enhancements being implemented and the systems established for conducting systematic and regular reviews would help in addressing the Vienna Declaration on Nuclear Safety. Further as brought out above, the actions by AERB for incorporating the lessons learned from the accident at Fukushima Daiichi NPPs in the regulatory documents ensure that the national regulations incorporate the requirements consistent with the principles of Vienna Declaration on Nuclear Safety.

UPDATES ON THE COMMON ISSUES IDENTIFIED IN THE SUMMARY REPORT OF 7TH REVIEW MEETING

Safety Culture

The high level requirements for inculcating and enhancing the safety culture within utilities are given in the regulatory documents of AERB. Utilities have established their management systems and internal processes for fostering safety culture & its assessment. AERB makes observations on the safety culture of the utilities as part of its safety review and safety monitoring programmmes. AERB is continuing the work on developing mechanism for systematic assessment of utility's safety culture through safety culture indicators.

AERB management system has internal process for promotion & sustenance of safety culture. AERB has a process for self-assessment of safety culture. AERB and NPCIL have been participating in various international workshops, meetings, missions, etc. in order to adopt best practices for promotion and assessment of safety culture.

Details are covered in section 10.5 of Article-10.

International Peer Reviews

NPCIL is engaged in the activities undertaken on other fora for operators like WANO and the COG. Apart from regular peer reviews of the NPPs by the WANO, NPCIL had hosted the WANO Corporate Peer Review in 2015. NPCIL also hosted a 'Restart Review' by WANO in the year 2019 at KAPS-1 post its long outage for carrying out En-masse Coolant Channel Replacement (EMCCR). Earlier, India had invited the IAEA OSART mission for the peer review of Rajasthan Atomic Power Station 3&4 in November, 2012 with the Follow up Mission in February 2014. India has declassified the OSART mission report for making it available in IAEA - OSMIR (OSART Mission Results) database. Details of these international peer reviews are given in sections 6.1.5 and 9.6 of the report.

AERB hosted an IAEA IRRS Mission for peer review of the regulatory framework for safety of NPPs during March 16 – 27, 2015. The report of this IRRS Mission has been made public on the website of AERB. Actions have been taken to address the recommendations and suggestions of the IRRS Mission. AERB is in preparatory phase for hosting IRRS follow-up mission. Details are given in section 8.4 of the report.

Legal Framework and Independence of Regulatory Body

Atomic Energy Regulatory Board (AERB) was established by the President of India, in 1983, using the powers under the Atomic Energy Act, 1962 with the mandate for carrying out the safety and regulatory functions under sections 16, 17 and 23 of the Act. AERB also has the powers of the 'Competent Authority' to enforce the safety related rules issued under the Atomic Energy Act, 1962, which provides the Board functional independence and the necessary legal & statutory powers for the regulatory activities.

Towards further strengthening the legal status of the regulatory body, the Government of India has been in the process of creating a separate primary legislation for regulating nuclear and radiological safety in the country. Nuclear Safety Regulatory Authority (NSRA) Bill, 2011 was introduced in the Parliament to fulfil this objective. However, the term of the Lok Sabha (Lower House of the Parliament) expired before the Bill could be taken up for consideration of the House. A fresh Bill is under examination and processing.

Further details on the status of AERB including the legal and regulatory framework, are given under Article 7 of the report.

Financial and human resources

The regulatory body in India, AERB, is fully supported by the Government of India and its finances are appropriated as part of the budget of Central Government. AERB has full powers to operate its financial budget. It has the human resource programme commensurate with the regulatory programmes for the facilities & activities it regulates, details of which are given in sections 8.1.2.5 & 8.1.2.6 of Article-8.

Knowledge management

NPCIL has human resource programme to cater the challenge of ageing/retiring manpower in a phased manner. It ensures that replacements are systematically groomed to fill key vacancies, and that individuals have the development capacity to assume greater responsibilities and exercise increased technical proficiency and expanded management role in their work. NPCIL has developed an elaborate plan for grooming up the next chain of successors. On job rigorous training is in place to take up the assignment in all domains of NPCIL functioning. Based on the available competency of the likely candidate and required competency for the position is assessed and accordingly training, job rotation etc. are planned so as to help him to fill the gap.

AERB is a relatively young organisation and the average age of its staff is 39 years. The attrition rate in AERB is extremely low. Therefore, the strategy is to enhance the knowledge & competence of its existing staff and to retain the knowledge & experience of the limited number of personnel who are leaving the organisation on superannuation. AERB has been engaging the experienced personnel as consultants who have retired from AERB as well as from TSOs, to support AERB in the safety review activities. This was primarily in the form of members of some of the committees of AERB, wherein the younger staff of AERB could undergo on-job training/mentoring in the review activities. Recently, AERB has taken steps to further reinforce the in-house R&D and analytical competences by engaging the domain experts who have retired from AERB and its TSOs. These experts are engaged to mentor and guide the younger AERB staff in identifying & managing safety related R&D projects & experimentation and enhance the in-house analytical capabilities & infrastructure. This programme has provided an added impetus to the competence development programme of AERB. Details are covered in Article-8.

Supply Chain

Obsolescence is mainly faced in electronics items (shorter usable life) as the field is fast changing with respect to technology. The issue is addressed by advance planning and maintaining adequate spares and by redesigning the cards with latest components (Integrated Circuit) to meet same input and output.

NPCIL, being designer of nuclear components, has full control of the quality requirement and has well established quality management programme, which is updated on regular basis based upon operation feedback and regulatory requirement. The system is audited at design & engineering, procurement, quality control, installation, operation & maintenance areas.

To ensure products of right quality is supplied to Indian NPPs, multilayer quality control system is applied from raw material stage to finished products. For input materials, original certificate verification is done including sample testing witness by NPCIL in approved labs. Further, multilayer inspection in various stages in the manufacturing process is conducted as per well-defined quality assurance plans. Details are covered in Article-13.

Managing the Safety of Ageing Nuclear Facilities and Plant Life Extension

The nuclear power plants in India have been undergoing Periodic Safety Reviews (PSR) as mandated by the established regulatory requirements, since the year 2000. The requirements and guidance for the PSR are given in the AERB Safety Code on NPP Operation and AERB Safety Guide on Renewal of Authorisation for Operation of NPPs, respectively. This programme has been instrumental in the identification and implementation of a number of safety upgrades in the operating NPPs, towards addressing the current safety requirements, detailed account of which is given under Article 6 in this report. Another important outcome of these PSRs has been the development and implementation of effective ageing management programmes for all the operating NPPs in India. AERB Safety Code on NPP Operation and the Safety Guide on Life management of NPPs provide the related requirements and guidance in this regard. Currently all the operating NPPs in India have such ageing management programmes, which are revisited and revised (as necessary) as part of the PSR of NPPs. Further details on these issues are given under Articles 6, 14 and 19.

Emergency Preparedness

India being a contracting party to 'Convention on early notification of a nuclear accident' and 'Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, have the systems for notifying the IAEA in case of any accident at Indian NPP as well as for providing necessary assistance, under the framework of these conventions. India has recently undertaken a holistic review and revision of the existing requirements and guidance related to emergency preparedness and management of nuclear and radiological emergencies. This takes account of the existing EPR requirements, including aspects related to multi-unit sites, developments including the change in the approach to public protection during emergency conditions as elaborated in ICRP publications, current IAEA standards, lessons learned from the accident at the Fukushima Daiichi NPP and subsequent safety review of Indian NPPs as well as the national emergency response framework. The NPPs in India are located such that the neighbouring countries are at large distances from the location of the NPPs. Further details on this are given under Article 16.

Stakeholder Consultation & Communication

The management system of AERB identifies public communication and outreach as one of the important processes. It has been adhering to a high level of transparency in communicating to the public on its regulatory decisions, activities and safety issues. The professional approach of the regulatory body in its regulatory activities and high level of transparency has helped in gaining credibility among the Indian public over the years. The management processes for public communication and outreach address both normal scenarios as well as under emergency situations. Capacity enhancement for effectively and efficiently reaching out to the public and providing information is one of the areas the regulatory body is currently working on. AERB has a dedicated directorate for handling the public communication and is supported by domain experts. Apart from maintaining transparency on the regulatory decisions and activities, it has introduced suitable mechanisms for providing the public opportunities to examine and offer comments in the development of regulatory requirements. Further, the process for siting consent of NPPs in India requires consultation of public as part of the environmental clearance.

AERB is conducting the annual National Conference on Regulatory Interface (NCRI) since the year 2017, with an objective to foster an environment wherein, the Licensees, Stakeholders and Professional Associations could interact, discuss and provide valuable feedback to AERB on various issues related to Nuclear / Radiation Safety, regulatory requirements and practices world-wide, emerging trends in design and manufacturing, challenges in supply chain and other issues of regulatory interest. AERB also organises forums for discussion among various stakeholders for obtaining their feedback on its regulatory activities.

NPCIL has been carrying out various public awareness activities in structured manner for the dissemination of accurate and authentic information on nuclear power and other associated aspects to different target groups. Special emphasis of awareness is placed on public living in the vicinity of operating stations and upcoming projects. NPCIL regularly organises exhibitions on nuclear power to directly communicate with public, industries, students etc., for dissemination of authentic information and to dispel their apprehensions and informative booklets/pamphlets are distributed to the visitors.

NPCIL has been carrying out a gamut of public outreach activities conveying the facts on nuclear power in a simple transparent and credible manner and addressing apprehensions and concerns of people. “Halls of Nuclear Power”, permanent exhibition centres have been set up at different locations in India as a part of public outreach programmes.

Details are covered in Articles-8 & 9.

CHALLENGES AND PLANNED MEASURES

India as a country with serious interest in nuclear power to meet its developmental aspirations, remains committed to achieving and maintaining the highest level of safety at its nuclear facilities. India is fully committed to speedy completion of the remaining activities for implementation of safety enhancements based on the lessons learned from the accident at Fukushima Daiichi NPP, at all the NPPs. India is committed to address these lessons in the requirements and guidance related to siting and design of new NPPs. The planned measures are directed to meet these objectives. These include (a) completion of the remaining activities related to the long term safety enhancements and the on-going action for issuance of the remaining regulatory requirement and guidance documents, (b) actions related to holistic review and reinforcement of emergency preparedness & response including issuance of the corresponding regulatory requirement and guidance documents. It is planned to utilise the experience from commissioning and operation of FOAK systems of the first 700 MWe PHWR unit (KAPP-3) for the upcoming fleet of PHWRs. Further, it is planned to host the follow-up mission of IAEA IRRS.

The increasing use of digital technologies in the design of I&C systems in nuclear applications with growing reliance on software has brought in certain challenges from regulatory perspective. New issues are emerging such as aspects related to Common Cause Failure (CCF) due to use of software in these systems, evidences to support safety demonstration of these systems and their regulatory acceptance especially with respect to commercially available digital I&C systems. Interface between safety and security aspects with respect to digital I&C systems is an additional area of focus. In order to address these issues, it is important to keep the regulatory requirements and guidance up-to-date for acceptance of these systems. It is intended to address these challenges through comprehensive review and revision of the current regulatory guidance documents on I&C for application in nuclear power plants.

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ARTICLE 6: EXISTING NUCLEAR INSTALLATIONS

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

6.0 GENERAL

At present twenty-two nuclear power reactors in India are being operated by NPCIL. The first NPP in the country, TAPS-1&2, boiling water reactors (BWR), supplied by General Electric, USA, became operational in the year 1969. Thereafter, the mainstay of India's nuclear power programme has been the Pressurised Heavy Water Reactor (PHWR) technology. The first two 200 MWe units (RAPS-1&2) were established in the 1970s, at Rawatbhata in Rajasthan, with the technical cooperation of AECL (Canada). In 1980s, two 220 MWe PHWRs (MAPS-1&2) were constructed at Kalpakkam in Tamil Nadu, with indigenous efforts. Subsequently, indigenous design for standardised 220 MWe PHWRs was developed and two units at Narora were commissioned in early 1990s. The design incorporated the state of art features viz. integral calandria & end shields, two independent fast acting shut down systems, high pressure ECCS, water filled calandria vault and provision of double containment with passive vapour suppression. Additional ten units of 220 MWe PHWRs based on this standard design with compact layout and further improved safety features and containment were constructed in the next two decades and are in operation.

In 1990, India undertook design and development of 540 MWe PHWR. Two units based on this design became operational in 2005-2006 at Tarapur (TAPS-3&4). This design is now further modified to incorporate limited boiling of the coolant in the channels at the outlet and the capacity has been increased to 700 MWe. Currently, six such units are being set up at Kakrapar, Rawatbhata and Gorakhpur-Haryana sites (KAPP-3&4, RAPP-7&8 and GHAVP-1&2). Of these, KAPP-3 is under commissioning and other units in Kakrapar & Rawatbhata are in advanced stage of construction. Site excavation for construction of GHAVP-1&2 is in progress.

India has set up two units of 1000 MWe light water reactors, at Kudankulam (KKNPP-1&2) in Tamil Nadu, with co-operation of Russian Federation. KKNPP Unit-1 and Unit-2 are in commercial operation since December 31, 2014 and March 31, 2017 respectively. Further, construction of four more units of similar design at Kudankulam (KKNPP-3&4 and KKNPP-5&6) is in progress.

Pre-commissioning activities of PFBR (500 MWe) are in progress.

The list of NPPs in India is given in Table-1&2 in the Introduction of this report.

6.1 PERFORMANCE AND SAFETY STATUS OF OPERATING NPPs

6.1.1 Collective dose to occupational workers

There exists a practice for preparation of annual budget for collective exposure of occupational workers for each station based on previous year's exposures and also taking account of the jobs to be taken up during the year. This budget is reviewed and approved by AERB at the beginning of each calendar year. Finally, at the end of the calendar year, the actual collective dose consumed is also reviewed to get the feedback on the operating practices.

In the last three years collective dose consumed was around 1.39 person-Sievert/ reactor/year for old NPPs, 0.72 person-Sievert/reactor/year in the new generation NPPs (except KAPS-1&2). The total collective dose consumed for EMCCR activities in KAPS-1&2 during the years

2016-19 was 8.72 person-Sievert. For KKNPP-1&2, the collective dose is around 0.24 person-Sievert/reactor/year.

6.1.2 Radiological impact due to operation of NPPs

The radiological impact due to operation of NPPs on the environment for each site is monitored by the Environmental Survey Laboratory (ESL), which is established by BARC (a TSO of AERB) well before the commencement of operation of NPP. The ESL, which is independent of the utility, carries out periodic surveillance of the areas around NPPs, based on which the radiological impact of NPP operation on the environment and public around the NPP is assessed annually.

The aspects related to the impact of plant operation on the environment and public are also re-assessed during PSR of the NPPs. The area up to a distance of 30 km is covered under the environmental survey programme.

The estimated dose at the plant boundary due to operation of NPPs during last three years is negligible as compared to limits prescribed by AERB. The details are given in Article–15.

6.1.3 Operational performance of NPPs

Operating nuclear installations in India are subjected to continuous appraisal of safety by NPCIL and AERB as per the established requirements. The operational performance and significant events are reviewed and the required modifications are implemented. The operational performance of all operating NPPs has remained satisfactory. Seven PHWR reactors had spells of continuous operation exceeding 500 days during the last four years. RAPS-3 operated continuously for 778 days. KGS-1 operated continuously for 962 days, achieving the record for the longest continuous run for any reactor in the world. This long spell of operation of the unit was subject to extensive reviews by AERB of safety aspects including maintenance practices, previous surveillance results, assessment of performance of safety systems as observed during the on-line surveillance tests. Close regulatory monitoring through inspections was carried out to verify the on-field status of performance of various SSCs, conduct of the operating staff & status of safety management at the plant.

TAPS-1&2 has completed 50 years of safe operation. The units have undergone various safety enhancements and in-service inspections in the past as reported in the National Reports for the 2nd Extra Ordinary Meeting and 4th and 5th Review Meetings of the Convention. In addition, CFVS and refurbished Containment Inerting System are installed in both units. In-service inspections of inaccessible weld joints of Reactor Pressure Vessel (RPV) with the help of indigenously developed Weld Inspection Manipulator (WIM) demonstrated that RPV is healthy and fit for reactor operation.

6.1.4 In-Service Inspections (ISI)

All the nuclear power plants have ISI programmes approved by AERB. The programme covers all the important equipment and piping of primary and secondary systems. In addition, the programme covers areas vulnerable to Flow Assisted Corrosion (FAC) for primary coolant piping. A separate ISI programme covers areas vulnerable to FAC in secondary system piping. ISI results are analyzed to assess the health of Structures, Systems and Components (SSCs) and to take necessary steps to maintain health of the systems and components.

In-Service Inspection of coolant channels for PHWRs is being carried out using a specially developed tool called BARCIS. The critical parameters such as ID, wall thickness, spacer location, as well as presence of flaws, creep / growth are monitored at specified intervals as part of the ISI programme. Recently, based on experience from the events of leaks from pressure tubes in KAPS units-1&2 (2015-16) and the observation of localized corrosion spots on the outer surface of pressure tubes, the BARCIS inspection tool was augmented to detect existence of such corrosion spots. The regular ISI programme for coolant channels has been augmented to include this aspect also.

In addition, as part of ISI programme of coolant channels, there is also a material surveillance programme which involves sampling of the pressure tube material for evaluation of hydrogen/deuterium content and post-irradiation examination of irradiated pressure tubes.

Inspections were done on the reactor pressure vessels of TAPS-1&2 as part of its health assessment for continued operation.

In-service inspection programme of nuclear power plants is periodically updated based on operating experience.

6.1.5 IAEA OSART Peer Review of Rajasthan Atomic Power Station -3&4

RAPS-3&4 underwent an IAEA OSART mission in the year 2012. This was followed by an OSART follow-up mission in February 2014. Currently, 86% of the actions for addressing the observations of OSART mission have been completed. Actions in progress pertain to long term safety enhancements viz. establishment of On-Site Emergency Support Centre and installation of Post-Accident Hydrogen Management System. These actions are progressing as planned. Status of these long term safety enhancements is covered in section 6.5.1 of this Article.

6.1.6 Light water reactors at Kudankulam

KKNPP-1 was issued licence for regular operation in July 2015. KKNPP-2 achieved rated power of 1000 MWe in January, 2017 after satisfactory completion of all requisite commissioning tests. During the first refuelling outage of this unit, extensive inspections were carried out on a number of equipment / components for generating base-line data. After satisfactory completion of regulatory review, KKNPP-2 was issued licence for regular operation in March 2018.

6.2 SIGNIFICANT EVENTS

The technical specifications for operation of NPPs specify the criteria for reporting of significant events. During the period from year 2016 to 2018, there were 108 such events reported by the operating NPPs. All these events were reviewed both by the utility as well as AERB. Out of these, 104 events were rated at level 0 or below scale on INES (having no safety significance). Three events were rated at level-1 on INES and one event was rated at level-2 on INES. Some of the events from which important lessons were learned are described below.

6.2.1 Leak from JDJ (Quick Boron Injection System) vent nozzle connection to pressuriser spray header in KKNPP-1

There was an event of minor leak from primary coolant system of KKNPP-1 on November 26, 2016 which was within the technical specifications. The leak was identified from a vent line nozzle (of 32 mm OD) of Quick Boron Injection System (QBIS) tank. QBIS is a First of a Kind (FOAK) system designed to cater to Anticipated Transient Without SCRAM (ATWS). Surface cracks were found in other similar vent line nozzles of two more QBIS tanks and on the pressuriser spray header. Investigations revealed that the defect locations were subjected to thermal fatigue due to level fluctuations caused by switching on/off of the heaters of QBIS tanks. The event had no safety significance but had potential for small leak and hence was rated at Level-1 on INES.

Pressuriser spray header along with QBIS vent nozzles were replaced with new spray header and nozzles of modified design (with thermal sleeves) in both the units of KKNPP. Also an ISI programme is developed for the replaced portion.

6.2.2 Loss of normal power supply in NAPS-2

On September 16, 2016, there was an event of complete loss of Class-IV power supply in NAPS-2 resulting in reactor trip. Following the event, all the three emergency DGs started automatically for catering power supply to essential loads. However, only one DG could automatically connect to its bus and restore power supply to essential loads. The other two DGs failed to connect to their respective buses due to malfunctioning of relays of circuit breakers in electrical systems. One of the two affected DGs could be connected to its respective bus without delay by manual intervention. The second affected DG required a minor maintenance (i.e.

replacement of relay) and was made functional within about 15 minutes. The availability of safety systems was as per the minimum requirements of OL&Cs. The event was rated at Level-1 on INES.

The cause of the event was identified to be weakness in maintenance procedures. Subsequently, maintenance procedures were revised and additional verification checks were instituted.

6.2.3 Leak from moderator system and internal uptake beyond investigation level in TAPS-4

On May 14, 2017, when TAPS-4 was under planned maintenance shutdown, there was an incident of leak from the moderator system leading to spillage of about significant amount of tritiated heavy water.

The leak occurred during normalization after maintenance of a valve on the non-isolable part of a line connected to the calandria. Maintenance of the valve required its isolation by forming ice-plug on the line. The leak occurred during thawing of the ice-plug, as the valve bonnet was not installed properly after maintenance. The leak was arrested by tightening the bolts of valve bonnet. During the process, thirteen personnel received tritium uptakes exceeding the investigation level. Maximum radiation exposure to a plant personnel due to the event was 14.4 mSv. The event had no implication to reactor safety, however the INES rating was uprated to level-1 due to safety culture aspects during handling of the event.

The event was caused due to inadequate maintenance procedure, absence of leak testing requirement for the valve after maintenance and weakness in contingency planning. Following the event, appropriate actions have been taken to address these shortfalls / weaknesses.

6.2.4 Event of leak from pressure tube in KAPS-1

On March 11, 2016, KAPS-1 experienced an event of leak from pressure tube. Following the leak, reactor underwent automatic shutdown. The safety systems viz. emergency core cooling & containment isolation got actuated and performed as intended. The event did not result in any radiation overexposure to plant personnel. The radioactivity releases were within the specified limits for normal operation. The details of this event and the status of investigations were included in the national report to the 7th review meeting of CNS. The event was provisionally rated at level-1 on INES and subsequently uprated to level-2 on INES based on investigations. The national report to the 7th review meeting of CNS also contained information on the pressure tube leak event in KAPS-2 on July 1, 2015. The event at KAPS-2 was rated at level-1 on INES.

Investigations for establishing the root causes of these pressure tube leak events have been completed. Failure analysis of the leaky pressure tube in KAPS-1 showed through wall longitudinal cracks. In KAPS-2, the leaky pressure tube had tight through wall crack near the rolled joint at the cold end. Both the pressure tubes showed presence of high hydrogen content in the PT material and associated reduction in fracture toughness. In both cases, there were presence of localized corrosion spots on the outer surface of pressure tubes, which was an unusual observation. In-situ inspection and post-irradiation examination done on a number of other pressure tubes from KAPS-1&2 also showed presence of similar localized corrosion spots. It was seen that the density of these spots reduced towards the outlet end of annulus gas monitoring system (AGMS), indicating a possible connection with the AGMS. Special inspections undertaken for corrosion spots in other operating PHWRs confirmed that this phenomena was limited only to KAPS-1&2. The corrosion spots were not seen during the post-irradiation examination of pressure tubes from these reactors earlier in years 2005 & 2012, indicating that this phenomenon could be attributable to causes subsequent to the year 2012.

Chemical analysis of carbon dioxide gas used in AGMS at KAPS-1&2 showed presence of unlisted hydrocarbon impurities. Scrutiny of the operating history & records of AGMS showed that the carbon dioxide for AGMS of KAPS-1&2 was sourced from industry making mono-ethyl glycol (Naphtha cracking) since the year 2012. Earlier, carbon dioxide produced through combustion route was being used in AGMS.

Detailed studies, experiments and long term corrosion tests showed that AGMS gas mixture in combination with hydrocarbons under reactor conditions could result in formation of reactive chemical species and these can damage the protective oxide (autoclave) layer on the outer surface of pressure tubes. Oxidation of bare surface leads to formation of localized corrosion spots (monoclinic, non-adherent & porous ZrO_2; also referred as nodules). The observation of reducing density of corrosion spots from the AGMS inlet to outlet end corroborated this degradation mechanism, indicating progressive consumption of the chemical species towards the AGMS outlet end. This was also confirmed during the experiments done as part of investigations. The radiolysis of hydrocarbons also produced hydrogen which could have been picked up by the pressure tubes through porous oxide nodules. High hydrogen content in the affected pressure tubes of KAPS-1&2 eventually led to crack initiation and its propagation through Delayed Hydride Cracking (DHC).

In KAPS-1, degradation in material properties of pressure tubes was higher due to longer period of operation with contaminated carbon dioxide gas compared to KAPS-2 and therefore the crack grew to critical size in the affected pressure tube and led to its failure. However, in KAPS-2, the material properties of the affected pressure tube were adequate enough to allow for the crack to grow in a stable manner following leak before break (LBB).

Based on the investigation findings, it was concluded that the event occurred due to a small amount of unlisted impurity in carbon dioxide used for AGMS. There was a latent deficiency in the specifications of carbon dioxide gas. Limit on hydrocarbon impurities in carbon dioxide gas was not specified.

These events brought into focus the importance of AGMS gas specifications. Based on the review of investigation findings and the root cause, corrective measures were implemented at operating PHWRs which include strengthening of AGMS specifications and quality checks and enhanced surveillance & monitoring of AGMS. The scope of in-service inspection programme of coolant channels has been strengthened for all operating PHWRs by including a requirement of periodic inspection for localized corrosion on outer surface of pressure tubes. The capability of AGMS was also analyzed and confirmed to meet the design requirements in all PHWRs. Also the operational mode of AGMS was modified to further enhance its sensitivity in NAPS-1&2 and KAPS-1&2, in line with the configuration in subsequent PHWRs.

Both the KAPS reactors have undergone En-Masse Coolant Channel Replacement (EMCCR). After completion of EMCCR activities and necessary regulatory review & clearance, KAPS-1&2 are now operational.

6.3 PERIODIC SAFETY REVIEW

Periodic Safety Reviews (PSR) of the nuclear power plants are carried out as a regulatory requirement for renewal of licence for operation of NPP. All the operating NPPs, except RAPS-5&6 and KKNPP-1&2, have undergone PSR. The first PSR of these NPPs will be completed in the year 2020. As per the existing requirement, the NPPs are required to undergo PSR once in 10 years. For NPPs of new design, the first PSR is required to be carried out after five years of initial operation.

Safety assessments performed during PSR take into account current regulatory requirements, safety standards and operating practices. It also considers factors such as cumulative effects of plant ageing & obsolescence, modifications, feedback of operating experience, safety analysis 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 prepared by NPP is subjected to regulatory review for satisfactory resolution of the identified issues. PSR is used for identifying and timely implementing necessary safety upgrades in the NPPs.

During the last three years (2016-till date), PSR was undertaken for two stations, viz. KGS-3&4 and RAPS-1&2 (currently in progress). PSR of KGS-3&4 did not bring out any major safety issue. The long term actions identified based on the lessons learned from the accident at Fukushima Daiichi NPP are being implemented at KGS-3&4 as per schedule.

6.4 OPERATIONAL EXPERIENCE FEEDBACK PROGRAMME

Utility and AERB have established structured programme for reviewing external as well as internal Operating Experience (OE) pertaining to operating NPPs. The programme includes systematic collection of information, screening, review, dissemination and finally monitoring the implementation of the review recommendations.

For reviewing international operating experience at AERB, IRS reports received are screened and a group of experts review the screened reports. To implement a graded approach in operating experience utilisation, screening guidelines have been developed. Review reports are prepared encapsulating the highlights. Events which demand further review are selected for discussion in a high level review group, OERG. These information and feedbacks are used by the AERB officers during regulatory inspections and safety review process. The lessons learnt for safety enhancements in NPPs and improvement of regulatory practices are implemented in core regulatory activities for meeting the complete intent of OE.

Further details are covered in Article-19: Operations

6.5 SAFETY ENHANCEMENTS OF OPERATING NPPs

Right from the early stages of nuclear power programme in India, emphasis has been placed on learning lessons from the operating experience and utilising it to enhance the safety of NPPs. A structured mechanism for safety reviews within the utility and the regulatory body has evolved over a period of time.

With an active nuclear power programme, the designs of NPPs have been seeing enhancements over time, particularly in respect of safety, in tune with the prevailing international benchmarks and best practices. This has facilitated the Indian NPP design approach to stay up to date with the state of art.

India has a robust operating experience feedback programme through which the important events / developments and their implications with respect to safety of NPPs are reviewed for identifying the need for any safety enhancements in the existing plants and / or the design of new NPPs. Special safety reviews were undertaken following major events like Three Mile Island accident of 1979, the Chernobyl accident of 1986, the fire incident at unit-1 of Narora Atomic Power Station (NAPS) in 1993, the flood incident at the Kakrapar Atomic Power Station (KAPS) in 1994, the tsunami at the Madras Atomic Power Station (MAPS) in 2004, the accident at Fukushima Daiichi NPP in 2011, and pressure tube leaks at KAPS in 2015-16.

India has adopted the Periodic Safety Review (PSR) process involving comparison with the current safety requirements / practices. PSR is carried out once in ten years and is one of the basis for renewal of operating licence which ensures that safety upgrades identified are implemented in a timely manner.

While the older NPPs have seen maximum of these upgrades, the plants built subsequently have incorporated these features as part of the design. The examples of safety enhancements in Indian NPPs based on the above reviews are as follows:

- Enhancement of emergency power supplies with specific emphasis to avoid common cause failures
- Fire protection measures: augmentation of fire detection systems, cable segregation, and fire localisation measures
- Dedicated instrument air supply to critical valves within the containment and isolating other inputs of air supply with the objective of maintaining functionality while minimizing post-accident over pressurisation of containment
- Diesel engine driven fire water pumps

- On-site water storage and provision for injection from (diesel driven) fire water pumps as back-up emergency water supply to SGs and ECCS through independent line
- Enhancing the redundancy of off-site power
- Supplementary Control Room (SCR): Installing where the SCRs were not existing and enhancing the functionality including back-up power supply
- Unit-wise segregation of shared safety and safety related systems
- Revision of safety analysis using state of the art analytical tools, taking account of current configuration
- Systematic programmes for Ageing Management and Equipment Qualification
- Seismic re-evaluation of old plants and consequent strengthening of SSCs, where necessary
- Reassessment of flood levels at existing sites considering upstream dam failure for in-land sites and tsunami hazard at coastal sites resulting in implementation of improvements such as
    - Installation of additional DGs at higher elevation
    - Additional air compressors at higher elevation
    - Providing protection for safety critical equipment in potential wet areas
- Consideration of station blackout as part of design which calls for provision of passive poison injection to moderator system to achieve long term sub-criticality in PHWRs,
- Onsite storage of fuel for Emergency DG and water for 7 days of reactor core cooling requirement.

As brought out above, substantial safety enhancements were made in the past in the existing NPPs and the design of new NPPs. The safety reviews carried out following the accident at Fukushima Daiichi NPP also corroborated the inherent strengths in the design, operational and regulatory practices and requirements associated with the Indian NPPs. The post Fukushima Daiichi NPP accident strengthening measures identified and being implemented for the Indian NPPs are associated mainly with enhancing the resilience of the plants to cope with extreme external events exceeding the design bases and to strengthen the provisions for mitigation of severe accidents. The identified safety enhancements were classified as short term, medium term and long term measures taking account of aspects such as feasibility for implementation, need for assessments/analysis/development, engineering & procurement and scheduling of planned outages for implementation. The specific enhancements following Fukushima Daiichi NPP accident based on safety review conducted in Indian NPPs were presented in detail in the National Reports to the 2nd Extraordinary Meeting (2012) and 6th & 7th Review Meetings of CNS.

The current status of implementation of these safety upgrades at operating NPPs is as below:

- Short term measures
    - External hook up points for addition of water to important reactor systems and spent fuel bay
    - Additional emergency lighting backed up by solar cells
    - Review and revision of Emergency Operating Procedures
    - Training and mock-up exercises of operating personnel

These short term measures have been completed at all operating NPPs. The modifications are covered under the surveillance programme of NPPs, which is overseen by AERB.

- Medium term measures
  - Introduction of automatic seismic trip
  - Provision of additional backup DGs (air cooled mobile/fixed) at higher elevation
  - Strengthening provision for monitoring of critical parameters under prolonged loss of power
  - Provision of diesel driven pumps for transfer of water from deaerator storage tank to steam generators
  - Additional mobile pumps and fire tenders
  - Steps for seismically strengthening and further augmentation of onsite water storage, wherever required

500 kVA air cooled mobile DG in KKNPP-1&2

Emergency Water Storage Tank at MAPS-1&2

These medium term measures have been completed at all operating NPPs as required. The modifications are also covered under the surveillance programme of the NPPs, which is overseen by AERB.

- Long term measures (Refer Section 6.5.1 below)
  - Enhancing Severe Accident Management programme
  - Strengthening hydrogen management provisions
  - Provision for filtered venting of containment
  - Creation of on-site emergency support centre capable of withstanding extreme flood, cyclone & earthquake etc.

6.5.1 Status of implementation of long term measures

The status of long term measures identified for Indian NPPs is summarized below.

a) Enhancement of severe accident management programme: The severe accident management guidelines for different NPP designs (PHWR, BWR & PWR) were developed based on technical bases reviewed and accepted by AERB. Accident Management Guidelines developed based on these have been implemented at all the operating NPPs, including implementation of the necessary hardware enhancements, training of the operating personnel, mock up tests and periodic surveillance (details are given in section 19.4 of Article-19). In addition to regular drills on utilising accident management provisions, exercises were conducted at all stations simulating multi-unit accidents. Apart from this, table top exercises are being carried out linking on-site accident management actions with off-site actions making use of decision support system.

b) Strengthening Hydrogen Management Provisions: The hydrogen management scheme in Indian PHWRs includes provision of suitable number of Passive Catalytic Recombiner Devices (PCRD) along with provisions for homogenizing the containment atmosphere and maintenance of the inert steam atmosphere. Activities related to indigenous development, testing and qualification of PCRDs addressing the post-accident hydrogen management needs for the Indian PHWR containments have been completed. After completion of regulatory review, technology transfer for large scale manufacturing of PCRDs has been carried out. Industrial scale manufacturing of these devices is currently in progress. Installation of these PCRDs along with the associated instrumentation and equipment of Post-Accident Hydrogen Management System (PAHMS) is in progress in the operating NPPs based on agreed schedule, primarily based on the planned shutdowns. Currently, PCRDs have been installed in MAPS-2, KGS-1&2, NAPS-1, KAPS-1 and RAPS-5. For the PWR units of KKNPP-1&2, the Passive Autocatalytic Recombiners (PARs) for hydrogen management are already incorporated as part of the design. In TAPS-1&2, containment inerting system has been indigenously refurbished and the refurbished system is put in operation.

Nitrogen Inerting System in TAPS-1&2

Passive Catalytic Recombiner Device

c) Provision of Containment Filtered Venting System (CFVS): Technology development of CFVS System has been completed and detailed engineering of the system has been finalized after analysis and testing. CFVS has been installed in TAPS-1&2 (BWR). Necessary Commissioning tests have been conducted and surveillance requirements have been finalized. Installation of CFVS is in progress in PHWR based NPPs, where the requirement has been envisaged. For the PWR units at KKNPP-1&2, the requirement of containment venting is not envisaged. Further details are given in Article-18.

CFVS in TAPS-1&2

d) Creation of On-Site Emergency Support Centre (OESC): AERB has framed requirements and guidelines for establishing On-Site Emergency Support Centres (OESCs) at all NPPs, which takes into account the NPPs at the given site and the accident scenarios. The bases for arriving at the design parameters have also been specified, based on extensive in-house evaluations and in consultation with the domain experts in the country. OESC should have capability to remain functional under radiological conditions following a severe accident and should be capable of withstanding extreme external events (flood, cyclone, earthquake, etc.). This facility will be in addition to the existing emergency control centres. After regulatory approvals, construction of the OESCs at two sites is in progress.

The provisions with respect to severe accident management are part of the design requirements for NPPs for which construction consent was issued after the year 2015.

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 continually monitored by an established system. India follows a periodic safety review (PSR) programme which forms one of the basis for renewal of operating licences of NPPs. Replacements or modifications of the structures, systems and components important to safety are carried out as necessary. Enhancements are also carried out to resolve obsolescence issues. Robust programme exists for feedback of operating experience for learning lessons and to take timely actions to enhance safety. A system exists for comprehensive and systematic safety reviews of NPPs to be conducted regularly and periodically throughout their lifetime. Based on these reviews, safety enhancements are identified and implemented. The long term safety enhancements identified based on the lessons learned from the accident at Fukushima Daiichi NPP have been addressed. These ensure that India complies with the obligations of Article-6 of the Convention as well as the principles of the Vienna Declaration on Nuclear Safety.

ARTICLE 7: LEGISLATIVE AND REGULATORY FRAMEWORK

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

7.0 GENERAL

India is a Union of States. It is a Sovereign Socialist, Secular and Democratic Republic. The Constitution of India provides for a Parliamentary system of government which is federal in structure. The Constitution distributes legislative powers between the Parliament and the 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. Accordingly, the laws pertaining to atomic energy are enacted by the Parliament and enforced by the Central Government.

7.1 LEGISLATIVE AND REGULATORY FRAMEWORK

The legal framework for atomic energy was established in India in the year 1948 and legislation by the name Atomic Energy Act, 1948 was enacted. The Atomic Energy Act, 1948 was repealed and the Atomic Energy Act, 1962 was enacted subsequently. The Atomic Energy Act, 1962 provides for the development, control and use of atomic energy for the welfare of the people of India and for other peaceful purposes. Atomic Energy Act, 1962 and rules framed thereunder provide the main legislative and regulatory framework pertaining to atomic energy in the country. The Act provides the Central Government with the powers to frame rules and issue notifications to implement the provisions of the Act. The Rules framed under the Act are laid on the floor of both the houses of the Parliament.

In addition to the provisions of the Atomic Energy Act, the provisions of several other legislations related to environment, land use, etc. have also to be met for locating and operating Nuclear Power Plants (NPPs). The provisions of these Acts are enforced by Central or State Government, as the case may be. Important legislations that have a bearing on the establishment and operation of NPPs are summarised below:

7.1.1 Atomic Energy Act, 1962

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

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

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

ii. Control over Mining or Concentration of Prescribed Substances

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

iii. Control over production and use of atomic energy

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

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

iv. Control over radioactive substances

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

v. Special Provisions as to safety

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

vi. Special provisions as to electricity

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

vii. Administering Factories Act, 1948

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

viii. Offences and Penalties

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

ix. Delegation of powers

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

x. Power to make rules

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

Amendments in the Atomic Energy Act, 1962

The Atomic Energy Act, 1962 has seen three amendments so far. The first amendment was effected in December 1986 for amending section 6 of the Act and to introduce a new section 11a in the Act which dealt with the issue of acquisition of Uranium. The second amendment was effected in September 1987, with amendments in sections 2, 3 and 22 of the Act. This amendment was to facilitate a government company and/or authority or corporation of the government to conduct the activities related to production, development, use and disposal, of atomic energy. The third amendment was effected in December 2015, to re-define a Government Company and to specify certain specific aspects related to granting licences under Section 14 of the Act to such companies.

7.1.2 Indian Electricity Act, 2003

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

7.1.3 Environment (Protection) Act, 1986

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

Clearances, as applicable, are also required under Coastal Regulation Zone (CRZ) Notification (amended in 2019) for setting up NPP in coastal areas, Forest (Conservation) Act 1980 for use of forest land and Wild Life (Protection) Act, 1972 if the project has impact on wildlife

7.1.4 Factories Act, 1948

The Factories Act is a social legislation which has been enacted for occupational safety, health and welfare of workers at work places. The administration of the provisions of the Factories Act 1948, in the units of Department of Atomic Energy (DAE) is done through Atomic Energy (Factories) Rules, 1996, as per the provisions in Section 23 of Atomic Energy Act.

7.1.5 The Disaster Management Act, 2005

The Disaster Management Act, 2005 provides for effective management of disasters including accidents involving NPPs. As per the provisions of the Act, the National Disaster Management Authority (NDMA) has been established. The NDMA has the responsibility for laying down policies, plans and guidelines for disaster management for ensuring timely and effective response to any disaster including radiological/nuclear disasters.

7.1.6 Other Applicable Legislations

The other applicable legislations, as amended, for locating and operating NPPs in the country include:

i. The Water (Prevention & Control of Pollution) Act, 1974

ii. The Air (Prevention & Control of Pollution) Act, 1981

iii. The Water (Prevention & Control of Pollution) Cess Act, 1977

iv. The Explosive Act 1884

v. The Indian Boilers Act, 1923

vi. The Civil Liability for Nuclear Damage Act, 2010

7.1.7 International Conventions related to Nuclear Safety

India has ratified the following international conventions:

i. Convention on Early Notification of a Nuclear Accident
ii. Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency
iii. Convention on the Physical Protection of Nuclear Material and its amendment
iv. Convention for Suppression of Acts of Nuclear Terrorism
v. Convention on Nuclear Safety
vi. Convention on Supplementary Compensation for Nuclear Damage

7.2 PROVISIONS OF LEGISLATIVE AND REGULATORY FRAMEWORK

7.2.1 National Safety Requirements and Regulations

7.2.1.1 Subordinate Legislation for Nuclear Safety

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

I. Rules Framed under the Atomic Energy Act, 1962

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

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

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

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

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

Atomic Energy Regulatory Board (AERB) was established in 1983 under the provisions of the Atomic Energy Act, 1962. AERB is the national regulatory body having powers to frame safety policies, lay down safety standards & requirements and powers to monitor & enforce provisions under the Act and rules thereof, in nuclear and radiation installations and practices.

Further to provide statutory strength to AERB and to convert its functional independence into de-jure independence, the proposal for setting up a Nuclear Safety Regulatory Authority (NSRA) has been under consideration. Accordingly, Government had introduced the Nuclear Safety Regulatory Authority Bill, 2011 in the parliament in the year 2011. The Bill could not be taken up for consideration before the dissolution of 15th Lok Sabha (Lower House of the Parliament). A fresh Bill is under examination and processing.

II. Atomic Energy (Factories) Rules, 1996

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

III. Rules arising from other Legislations

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

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

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

   a. The Water (Prevention & Control of Pollution) Act, 1974

   b. The Air (Prevention & Control of Pollution) Act, 1981

   c. The Water (Prevention & Control of Pollution) Cess Act, 1977

   d. The Hazardous Waste (Management, Handling and Transboundary Movement), Rules 2016.

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

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

v. The Explosives Act, 1884 and The Explosives Rules, 2008 provide the Central Government power to prohibit manufacture, possess, use, sale, transport of explosives except under a licence granted by it. Petroleum and Explosives Safety Organisation (PESO) regulates the provision of this Act and the rules thereunder

vi. Civil Liability for Nuclear Damage Rules, 2011

vii. Nuclear Liability Fund Rules, 2015

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

7.2.1.2 Regulatory documents

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, Site Evaluation, Design, Operation, Radiation Protection, Radiation Waste Management and Quality Assurance and several safety guides and manuals under these Codes. AERB has issued safety guidelines for emergency preparedness and response of NPPs. Safety codes/guidelines establish objectives and specify minimum requirements that have to be fulfilled to provide adequate assurance for safety in nuclear and radiation facilities. The Atomic Energy (Radiation Protection) Rules, 2004, provides the Competent Authority, the legal powers for issuing the codes and to enforce the requirements. Safety Guides provide guidance and indicate methods for implementing specific requirements prescribed in the Codes. In addition to these, AERB also issues Safety Manuals which elaborate specific aspects and contain detailed technical information and procedures.

During the preparation of these documents, the safety requirements recommended by IAEA and the regulatory agencies of other countries are also considered. The safety documents are reviewed and updated based on experience and scientific developments and to harmonize these with the recommended current safety standards of IAEA. The requirements / guidance/practices available in other relevant international sources are also suitably considered.

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

7.2.1.3 Process of Developing and Revising regulatory documents

As mentioned above, one of the mandates of AERB is to develop safety codes and guides for regulation of nuclear and radiation facilities. AERB follows multi-tier process to prepare and revise safety documents. The process also ensures that safety documents are based on expert opinion and are unbiased.

Integrated Management System (IMS) of AERB elaborates the document development process. The same is shown in figure below.

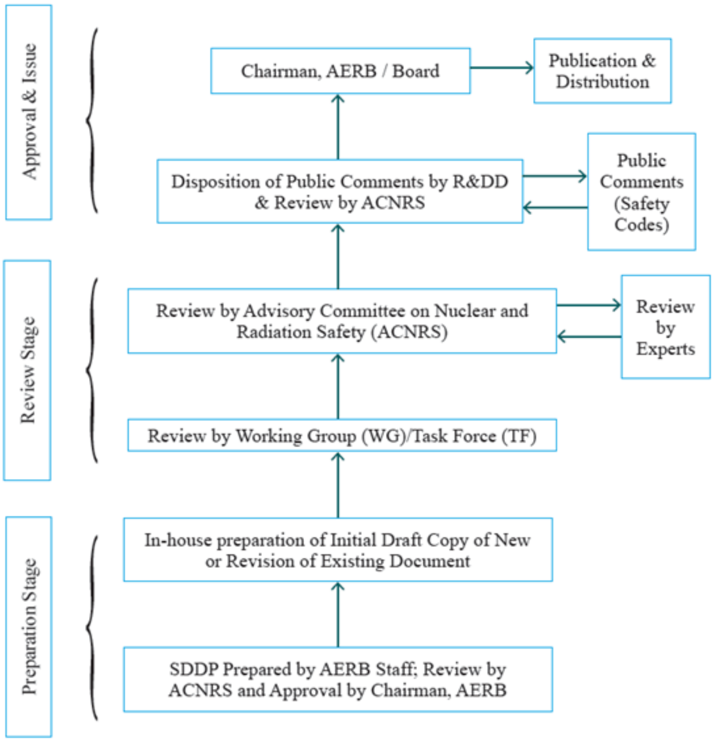


Figure 2 Document Development Process

Safety Document Development Proposal (SDDP) is prepared by AERB staff based on the requirement for development/revision of safety documents. The SDDP, after due internal reviews, is further reviewed by Advisory Committee on Nuclear and Radiation Safety (ACNRS), which is the apex committee for review of safety documents. The SDDP is approved by Chairman, AERB.

Based on the SDDP, the draft safety document is prepared by AERB staff. The draft is subjected to review in multi-tier process which includes review by ACNRS and domain experts. The AERB safety codes are approved by the Board of AERB and other safety documents are approved by Chairman, AERB.

India also has a mechanism for obtaining and addressing comments from members of public on the safety codes under development. This mechanism enables public participation in framing of safety requirements.

7.2.2 System of Licensing

7.2.2.1 Requirements and Legal Provisions of Licensing under the Atomic Energy Act, 1962

As per the provisions of the Atomic Energy Act, 1962, in India, only the Central Government; or any authority or corporation established by it; or a Government Company can be allowed to establish and operate a Nuclear Power Plant. Section 14 of the Act specifies the requirement of obtaining licence from the Central government for production and use of atomic energy. Section 16 of the Act prohibits the manufacture, possession, use, transfer by sale or otherwise, export and import and in an emergency, transport and disposal, of any radioactive substances without obtaining the consent of the Central government. Further, Section 17 of the Act gives the Central Government power to prescribe the requirement for safety and waste management.

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

AERB safety code on 'Regulation of Nuclear and Radiation facilities (AERB/SC/G, 2000)' specifies the minimum safety related requirements/obligations to be met by a nuclear or radiation facility to qualify for the issue of regulatory consent / licence at every stage during the life cycle of an NPP. The code also elaborates on regulatory inspection and enforcement to be carried out by the Regulatory body in such facilities.

After the issuance of licence for operation, renewal of licence is based on limited scope safety review once in five years and conduct of PSR, once in 10 years. AERB carries out continual safety supervision by way of reporting obligations, regulatory inspections & enforcements. AERB adopts a multi-tier review and assessment process for new projects and operating NPPs. Annex 7-2 typically indicates various regulatory documents issued by AERB pursuant to primary legislations pertaining to atomic energy in India.

The detailed consenting/licensing process in India is described in Article-14 (Assessment and Verification of Safety).

7.2.2.2 Consenting Process for Nuclear Power Plants

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

Safety in siting, design, construction, commissioning and operation of the facilities is ensured primarily through regulatory actions including issuance of consent/licence for activities and imposition of conditions on the applicant. AERB performs these actions on the basis of its review and assessment. In general, a three-tier review process is followed by AERB before any major activity concerning NPP is issued consent. The extent of review is commensurate with the safety significance of the issue, following graded approach.

7.2.3 System of Regulatory Inspection and Assessment

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

i. compliance with the safety provisions of the primary and subordinate legislations and other consenting conditions;

ii. that nuclear facilities are sited, constructed, commissioned and operated in conformity with design intent duly approved by AERB;

iii. that safety-related structures, components and systems are of approved quality based on acceptable standards; and

iv. facilities operate within the approved Technical Specifications for Operation and the respective operating personnel are competent to operate the facility safely.

7.2.3.1 Legal Provision for Regulatory Inspection

Section 8 of the Atomic Energy Act, 1962 gives the Central Government powers to enter and inspect any mine, premises and land for the purpose of the Act. For the purpose of safety, subsections 4 and 5 of Section 17 of the Act gives the Central Government powers to inspect any premises, vehicle, vessel or aircraft and take enforcement actions to prevent any contravention of the rules framed under the provision of this section. The provisions of Atomic Energy (Radiation Protection) Rules, 2004, Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987 and Atomic Energy (Factories) Rules, 1996 are also enforced by AERB. A system of regulatory inspection is established to verify compliance with the rules. The powers to inspect and take enforcement actions for industrial safety are drawn from the provisions of section 8 & 9 of the Factories Act, 1948. AERB Safety Code on ‘Regulation of Nuclear and Radiation facilities’ (AERB/SC/G, 2000) and safety guides and manuals issued thereunder provide the details regarding the system of regulatory inspection and enforcement.

AERB is empowered to exercise the powers for entry and inspect the nuclear and radiation facilities, including the related designers, manufacturers and vendors.

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

7.2.3.2 Inspection programme, strategies and assessment method

AERB has formed a Directorate of Regulatory Inspection (DRI) with dedicated manpower for coordinating, integrating and harmonizing the regulatory inspection programme of AERB. The functions of DRI are given in section 8.1.2.3 of the report. DRI carries out periodic evaluation of the issues arising from the inspection findings to obtain feedback on the improvements required in the inspection related processes with the objective of continual improvement in the inspection process and coverage.

The regulatory inspection strategies are comprehensive and developed to ensure that NPPs comply with the regulatory requirements. Inspections are carried out during all stages of consenting process. The frequency, scope and depth of inspections depend upon the significance of the consenting stages and sub-stages therein with respect to safety and potential, magnitude or nature of the hazard associated with the type of activity.

The inspection process is complimentary to the safety review & monitoring and enables the on-site verification. Details of safety review process are given in Article-14.

The programme for carrying out regulatory inspections is dynamic in nature. The programme envisages a minimum number of routine inspections at each NPP in terms of frequency, scope and depth. Additional inspections are carried out over and above the routine inspections with the frequency, scope and depth decided by safety reviews of the NPPs and previous inspection findings. Special inspections are also carried out as warranted by any event or specific activity at the NPP. The inspections can either be announced in advance or unannounced.

The inspections may include examinations of actual physical status of NPPs, various procedures, records and documents, surveillance tests, and interviews with the utility personnel as well as conduct of investigations, and collection of samples among others for verifying compliance with regulatory requirements.

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

AERB has enhanced the regulatory presence at sites by increasing the frequency of regulatory inspections. In each regulatory inspection, the status of safety and safety related systems are essentially checked, irrespective of the scope of inspection. AERB has also started deploying the Site Observer Teams (SOTs) to provide continuous on-site regulatory presence. On a trial basis, SOTs have been deployed at sites where NPPs under construction/ commissioning and operation are co-located (four sites), to observe the activities at these sites. SOTs independently provide first-hand information to AERB Headquarters (HQ) on a daily basis. The inputs of SOTs are also considered for deciding the conduct of regulatory inspections at NPPs. In other operating NPPs, the frequency of regulatory inspections is higher as compared to sites having SOTs. In addition, unannounced inspections are also carried out for these operating NPPs.

The above strategies have further enhanced the efficiency and effectiveness of regulatory inspection activities.

AERB is also considering further extension of the scope of inspections to activities related to design, procurement and off-site fabrication of components of NPPs in a phased manner.

Further details on inspection programme are given in Article-14.

7.2.4 Enforcement of Applicable Regulations and Terms of Licences

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

7.2.4.1 Legal Provision and Power for Enforcement

Subsections 4 and 5 of Section 17 (Special provisions as to safety) of the Atomic Energy Act give the Central Government powers to inspect and take enforcement actions to prevent any contravention of the rules. AERB has been identified as the Competent Authority to enforce the provisions of Atomic Energy (Radiation Protection) Rules, 2004, Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987 and Atomic Energy (Factories) Rules, 1996. AERB Safety Code on 'Regulation of Nuclear and Radiation facilities' (AERB/SC/G, 2000) and safety guides issued under it provide the details regarding the system of enforcement.

7.2.4.2 Elements for Enforcement Actions

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

i. a written directive for satisfactory rectification of the deficiency or deviation detected during inspection;

ii. written directive for improvement within a reasonable time frame;

iii. orders to curtail or stop activity;

iv. modification, suspension or revocation of operating consents; and

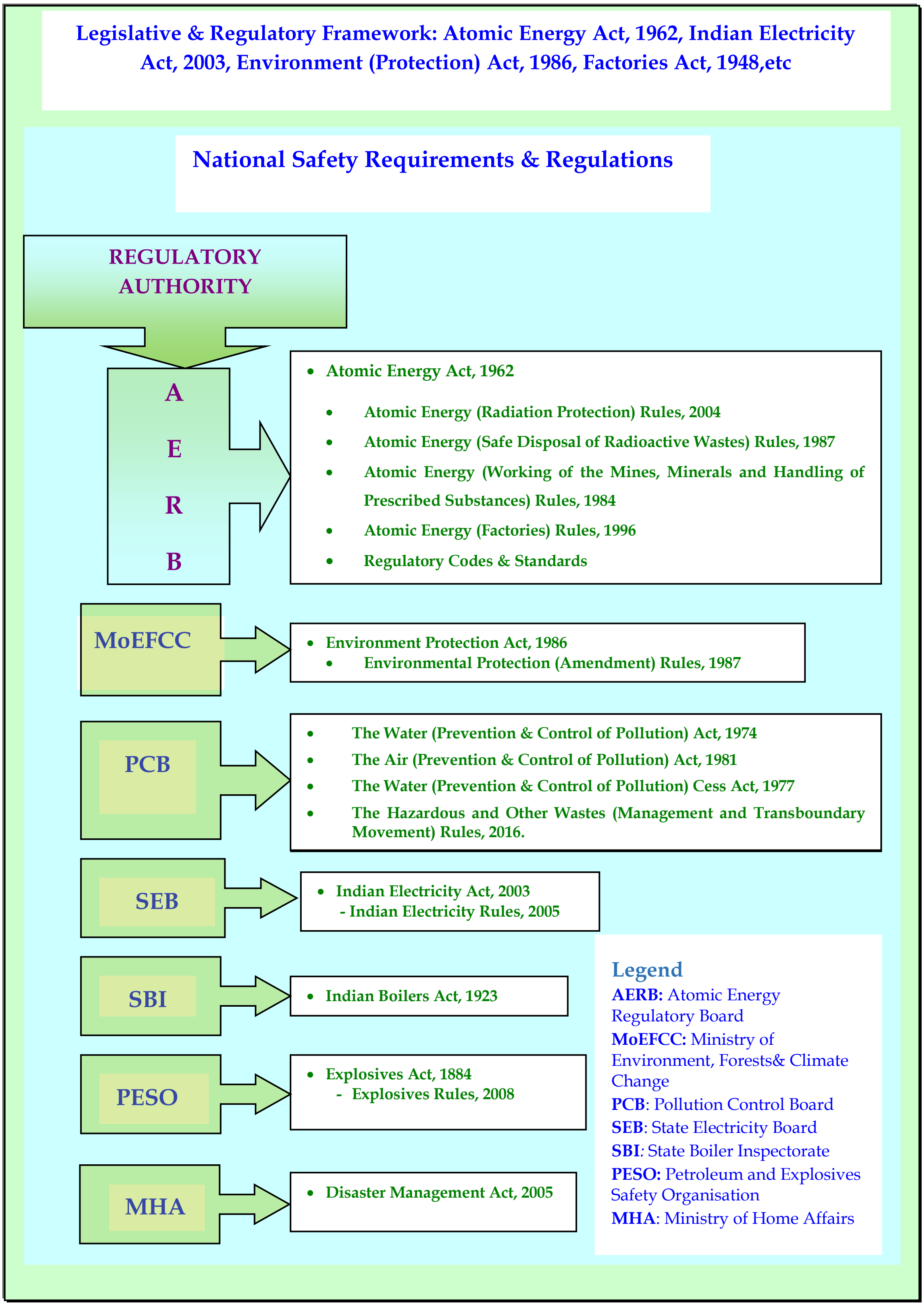
v. Initiating penal actions.

The enforcement measures taken by AERB during the past three years are brought out in Article 14 (Assessment and Verification of Safety).

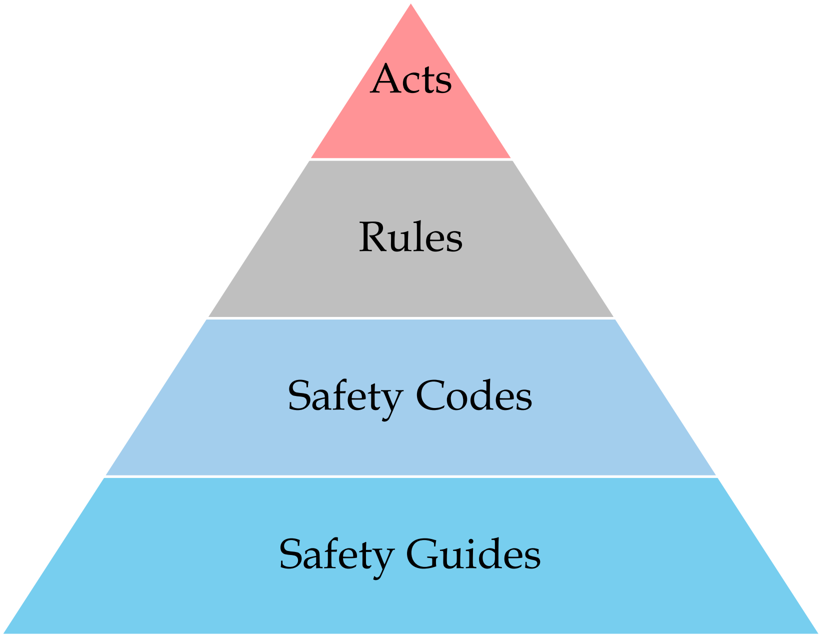
7.3 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

Since the inception of the atomic energy programme in the country, an elaborate legislative and regulatory framework is in place. The national safety requirements pertaining to atomic energy emanate from the Atomic Energy Act, 1962 and rules issued thereunder. The Act and the Rules establish the basic national system of licensing, inspection and enforcement. Pursuant to the objectives identified in the system of licensing, AERB has laid down a comprehensive framework of safety requirements in various Safety Codes issued by it including Safety Code on Regulation of Nuclear and Radiation Facilities and several guides issued under the Code. These safety guides provide guidance on acceptable ways to adhere with safety requirements laid down in the Safety Codes. The Legislative and Regulatory framework in the country is comprehensive to harness the benefit of atomic energy in a safe and secured manner and dynamic enough to embrace the evolving aspirations. This enables India to comply with the obligations of Article 7 of the Convention.

Annex 7-1: National Safety Requirements and Regulation



Annex 7-2: Regulatory documents pursuant to primary legislation pertaining to nuclear energy



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

- Atomic Energy Act, 1962 – Latest amendment in 2015
- Factories Act, 1948

- Atomic Energy (Factories) Rules, 1996
- Atomic Energy (Radiation Protection) Rules, 2004
- Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987
- Atomic Energy (Working of the Mines, Minerals and Handling of Prescribed Substance) Rules, 1984

- Regulation of nuclear and radiation facilities [AERB/SC/G]
- Safety in NPP Operation [AERB/SC/O (Rev.1)]
- QA for Safety in NPPs [AERB/SC/QA (Rev.1)]
- Site Evaluation of Nuclear Facilities [AERB/NF/SC/S (Rev.1)]
- Design for Safety in PHWR Based NPPs [AERB/NPP-PHWR/SC/D (Rev.1)]
- Design for Safety in LWR Based NPPs [AERB/NPP-LWR/SC/D]
- Design for Safety in SFR Based NPPs [AERB/NPP-SFR/SC/D (Under preparation)
- Radiation Protection for Nuclear Fuel Cycle Facilities [AERB/NF/SC/RP]
- Management of Radioactive Waste [AERB/NRF/SC/RW]
- Safe transport of radioactive material[AERB/NRF/SC/TR-1]
- Emergency Response Planning and Preparedness for Transport Accidents Involving Radioactive Material [AERB/NRF/SC/TR-3]

- Safety Guides under Code on Regulation of nuclear and radiation facilities (**10** nos.)
- Safety Guides under Code on Site Evaluation of Nuclear Facilities (**11** nos.)
- Safety Guides under Code on Design for Safety in NPPs (**23** nos.)
- Safety Guides under Code on Safety in NPP Operation (**15** nos.)
- Safety Guides under Code on Management of Radioactive Waste (**08** nos.)
- Safety Guides under Code on QA for Safety in NPPs (**09** nos.)
- Safety Guidelines on Emergency Preparedness (**03** nos.)

ARTICLE 8: REGULATORY BODY

1. Each Contracting Party shall establish or designate a regulatory body entrusted with the implementation of the legislative and regulatory framework referred to in Article 7, and provided with adequate authority, competence and financial and human resources to fulfill its assigned responsibilities.
2. Each Contracting Party shall take the appropriate steps to ensure an effective separation between the functions of the regulatory body and those of any other body or organisation concerned with the promotion or utilization of nuclear energy.

8.0 GENERAL

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

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

8.1 ESTABLISHMENT OF AERB

8.1.1 Mandate and Duties of AERB

The basic regulatory framework for safety for all activities related to atomic energy programme and the use of ionising radiation in India is derived from Sections 16, 17 and 23 of the Atomic Energy Act, 1962. These provisions have been described in detail in Article 7. AERB carries out regulatory and safety functions as per 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:

i. 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.

ii. Powers of the Competent Authority to enforce rules and regulations framed under the Atomic Energy Act, 1962 for radiation safety in the country.

iii. Authority to administer the provisions of the Factories Act, 1948 for the industrial safety of the units of DAE as per Section 23 of the Atomic Energy Act, 1962.

The functions & responsibilities of AERB are summarized below:

i. Develop safety policies in nuclear, radiological and industrial safety areas.

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

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

iv. Ensure compliance of the regulatory requirements prescribed by AERB during all stages of consenting through a system of review and assessment, regulatory inspection and enforcement.

v. Prescribe the acceptance limits of radiation exposure to occupational workers and members of the public and approve acceptable limits of environmental releases of radioactive substances.

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

vii. Review the training programme, 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. Assessment of competence of key personnel for operation of NPP.

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

ix. Promote research and development efforts in the areas of safety.

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

xi. Review of 'Nuclear Security affecting Safety' at Nuclear installations

xii. Notify Nuclear incident under Civil Liability for Nuclear Damage Act, 2010

Deriving powers and functions specified in the gazette notification, AERB Safety Code, on 'Regulation of Nuclear and Radiation Facilities' (AERB/SC/G, 2000) establishes the regulatory practices in the country.

8.1.2 Structure of AERB

8.1.2.1 The Board

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

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

AERB sends periodic reports to AEC on safety status including observance of safety regulations, standards and implementation of the recommendations in all DAE units. In addition, the safety status for non-DAE units is covered in these periodic reports.

8.1.2.2 Committees of AERB

AERB has constituted several committees for supporting its review activities. The technical support to these committees is provided by the experts from BARC, IGCAR, and National laboratories, industrial and academic institutions in the country. The norms for establishing these committees, as part of the integrated management system of AERB, ensure a dominant representation of AERB staff with the building up of requisite in-house competence over a period of time. Availability of the competent in-house resources has also enabled optimisation of the number of committees, and thereby, increased the efficiency of regulatory processes.

The apex committees of AERB are Safety Review Committee for Operating Plants (SARCOP) and Safety Review Committee for Application of Radiation (SARCAR) for safety review of nuclear facilities and radiation facilities respectively.

AERB is also supported by advisory committees for various regulatory activities and development of regulatory documents.

The Advisory Committee for Nuclear and Radiation Safety (ACNRS) 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 Committees on Project Safety Reviews (ACPSRs) advises AERB with respect to safety review and consenting of new projects.

The Advisory Committee for Security (ACS) advises on generic security issues concerning nuclear safety aspects for nuclear power plants.

The administrative and regulatory mechanisms, which are in place, ensure multi-tier review, following a graded approach. The multi-tier review mechanism of AERB is given in Article-14 of the report.

8.1.2.3 Organisation of AERB

AERB has its head office located in Mumbai to perform its regulatory functions. AERB has three regional offices, the Southern Regional Regulatory Centre (SRRC), the Eastern Regional Regulatory Centre (ERRC) and the Northern Regional Regulatory Centre (NRRC) to support its regulatory inspections. AERB has a Safety Research Institute (SRI) at Kalpakkam, which carries out research in various safety-related topics and organises seminars, workshops and discussion meetings periodically.

During the last three years, AERB has implemented organisational changes with a view to effectively utilise its resources, focus its resources on different subject matters of regulatory interest and further enhance expertise in these areas. AERB has formed Directorate of Regulatory Inspection (DRI), Directorate of Radiation Protection & Environment (DRP&E) and Directorate of Regulatory Affairs & Communication (DRA&C) with dedicated manpower for carrying out the related regulatory activities in nuclear and radiation facilities in the country. AERB has also strengthened its regional offices for enhancing its regulatory activities in accordance with the increasing numbers of radiation facilities in every region of the country.

The organisation of AERB is given in Annex 8-1. The primary responsibilities of the various groups/directorates/divisions of secretariat, as spelt in the IMS document of AERB, are as follows:

Nuclear Facilities Regulation Group (NFRG)

NFRG is responsible for regulatory oversight of all Nuclear Facilities and Industrial Plants of DAE through two major divisions, namely Operating Plants Safety Division (OPSD) & Nuclear Projects Safety Division (NPSD).

Operating Plants Safety Division (OPSD)

- Enforcement of Atomic Energy (Radiation Protection) Rules, 2004 in operating NPPs and nuclear fuel cycle facilities Safety Review of operating NPPs and Fuel Cycle facilities
- Renewal of Licence for operation of operating NPPs and Fuel Cycle facilities

- Issuance of Technical Specifications for operation of NPPs and Fuel Cycle Facilities
- Administration of industrial safety under factories act in operating NPPs and Fuel Cycle facilities
- Review of Nuclear security aspects affecting safety of operating NPPs and Fuel Cycle facilities
- Licensing of Operating and Management Personnel
- Organisation of DAE safety & occupational health professionals meet and AERB safety awards

Nuclear Projects Safety Division (NPSD)

- Safety Review of Nuclear Projects.
- Enforcement in Nuclear Projects.
- Review of industrial & fire safety and occupational health safety aspects of Nuclear Projects
- Issue of authorisations at various stages of the Nuclear projects
- Review of Nuclear security aspects affecting safety in Nuclear Projects

Resources and Documentation Division (R&DD)

- Development & Publication of Regulatory Safety Documents
- Management of Resources for AERB including Human Resources, Financial Planning, Establishment and Infrastructure
- Human, Organisational and Technical factors
- Promotion of Safety Research Projects
- Coordination for AERB audits
- Compilation of AERB Annual Report
- Monitoring and update of AERB website
- Information Technology related activities
- Coordination for review of IAEA standards in India (Member State)

Nuclear Safety Analysis & Research Group (NSARG)

NSARG is responsible to supplement regulatory review and assessment activities through Nuclear Safety Analysis Division (NSAD), Mumbai and Safety Research Institute (SRI), Kalpakkam.

- Probabilistic Safety Assessment.
- Deterministic Safety Analysis.
- Nuclear Regulatory Research.
- Independent check for resolving issues related with nuclear plant safety requiring analysis.
- Nuclear & Reactor Safety Studies
- Radiation Safety Studies
- Nuclear Plant Thermal Hydraulics
- Fire Safety Studies
- Environmental Safety Studies

Radiological Safety Division (RSD)

- Safety Review and licensing of Radiation Installations, Radiation Generating Equipment and Devices containing Radioactive Sources
- Safety Review and licensing of BRIT facilities, RAPPCOF, DAE accelerator and LASER facilities
- Enforcement of Atomic Energy (Radiation Protection) Rules, 2004 in radiation installations other than Nuclear Fuel Cycle Facilities
- Enforcement of Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987 in radiation installation other than Nuclear Fuel Cycle Facilities
- Safety Review of Transportation of Radioactive Material

Directorate of Regulatory Inspections (DRI)

- Organise regulatory inspections at Nuclear, Radiation and other Industrial facilities
- Augmentation of Regional Regulatory Centres w.r.t. RI programme
- Deployment of on-site AERB observers at Nuclear Facilities

Directorate of Radiation Protection & Environment (DRP&E)

- Review and Assessment of operating NPPs and facilities with respect to radiological safety
- Authorisation for Waste management under Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987
- Review of Radiological Impact on Public and Environment
- Infrastructure and resources for monitoring and assessing emergency response actions
- Review of on-site and off-site emergency preparedness plans of Nuclear and Radiation Facilities

Directorate of Regulatory Affairs and Communication (DRA&C)

- Providing support for legal affairs of AERB
- Providing support in management of affairs of the Board
- Coordination for enforcement and initiation of penal action
- Maintaining liaison with other agencies/ regulatory bodies /TSO for technical cooperation
- Coordination under international obligations and bilateral/multilateral arrangements
- Safety promotion, Public communication and outreach activities
- Redressal of Grievance /complaints and to enhance transparency and accountability

The Heads/Directors of the above divisions/groups are members of the AERB Executive Committee which meets periodically and takes decisions on important functional matters. The management of external affairs of AERB is carried out by External Relations Officer.

8.1.2.4 Technical Support

BARC is the Technical Support Organisation (TSO) to AERB. AERB has arrangement for obtaining technical support from BARC which takes into account the aspect for avoiding conflict of interest. The technical support is obtained in the areas of development of safety documents, radiological & environmental safety, review & assessment of safety cases and inspection & 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.

BARC is currently involved in the following R&D activities for improving the analytical capabilities in the areas related to nuclear safety:

- Assessment of Fuel Channel and Calandria integrity under severe accident conditions
- Participation in IAEA International Collaborative Standard Problem on Numerical Benchmarks for Multi-physics Simulation of Pressurized Heavy Water Reactor
- Participation in the OECD/NEA THAI-3 project for evolution of CFD based modelling methodology to address hydrogen recombination, hydrogen combustion, fission product re-entrainment and iodine re-suspension due to hydrogen deflagration.
- Establishment of National Fire Test facilities for evolving the Fire Hazard Analysis methodology in nuclear power and allied facilities.
- Development of analytical model for characterizing the aerosol deposition behaviour in piping systems of PHWRs and establishment of National Aerosol Facility.
- Development of PRABHAVINI code for design basis and severe accident source term estimation and PINAK code for Molten Fuel Coolant Interaction analysis.
- Studies on multi-unit PSA and external event PSA

AERB utilises the expertise available with Indira Gandhi Centre for Atomic Research (IGCAR). Experts from Council for Scientific & Industrial Research (CSIR) and various Indian Institutes of Technology (IITs) also provide technical support to AERB in its review and assessment functions. AERB appoints consultants having long experience in the national nuclear programme in various capacities for supporting it in the regulatory activities. AERB may also invite experts from other organisations having specific expertise. Another important resource for AERB’s safety review and safety documents development work is the large pool of retired senior experts.

The technical support from BARC, IGCAR, national laboratories, and industrial and academic institutions in the country to AERB also comes in the form of providing experts as members for its advisory committees and safety committees.

The technical support and expertise provided by the above organisations are considered as an input, as necessary, by AERB for its regulatory decision making.

8.1.2.5 Human Resources

The staff of AERB mainly consists of technical & scientific experts in different aspects of nuclear and radiation technology for meeting the requirement of consenting, safety review, research, inspections and analytical works. Besides AERB’s own staff, required expertise is drawn from Technical support organisation, premier research centres, academic institutions and retired experts. AERB has a staff strength of 339 as on March 2019. AERB is currently augmenting its staff strength for catering to the regulatory review / monitoring requirements of the expanding nuclear programme as well as the enlarging base of radiation facilities in the country. Fresh technical & scientific staff is inducted from various training schools and nuclear training centres as well as from Indian Institutes of Technology. Direct recruitment of experienced professionals is also done through open advertisements. The recruitment and training process is as follows:

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

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

iii. AERB sponsors a few students annually to complete the post-graduation from Indian Institutes of Technology. They are further trained in nuclear technology and given on-job training at NPPs after which they are assigned analytical and research activities to support the regulatory decision making process.

iv. AERB through its Safety Research Institute sponsors its employees for Post-Doctoral courses to develop expertise in the areas of regulatory interest. AERB also encourages persons to take up higher studies in the field of nuclear engineering.

Such an extensive training to fresh recruits before involving them in the regulatory job plays an important role towards their competence development.

In addition, AERB organises in-house orientation training programme for newly inducted staff. This programme covers the subject such as legislative and regulatory framework (Acts, Rules, Codes, Guides and Manuals), functioning of AERB, regulatory processes followed and basic aspects of nuclear, radiation and industrial safety in nuclear and radiation facilities. This training programme is of approximately two months duration.

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

Recently, AERB has taken steps to further reinforce the in-house R&D and analytical competences by engaging the domain experts who have retired from AERB and its TSO. These experts are engaged to mentor and guide the younger AERB staff in identifying & managing safety related R&D projects & experimentation and enhance the in-house analytical capabilities & infrastructure. This programme has provided an added impetus to the competence development programme of AERB.

AERB is a relatively young organisation and the average age of its staff is 39 years. The attrition rate in AERB is extremely low. Therefore, the strategy is to enhance the knowledge & competence of its existing staff and to retain the knowledge & experience of the limited number of personnel who are leaving the organisation on superannuation.

8.1.2.6 Financial Resources

AERB has full powers to operate its budget, which it prepares and submits to the Central Government for approval. The Budget of AERB forms part of the budget of the Central Government which is placed in the Parliament. The budget proposal is routed through AEC. The Central Government allocates the budget in the separate account heads of AERB. The allocated budget of AERB is adequate to fulfil its regulatory functions.

8.1.2.7 Safety Research

A large part of safety research important to regulatory activities is carried out by BARC, the technical support organisation. AERB also has its own Safety Research Institute (SRI) at Kalpakkam near the city of Chennai in order to achieve independent research and development capabilities and to complement the ongoing research and development work done in other R&D centres. The areas of research at SRI ranges from Light Water Reactor Physics, Fire Modelling Studies, Radiation Shielding & Transport and Criticality Computations, Assessment of Beam Characteristics of Medical linear particle accelerators, Reliability and Probabilistic Safety Assessment, Structural and Seismic Studies, Remote Sensing and Geographic Information System Applications, Safety Assessment of near surface disposal facilities. The institute helps building up competent human resources of high merit for regulatory purposes. It also organises workshops and seminars on specific safety topics of current importance.

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

8.1.2.8 Integrated Management System (IMS) in AERB

AERB has developed and implemented an Integrated Management System, which isin line with IAEA Safety Standards: Leadership and Management for Safety (No. GSR Part-2, 2016), IAEA Safety Guide: Application of the Management System for the Facilities and Activities (No. GS-G-3.1) and relevant inputs from standards of the International Organisation for Standardization ISO 9001:2015.

It integrates all the processes and practices required for functioning of AERB into one complete framework with primary focus on leadership for safety and quality at all levels in the organisation. It calls for grading the management system which allows AERB to deploy resources and to determine the types and extent of controls to be applied in a manner that is commensurate with the significance, complexity and risks associated with the regulated facilities and activities. Thus, the available resources with AERB are put to optimal use with focus on safety priority. The process performance and its effectiveness are periodically assessed by self-assessment and independent assessment.

8.2 STATUS OF THE AERB

8.2.1 Government Structure and the Regulatory Body

The Constitution of India places atomic energy and mineral resources necessary for its production under the Union List (List I- Seventh Schedule), pursuant to which the laws pertaining to atomic energy are enacted by the Parliament and enforced by the Central Government. The Atomic Energy Act, 1948 was the first legislation pertaining to the atomic energy in the country. The Atomic Energy Act, 1948 was repealed and the Atomic Energy Act, 1962 was enacted subsequently. In the year 1948, the Government of India constituted a high powered Atomic Energy Commission (AEC) to implement the Government's policy with regard to the atomic energy. Subsequently in the year 1954, Government of India created Department of Atomic Energy (DAE). With the creation of DAE, AEC was reconstituted in accordance with the Government resolution dated March 1, 1958, to advise the Central Government on matters pertaining to the atomic energy. Later, Central Government constituted Atomic Energy Regulatory Board (AERB) in 1983 and delegated to it the power to exercise certain regulatory and safety functions envisaged under the Atomic Energy Act, 1962 and rules thereof. AERB updates the AEC through annual report on all safety related matters pertaining to nuclear and radiation related activities in India.

8.2.2 Obligations of the Regulatory Body

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

i. Development of necessary rules and regulations to implement the provisions of the Act in the area of nuclear and radiation safety.

ii. Prescribing acceptable limits of radiation exposures and environmental releases of radioactive substances.

iii. Carrying out safety review on the basis of established regulatory requirements towards considering the grant of regulatory consent;

iv. Conducting regulatory inspections to ensure adherence with the laid down safety requirements and taking enforcement measures, as necessary and

v. To take necessary steps to keep the public informed on major issues of radiological safety significance.

8.2.3 Effective Separation between Regulation and Promotion Activity

The Atomic Energy Commission (AEC) is a high level body dealing with policy matters concerning nuclear energy in the country. Under the framework of the Atomic Energy Act, 1962 companies and organisations under the Department of Atomic Energy (DAE) carries out the activities related to development of nuclear power, applications of radiation technologies in the fields of agriculture, medicine, industry and basic research etc. There are a number of Public Sector Undertakings/Industrial Organisations under DAE for carrying out activities pertaining to nuclear power production like Uranium Corporation of India Ltd. (UCIL) for mining and milling of uranium and Nuclear Fuel Complex (NFC) for fabrication of fuel, NPCIL and BHAVINI for design, construction and operation of NPPs etc. All these public sector undertakings have been developed as ‘Government Companies’ and the Atomic Energy (Amendment) Act, 2015 redefines the nature of such companies.

AERB, the national safety regulator, is a separate body constituted by the Central Government specifically for exercising certain regulatory and safety functions envisaged under the Atomic Energy Act, 1962 and various rules thereof. Funding for AERB activities is provided by Government of India. AERB is functionally independent and presents its Annual Report once in a year to AEC. The Budget of AERB forms part of the budget of the Central Government which is placed in the Parliament. The budget proposal is routed through AEC. The Chairman AERB is the ‘competent authority’ under various rules promulgated under the Atomic Energy Act, 1962 on safety. The effectiveness of this functional separation accorded to AERB while carrying out safety regulation in India has also been ascertained by the IAEA-IRRS Mission to India in its report.

Further to provide statutory strength to AERB and to convert its functional independence into de-jure independence, the proposal for setting up a Nuclear Safety Regulatory Authority (NSRA) has been under consideration. Accordingly, Government had introduced the Nuclear Safety Regulatory Authority Bill, 2011 in the parliament in the year 2011. The Bill could not be taken up for consideration before the dissolution of 15th Lok Sabha (Lower House of the Parliament). A fresh Bill is under examination and processing.

8.3 INTERNATIONAL CO-OPERATION

AERB has been actively involved with various international bodies for exchange of information and in co-operation in the field of regulation of nuclear activities for peaceful purposes. AERB experts have been actively participating in various activities of IAEA and have been contributing at various other international fora. Some of these co-operation activities are brought out as follows:

i. International Atomic Energy Agency (IAEA)

AERB has been actively participating in the activities of IAEA. The staff of AERB participates in various Technical and consultants’ meetings organised by IAEA on a range of topics related to Nuclear

Power Plants, fuel cycle facilities, radiation facilities, transportation of radioactive materials and illicit trafficking of radioactive materials. AERB has been participating in IAEA Coordinated Research Programme (IAEA-CRP).

AERB is the national coordinator for IAEA–International Nuclear and Radiological Event Scale (INES) and IAEA-Incident Reporting System (IRS) and Fuel Incident Notification and Analysis System (FINAS). AERB participates in all activities related to their functioning. AERB experts are also serving as members to the IAEA Safety Standards Committees.

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

Officials from AERB participated as members in the IAEA's Integrated Regulatory Review Service (IRRS) Missions to various countries. AERB plays an active role in strengthening the global safety regime and towards this contributes in various meetings, peer review missions and development of safety standards of IAEA. AERB also utilises experience gained through these safety-cooperation activities towards further augmenting safety regulatory system within India.

Following the events of pressure tube leak in KAPS-1&2, the information on the event and the investigation findings were shared to the international community through IAEA-INES and IAEA-IRS. India also arranged a special event at IAEA, Vienna on the sidelines of 7th review meeting of CNS, for briefing the Member States of IAEA on the events.

ii. Nuclear Energy Agency (NEA)

India continued to participate in the activities of committees of NEA and their various working groups such as Committee on Safety of Nuclear Installations (CSNI) and Committee on Nuclear Regulatory Activities (CNRA). Recently, India's status in CNRA has been enhanced from 'Adhoc invitee' to 'Participant'. India participates in the following activities:

- CSNI activity on benchmark on seismic capacity of reinforced concrete shear walls(CASH)
- CSNI-NEA Thermal hydraulics, Hydrogen, Aerosols and Iodine Project – Phase 3 (THAI-3)
- Working Group on Operation Experience (WGOE),
- Working Group on inspection practices.
- WGRISK Working Group on focus areas, viz., "Risk Aggregation and Multi Unit Interactions and Dependencies.
- Working Group on the Regulation of New Reactors (WGRNR),
- Working Group on Public Communication of Nuclear Regulatory Organisations (WGPC)
- Working Group on Risk Assessment (WGRisk),
- Working Group on Analysis and Management of Accident (WGAMA)
- Working Group on Integrity and Ageing of Components and Structures (WGIAGE)
- Working Group on Fuel Safety (WGFS)

iii. Multinational Design Evaluation Programme (MDEP)

AERB is member in Multinational Design Evaluation Programme (MDEP) since year 2012. AERB continued its association with the MDEP in Policy Group (PG), Steering Technical Committee (STC) and few of the design and issue specific working groups. AERB participated in design specific working groups of EPR, VVER & AP1000 reactors and issue specific working groups of 'Digital Instrumentation and Control Working Group (DICWG)' and Code and Standards Working Group (CSWG).

India is also participating in the activities of subgroup of VVER working group in the areas such as Reactor Pressure Vessel, severe accident, and Fukushima Lesson Learned.

iv. CANDU Senior Regulators Forum

AERB participates in annual meetings of CANDU Senior Regulators, organised by IAEA, for exchange of information on issues specifically related to safety of PHWRs. The last annual meeting of 'CANDU Senior Regulators' was held in Vienna, Austria during December 10-14, 2018. The meeting provided a technical platform to discuss the current issues related to improvement in nuclear safety after Fukushima NPP accident, generic issues of CANDU reactors etc.

AERB is one of the key contributors in CANDU PSA Working Group established by IAEA as suggested by CANDU senior regulators forum. The objectives of the CANDU PSA Working Group are to support regulatory authorities, utilities and designers in their area of PSA by harmonizing regulatory approaches and utilities practices on the use of PSA and to make recommendations to CANDU Senior Regulators Forum.

v. VVER Regulators Forum

VVER Regulators Forum is for exchange of information and experience on issues specifically related to safety of Russian VVERs. AERB is a member of this forum and regularly contributes to the activities of the Forum. AERB participates in the PSA Working Group, Reactor Physics Working Group of VVER Regulator's Forum. AERB hosted 5th meeting of Reactor Physics Working Group (RPWG) of VVER Regulator Forum, in July 2017. Officials from AERB participated in the 24th Annual Meeting of the Forum held in May 2017.

vi. United States Nuclear Regulatory Commission (USNRC)

Cooperation in nuclear safety between AERB and USNRC was resumed in February 2003. Since then sixteen meetings have been held between AERB and USNRC both in India and USA. As a part of nuclear safety cooperation programme between AERB and USNRC, a bilateral meeting was held in August, 2018 at AERB, Mumbai.

The bilateral arrangement between AERB and USNRC, which was initially signed in 2013 was renewed on September 20, 2018. The arrangement envisages, among other things, the exchange of technical information, co-operation in safety research and training of regulatory staff.

vii. ASN and IRSN, France

The arrangement between AERB and Nuclear Safety Authority (ASN), France for the exchange of technical information and co-operation in the regulation of nuclear safety and radiation protection was renewed in April, 2016. The arrangement provides for mutual assistance related to training of scientific personnel, setting of joint working group to carry out specific studies and projects, exchange of information and documentation and exchange of personnel among other things.

The cooperation agreement between AERB and IRSN (Institute for Radiological Protection and Nuclear Safety, France, was also renewed in May, 2016. The agreement provides for cooperation in several aspects of nuclear reactor safety including containment safety, reactor fuel behavior and accident analysis. In the year 2018, a delegation visited ASN and IRSN, France, as a part of the bilateral agreement to discuss various technical matters.

viii. Radiation Safety Authority, Russia

AERB and the Federal Nuclear and Radiation Safety Authority of Russia ROSTECHNADZOR entered into an agreement for cooperation in the field of safety regulation of nuclear energy for peaceful purposes. This agreement came into force on February 15, 2003. Under this bilateral agreement, workshops were conducted in the field of nuclear safety. Currently, both the regulators are actively pursuing to renew the bilateral agreement.

ix. CNCAN, Romania

A Memorandum of Understanding (MoU) was signed between AERB and National Commission for Nuclear Activities Control (CNCAN) of the Government of Romania on September 19, 2012. The MoU is signed for the exchange of information and co-operation in the field of regulation of nuclear activities of peaceful purposes such as application of radiation for societal benefit in industry, medicine, agriculture and research & field of regulating nuclear and radiation safety.

x. SNRIU, Ukraine

A Memorandum of Understanding (MoU) was signed between AERB and State Nuclear Regulatory Inspectorate of Ukraine (SNRIU) on December 10, 2012. The MoU is signed for the exchange of information and co-operation in the field of regulation of nuclear activities of peaceful purposes such as regulatory process, nuclear safety, radiation protection, emergency planning, environmental impact evaluation of nuclear facilities, quality assurance and sharing of operating experience including information concerning research and development programmes.

xi. CNSC, Canada

AERB signed an arrangement with regard to cooperation and exchange of nuclear regulatory information with the Canadian Nuclear Safety Commission (CNSC) in September 2015. The agreement inter-alia provides for regulatory cooperation pertaining to exchange of information and the officials of the regulatory authorities, training of personnel in the field of nuclear and safety regulation.

xii. STUK, Finland

In 2014, AERB and the Radiation and Nuclear Safety Authority of Finland (STUK) signed an arrangement for cooperation in the field of nuclear and radiation safety regulation. The agreement amongst other things provides for the exchange of information and personnel, use of information and rights and obligations of both the regulatory authorities. In the year 2018, a team of delegates visited STUK as a part of the bilateral agreement to discuss various technical matters.

xiii. Bangladesh Atomic Energy Regulatory Authority (BAERA)

AERB signed a bilateral arrangement with Bangladesh Atomic Energy Regulatory Authority (BAERA) on April 08, 2017 for exchange of technical information and co-operation in the regulation of nuclear safety and radiation protection. The arrangement provides for sharing of knowledge and expertise on various issues related to nuclear and radiation safety, education and training of the regulatory personnel and relevant assistance related to development of regulatory requirements of Bangladesh.

On 1st March, 2018, India, Russia and Bangladesh signed Memorandum of Understanding on trilateral cooperation in implementation of the Rooppur Nuclear Power Project in Bangladesh. The MoU envisages rendering of consultancy to Bangladesh in performance of work related to Rooppur Nuclear Power Plant construction and transfer and exchange of knowledge, expertise, consultancy advice, technical support and knowhow, sharing of resources and experience on regulatory aspects, rendering assistance in respect of Indian personnel and qualified Indian institutions experienced in construction, commissioning and operation of technically demanding industrial facilities to the Rooppur Nuclear Power Plant.

xiv. Office for Nuclear Regulation of Great Britain (ONR)

AERB signed a bilateral arrangement with the Office for Nuclear Regulation (ONR) of Great Britain on April 17, 2018. The scope of the arrangement provides for the information exchange concerning the regulation in various mutually interest areas such as siting, construction, commissioning, operation, radioactive waste management and decommissioning of civil nuclear installations; preparedness and management of nuclear and radiological emergencies and co-operation in safety research, training and assignments.

8.4 INTERNATIONAL PEER REVIEW OF AERB: IAEA-INTEGRATED REGULATORY REVIEW SERVICE (IRRS)

The IAEA - IRRS Mission visited India during March 16-27, 2015. The detailed outcome of the mission was submitted to India by IAEA in form of Report on IRRS Mission to India, which was made available to the public through AERB's web-site (www.aerb.gov.in). AERB has taken various actions to address the recommendations and suggestions made by the IRRS Mission. These include strengthening of management system of AERB by implementation of IMS, changes in organisational structure of AERB for efficient & effective utilisation of resources, enhancement of regulatory inspection activities, improvements in regulatory functions related to emergency preparedness & response. For further details, sections-8.1.2.8, 8.2.3, 7.2.3.2, Articles-14 & 16 respectively may be referred.

AERB is in preparatory phase for hosting IRRS follow-up mission.

8.5 ENGAGING WITH PUBLIC AND OTHER STAKEHOLDERS

AERB provides all necessary information to its stakeholders through its periodic newsletters, annual reports, web-site, press releases/ briefings and TV interviews. The AERB annual reports contain detailed information on safety status of nuclear facilities and findings of regulatory reviews. It also includes information on safety significant events reported by licensees and the regulatory inspectors. The AERB Bulletin, which is the popular version of the Annual Report of AERB, presents the most important activities in a more understandable and public friendly format. The annual reports and bulletins of AERB are issued in different languages for wider public outreach.

Formal sharing of information with any member of the public on request is a statutory responsibility of AERB under the 'Right to Information' Act, 2005. Commensurate with the established formal processes in India, AERB also responds to the queries put forth by the Members of the Parliament along with the substantiating information, as necessary. These responses are made public on the websites of the Parliament. In accordance with its mandate, AERB undertakes steps necessary to keep the public informed on any major issue of radiological safety significance through various means including press releases, website and media interactions, as appropriate.

AERB involves the relevant stake holders and experts in development of regulatory documents. The process of development of regulatory requirement documents also involves seeking the views/ comments from public on the draft documents before they are published. AERB has established mechanisms wherein the users and stakeholders (TSO, public etc.) can provide feedback on published regulatory documents. The feedback obtained is used for identifying the need for any revision/updation.

AERB regularly conducts awareness programmes on nuclear & radiation safety and regulatory issues, which include seminars, discussion meetings, conferences and feedback meetings wherein the licensees, TSO & experts and key interested parties are invited. These provide opportunities to AERB for obtaining feedback on its regulatory activities. AERB has started conducting the annual National Conference on Regulatory Interface (NCRI) since the year 2017, with an objective to foster an environment wherein, the stakeholders and professional associations could interact, discuss safety & regulatory issues and provide valuable feedback to AERB on various issues related to regulatory requirements and practices world-wide, emerging trends in design and manufacturing, challenges in supply chain and other issues of regulatory interest.

AERB website plays a pivotal role in keeping the public informed on issues related to radiological safety, major regulatory decisions and special technical reports etc. In year 2017, AERB undertook a major revamping of its website to provide more information of public interest, increase radiation safety awareness among the public and to provide more interactive features in specific areas. AERB has made all the National Reports from India to CNS review meetings publicly available on its website. Further, answers to the questions on the Indian National Report for 7th review meeting are also available on AERB website. Based on the suggestions from President of 7th review meeting of CNS, the Country Review Report on India was also posted on the website of AERB.

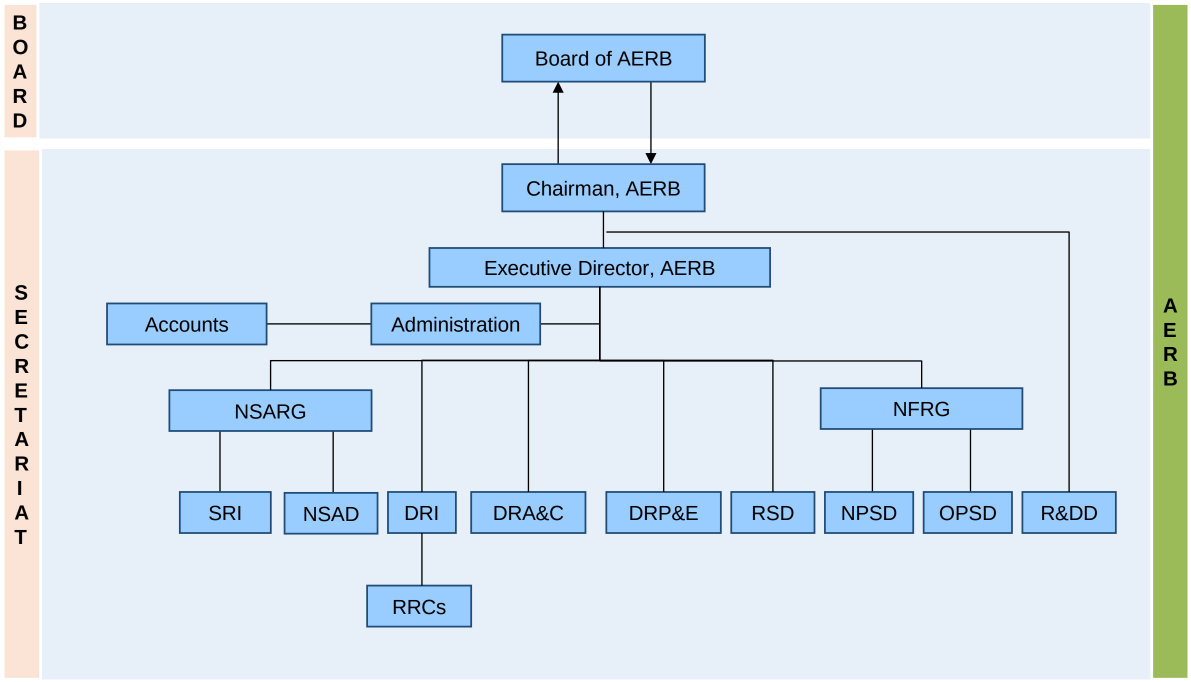
Subsequent to the incidents of leak from pressure tubes at KAPS-1&2, AERB promptly issued a press release on the safety status of the plant and functioning of respective safety systems. Thereafter, AERB kept the public/media informed by issuing updates on the incident and the subsequent investigations. After the conclusion of the IRRS Mission, AERB held a press-briefing for disseminating the information on the international peer review of the safety regulatory activities in India. Further, India also made public the report of IRRS Mission on AERB's website. The outcome of statutory audits of AERB's regulatory activities has also been made public together with their assessment by high level parliamentary committees.

In order to formalise its methodology related to sharing of information and engaging with the media and the general public, a formal communication strategy is being issued.

8.6 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

As atomic energy programme in India is expanding, the regulatory body has made significant efforts to keep pace with the developments. Since its constitution in 1983, AERB has built up its technical and managerial capabilities to meet these requirements. The position of AERB in the government set up ensures administrative and financial independence in its functioning. The Central Government provides the financial resources to AERB according to its proposed budget. Technical support is drawn from various national laboratories as well as from other national academic and research institutions. The statutory and legal provisions of the Atomic Energy Act and various rules framed thereunder and the powers conferred by the gazette notification provide AERB with the necessary authority for independent and effective functioning. Hence, India complies with the obligations of Article 8 of the Convention.

Annex 8-1: Organisation Structure of AERB



The Board is assisted in execution of its mandate by Secretariat. Chairman of the Board is also vested with the executive functions of the Secretariat. The Secretariat of AERB has its Offices at Head Quarters, Mumbai, Regional Regulatory Centres (RRCs) at Chennai, Kolkata and New Delhi and a Safety Research Institute at Kalpakkam.

The jobs and responsibilities of the Secretariat is distributed among various Groups/Directorates/and is supported by Accounts Division (w.r.t financial matters) and Administration Division (w.r.t establishment and office administration matters). All the Groups, Divisions and Directorates, until and unless specified, function under the general guidance and supervision of Executive Director, AERB, who in turn reports to Chairman of the Board.

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ARTICLE-9: RESPONSIBILITY OF THE LICENCE HOLDER

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

9.0 GENERAL

Under the Atomic Energy Act, 1962, a licence is required for acquisition, production, use, export or import of any plant designed or adopted or manufactured for the production and development of atomic energy or research. The Act requires that only Central Government or any authority or corporation established by Central Government or a Government Company can produce, develop, use and dispose atomic energy and carry out research into matters connected therewith. The Atomic Energy (Amendment) Act, 2015 makes consequential amendments and re-defines the term 'Government Company'. Any licence granted to a Government company shall stand cancelled in case the licensee ceases to be a Government company.

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

As brought out in Article-8, Government of India has established Atomic Energy Regulatory Board (AERB) to carry out regulatory and safety functions envisaged in the Atomic Energy Act, 1962 with regard to safety during nuclear power generation and use of ionizing radiation in the country. AERB is mandated to develop safety regulations for NPPs in the country.

The regulatory requirements assign the primary responsibility for safety in design, construction, commissioning, operation, maintenance and decommissioning of NPPs to the licensee. It is the responsibility of the licensee and its constituent units to establish the appropriate management systems to perform their activities as per the regulatory requirements and demonstrate to the regulatory body that all the activities of the NPP meet the established safety norms.

This report describes, inter alia the systems and organisational set-up in NPCIL, AERB and other organisations for fulfilment of the intent of this Article. Broadly all requirements/obligations as applicable to NPCIL with regard to responsibility of licence holder are also applicable to BHAVINI. Hence, all aspects discussed in the report relating to NPCIL are also to be read as applying to BHAVINI too. However, as NPCIL is currently involved with light water and heavy water reactors and BHAVINI with fast breeder reactor, specific requirement related to the respective reactor technologies would be different. Presently, BHAVINI is involved in setting up of Prototype Fast Breeder Reactor at Kalpakkam and does not operate any nuclear power plant.

9.1 NATIONAL LAWS AND REGULATIONS

Atomic Energy Act, 1962 and the rules framed there-under provide the main legislative and regulatory framework pertaining to atomic energy in the country and provide for the development, control and use of atomic energy for the welfare of the people of India and for other peaceful purposes and matters connected therewith. The presidential (gazette) notification for establishment of AERB in the year 1983, gives power to frame rules and regulations in regard to regulatory and safety requirements envisaged under the Atomic Energy Act, 1962 and enforce them as 'Competent Authority' for radiation safety in the country. AERB is mandated to develop safety codes and standards applicable to NPPs in India. 'Atomic Energy (Radiation Protection) Rules, 2004' issued under the Atomic Energy Act, 1962 defines the 'Responsibilities of Licensee'. As per the rules, the Licensee shall ensure compliance with the Safety Codes and Safety Standards issued by the competent authority (AERB) from time to time.

AERB Safety Code on 'Regulation of Nuclear and Radiation Facilities' (AERB/SC/G,2000), brings out requirements and obligations to be met by nuclear or radiation facility to qualify for issue of regulatory consent at every stage. As per the safety code, the licensee is solely responsible for ensuring the safety in siting, design, construction, commissioning, operation and decommissioning of a Nuclear Power Plant and shall demonstrate to regulatory body that the safety is ensured at all the times. The Safety Code on Nuclear Power Plant Operation (AERB/NPP/SC/O, Rev.1, 2008) also specifies that the Responsible Organisation, as Consentee, shall have the primary responsibility for the safe operation of the NPP.

9.2 RESPONSIBILITIES OF LICENSEE AND MEANS TO FULFIL OBLIGATIONS

Primary responsibility for safety rests with the licence holder as per regulatory requirements. AERB oversees the licensees' activities and management systems for ensuring safety in various stages of NPP viz. siting, construction, commissioning, operation and decommissioning through a system of regulatory consents. The applicant seeking consent submits all the necessary information to the AERB as laid down in the requisite regulation in support of the application for consent. The licensee is responsible to make proper arrangements with vendor(s) and/or contractor(s) to ensure availability of all the required information and also keep the regulatory body constantly informed of all relevant additional information or changes in the information submitted earlier.

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

i. ensure that the operation of NPP is carried out according to the relevant laws, regulations and condition of the licence granted.

ii. develop, preserve, update and maintain a complete set of records related to the safety of the plant.

iii. provide the authorized representatives of AERB full access to personnel, facilities and records that are under its control.

iv. keep AERB fully and currently informed with respect to any significant events or potential for significant event or changes in the considerations, information, assumptions, or expectations based on which the consent was issued.

v. take such corrective actions or measures as required by AERB for safety.

vi. not undertake any activity beyond those authorised in the licence, without the prior approval of AERB.

vii. report all accidents and events related to safety.

viii. keep AERB informed of the changes in station management positions.

ix. ensure that an adequate level of safety shall be maintained during operation through proper operational and maintenance procedures.

x. establish policies to achieve high standards of safety and promote safety culture in the organisation.

xi. make sure that the organisational structures and training & qualification of the operating personnel are adequate to achieve required level of safety.

xii. make sure that the stated procedures for surveillance, operation, maintenance and emergency planning are up to date and followed.

xiii. make sure that radiation protection of the public and the plant personnel is according to the radiation protection regulation. Radiation doses to the public & plant personnel & radioactive discharges from the NPPs are consistent with the principle of ALARA.

xiv. make sure that after a stoppage mandated by AERB, the cause of stoppage has been resolved to the satisfaction of AERB.

xv. make sure that the conditions for renewal of consent as prescribed by AERB are met.

NPCIL Corporate Management System elaborated in the document "Corporate Management System – Quality Management System Requirements" provides the necessary directives for implementation, maintenance, assessment, measurement and continual improvement of the management system for compliance with the regulatory requirements and intents in all phases of the NPPs. This document is applicable for design, procurement, manufacturing, construction, commissioning and operations and other supporting processes for the NPPs. Article-13 on Quality Assurance describes the Safety Management System of NPCIL.

NPCIL carries out assessment and verification of safety at all stages of NPPs through an elaborate internal review mechanism. The mechanism involves review at plant and headquarters level, before each submission is made to the regulatory body. Article-14 describes in detail the internal review mechanism at NPCIL. A typical organisation put in place at an operating NPP to discharge its responsibilities is given in Article-19 (Operation). Article-11 (Financial and Human Resources) covers adequacy of resources to support the safety of each nuclear installation throughout its life and for effective management of accident. Article-16 (Emergency Preparedness and Response) covers EPR infrastructure for management of nuclear emergency in India. Mechanism by which India ensures that the licence holder of the nuclear installation has appropriate resources (technical, human, financial) and powers for the effective on-site management of an accident and mitigation of its consequences, is given in Articles-11 & 16.

India has ratified the Convention on supplementary compensation for nuclear damage and it has a liability regime to cover the damages arising out of a nuclear accident from an NPP, consistent with the convention. The regime of civil nuclear liability is governed by Civil Liability for Nuclear Damage (CLND) Act, 2010, the Civil Liability for Nuclear Damage Rules, 2011 and the Nuclear Liability Fund Rules, 2015.

9.3 REGULATORY MECHANISMS TO ASSESS SAFETY PERFORMANCE & INFLUENCE THE UTILITY FOR FULFILLING ITS PRIME RESPONSIBILITY FOR SAFETY

The regulatory control for assurance of safety during all the stages of NPPs is exercised by AERB through a system of consenting, which authorises the consentee to carry out a specified activity and prescribes requirements and conditions that has to be complied to ensure safety during the authorized stage. AERB prescribes the safety requirements for all stages of NPPs through its regulatory documents, directives and licensing conditions and ensures their compliance by utilities.

For NPPs under construction, AERB monitors safety and ensures compliance with the regulatory requirements by establishing mechanisms of review and assessment, regulatory inspection and enforcement. Licence for operation of NPP is issued for a maximum period of five years. After the issuance of licence for operation, AERB ensures regulatory control over the activities of licensee by way of reporting obligations, inspections, enforcement and Periodic Safety Review (PSR). These are described in detail in Article-14 (Assessment and Verification of Safety) of this report.

AERB has a regulatory oversight programme to overview the aspects pertaining to safety regulation of NPPs. The focus of this programme is to verify effective implementation of licensee's safety management system at all stages of an NPP. Though the primary responsibility for safety lies with the licensee, AERB's oversight programme, in addition to monitoring of safety and ensuring compliance with regulatory requirements, enables AERB to independently verify and confirm that the licensee has an effective self-regulation mechanism and gives overriding priority to safety. AERB also ensures that it accepts the submissions made by the licensee only if the submissions are made after the required internal review by the licensee. In the country the regulatory focus is on encouraging the licensee to self-identify, understand and take ownership of safety issues and improvements. Licensees are also encouraged to analyse the safety issues in more depth and reinforce their continuous improvement programme to ensure safety. Notwithstanding this, the formal regulatory processes of AERB further reinforces the safety in NPPs.

AERB takes initiatives to positively influence the safety culture of licensees so that licensees act voluntarily to comply with the regulatory requirements and need for enforcement actions are minimised. AERB conducts meetings with senior management of licensee to discuss important safety issues to draw management's attention for their timely resolution. AERB has recently started formal programme (National Conference on Regulatory Interface) for obtaining feedback from the licensees and interested parties on the issues pertaining to regulatory processes and to increase the awareness on regulation and safety. Refer Article-8 for details.

9.4 OPENNESS AND TRANSPARENCY

Openness and transparency are two key attributes to achieve confidence of the stakeholders. DAE the nuclear promoter of the country, NPCIL, the NPP operator and AERB, the regulatory body, have been carrying out various public awareness activities in a structured manner for the dissemination of accurate and authentic information on nuclear power, safety aspects of the NPPs, safety regulation of the NPPs and other associated aspects to different target groups of the stake holders on sustainable basis. To achieve this, all modes of communication are being utilised to reach out to the masses. Special emphasis on awareness is placed on public, living in the vicinity of operating stations and upcoming projects. Use of TV commercials, promos in digital cinema, radio jingles, publications, advertisements, street plays, exhibitions, lectures, scientific meets for professionals and media, visit to nuclear power plants, mobile exhibitions in villages, roping in professional public relations agencies are some of them.

NPCIL has created three state-of-the-art permanent "Hall of Nuclear Power" in Mumbai, New Delhi and Chennai. Large number of people, particularly students visit these nuclear galleries every year. The objective of setting up of the galleries is to make people aware of various aspects of nuclear energy through various interactive and user-friendly innovative exhibits. The galleries comprise of innovative displays, touch screen kiosks, interactive games, panels, banners, placards, cut-outs, static/dynamic models, audio/visual presentations, 2D/3D films, quiz, games etc. One of the most striking parts of the gallery is the "Digital Walk-through", which enables visitors to feel as if they were moving inside a nuclear power plant.

Similarly, semi-dynamic nuclear power plant models are also provided by NPCIL to various Science Centres located across the country to showcase working of nuclear power plants with various safety features.

Various Articles, Reports, Press Releases, Rejoinders, Responses, Presentation etc. on Public Awareness, Media Relations and other activities are being posted on NPCIL Website on a regular basis to keep public updated and informed.

NPCIL is also involved in a number of corporate social activities around the NPP sites. NPCIL also shares information with any member of public on request as a statutory responsibility under Right to information Act, 2005. Also, NPCIL promotes open information system concept for sharing information with the public.

AERB also carries out the public awareness programme on safety regulation of NPPs. The public awareness activities being undertaken by AERB are given in Article-8 of this report.

9.4.1 Right to Information

Right to Information Act, 2005 was enacted by the Parliament of Government of India for setting out the practical regime of right to information for citizens to secure access to information under the control of public authorities, in order to promote transparency and accountability in the working of every public authority. The act was amended suitably by the Parliament with latest revision in the year 2013. NPCIL is a Government of India enterprise and hence the provisions of the act are applicable.

NPCIL practices openness and transparency within the framework of above and other applicable legal provisions of the country. In NPCIL an elaborate RTI Application management mechanism exists with functional arrangement of eight Central Public Information Officers (CPIO) and seven Assistant Public Information Officers (APIO), one each at each Station / Site along with one CPIO, one APIO and one Appellate Authority at Head Quarters, to deal with the requests received under the RTI Act 2005.

The mandatory information required under the act is posted on NPCIL website and the information is updated from time to time.

The online RTI applications and appeals received by NPCIL are being effectively disposed off through the online portal of Department of Personnel & Training of Government of India.

9.4.2 Open information system concept

NPCIL has web-based information system, where the information about NPPs is available. In addition, citizens are free to post questions about NPP and prompt information is provided by NPCIL. Citizens are also free to request visit to any NPP and NPCIL arranges the visit to NPPs and provides necessary information to the visitors with link at web address,

https://www.npcil.nic.in/main/knowmore_Nuclear_Power.aspx.

9.5 NATIONAL AUDITS

The India's Comptroller & Auditor General (CAG) has powers to audit the performance of all the institutions of the government and the public sector entities in India. The CAG audit findings are open to the public and can be further examined through the Public Accounts Committee of the parliament of India. Both the regulatory body, AERB and the licensee organisation, NPCIL have undergone such audits in the past.

9.6 INTERNATIONAL PEER REVIEWS

NPCIL is committed to international peer review of its NPPs to bring home learning opportunities from international peers. The details on such reviews are as follows:

9.6.1 WANO Peer Reviews

NPCIL is one of the founder members of World Association of Nuclear Operators (WANO) and has been actively participating in all its programmes like Performance Analysis (Operating Experience, Performance Indicator, Industry Analysis), Peer Review, Training & Development (Training, Workshops, Seminars), Member Support (Member Support Missions, Guidelines and Good Practices, New Unit Assistance, Member Performance Improvement) and Corporate Communications.

Being committed to international peer review programme, NPCIL first invited WANO Peer Review team in 1998 to one of its plants. Since then, first round of WANO peer review has been completed for all the operating NPPs in India. Second round of WANO peer review is completed in most of the NPPs.Third and fourth round of WANO peer review has been completed in some of the NPPs. NPCIL was the first member under WANO Tokyo Centre, which invited WANO Pre-Startup Review team for its construction plant in 2006. So far WANO Pre-Startup review of its six plants at construction stage has been completed including KAPP-3. In the year 2015, Corporate Peer Review of NPCIL was carried out by WANO. The purpose of the review was to assess the effectiveness of the support provided by the corporate office to stations for ensuring safety and reliability. Restart Review of one of the plants which was shut down for a longer duration was also carried out by WANO in the year 2019. In addition, in the past few years WANO has introduced follow-up review in between the WANO peer reviews/Corporate Peer Reviews to follow-up the status of actions taken by the stations/HQ to address the areas for improvements identified during WANO peer reviews/Corporate Peer Reviews.

More than 200 engineers of NPCIL have undergone Standard Peer Review Training conducted by WANO. NPCIL has provided the services of about 65 reviewers to WANO to support its Peer Review programme. The bar chart shown below is indicative of WANO Peer Review, Pre-Start-up Review, Follow-up Review of NPPs and Corporate Peer Review & Follow-up Review of Corporate Peer Review of NPCIL since 2013.

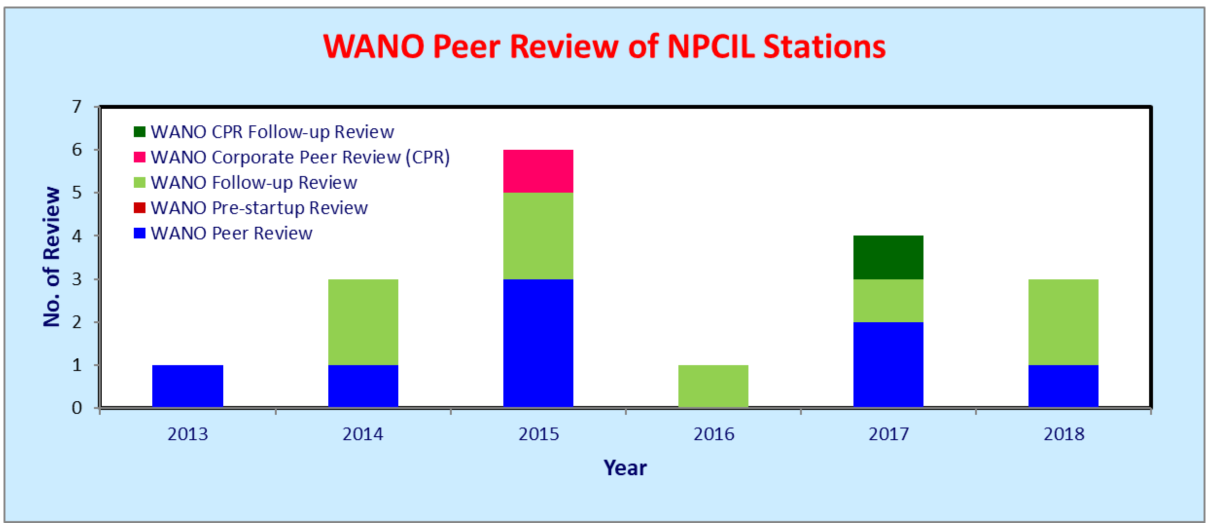

Figure 3 WANO Peer Review of NPCIL stations

Table 4 WANO Peer Review of NPCIL stations

2013	2014	2015	2016	2017	2018
KAPS	NAPS KGS-3&4 RAPS-5&6	RAPS-2 RAPS-3&4 TAPS-3&4 MAPS KAPS NPCIL (CPR)	NAPS	TAPS-1&2 RAPS-1&2 RAPS-5&6 NPCIL (CPR)	NAPS RAPS-3&4 RAPS-5&6

9.6.2 IAEA OSART Mission

Government of India invited IAEA OSART mission in 2012, as per the commitment made during IAEA general conference in 2011, for the peer review of RAPS-3&4 of NPCIL. The OSART mission was completed in November 2012. The OSART team identified a number of good practices of the plant and also made recommendations and suggestions related to areas where operations of RAPS-3&4 could be further reinforced. A comprehensive action plan for addressing all the identified recommendations and suggestions was drawn up by RAPS-3&4 and actions were initiated to address them. A follow-up OSART mission was carried out in February 2014, in which the team noted that action on most of the recommendations and suggestions have been completed and for the remaining ones the action was in progress. Out of 14 OSART observations (7 recommendations and 7 suggestions), 11 observations (79%) were considered fully resolved and 3 observations (21%) were considered as progressing satisfactorily during OSART follow-up mission. Subsequent to follow-up mission, actions on one more observation have been completed (i.e. 86% actions have been completed). Long term safety enhancement actions (i.e. establishment of On-Site Emergency Support Centre and installation of Post-Accident Hydrogen Management System) for resolution of two pending observations are progressing satisfactorily. Status of long term actions is covered in section 6.5.1 of Article-6.

9.7 SHARING INFORMATION INTERNATIONALLY

NPCIL has been sharing information internationally by active participation in operating experience programme of WANO, COG and other international organisations; participation in international meetings and workshops; participation in benchmarking visits.

i. Operating experience

Event sharing under operating experience programme of WANO supports prompt information exchange so as to learn from each other and eliminate recurrence of events. On an average NPCIL shares about 40 events in a year having lessons to be learnt. Following chart demonstrates the sharing of events in the recent past:

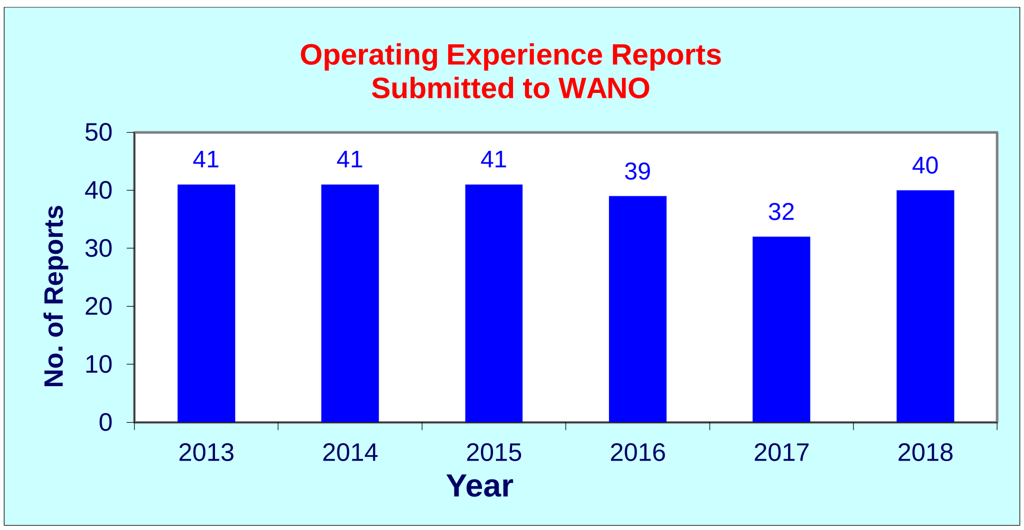

Figure 4 Operating Experience Reports submitted to WANO

Also, a Head Quarter Instruction (HQI) has been issued by NPCIL Corporate Office to guide the stations in implementing OE programme. Each station has an Operating Experience Review Committee (OERC) which periodically reviews and discusses the OE information. The implementation status of the OERC recommendations is regularly monitored.

NPCIL fulfils its international obligation of OE sharing and thus promoting global nuclear safety across the world by periodically sending the event reports of its plants to WANO in the standard event reporting formats. These reports bring out the root cause of the events and the lessons learnt which may be useful to other plants.

ii. Performance indicators

NPCIL shares all the WANO performance indicators (PI) data through web-based data entry system of WANO with all the operating NPPs of the world. The PI programme provides opportunities to improve safety and reliability of our NPPs. All performance indicators are shared on quarterly basis with WANO and industry. While NPCIL shares with nuclear industry performance indicators of NPPs, it also utilises this programme for benchmarking the indicators with nuclear industry elsewhere in the world to support long term improvement in safety and reliability.

iii. WANO Meetings, workshops and seminars

NPCIL has been deputing its officials for participating in various workshops, seminars and training courses conducted by WANO. The above programmes provide a forum for exchange of information on wide ranging topics in the field of nuclear power production, its safety and reliability.

iv. Benchmarking Visits

Benchmarking Visits (Technical Exchange visits) provide an opportunity to benchmark and exchange information between various NPPs and WANO helps in establishing the first contact between the host and visiting NPPs. First such exchange visit in the world was from MAPS, Kalpakkam to a plant in Moscow region. Technical agenda of the exchange visit is set with mutual consultation between host plant and visiting plant. Under this programme, NPCIL team of experts has visited several NPPs in countries like South Korea, Argentina, China, Ukraine, Romania, Russia, Canada and USA. In the year 2018, NPCIL had three Benchmarking visits to overseas NPPs.

Teams from other countries have also made visits to NPCIL plants. These visits have been very useful as NPCIL teams could discuss various issues related to plant operations, maintenance, safety and operating experience.

v. Sharing information with CANDU Owners Group (COG)

NPCIL is active member of COG and event reports are shared among PHWR operators providing focused exchange of information. NPCIL is also member of industry team formed by COG post Fukushima

vi. Sharing information with IAEA PRIS

NPCIL has been regularly sharing information with IAEA for its Power Reactor Information System (PRIS). Information which is shared with PRIS includes energy generation, energy loss (planned, unplanned, external etc.), outages with outage codes, net electricity generation in India from all sources including nuclear, energy supply for non-electrical applications, information about reactors in operation, under construction or planning stage, etc. NPCIL regularly participates in the Technical Meeting and Consultancy Meeting conducted by PRIS.

vii. Sharing information with Nuclear Energy Agency (NEA)

NPCIL has been participating in the meetings conducted by Nuclear Energy Agency (NEA) by nominating its experts as a member of various Working Groups and projects under the OECD / NEA.

9.8 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

The responsibility for the design, construction, operation and maintenance of NPP for producing electrical energy in a safe manner has been assigned only to Government Companies. 'Atomic Energy (Radiation Protection) Rules, 2004', the AERB Safety Code on 'Regulation of Nuclear and Radiation

Facilities' (AERB/SC/G) and AERB Safety Code on 'Nuclear Power Plant Operation' (AERB/NPP/SC/O) clearly assign the responsibility of safety to the licence holder and spell 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.

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ARTICLE 10: PRIORITY TO SAFETY

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

10.0 GENERAL

Atomic Energy Regulatory Board (AERB) and the utilities have policies which emphasize priority to safety in all their activities. Adherence to these policies nurtures and maintains the safety culture developed over the years of experience.

As described in Article-6, safety enhancement in Indian NPPs has been a continuous process. In addition to ensuring adherence to current regulatory requirements for new NPPs, the requirement of periodic safety review brings out the need for safety upgrades in the operating NPPs. Safety assessments were carried out following accidents in nuclear industry that led to safety upgrades in Indian NPPs. Lessons learned from the accident at Fukushima Daiichi NPP and the corresponding safety upgrades were covered in the Indian National Reports to the second extraordinary meeting, sixth and seventh review meetings of the Convention. Status of safety upgrades in Indian NPPs subsequent to the accident at Fukushima Daiichi NPP is covered in Article-6 of the report.

10.1 REGULATORY REQUIREMENTS TO PRIORITIZE SAFETY

The Atomic Energy Act, 1962 has a separate section which deals with safety and specify the requirements with respect to ensuring safety in all activities involving generation and use of nuclear energy and radiation. This section specifically includes the provisions for safety requirements, prohibitions, regulatory mechanism, including inspection and enforcements as well as initiating penal actions. These aspects are further elaborated in Atomic Energy (Radiation Protection) Rules, 2004 and the Atomic Energy (Safe Disposal of Radioactive Waste) Rules, 1987. AERB has been given the powers to exercise these provisions. With its mandate, AERB has formulated Safety Codes and Standards specifying detailed requirements for siting, design, construction, commissioning and operation of NPPs. Safety codes establish the objectives and set minimum requirements that shall be fulfilled to provide adequate assurance for safety. The mandate assigned to AERB is that of safety regulation and no responsibility assigned to it is in conflict with its regulatory role.

AERB Safety Code on ‘Quality Assurance in Nuclear Power Plants’ (AERB/NPP/SC/QA, Rev.1, 2009) provides basic requirements to be adopted for establishing and implementing quality assurance programme for assuring safety. Utility Management shall determine its effectiveness in establishing, promoting and achieving objectives of nuclear safety.

The mainstay of India’s nuclear power programme has been the Pressurized Heavy Water Reactor (PHWR) technology. Design of these reactors is governed by AERB Safety Code on ‘Design of Pressurized Heavy Water Reactor Based Nuclear Power Plants’ (AERB/NPP-PHWR/SC/D, Rev.1, 2009). These reactors being of indigenous design, NPPs get in-house design support for the entire life cycle. To enhance the power generation capacity, India is in the process of setting up Light Water Reactors with foreign collaboration while continuing its own programme of PHWRs and pursuing the design & development of light water reactors. AERB Safety Code on ‘Design of Light Water Reactor Based Nuclear Power Plants’ (AERB/NPP-LWR/SC/D, 2015) requires responsible organisation to set up a ‘design authority’ with responsibility for, and the requisite knowledge to maintain, the design integrity and the overall basis for safety of the plant through its life.

These Safety Codes require that the responsible organisation (utility) shall ensure that safety is given highest priority and shall

i. implement all regulatory policies addressing safety

ii. develop and strictly adhere to sound procedures

iii. review, monitor and audit all safety related design aspects on a regular basis.

iv. ensure that safety culture is maintained.

v. implement design features that have been proven in previous equivalent applications. Where a first-of-a-kind design or feature is introduced, safety is to be demonstrated to be adequate through appropriate supporting research and testing.

vi. ensure that a comprehensive safety assessment of the design and subsequent independent verification is carried out.

AERB Safety Code on 'Nuclear Power Plant Operation' (AERB/NPP/SC/O, Rev.1, 2008) which lays down the requirements for safe operation of NPP, requires that:

i. The plant management shall meet all the requirements of the code on quality assurance for safety in NPP and shall prepare and put in place a comprehensive quality assurance programme covering all activities, which may affect the plant safety.

ii. The management shall inculcate safety culture in plant personnel and develop a policy which gives safety the utmost priority at the plant, overriding the demands of production.

iii. Training shall be oriented to develop safety consciousness and safety culture at all levels of the plant organisation structure.

iv. The management programmes relating to operation review and audit should aim at ensuring that an appropriate safety consciousness and safety culture prevails.

This Safety Code also requires regular and systematic safety assessment of operating NPPs as part of Periodic Safety Review (PSR), wherein comparison of NPP with current safety requirements is made and implementation of necessary corrective actions is identified.

10.2 SAFETY POLICIES AND PROGRAMMES

The safety policies in India are generally in line with IAEA standards IAEA GSR-Part-1 and the IAEA Fundamental Safety Principles, and are enshrined in legal and regulatory requirements.

The NPPs in India are established, operated and maintained by the utilities, which are fully owned by Government of India. Utilities are responsible for design, procurement of manufactured equipment and components, construction, commissioning and operation of NPPs in India and carry out their functions with a commitment to safety and complying to regulatory requirements. Utilities comply with the AERB requirements by issuing and adhering to their safety policies and accord the highest priority to safety in all their activities. Priority to safety is embedded in the vision, core values, mission and objectives of utilities. NPCIL has issued Corporate Nuclear Safety Policy and Corporate Environment Policy. NPPs under operation have issued station level policies, covering both nuclear and conventional safety aspects. Similarly, Occupational Health &Safety Policy issued by BHAVINI gives importance to safety.

Utilities ensure that the consultants and contractors that carry out assignments and activities also follow the safety and quality assurance norms of the utility. Utilities have management systems in place to ensure that safety is accorded priority in its activities.

The management of NPCIL that owns and operates all the currently operating NPPs accords utmost importance to Nuclear, Radiological, Industrial and Environmental Safety overriding the demands of production or project schedules by

- maintaining high standard for safety within plant as well as in the surrounding areas
- ensuring that health, safety and environmental factors are properly assessed for all NPPs

- ensuring that all employees, contractors, transporters working for NPPs adhere to safety requirements while carrying out their responsibilities
- keeping the public at large informed about the safety standards and regulatory practices that are being adopted at NPPs

Each NPP ensures that their work place is safe and their employees including that of contractors adopt safe working procedures. Individual units also ensure that they have effective on-site and off-site emergency plans, which are implemented and rehearsed periodically so that in the unlikely event of any accident, the impact on the public and environment is minimized. Some of the important activities for implementation of safety policies are

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

All Indian NPPs are ISO-14001 (Environmental Management System) and IS-18001 (Occupational Health and Safety Management System) certified. Directorates at NPCIL HQ responsible for engineering, procurement, safety, quality assurance and knowledge management functions have obtained ISO 9001: 2015 certifications.

Regulatory processes like continuous safety surveillance of NPPs (through review of performance reports, radiological safety aspects, event reports and other routine submissions from NPPs), regulatory inspections, periodic safety review for licence renewal, safety culture assessment etc. are employed to oversee arrangements used by the licence holder to prioritize safety. In addition, AERB has developed safety performance indicators for assessing the safety performance of the operating NPPs. These indicators are based on factors such as occurrence of significant events, adherence to technical specifications for operation, review of radiological safety aspects, findings of regulatory inspections and safety reviews. Towards formalizing the safety performance indicators, feedback is being obtained on these indicators from the utility.

AERB has adopted Integrated Management System (IMS) in line with IAEA Safety Standards and by taking relevant inputs from ISO 9001:2015. It integrates all the processes and practices required for functioning of AERB into one complete framework with primary focus on leadership for safety at all levels in the organisation. AERB's Management System identifies safety as a priority and provides guidance for its promotion and continuous improvement.

For pursuing the stated policies, certain general safety principles are followed in all aspects pertaining to NPPs and their regulation, as brought out in the ensuing sections.

10.3 GENERAL SAFETY PRINCIPLES

Nuclear installations are established and operated by keeping the safety objectives as a priority goal. The Codes, Guides and Standards issued by the AERB are the primary documents detailing principles, requirements, practices and policies for safety in siting, design, construction, commissioning and operation of NPPs. These Codes, Guides and Standards have evolved over years taking into account experience gained from Indian NPPs, relevant documents issued by IAEA and regulatory bodies of other countries.

The broad concepts of Defence-in-Depth and ALARA are the main guiding principles followed in design and operation of plants.

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

In general, the safety principles, practices and procedures are adhered to during various phases of NPP and are described in the following sub-sections:

10.3.1 Siting of NPP

Siting being the first phase in setting up an NPP, safety practices in this phase include

i. Rigorous assessment of design basis for external events.

ii. Considerations for exceedance of design basis.

iii. Graded dose criteria defined for different plant states correlating with requirements for countermeasures and avoiding long term off site contamination

iv. Determining the adequacy of protection of the nuclear power plant against internal and external hazards as part of periodic safety review

Consideration of natural and human induced hazards during siting of NPP and in the entire lifetime is covered in Article-17.

10.3.2 Design, Construction & Commissioning of NPP

All through the process of design, manufacturing, construction and commissioning, QA systems (refer Article-13) are implemented effectively to assure that safety principles are given highest priority. These processes are indicated below:

i. A thorough and systematic approach is followed in the design, review and approval in line with applicable quality requirements.

ii. Safety design criteria defined in the different design documents are reviewed and approved by AERB. The safety design criteria also take into account feedback from the operating experience. The design is based on National and International codes and guides.

iii. The detailed safety design is presented through design notes, design calculations and drawings. QA procedures are followed by utility for preparation, review and approval of all design documents. Proper control is exercised for implementing design changes and 'as-built' drawings are maintained.

iv. At appropriate stage, plant systems are formally handed over from construction group to operations group. This transfer is systematically documented in the form of construction completion certificates and system transfer documents.

v. For each system, commissioning procedures are prepared to verify design through individual equipment tests and integrated tests. During commissioning, base line data are collected for future reference. Commissioning reports for each system are prepared, reviewed and preserved.

vi. For computer based systems, independent verification and validation is carried out as per AERB safety guide 'Computer based systems of PHWRs' (AERB/NPP-PHWR/SG/D-25).

NPCIL Safety Review Committee on Project & Design (SRC(P&D)) reviews the safety related design documents to ensure that safety principles are adhered to in design. The committee reviews features related to safety in new designs, design changes in already approved safety and safety related systems, Technical Specifications for Operation which translates the design requirements to safe operating policies, feedback from any safety related event at operating units etc. The reviews also assure that the outcome of regulatory reviews has been effectively considered.

Similarly, internal review mechanism has been established for BHAVINI for review of the design safety aspects of PFBR project.

10.3.3 NPP Operation

The NPP operations are governed by safety policies, safety culture and the good operating practices with the following elements:

i. In the normal operation regime, ALARA is the governing principle. Dose limits for normal plant operation are specified by AERB which are in line with ICRP recommendations.

ii. The limits specified in the Technical Specifications for Operation are approved by AERB. Adequate margins between safety limits and operating parameters are maintained by appropriate interlocks and administrative measures.

iii. NPP is operated by qualified and licensed staff only. The licence to operating personnel is issued by following a well-established procedure approved by AERB.

iv. Annual Collective radiation dose budgets for normal operation and for special maintenance campaigns are prepared by utilities and approved by AERB after multi-tier review. As a part of regulatory review, compliance to approved dose budget is ensured.

v. Equipment and instruments are subjected to regular surveillance as per the frequency defined in Technical Specifications for Operation and other governing documents.

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. NPP operation, incidents and safety issues are reviewed by Station Operation Review Committee (SORC) at NPP level. The station management keeps AERB informed of the outcome of these reviews.

ix. Submissions made by NPP for regulatory clearances are first reviewed by SORC and then by Safety Review Committee (Operations) at the Corporate office of NPCIL.

x. For all significant events, root cause analysis is carried out and corrective actions are implemented.

xi. For non-standard jobs involving safety, special procedures are made and regulatory approval is obtained. Appropriate mock ups are also carried out wherever necessary.

xii. The Radiological Safety Officer (RSO) at each NPP maintains a close watch on radiological status and events at plant and submits periodic report to AERB (refer Article 15).

The QA group and the Technical Audit Engineer at NPP give independent feedback to the station management on operation and maintenance of plant. NPCIL's corporate QA group also conducts periodic audits. Each station is subjected to a corporate peer review conducted by a team constituted by corporate office drawn from other stations owned by NPCIL. This review is carried out once every three years for each NPP. In addition, NPCIL stations also undergo WANO peer reviews.

Well-defined procedures exist within NPCIL which address issues related to safe operation. These are detailed below:

i. The normal plant operation is governed by Technical Specifications for Operation, which is approved by AERB. The Limiting Conditions of Operation (LCO) for various systems and their surveillance frequency are a part of the Technical Specification for Operation. Protection system actuation set points are defined through Limiting Safety System Settings (LSSS) and the set points are tested as per frequency defined in Technical Specification for Operation. In addition, Safety

Limits are specified in Technical Specifications. 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. For routine operations, NPPs maintain Operating Procedures cum Check Lists (OPCCs), Maintenance Procedures, Operating Instructions, QA Procedures, ISI Procedures etc.

ii. Event based Emergency Operating Procedures (EOPs) for internal and external events are prepared for NPPs. These EOPs are part of control room operator licensing curriculum and to the extent practical are implemented on simulators for training purposes. Additionally, Symptom based EOPs have been prepared and are under implementation.

iii. Accident Management Guidelines (AMG) are prepared by utility, the technical bases of which are reviewed by AERB. These guidelines are available at all NPPs and operating staff have been trained for implementing the same.

iv. The Emergency Preparedness and Response Plans for both On-site and Off-site emergencies are available at all NPPs. Emergency exercises are carried out routinely to ensure the adequacy of these plans. (refer Article-16).

10.4 SAFETY PRINCIPLES OF AERB

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

i. Permits activities according to the mandate given to it, through a consenting process. AERB stipulates and enforces the conditions of consent.

ii. Develops safety, codes, standards and guides taking into account the Indian conditions, requirements for the country, recommendations of international organisations and the best practices of other countries.

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

iv. Adopts the principle of “management by exception” following a graded approach through a system of safety committees where issues of greater safety significance are given consideration in higher-level safety committees for resolution.

v. Encourages self-regulation by the licensee.

vi. Considers licensee as a partner in safety and extends all necessary assistance in the interest of safety, where appropriate.

vii. Invites participation of utilities in the regulatory process.

viii. Conducts periodic inspections of NPPs and channels its resources according to the safety performance of the licensee.

ix. Encourages licensee to achieve high level of safety culture.

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

xi. Conducts its activities in an open and transparent manner.

AERB follows a multi-tier review process for safety review of new and operating NPPs (refer Article-14). The activities of siting, design, construction, commissioning, operation and related regulatory consents follow procedures and policies prioritizing safety.

AERB has established graded approach for regulatory functions. The staff at AERB is involved in effective implementation of graded approach and detailed guidelines in this respect are being formulated.

10.5 SAFETY CULTURE, ITS DEVELOPMENT AND ASSESSMENT

AERB encourages every utility to institute a good safety culture during all the stages including design, construction, commissioning as well as operation of NPP. The regulatory requirement for establishing safety culture within utility is delineated in the AERB Safety Code for Quality Assurance in NPPs (AERB/NPP/SC/QA (Rev.1)), Safety Codes for design of NPPs (AERB/ NPP-PHWR/ SC/D (Rev.1), AERB/NPP-LWR/SC/D) and Safety Code for NPP operation (AERB/NPP/SC/O (Rev.1)).

NPCIL has established a system for safety culture assessment of operating NPPs. This is in accordance with the requirements of NPCIL HQI titled 'Assessment and Fostering of Safety Culture at Nuclear Power Stations'. The system involves both safety culture assessment based on documented data in the station and safety culture survey.

As a part of this system, each station carries out following activities.

- Evaluation of various safety culture process inputs by Safety Culture Assessment Panel (SCAP) members independently against the set criterion.
- Conducting quarterly review of outcome of the said evaluation process by SCAP members jointly to identify significant safety culture issues and corrective actions to address them.
- Conducting annual safety culture survey
- Review of safety culture survey results by SCAP
- Overall assessment of safety culture annually by station management and issuing corrective action programme.

The above process is supported by training and effective top down and bottom up communication at the station.

The review and assessment of the safety culture is also a part of AERB's continual safety review process. Continual safety review involves extensive interactions with plant, personnel and management which provide opportunity for the regulators to assess the broader perspective on the safety culture prevailing at the NPP. Events occurring at the nuclear installations, findings of regulatory inspections and management response to events and regulatory recommendations, implementation of operational experience feedback, trends in radiological performances, observations of AERB personnel participating in licensing interviews of control room staff and plant management also give insights on the safety culture prevailing at the NPP.

AERB is in the process of developing the mechanism for assessing the safety culture of NPPs. Currently, Safety Culture assessment for operating NPPs is carried out on an annual basis by AERB. This assessment is based on indicators which have been developed in-house in AERB to recognize early symptoms/signs of declining safety culture. In developing these indicators, AERB has used inputs from the documents of OECD-NEA and IAEA. In order to evaluate the safety culture of NPPs, regulatory inspection findings along with insights from safety review are mapped to these indicators.

AERB management system has an internal process for promotion & sustenance of safety culture in AERB. AERB has a process for self-assessment of safety culture. Based on the established procedure, safety culture survey for AERB staff had been carried out. The survey results were analyzed and mapped to the established safety culture attributes. If the result of the analysis shows degrading trend in any of its attribute, management action is initiated regarding the same.

AERB and NPCIL have been participating in various international workshops, meetings, missions etc. on safety culture, in order to adopt best practices for promotion and assessment of safety culture. Arrangements for safety management, safety monitoring and self-assessment, independent safety assessments are elaborated in Article-14 (Assessment and Verification of Safety).

10.6 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

Safety is given overriding priority by all organisations engaged in activities directly related to nuclear installation. AERB and utilities have stated safety policies that give utmost priority to nuclear safety. Principles, practices, procedures and the review mechanisms adopted towards meeting the objectives of these policies ensure that safety is given overriding priority in all the activities related to safe operation of NPPs. Therefore, India complies with the obligations in the Article-10 of the Convention.

ARTICLE 11: FINANCIAL AND HUMAN RESOURCES

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

11.0 GENERAL

This Article describes 'Financial and Human Resources' of the utilities. The resources of AERB are described in Article-8: Regulatory Body.

11.1 FINANCIAL RESOURCES

The Nuclear Power Corporation of India Limited (NPCIL) is a Public Sector Enterprise under the administrative control of the Department of Atomic Energy (DAE) of Government of India. NPCIL was formed in September 1987 by converting the erstwhile Nuclear Power Board, a Central Government department into a government owned corporation in accordance with the provisions of the Atomic Energy Act, 1962. At the time of formation of NPCIL, all the assets (except the first unit of Rajasthan Atomic Power Station RAPS–1) were taken over by NPCIL. RAPS-1 has been retained as a Government owned unit, being managed by NPCIL on behalf of the Government. The main objective of NPCIL has been to increase nuclear power generation capacity in the country, consistent with available resources in a safe and economical manner in keeping with the growth of energy demand in the country.

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

NPCIL is a wholly owned company of Government of India and is registered under Indian Companies Act,1956. The company has a fully subscribed and paid up share capital of ₹ 114912 Million. The company has reserves in excess of about ₹ 238921 Million. The gross block of the company at its inception (comprising of TAPS - 1&2, RAPS - 2 and MAPS - 1&2, totaling 960 MWe) was only ₹ 4480 Million which has now grown to (6680 MWe excluding RAPS-1) about ₹ 346625 Million as of March, 2019 end. NPCIL is a profit-making company and has been paying annual dividends of the order of 20% to 30% of profit after tax to the Government of India.

The financial resources of NPCIL come from 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 and internally generated resources by sale of electricity. The expenditure towards safety improvements in the NPPs throughout its lifetime are met through internal resources generated by NPCIL. Adequate financial discipline and prudence are exercised in borrowing money from the market. Gestation periods of the projects are progressively optimised so as to keep financing cost including interest during construction, at a reasonable level. Due diligence is exercised about debt obligations and there is no default in repayment of principal and/or interest. The credit rating conferred for market borrowings of NPCIL by agencies like CRISIL, CARE, and Acuité Ratings & Research is AAA denoting the highest safety, which helps the company to borrow money from the capital market at the most competitive rates.

BHAVINI is a fully owned Enterprise of Government of India. Mandate of BHAVINI is to construct, commission and operate the first 500 MWe PFBR at Kalpakkam in Tamil Nadu and follow it up with future Fast Breeder Reactors. Majority of the equity share capital of BHAVINI is held by the Government of India with nearly 5% share capital held by NPCIL.

11.1.1 Operation and Maintenance

NPCIL, as the owner of NPPs has the obligation to provide adequate finances for operating the nuclear power plants in a safe manner to meet its own mission and the requirements of AERB.

NPCIL generates its revenue primarily by sale of electricity. Its present annual revenue is typically ₹ 117533 Million. In line with the provisions of the Atomic Energy Act, 1962, the tariff for electricity from each station of NPCIL is notified by DAE in consultation with Central Electricity Authority. The parameters such as the capital cost, the market borrowings, input costs are factored into arriving at the various components of tariff.

NPCIL sells its electricity to 30 State Electricity Boards (SEBs) / distribution companies (DISCOMS) primarily located in Northern, Western and Southern regions of the country. The monthly invoices based on the approved tariff along with the price variation adjustment are raised on SEBs/DISCOMs in the first week of subsequent 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 invoices and payments are expected to be received during the next two months of billing.

The Operation and Maintenance (O&M) expenditure for each station is budgeted every year. It is being funded by internal resources generated by the NPCIL. In addition, whenever it is necessary to finance any major capital works/upgradation etc., the resources are raised through borrowings or from internal surplus. Since the tariff is similar to the principle of cost plus basis, O&M expenditures are covered through tariff in addition to recovering the capital charges such as giving a return on equity capital and providing depreciation subject to the units operating at normative capacity factors. The internal surpluses are deployed for the nuclear power plants in operation as may be required and for nuclear power projects under construction. The financial resources are budgeted on a yearly basis. Adequate planning is done throughout the lifetime of the plant, to ensure availability of financial resources to avoid any constraints, either existing or foreseen, for the safe operation and maintenance of the NPPs.

In accordance with the Disaster Management Act, 2005, the responsibilities for handling off site radiological emergencies have been assigned to the state and central government agencies and further elaborated in the EPR plans (Refer Article-16). The central and state governments provide funds for immediate relief and rehabilitation to address the needs of the affected population in case of a radiological emergency. The Civil Liability for Nuclear Damage Act enacted in the year 2010 provides for prompt compensation to the victims of nuclear incident through a no fault liability regime channeling liability to the operator. Pursuant to the Civil Liability for Nuclear Damage Act, 2010, the Nuclear Liability Fund Rules, 2015 have been promulgated. The rules establish a Nuclear Liability Fund which comprises the levy collected from operators of nuclear installations.

11.1.2 Renovation and Modernization (R&M)

R&M activities for NPPs in operation are of two types. The first involves routine replacement of operation and safety related components and equipment based on their performance requirements in which expenditure is relatively small. Expenditure on this type is met through the revenue budget of the respective stations and is covered by the tariff as part of O&M expenditure. The second type involves funding for any major safety up-gradations in line with the regulatory requirements generally based on a PSR or based on operating experience feedback both national/international events or refurbishment of the major components of the plant because of operation requirements or technological obsolescence (R&M activities are brought out 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 5 paise per kWhr was started in the year 1996 primarily with the intent of carrying out the renovation and modernization of older generation reactors. The money collected through R&M levy was kept in a committed reserve account. R&M levy was started in 1996 and after accumulating adequate reserves, the same was stopped from 1st December 2003. Situation will be reviewed from time to time, taking into account the adequacy of resources available with the corporation. In case R&M expenditure is incurred by NPCIL, the same is considered at the time of fixation of tariff for recovery through sale of power.

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

11.1.3 Decommissioning and Waste Management

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

Out of the 22 operating nuclear power reactors, the two boiling water reactors at Tarapur are the oldest. They were commissioned in the year 1969 and have completed 50 years of operation. The units have progressively undergone safety enhancements in the past (Refer Article-6). Similarly, the PHWR based NPPs have been undergoing renovation and modernization programmes. In this connection, En-masse Coolant Channel Replacement (EMCCR) and En-masse Feeder Replacements and necessary safety up-gradations of RAPS-2, MAPS-1&2, NAPS-1&2 and KAPS-1&2 have been completed as applicable. These major jobs have given a very good insight of technical capabilities and financial requirements for decommissioning.

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

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

11.2 HUMAN RESOURCES

Availability of qualified and trained manpower for the nuclear power programme has been one of the greatest strengths in India. Realizing the importance of qualified and trained manpower, DAE started Human Resource Development programme in early 1950s, 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 are recruited on an annual basis and are trained in the BARC Training schools, premier institutes for training in nuclear science and technology, through one-year rigorous training course including theoretical and practical aspects of nuclear engineering and sciences. Subsequently when the training needs for the operating nuclear power stations arose, the Nuclear Training Centres (NTCs) have also been set up at the NPP sites. The core of the manpower for the nuclear power programme comes through these training centres. In addition, experienced manpower from conventional power and industry are inducted.

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

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

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

11.2.1 Arrangements and Regulatory Requirements for Human Resources at NPPs

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

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

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

11.2.2 Competence Requirements and Training Needs of NPP Personnel

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

NPCIL has qualified and trained manpower, meeting the job requirements at all levels, be it technicians, scientific assistants or engineers and scientists. NPCIL has embarked on a large recruitment plan in the last few years and the staff strength as on March, 2019 was more than 11400 out of which more than 9500 were Scientific & Technical personnel. Competence requirements and training needs of all key persons are ensured before they are deployed for carrying out the safety related activities in nuclear installations.

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

More than 100 training officers are posted in all the training centres to look after the initial induction training, qualification and re-training requirements at stations. Additionally, for imparting training in a specific field / area, experts from stations, as well as other organisations including AERB are invited. The trainers have operation and maintenance experience. Some of the trainers are licensed control room operators who also provide training on simulators.

A total financial resource of approximately 2% of the revenue budget is allocated for training activities in NPCIL viz. training, qualification, re-training and training infrastructure requirement.

11.2.3 Training of Operations Staff

The training and licensing scheme of the operating staff is as per AERB requirement. Presently, NPCIL has eight Nuclear Training Centres (NTCs), where graduate engineers and technicians are trained. NPCIL has full-scope training simulators at RAPS, KGS, TAPS-3&4, KAPP-3&4 and KKNPP. Full scope training simulator is also available in PFBR. These training simulators provide necessary training to the operating personnel.

11.2.3.1 Induction and Initial Training

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

i. Academic Qualification and Experience

The personnel occupying positions at level I, II and III need to be graduate engineers with relevant work experience of 8, 6 and 3 years respectively. Those who are diploma in engineering can occupy positions at level III and IV 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 programmes of 1, 1½ and 2 years duration is an essential entry Level pre-requisite for those entering directly at Level- III, IV & V respectively. Training mainly focuses on providing sound foundation on nuclear reactor fundamentals, station specific equipment and system knowledge, training towards nuclear and industrial safety, radiation protection, emergency preparedness and work controls.

11.2.3.2 Licensing, Qualification and Certification Programme

i. Authorisation Based Training

After completing the initial training, a candidate is required to complete the authorisation based training programmes such as Radiation Protection Training, Station Protection Code (SPC) and Electrical Authorisation. Successful completion of these authorisation based training is mandatory before taking up final certification examinations.

ii. On Job Training

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

iii. Simulator Training

Simulator training mainly provides experiential learning of control room operation. Training is based on the approved guidelines for normal operations i.e. start-ups / shutdowns, handling of anticipated operational occurrences (AOOs) and use of emergency operating procedures (EOPs) related to main plant. In respect of fuel handling system operations, it provides necessary practice of safe Fuel Handling operation and handling of AOOs. In the absence of plant simulator at a plant, the requirement of simulator training is met by providing training at a simulator located at a plant having similar design (refer section-11.2.4).

iv. Licensing / Certification Stage

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

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

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

A candidate after successfully completing the pre-requisites of licensing procedure appears before the Final Assessment Committee. Final Assessment for level–I, II & III position is conducted by a committee constituted by AERB and only after satisfactory performance the candidate is licensed for the given position.

v. Qualification

The personnel occupying level-IV & V positions in control room are qualified by the plant management and the process of qualification is carried out under its control. This task is performed by a Committee constituted by NPCIL.

vi. Management Training for level-1 position

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

vii. Senior Management 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 a committee constituted by AERB.

The management structure at the NPP is included in the Technical specifications for operation approved by AERB. Accordingly, any change in management structure has to be reviewed and approved by AERB.

11.2.3.3 Re-training/Re-Licensing Process

i. Re-training Process

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

ii. Re-Qualification Process

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

iii. Re-authorisation Process

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

11.2.4 Plant Simulators

Each Nuclear Power Plant site of NPCIL has a training centre. The training centre is for captive use of the station for plant specific training and has a centralized nuclear orientation school for induction training. Advanced training facilities such as plant simulators are provided for reactors of different technologies. These training centres conduct approved training programmes under supervision of the Corporate Training Group of NPCIL.

Simulator with KAPP-3 as reference unit

As mentioned earlier, currently there are six full-scope simulators catering to the varied nature of training requirements in NPCIL. The simulator with RAPS-2 as the reference plant caters to imparting training for personnel working in old PHWR based plants RAPS-1&2 and MAPS-1&2. The two simulators with RAPS-3 and Kaiga-1 as the reference plants are based on the design of standardised 220 MWe PHWR reactors and cater to the requirements of such 220 MWe PHWRs in NPCIL. The simulator with TAPS-4 as reference plant, is based on the design of 540 MWe PHWR and provides training to operators of two such units. The VVER based simulator has been commissioned at KKNPP site to take care of the training requirements of 1000 MWe reactors of VVER design. The sixth simulator with KAPP-3 as the reference plant has been released for training the operators of the two upcoming units of the first 700 MWe PHWRs in NPCIL. With these simulators, NPCIL is able to provide simulator training to all the operating personnel working in its NPPs. In addition, there are three PC based Fuel Handling System (FHS) simulators at Kaiga-1&2, RAPS-3&4 and TAPS-3&4 for imparting training in Fuel handling operations.

Similarly, the full scope simulator of PFBR caters to the training needs of operating personnel of BHAVINI.

11.2.5 Training of Maintenance and Technical Support Staff

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

Arrangement for initial training, qualification and retraining of maintenance and technical support staff also exists at all NPPs in line with operation staff. By ensuring that the operational licence and qualification of the personnel in Technical Services, Quality Assurance and Training sections is maintained, flexibility remains for redeployment of these personnel in operational roles in case of need.

11.2.6 Improvements to Training Programmes

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

Training centres at all NPPs conduct regular training courses and refreshers courses to cover new insights from safety analysis, operating experience, industrial/fire safety, radiological safety and regulatory issues etc. to maintain the personnel competency. Training course material is periodically reviewed to incorporate improvements to training programmes resulting from operational experience, plant modifications and insights from safety analyses. All licensed and qualified personnel undergo periodic training on accident management. Periodic drills are also carried out in which usage of accident management measures are rehearsed, which involve assessment of competence and sufficiency of additional staff required.

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 utilised to promote understanding of difficult dynamic devices.

11.2.7 Sufficiency of Staff at Nuclear Installations

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

There are administrative controls regarding the minimum number of Senior Managers to be present at NPP site to ensure safety of the NPP. In India, multi-unit sites adopt twin unit station concept in order to leverage its managerial resources, while ensuring the availability of dedicated operating staff with regard to safe operation of each unit. The minimum requirement of operating staff, considering the requirements of individual units, is specified in the AERB approved Technical Specifications of Operation. In case of an accident at any of the units, existing staff of the affected unit can be augmented from the other unit while ensuring availability of key staff for safe operation/shutdown of the other unit. This arrangement enables the utility to manage any severe accident with existing manpower at the station. If required, the staff can be further supplemented by trained personnel from other similar design NPPs and NPCIL HQ.

11.2.8 Use of Contract Personnel

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

Contractor's personnel are not allowed to carry out any job without supervision. They are not deployed for carrying out any operations in the control room and vital areas. Requirement of contractor personnel is also not envisaged in accident management.

Contract personnel have appropriate training and instructions in radiation safety as per the Atomic Energy (Radiation Protection) Rules, 2004 in addition to the appropriate qualification and training required for performing their intended tasks.

11.2.9 Regulatory Review and Control Activities

AERB's assessment of aspects related to human resources are carried out at the time of initial licensing (based on which the LCOs are included in the Technical Specifications for Operation of the NPPs) and during the PSRs.

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

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

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

11.3 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

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 these needs. Therefore, India complies with the obligations of Article-11 of the Convention.

ARTICLE 12: HUMAN FACTORS

Each Contracting Party shall take the appropriate steps to ensure that the capabilities and limitations of human performance are taken into account throughout the life of a nuclear installation.

12.0 GENERAL

Human and organisational factors have a very important role in assuring safety. Therefore, human factors need to be duly accounted while considering siting, design, construction, commissioning and operation of NPPs to ensure that the capabilities and the limitations of human performance are taken into account. Assessment of human and organisational performance is an ongoing process and corresponding improvements are made based on the insights gained.

12.1 REGULATORY REQUIREMENTS

AERB Safety Codes on 'Design of PHWR based NPPs', AERB/NPP-PHWR/SC/D (Rev.1, 2009) and 'Design of LWR based NPPs' AERB/NPP-LWR/SC/D (Rev-0, 2015) inter-alia establishe~~s~~ the requirements for design for optimised operator performance. This includes the need for designing working areas and environment according to ergonomic principles, a systematic consideration of human factors and the man-machine interface. Safety Guides on 'Safety Related Instrumentation and Control for Pressurised Heavy Water Reactor Based Nuclear Power Plants' (AERB/NPP-PHWR/SG/D-20) and 'Radiation Protection in Design' (AERB/NPP-PHWR/SG/D-12) provide guidance regarding design for optimum human performance. AERB Safety Code on 'Nuclear Power Plant Operation' (AERB/NPP/SC/O, Rev.1, 2008) gives requirements to reduce the human errors. AERB technical document on 'Human reliability analysis (methods, data and event studies) for NPPs' (AERB/NPP/TD/O-2) provides various methods and illustrative examples for estimation of human error probabilities.

Organisational factors and managerial aspects have a major impact on the behaviour of individuals. AERB Safety Code on Quality Assurance in NPPs (AERB/NPP/SC/QA, Rev.1, 2009) covers the managerial commitment to improve human factors to enhance the safety in NPPs. It requires that management shall determine the competence requirements for individuals at all levels and shall provide training or take other actions to achieve the required level of competence.

AERB has identified the significance of consistency in application of regulatory requirements as well as decision making and developed dedicated methodologies/ procedures for various regulatory processes for safety oversight.

12.2 HUMAN FACTOR CONSIDERATIONS

12.2.1 Siting

During the siting stage, multi-disciplinary inputs (such as data obtained from geotechnical and meteorological investigations, site seismicity studies, hydrological studies, epidemiological studies and feasibility of off-site emergency response plan) are obtained from various agencies for site suitability assessment for proposed nuclear installation. Proper organisational arrangements for effective interfaces and assessment of human factors such as competency of personnel performing these investigations/ studies are required to be ensured for acceptable quality of data analyses needed for siting consent. These aspects are addressed in the utility's QA Manual for Siting which is also reviewed by AERB, in addition to Site Evaluation Report prior to issuance of Siting consent.

12.2.2 Design

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

12.2.3 Operation

The nuclear installations are operated within the limits specified in the technical specifications for operation, reviewed and approved by AERB. To ensure a high degree of quality in operation of an NPP, all control room operators are graduate engineers who are trained and licensed as per the licensing procedures approved by AERB. All activities including surveillance testing are performed using 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. Post-job debriefing is done for certain types of jobs to identify the areas of improvement with respect to best practices and taking appropriate actions for enhancing human performance. NPCIL establishes plant configuration control procedures to prevent human errors during outage management, maintenance and implementation of engineering changes. Human factors are considered during the design modification as a part of configuration management. Necessary changes in the relevant documents, training and O&M procedures are carried out after every modification subjected to appropriate review and approvals.

12.2.4 Training

Training of staff for normal and off-normal operating conditions on full scope simulator is a mandatory regulatory requirement for their licensing. The simulator training focuses on reinforcement of operator fundamentals and use of human error prevention tools like pre-job briefing, three way communication, peer-check and self-check to minimize probable errors. Performance based training, need based training and training at manufacturers place are also imparted for error free maintenance. The training programme also covers aspects related to human performance during accident conditions, as a part of validation of Emergency Operating Procedures (EOPs) during training on simulators. Human response studies are being carried out on plant simulators at KGS-1&2, RAPS-3&4 and TAPS-3&4. Human reliability studies on crew response to plant transients & accident scenarios and the recording of respective timelines for PSA studies has been regularized as a part of crew training programme.

Special training courses are also arranged for all the concerned personnel on the design changes that are carried out. Training sessions relevant to human performance are also organised at different plants in coordination with international organisations like WANO. WANO programmes related to human performance are conducted, with emphasis on human performance enhancement, approach and conduct of operation in handling beyond design basis accident and improving oversight functions to enhance managerial effectiveness.

Training of the NPP staff is described in detail in Article-11: Financial and Human resources.

12.2.5 Event Analysis

An event reporting system is adopted and maintained to report events of varied significance to bring out underlying weaknesses in the system. All the events including low-level events are reported and analysed at various levels in NPCIL. The Significant Event Reports (SERs) are reviewed in AERB. During these reviews, due consideration is given to aspects related to human performance. The lessons learned and corrective actions taken are disseminated through an operating experience feedback system. The weaknesses and areas of concern including safety culture highlighted by the event analysis are specifically addressed during training /retraining of the operation staff. The event reporting and analysis is carried out at station as per the guidelines given in the NPCIL Head Quarter Instructions on 'Event reporting to headquarters including WER for sending to WANO, review and processing' and on 'Root cause analysis of the events'. NPCIL HQI on 'Root cause analysis of the events' includes the methodology to identify if the event has taken place due to human errors.

The low level event management programmes are implemented at NPPs as per the guidelines given in NPCIL HQI. As per these guidelines, the low level events, which are large in numbers, are monitored and trended for identifying latent weaknesses. The remedial measures are implemented by way of design modifications, procedural changes or through specific training modules.

In order to take care of significant events and changes having potential for impact on safety during different consenting stages of NPPs prior to operational stage (i.e. Siting, Construction and Commissioning), regulatory requirements have been introduced to submit report on the event/design change giving details as per Significant Event/Change Reporting Criteria (SECRC). The procedure requires conducting root cause analysis including those related to human factors. The reports submitted under SECRC are reviewed in AERB.

12.2.6 Maintenance

Performance monitoring of maintenance activities with respect to the human factors is carried out on a regular basis. Maintenance activities are carried out adhering to the approved procedures with appropriate stop points to ensure error free maintenance. Use of appropriate tools like training on mock-up facilities, pre-job briefing, three-way communication, peer checking, self-check are inculcated to minimize probable errors due to human factors. Post job de-briefing is done for certain types of jobs to identify the areas of improvement with respect to best practices and taking appropriate actions for enhancing human performance. Easy maintainability, ambient conditions and access to the equipment for carrying out the maintenance are considered during design stage for better human performance.

Since 2016, WANO programmes related to maintenance viz. 'Environment Qualification of Equipment', 'Single Point Vulnerability' & 'System Performance Monitoring' and 'Equipment Reliability' have been carried out.

12.2.7 Programmes for addressing human errors in NPPs

Methods for preventing human errors during the operations and maintenance of nuclear installations are detailed in sections 12.2.3, 12.2.4, & 12.2.6. Methods for analyzing & detecting human errors and means to correct them are given in section 12.2.5.

Human Performance Enhancement programme has been implemented at all stations based on the guidelines given in NPCIL HQI. In accordance with the HQI, the sectional and station level human performance coordinators are identified at each station. The human performance coordinators identify the human performance related issues through various station programmes during operation and maintenance of NPPs and discuss in the meetings of Human Performance Review & Enhancement Committee (HUREC). The committee suggests methods for enhancement of human performance programmes at the station.

12.3 SELF-ASSESSMENT OF MANAGERIAL AND ORGANISATIONAL ISSUES

Self-Assessment and Corrective Action Programmes are implemented in all the consenting stages of NPPs with the objective of continuous improvement in equipment condition, plant performance, work practices and safety culture. Human performance, leadership in safety, managerial and organisational aspects are adequately emphasized in the process of self-assessment. The self-assessment programme is periodically reviewed considering the operating experience and international feedback on such programmes and NPCIL headquarter instruction is suitably revised. The following peer-assessment activities are also carried out at NPPs:

i. NPCIL Corporate Peer Review of NPPs

The Corporate Peer Review (CPR) of NPPs is performed once in three years by a team of experts constituted by NPCIL headquarters for a duration of 9 days. Most of the team members are qualified reviewers and have attended WANO Peer Review Standard training. Some of the team members have WANO peer review experience also. This review is performed based on the document 'Performance Objectives & Criteria for Corporate Peer Review, Revision-1, June 2015', which is similar to the document 'WANO Peer Review Performance Objectives & Criteria'. The team reviews two foundations, seven main functional areas and ten cross functional areas and submits its report to plant management and the corporate office. Team leader of the corporate review team makes a detailed presentation to the Apex Committee for Review of Operating Station Safety (ACROSS). The concerned Station Director briefs about the actions taken on the observations of the corporate review team. The status of corrective actions implemented by the station is submitted to headquarters which is further reviewed by the apex committee at headquarters.

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

ii. NPCIL Corporate Peer Review Follow-up

Each Corporate Peer Review is followed by two CPR Follow-up Reviews in the next two years; first follow-up review in the second year and second follow-up review in the third year. Thus, in a cycle of three years, there is one CPR, and two CPR follow-up reviews as shown in the sketch below:

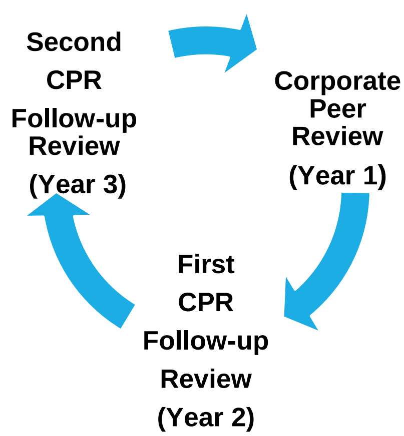


Figure 5 NPCIL Corporate Peer Review

The first and second CPR follow-up reviews are done based on the document 'Performance Objectives & Criteria for Corporate Peer Review, Revision-1, June 2015'. The team is constituted by Station Director of the respective NPP drawing experienced reviewers from the host plant. Some team members are taken from headquarters and other NPPs. The duration of first and second CPR follow-up review is 6 days each. After the review, the NPPs submit the Action Taken Report on the observations made during the first and second CPR follow-up reviews to ACROSS.

iii. Routine Self -Assessment

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

iv. Assessment of Safety Culture

NPCIL has prepared a list of safety culture indicators applicable to all the NPPs. NPP management carries out periodic self-assessment of safety culture through written questionnaire, interviews and audit activities. The assessment is used to identify good practices and areas for improvements. The aspects related to safety culture are also assessed in the Corporate Peer Review and WANO Peer Review programmes (Refer section 10.5).

12.4 EXPERIENCE FEEDBACK ON HUMAN FACTORS AND ORGANISATIONAL ISSUES

NPCIL Head Quarter Instruction (HQI) provides guidance to plant management for the implementation of a structured operating experience programme (please refer sections 19.6 & 19.7). This helps in identifying further issues and areas related to human factors. To address such issues, suitable training programmes are developed and organised viz. training programme on team building, root cause analysis and human performance enhancement. Refresher training programmes for operation and maintenance personnel are organised periodically by training centres at respective NPPs.

12.5 REGULATORY REVIEW AND CONTROL ACTIVITIES

The multi-tier review system is a crucial element of AERB's regulatory system. All the core regulatory processes including establishment of the regulatory requirements are carried out following the methodologies based on the multi-tier review system. The practice of founding the regulatory decisions on well-established and communicated regulatory requirements coupled with the multi-tier review, ensures that AERB's regulatory control maintains necessary stability and consistency in its approach and implementation. AERB has formulated several procedures and checklists to perform safety review, issue licences and carryout regulatory inspection respectively, with a view to minimize individual perceptions and varying interpretations in regulatory decision making. These procedures/ checklists provide a common ground for bringing coherence in understanding of various regulatory concepts/ approaches. The training programme of AERB further supports the consistent application of regulatory requirements by integrating various human factors and highlighting the intent of the newly formulated regulatory requirements/ criteria.

AERB is also enhancing the scope of a programme which was developed specifically for competency management within the regulatory body by identifying relevant areas for knowledge upgradation, facilitating the competence enhancement of the officials and more efficient allocation of job-assignments. Towards this, AERB arranges training programmes on issues related to current regulatory interest which span across multi-disciplinary areas and have requisite depth for regulatory application. AERB has conducted several training courses on specialized technical topics and human& organisational aspects. AERB has organised a comprehensive training programme on human and organisation aspects conducted by faculty from premier institute of India. AERB regularly conducts colloquiums on topics of regulatory interest, including human & organisational factors. Recently, AERB has also undertaken a programme for training on management development for its staff.

AERB has specified the requirement for addressing aspects related to human performance in the design of NPPs. These topics form one of the important areas of regulatory review and assessment. AERB has established multi-tier system for regular monitoring of safety at NPPs. Events, design modifications for systems important to safety, operational performance and radiological performance are also reviewed as they have close relationship with human factor. Human factor, which is one of the safety factors of PSR, is assessed periodically.

12.6 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

Human factors are given adequate consideration during all stages of NPPs. Systems for training and retraining of operating personnel including use of simulators, operational feedback including lessons learned from the events and regulatory control are well established. Further emphasis is placed on maintaining a stress-free working and living environment. Hence, India complies with the obligations of Article-12 of the Convention.

ARTICLE 13: QUALITY ASSURANCE

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

13.0 ARRANGEMENTS AND REGULATORY REQUIREMENTS FOR QUALITY ASSURANCE

Quality Assurance Programme in India has evolved and is continually improved following National Standards and Safety Codes, which are in line with International Standards followed in the nuclear industry. The AERB Safety Code on 'Quality Assurance in Nuclear Power Plants (NPPs)' (AERB/NPP/SC/QA, Rev. 1, 2009) provides the basic requirements for establishment, implementation and continual improvement of QA programme for all stages of the nuclear power plant viz. siting, design, construction, commissioning, operation and decommissioning. Set of safety guides issued under the Safety Code provide guidance to meet the requirements specified in the Safety Code. Earlier, the safety guides were being reviewed/ revised to make them in line with the then IAEA Safety Requirements GS-R-3 on 'The Management Systems for Facilities and Activities' and IAEA Safety Guide GS-G-3.1 on 'Application of the Management System for Facilities and Activities'. However, after publication of the IAEA GSR Part-2 on 'Leadership and Management for Safety', now the entire set of AERB's requirements and guidance documents on quality assurance are being reviewed/revised to be in line with the latest IAEA standards. The safety code AERB/NPP/SC/QA includes requirements on Management, Process Implementation and Measurement, Assessment, Review & Improvement. The review and assessment carried out by AERB during identified stages of consenting includes considerations of applicant's QA Programme, as mentioned in Article-14 on 'Assessment and Verification of Safety'.

NPCIL is the Responsible Organisation (RO) for the NPPs other than Fast Breeder Reactors (FBRs) and BHAVINI is the RO for FBRs in India. NPCIL and BHAVINI have established policies, systems and programmes for quality assurance in accordance with the regulatory requirements. The following paragraphs provide the summary of the corporate management system as established and maintained in NPCIL. Similar practices are being followed at BHAVINI.

13.1 QUALITY ASSURANCE POLICIES AND MANAGEMENT SYSTEMS

Requirements of NPCIL quality management system are given in NPCIL document titled 'Corporate Management System - Quality Management System Requirements'. The document emphasises on integrated approach for the management system for safety through Quality requirements. The document is based on AERB codes and guides, IAEA Safety Guide GS-G-3.1, ISO standards and other relevant documents.

13.1.1 Organisational Policies

The Head of the NPCIL has issued the 'Statement of Policy and Authority' for the Organisation. The statement directs that a management system for Quality in the various stages of the NPPs needs to be adopted so that the safety of the NPPs, plant personnel, public and environment is assured. In the said statement, sufficient authority has been delegated to the Heads of functional wings for ensuring implementation, maintenance, assessment and continual improvement of the Management System.

13.1.2 Quality Management System

The integrated Quality Management System elaborated in the "Corporate Management System Document-Quality Management System Requirements" of the NPCIL ensures implementation of the applicable AERB codes and guides. This document provides necessary directives for implementation, maintaining, assessment, measurement and continual improvement of the management system for compliance with the regulatory requirements and intents in all stages of the NPPs.

Directorates at NPCIL HQ responsible for engineering, procurement, safety, quality assurance and knowledge management functions have obtained ISO 9001: 2015 certifications. Controls are exercised on vendors and contractors also to ensure quality.

13.1.3 Documentation

The policies, management system requirements, authority, responsibilities, procedures, work instructions, processes, activities, records and other relevant supporting information describing management of the work are duly documented and controlled. These documents reflect characteristics of the processes, activities' sequence and their interactions. The documents are categorised into three levels as follows:

i. Level-I Document

This is the "Corporate Management System" document of the NPCIL 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 processes, technology and the organisation.

ii. Level-II Documents

These documents derive directives from the Corporate Management System Document and consist of Management System Manuals for respective Directorates and all other related documents translating the corporate policies and commitments to practices and details.

iii. Level-III Documents

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

13.1.4 Process Management

The processes needed to achieve the mission and objectives of the NPCIL 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, health, environment, security, quality and financial performances, monitoring achievement of the objectives and effectiveness, and taking corrective measures where required.

Processes and activities involved in siting, design, procurement, manufacture, construction, commissioning, operations and all other supporting processes are duly documented. Requirements, sequence and interaction of processes and activities, criteria and methods needed for implementation and control, process inputs and outputs are specified and their effectiveness is ensured. Interfaces and activities of various functional directorates are planned, managed and effectively communicated to groups & individuals concerned for the specific processes; responsibilities assigned and implemented.

13.1.5 Graded Approach

It is recognised that 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 indifferent processes, items and services.

13.1.6 Document Control

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

13.2 QUALITY ASSURANCE PROGRAMME

13.2.1 Organisation and Responsibilities

i. Organisation

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

The Functional Heads are assisted by 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.

ii. Responsibilities

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

iii. Interface Arrangements

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

iv. Resource Management

Resources viz. personnel, infrastructure, work environment, information, communication, suppliers and partners, materials and finance, essential for the implementation and strategy of the 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 competencies in achieving the mission of the Utility. For this purpose, suitably skilled, qualified, certified and authorised personnel are deployed and their skills are continuously upgraded by suitable training processes, thus enhancing their competence level.

13.2.2 Quality Assurance in Siting

The QA requirements for siting stage are described in Siting QA manual prepared by NPCIL. Site Selection is carried out by committee appointed by DAE and includes experts from NPCIL. For Site evaluation and Site confirmation of newly approved NPP sites, a composite group formed by CMD, NPCIL is assigned with the responsibility of various activities related to siting.

Site evaluation includes data collection, actual site investigation, detailed site evaluation and analysis of site related characteristics important to safety such as seismicity, meteorology, geology, hydrology as well as human activity in the vicinity of site, etc. Site confirmation includes confirmation of compliance with the requirements specified in regulatory codes, guides and MoEFCC notification. Siting activities are executed through reputed contractors/ Government approved agencies/ expert specialised agencies following approved procedures.

13.2.3 Quality Assurance in Design and Development

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

13.2.4 Quality Assurance in Procurement

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

13.2.5 Quality Assurance in Manufacturing

Quality Management System during manufacturing assures that stated requirements for manufacturing process of 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 requirements. This responsibility is imposed on manufacturers through contractual arrangements. However, the overall responsibility for effectiveness of the Quality Assurance Programme remains with Utility. The utilities ensure maintenance of the documentation, complying with the requirements specified in the Quality Management System, throughout the lifetime of the product.

Manufacturers supplying SSCs for the Nuclear Power Plants are responsible for the Quality Management processes at their premises. The utility monitors the adequacy and effectiveness of supplier's Quality Management System through the established verification processes like surveillance and audits.

All the outsourced activities (such as manufacturing/ supply of items) are governed by a formally agreed contract document. All the activities are performed according to approved QA programme, plan and procedures. The utilities or their authorised representative(s), have access to relevant areas where work involving the concerned Contract/ Purchase Order, for carrying out quality surveillance. This includes access necessary for inspections of contractors' facilities/ activities to verify implementation of all aspects of the Quality Management System / Quality Assurance Programme, products and to their supplier's premises. Findings of these inspections and required corrective actions are documented.

13.2.6 Quality Assurance during Construction

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

The Head of the NPP construction site is responsible for establishing and implementing the management systems during 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. Independent PSI and Corporate QA audits of projects are carried out by Head Quarter QA unit of Utility at pre-defined intervals.

13.2.7 Quality Assurance in Commissioning

Commissioning activities commence after completion of respective construction activities. The transfer of responsibility from construction to commissioning is documented through Construction Completion Certificate (CCC) and System Transfer Documents (STDs). All commissioning work is systematically planned, accomplished, assessed by the competent personnel and documented. Quality Management system implemented during commissioning assures commissioning is performed as per the approved procedures. 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 rectified. All corrective and preventive actions, as required, are implemented after due analysis of non-conformances / potential non-conformances.

13.2.8 Quality Assurance during Operation

Quality Management Systems implemented during operation assure that the NPPs 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 is headed by a Station Director (SD) reporting to the Head of Operations at Corporate level. SD is responsible for establishing, implementing and monitoring the effectiveness of Management system Programme for safe operation of the station. He has the overall responsibility for safe operation of the plant, in implementing all relevant requirements, instructions and procedures laid down by the NPCIL, AERB and Statutory Bodies. Responsibilities and authorities of plant management and functional positions have been stated in the Station Policies for each station. The QA group at NPP is responsible for inspection, testing, quality assurance, checking compliance to surveillance requirements, verification, auditing, ISI, monitoring and assessing the effectiveness of QMS and its improvement, for all activities of station operation and following the applicable QMS Documents.

13.3 IMPLEMENTING AND ASSESSING QUALITY ASSURANCE PROGRAMMES

The Management System of NPCIL 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 NPCIL objectives. By due assessment process at all levels effective implementation of the organisation's QA 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 (benchmarking), meeting stakeholder requirements and expectations, regulatory and statutory requirements, and to identify areas based on any incidences those take place worldwide or any other inputs received needing improvement.

13.4 REVIEWS AND AUDIT PROGRAMME

A system of planned and documented audits/reviews within the NPCIL 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 and for continual improvement of the programme. Similar audits are also carried out in the organisations of suppliers and sub-suppliers.

13.5 REGULATORY REVIEW AND CONTROL ACTIVITIES

The AERB's integrated management system identifies safety as a priority and provides guidance for its promotion and continual improvement as referred in 8.1.2.8. The review and assessment by AERB includes consideration of the applicant's organisation, management, procedures and safety culture, which have a bearing on the safety of the plant. The applicant should demonstrate that an effective management system is in place that gives the highest priority to nuclear safety and security matters. Specific aspects as mentioned in the AERB Safety guide 'Consenting Process for NPPs' (AERB/NPP&RR/SG/G-1) subject to review and assessment, include:

i. 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.

ii. 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.

iii. 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.

iv. Whether the applicant has a system in place to periodically audit its safety performance.

v. 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.

vi. 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 specifications, operating limits and conditions, planning and monitoring of maintenance, inspection and testing, documentation, control of contractors, and implementation of additional features based on incidences worldwide).

AERB review also includes assessment of effectiveness of vendor inspections carried out by NPCIL or its authorised representative(s), following graded approach.

13.6 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

The quality management systems in the regulatory body and the utilities have been developed in accordance with the national and international standards, which are maintained and further improved through programmes of monitoring and assessment of their effectiveness. The regulatory review and assessment activities ensure that there is an effective safety management system in place that gives nuclear safety matters the highest priority. Therefore, India complies with the obligations of the Article-13 of the Convention.

ARTICLE 14: ASSESSMENT AND VERIFICATION OF SAFETY

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

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

14.0 GENERAL

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

The utilities perform their own safety assessment and verification functions to ensure the likelihood of occurrence of an accident with serious radiological consequences is extremely low and that the radiological consequences of such an accident would be mitigated to the fullest extent practicable, in line with regulatory requirements. Even in the accident with core melt, only limited countermeasures in area and time are needed in the public domain and sufficient time is available to implement these measures. The utilities carry out these functions during design, manufacturing, construction, commissioning and operation. Separate corporate level safety committees for the projects (plants under construction and design) and for operating plants are constituted for safety review and assessment. All the information generated during the entire design, construction and commissioning phases is documented and handed over to the Plant Management before the commencement of reactor operation.

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

14.1 ASSESSMENT OF SAFETY

14.1.1 Regulatory Process for Safety Assessments

14.1.1.1 Consenting Process

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

Licence for operation of NPP is issued for a period of five years at a time. The renewal of licence for operation is carried out based on review of (a) application from the utility based on limited scope safety review, once in five years and (b) Periodic Safety Review (PSR) once in ten years. Thus in a ten year cycle, NPPs seek two licence renewals for operation, first after five years based on limited scope safety review covering operational safety aspects and the second after ten years based on PSR. In case of NPP of new design, the first PSR is carried out after five years of operation and the subsequent PSRs are carried out at 10 year intervals.

14.1.1.2 Safety Review Mechanisms

i. Utility

In accordance with the regulatory requirements of an independent internal review of design and operational aspects of NPPs, utilities have set up internal review mechanisms (as depicted below).

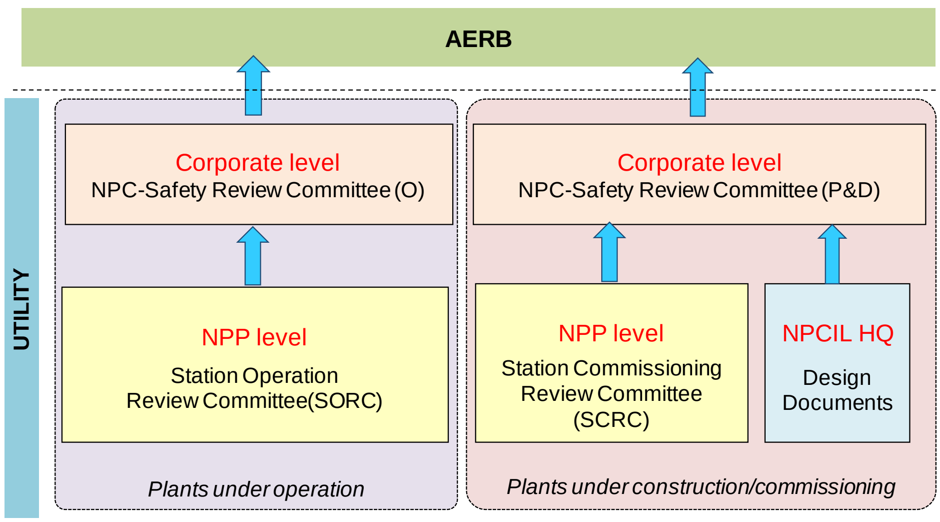


Figure 6 Internal review mechanism at utility

The documents related to design of Nuclear Power Plants are submitted to regulatory body after in-house reviews by the utility. Where a first-of-its-kind design or feature is introduced or there is a departure from an established engineering practice, utility is required to demonstrate its adequacy by appropriate supporting research programmes, analytical and experimental studies or by examining operational experience from other relevant applications. The new design or features are adequately tested before being brought into service and monitored during service, to verify that their behavior is as expected. In case of repeat design, any change in design involving a new concept (e.g. software based system compared to hardwired system) goes through an independent review. All the issues raised by the independent reviewer are resolved. Subsequently, Safety Review Committee (Projects and Design) of the utility organisation independently reviews the documents and after satisfactory resolution of the identified issues, documents are submitted to AERB. The observations / issues coming out of review in AERB are resolved, documents are revised and re-submitted to AERB for review & clearance. The document finally cleared by AERB forms the basis for the detailed design and further engineering.

Before start of commissioning activities, utility prepares a comprehensive programme for the commissioning of plant components and submits the same for review and acceptance by AERB. During commissioning of plant, utility assesses the performance of various systems of the plant to verify that it meets the design objectives.

Elaborate organisational structure (please refer Article-19) is established at each plant for reviewing safety aspects during operation. Station Operation Review Committee (SORC) headed by

Station Director is established at each NPP. SORC reviews station operations on routine basis to detect any potential safety issue. At the corporate level, Safety Review Committee (SRC) for operating NPPs with representation from design, safety, operation and quality assurance groups at utility headquarters reviews all safety related proposals, including engineering changes, which require review and concurrence by AERB. The recommendations made by SRC are incorporated before the proposal is submitted to AERB.

ii. Regulatory Body

AERB adopts a multi-tier review process for safety review and assessment of NPPs during all the consenting stages as shown in figure 7 below.

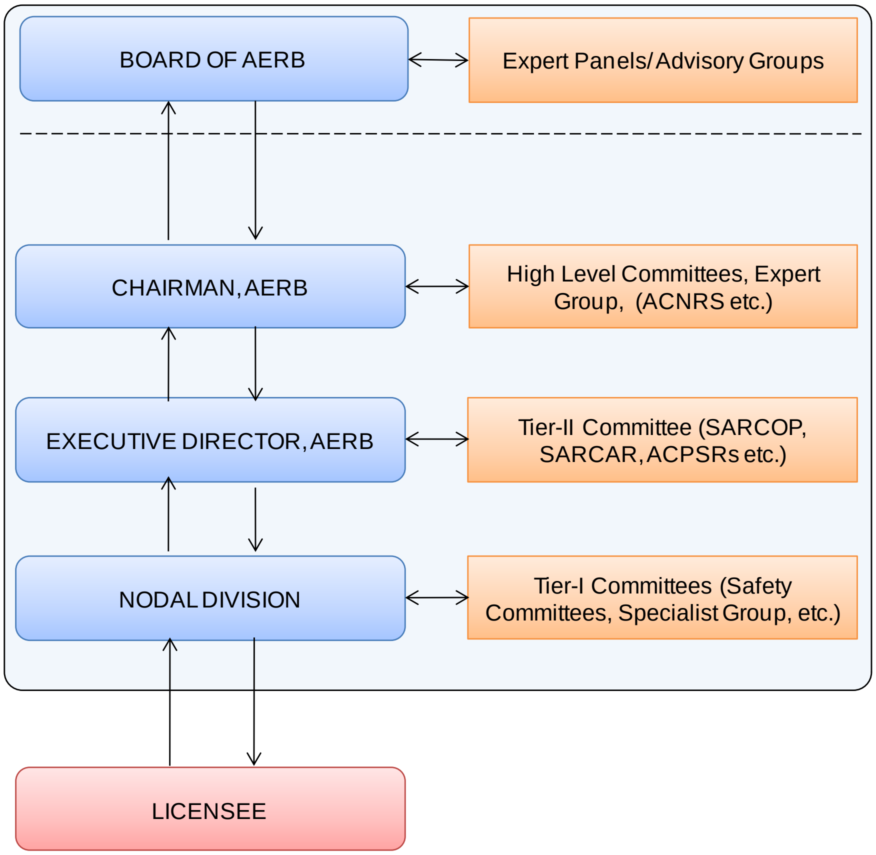


Figure 7 Multi-tier review mechanism of AERB

The in-house review of various design documents submitted by the utility during project stage, regulatory surveillance of the construction activities at project site, review of commissioning activities and enforcement of regulatory recommendations are done by Nuclear Project Safety Division (NPSD) of AERB with support from other divisions. AERB conducts independent verification and research activities in several subject areas such as safety analysis, thermal hydraulics, containment hydrogen distribution and mitigation, severe accident studies and assessments and computer code development. AERB uses internationally validated and accepted system codes, lumped parameter codes, structural analysis codes along with AERB in-house developed computer codes to carry out these independent activities. AERB also conducts research and development activities relating to structural integrity, seismic safety and flood hazard assessments. These activities are intended to support the processes of AERB for decision making, regulatory document development and development of state-of-the-art approaches & expertise/ capability.

Operating Plants Safety Division (OPSD) of AERB carries out regulatory surveillance of operating NPPs. This involves review of proposals for modification in design of safety system, technical specifications for operation of NPPs, periodic safety reviews related to licence renewals, events & significant events, etc. OPSD is supported by other divisions of AERB in some of these activities.

Directorate of Radiation Protection & Environment (DRP&E) of AERB provides technical support for review of radiological safety aspects, radioactive effluents and emergency preparedness plans of NPPs.

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

During operation, AERB follows a multi-tier approach for safety review and assessment. AERB is supported by committees viz. Unit Safety Committee (USC) and Safety Review Committee for Operating Plants (SARCOP) for carrying out safety review of operating NPPs. 'Unit Safety Committees' consist of representatives from AERB, experts in various aspects of nuclear technology drawn from Technical Support Organisation (TSO) and utility headquarters and provides observations &recommendations to OPSD. SARCOP is the apex committee to recommend on the matters of nuclear safety and has members from AERB staff, experts drawn from TSO, retired experts and one member from the headquarters of the utility. SARCOP provides recommendations to Executive Director, AERB. Annex 14-5 gives the aspects of safety review during operation of NPP.

ACNRS (Advisory Committee for Nuclear and Radiation Safety) advises on generic and specific safety issues concerning the nuclear & radiation installations or any other specific matter referred to by Chairman, AERB. Decisions concerning major policy issues and important consents require approval of the Board of AERB.

AERB has also constituted various Standing Committees and Expert Groups to support it in the reviews and to provide recommendations on specialized subjects of regulatory importance.

The multi-tier review system functions on the principle of "management by exception" following a graded approach. Safety issues of greater significance are further considered at higher levels in AERB for resolution. The recommendations of committees are considered by AERB, after ensuring that they are in line with the safety goals, principles and requirements laid down by AERB, for regulatory decision making.

14.1.2 Safety Reviews during Consenting Process

14.1.2.1 Safety Review for Siting

First order assessment of the sites is carried by Standing Site Selection Committee (SSSC), constituted by the Government of India. It evaluates the suitability of the various sites proposed by concerned state governments taking into account different site related factors as detailed in Article-17.

The first regulatory stage of consenting i.e. Siting, involves the review of the various site related safety aspects considering the conceptual design and issuance of siting consent for locating the NPP. This requires submission of a Site Evaluation Report which includes the salient features of the proposed site, basic design information of the proposed NPP, site characteristics affecting safety and impact of the proposed plant on surrounding population and environment. The Site Evaluation Report should contain information as per requirements specified in the AERB Safety Code on 'Site Evaluation of Nuclear Facilities' (AERB/NF/SC/S, Rev.1, July 2014) and various other relevant AERB Siting guides. This code considers the lessons learnt from the accident at Fukushima Daiichi NPP, including revised dose criteria for design of NPPs in normal operation as well as accident conditions giving due considerations for exceedance of design basis, evolution of hazard with time, multi-unit/multi-facility sites, periodic re-evaluation of hazards during the plant lifetime and requirements regarding ultimate heat sink.

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 and to determine the potential consequences of interaction between the plant and the site. The areas of review and assessment are as per AERB safety guide on 'Consenting Process for Nuclear Power Plants and Research Reactors' (AERB/NPP&RR/SG/G-1, 2007) and are given in Article-17. The regulatory process for reviews related to siting consent is given in Annex 14-1.

14.1.2.2 Safety Review for Construction

The second stage of consenting i.e. Construction, involves review of the design safety aspects and issuance of construction consent. Main aspects of interest for regulatory review and assessment of the adequacy of the design basis for a nuclear power plant are brought out in AERB Safety Codes such as AERB/NF/SC/S, AERB/NPP-PHWR/SC/D, AERB/NPP-LWR/SC/D, AERB/NPP/SC/QA and Safety Guides published thereunder.

The issuance of construction consent requires on the part of the applicant, submission of Preliminary Safety Analysis Report (PSAR) in the prescribed format, the applicant's site construction Quality Assurance manual, construction schedule and construction methodology document for the proposed NPP to AERB for review and acceptance. AERB also reviews the aspects related to industrial safety such as Construction Safety Management, Job Hazard Analysis etc. and monitors compliance to the requirements of Atomic Energy (Factories) Rules, 1996.

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

During the reviews related to this consenting stage, the design of plant is reviewed and assessed to reach a conclusion as to whether it can be built to operate safely. This review and assessment includes verification of the compatibility of the design with the site. The quality assurance organisation and programme of the utility are also reviewed. Review and assessment, carried out by AERB, is focused to ensure that in the design of a nuclear installation, all actual and potential sources of radiation exposure are identified and properly considered, and provisions are made to ensure that the radiation sources are kept under strict technical and administrative control.

During review and assessment, it is ensured that, the fundamental safety functions will be performed in all operational states, during & subsequent to design basis accidents and design extension conditions. The key aspects of interest of regulatory body, are:

- Application of Defence in Depth principles and Principal Technical Requirements including Safety Functions, Accident Prevention and Plant Safety Characteristics, Radiation Protection.

- Plant Design Requirements including Safety Classification, Categories of Plant States, Postulated Initiating Events, Design Limits, Internal Events, External Events, Site-related Characteristics, Combination of Events, Design Criteria, Operational States, Design Basis Accidents, Design Extension Conditions.
- Design for Reliability of Structures, Systems and Components which includes , Common Cause Failures, Single Failure Criterion, Fail-safe Design, Safety Support Systems, System Storage Capacities, Equipment Outages
- Provision for In-Service Testing, Maintenance, Repair, Inspection and Monitoring, Equipment Qualification, Aspects related to Ageing and Human Factors
- Sharing of Structures, Systems and Components in multi-unit NPPs, Fuel and Radioactive Waste Transport and Packaging, Escape Routes and Means of Communication, Control of Access and,
- Plant System Design Requirements for all systems important to safety.

The primary objective of NPP design is to prevent accidents and to mitigate the consequences should an accident occur, by application of principles of defence-in-depth.

AERB Safety Code on 'Design of Light Water Reactor based Nuclear Power Plants' (AERB/NPP-LWR/SC/D) issued in 2015 specifies the safety requirements for design of LWR based NPPs in India. The requirements given in this safety code are in line with the current IAEA Safety Standard 'Safety of Nuclear Power Plants: Design (SSR 2/1 (Rev.1))'. As per this code, provision shall be made in the design for automatic safety actions for the necessary actuation of safety systems or additional safety systems/features, to prevent progression of accident to more severe plant conditions. The safety code also requires provision of complementary safety features for mitigating the consequences of severe accidents, should they occur. Further, the design of NPPs shall be such that design extension conditions that could lead to large or early releases of radioactivity are practically eliminated. For design extension conditions that cannot be practically eliminated, only protective measures that are limited in terms of area and time shall be necessary for protection of the public, and sufficient time shall be made available to implement these measures. The design and regulatory assessment of new NPPs is done to meet these requirements.

These generic requirements and design principles specified in the safety code on design of LWR based NPPs are considered during design & safety review of the PHWR based NPPs also. The Safety Code on 'Design of Pressurised Heavy Water Reactor based Nuclear Power Plants' (AERB/NPP-PHWR/SC/D (issued in 2009)) is being revised to include these requirements.

These design objectives are consistent with the objectives of Vienna Declaration on Nuclear Safety.

14.1.2.3 Safety Review for Commissioning

Commissioning activities in NPP are initiated in parallel during the later period of construction. Various equipment and systems are individually commissioned as and when the prerequisites for their commissioning are met. The first regulatory clearance within the commissioning consent is required when the applicant desires to initiate the integrated commissioning activity e.g. hot conditioning (integral testing and passivation of primary heat transport system) in the case of PHWR based NPPs and hot run & related commissioning tests in the case of PWR based NPPs. Following this, there are a number of intermediate commissioning stages at which also regulatory clearances are required. The consent for commissioning is given in several interim stages as deemed necessary by AERB. These interim stages act as checkpoints where the results of previous activities and prerequisites for further activities are reviewed prior to issuing clearance for the subsequent stage. The guidelines for safety review and assessment for commissioning of NPPs are given in AERB safety guide AERB/NPP&RR/SG/G-1. Some of these interim stages e.g. containment integrity test, fuel loading, approach to first criticality, low power physics experiments, etc. are witnessed by the representatives of AERB, if required. AERB safety guides AERB/SG/O-4 and AERB/NPP-PWR/SG/O-4C provides guidance for the commissioning procedures for PHWR and PWR based reactors respectively.

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

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

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

i. Surveillance, maintenance and in-service inspection programmes.
ii. Performance review and operational experience feedback programmes
iii. Programmes for Ageing Management
iv. Radiation protection programme
v. Emergency Preparedness and Response plans
vi. Training programme for operating personnel
vii. Records and reporting system
viii. Quality assurance programme for all commissioning, operation and maintenance activities
ix. Nuclear Security aspects affecting safety

14.1.2.4 Safety Review for Licence for Operation

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

Before issuing licence for operation, AERB 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 licence for regular operation of NPP for a period up to five years.

14.1.2.5 Safety Review during Operation

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

i. Routine safety reviews and assessments

The safety supervision during operation mainly includes continual monitoring and assessment of operational and safety performance, radiological safety, maintenance and in-service inspection activities and the results thereof and findings of regulatory inspections.

ii. Safety reviews for renewal of licence

As mentioned earlier, licence for operation of NPPs requires renewal every 5 years based on specified reviews (limited scope safety review and PSR). Linking of renewal of operating licences with the safety reviews helps in ensuring that the identified safety enhancements are timely implemented. The PSRs are conducted in accordance with the guidelines given in AERB safety guide 'Renewal of Authorization of Nuclear Power Plants' (AERB/SG/O-12) which is in line with IAEA SSG-25.

The safety assessments performed during limited scope safety reviews include operational and radiological safety performance, operational experience feedback, physical status of plant including major modifications and public concern in operational safety. The report is submitted to AERB three months prior to the expiry of the operating licence. AERB conducts a detailed review of the same and issues the licence after being satisfied that the plant could be operated in a safe manner 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. During the last three years, limited scope safety reviews for licence renewal were conducted for KGS-1&2, RAPS-3&4, TAPS-3&4, KAPS-1&2 and NAPS-1&2.

The safety assessments performed during PSR take into account improvements in safety standards and operating practices, cumulative effects of plant ageing, modifications, feedback of operating experience, deterministic & probabilistic safety analysis and development in science and technology. As a part of this PSR, the hazard assessments are revisited with the latest available information. Through this process of PSR, strengths and shortcomings of the NPP against the requirements of current standards are identified. The report on PSR is submitted to AERB six months prior to the expiry of licence. During the last three years, PSRs were conducted for KGS-3&4 and RAPS-1&2 (currently in progress). The PSR of KGS-3&4 did not bring out any significant safety issue. The long term actions identified based on the lessons learned from the accident at Fukushima Daiichi NPP are being implemented at KGS-3&4 (refer Article-6).

The PSR is subjected to regulatory review in multi-tier review process. The experience gained from the review of PSR of one NPP is effectively utilised in reviewing the PSR of the subsequent NPPs. This has facilitated efficient and effective review of PSRs by AERB. All Indian NPPs, which have completed 10 years of operation have undergone at least one PSR since the initiation of the PSR process in the early 2000s.

The timely implementation of safety upgrades identified as part of PSR is monitored by AERB.

The established system of comprehensive periodic safety assessment and licence renewals of Indian NPPs to assess the safety of the plant with respect to the original design basis, current safety requirements / practices & operating experience and implementation of the identified upgrades, as is being practiced, addresses the principle of Vienna Declaration on Nuclear Safety.

iii. Safety reviews related to En-masse coolant channel replacement (EMCCR) including return to service in PHWR based NPPs

The pressure tubes of PHWRs are covered by extensive life management programme involving in-service inspections, material surveillance and measures for optimizing their operational lifetime. Once their useful safe lifetime is over, the pressure tubes are replaced. This is done in a planned long outage and the activity is called as En-masse coolant channel replacement (EMCCR).

EMCCR activity has implications with respect to control of occupational radiation exposure and safe management of radioactive pressure tubes & related components removed from reactor core. Further, it involves re-installation of the pressure tube components, re-qualification of the reactor components and safe re-commissioning of the reactor towards return to service. The planned long outage of the unit is also utilised for implementation of the identified major safety upgrades, if any, as well as conduct of inspections & health assessment of critical SSCs, which are otherwise not amenable for inspections and implementation of corrective measures, as necessary. Many of the PHWR based NPPs in India have undergone EMCCR in the past.

AERB has a mechanism for regulating the safe conduct of the EMCCR activities and return to service of the reactor subsequently. The utility submits applications covering various phases of EMCCR activity including return to service, apart from details of waste management, exposure control, technical specifications during the long outage, quality assurance aspects, etc. The applications are reviewed in AERB and stage wise clearances for EMCCR activities & subsequent return to service are given. Re-commissioning activities of the unit after EMCCR is subject to regulatory coverage and clearances which are very similar to that of commissioning of a new reactor.

14.1.3 Regulatory Review and Control Activities

14.1.3.1 NPPs under construction and commissioning

AERB undertakes regulatory review and control activities during various consenting stages like Siting, Construction, Commissioning and Operation. During construction and commissioning stages, there are a number of sub-stages at which regulatory clearances are required. These stages act as hold points where the results of previous activities and pre-requisites for further activities are reviewed till the plant is brought to operational state.

Responsibility of QA & QC during manufacturing, fabrication, construction and commissioning rests with the utility. Regulatory process calls for setting up mechanisms within the utility to carry out internal audits by specifically constituted groups of various activities/jobs executed by the constructors, vendors, utility etc. Regulatory Inspection teams check these audit reports in addition to physical verification and scrutiny of various documents/ records related to QA & QC, preservation and storage, industrial and fire safety aspects, adherence to regulatory stipulations etc. The inspection findings are required to be complied with and responded to by the utility. The utility is asked to check and apply these findings suitably on similar types of jobs/ activities. Utility reports the events/ design changes as per the Significant Event/Change Reporting Criteria (SECRC) of AERB during various stages of the project that may affect the characteristics of safety and safety related Structures, Systems and Components (SSCs).

Regular safety review and assessment for NPPs during construction and commissioning is conducted by the designated AERB staff. The observations during the regulatory inspections and the observations reported by AERB Observers at the project sites are also considered in the safety review and stage wise consenting process. In addition to routine regulatory inspections, AERB also identifies a list of important activities (hold points) during construction and commissioning for conducting Special Inspections or for deputing additional experts in the respective areas to observe these activities.

With this arrangement of regulatory supervision, all the important activities during construction and commissioning of NPPs which have bearing on safety get adequate regulatory coverage.

14.1.3.2 NPPs in Operation

AERB exercises regulatory control over the nuclear power plants following a system of safety monitoring, inspection and enforcement, and their periodic assessment. Apart from this, Periodic Safety

Reviews (described earlier) and special safety reviews are also used for safety assessments. Significant emphasis is placed on utilising feedbacks from experience in identifying and implementing safety enhancements.

In line with this, the regulatory system incorporates 'special safety reviews', undertaken following major events, wherein the implications of such experience and lessons are reviewed for identifying and implementing safety enhancements. Indian NPPs have undergone many such reviews, examples of which include the Three Mile Island accident of 1979, the Chernobyl accident of 1986, the fire incident at Narora Atomic Power Station (NAPS-1) in 1993, Flood incident at the Kakrapar Atomic Power Station (KAPS) in 1994, the Tsunami at the Madras Atomic Power Station (MAPS) in 2004, the Fukushima accident in 2011 and the incidents of pressure tube leaks in KAPS-1&2 in the year 2015-16. All these reviews have resulted in enhancements in the safety features and regulatory requirements.

The operational NPPs undergo safety reviews as described below:

i. Reports to AERB

The operating NPPs have reporting requirements covering regular periodic reports such as monthly and annual performance reports, reports on radiological safety status & radioactivity discharges, deliberations of the internal safety committees and specific reports such as event reports, reports on maintenance outages, in-service inspection reports, etc. These reports are reviewed in AERB for safety assessment. The event reports are reviewed for the root causes, lessons learned and corrective actions taken along with identification of any trends (refer section 19.6). The INES ratings of these events are also verified.

ii. Design modification in safety & safety related systems

Any design modification in the safety and safety related systems of the plant has to pass an in-depth regulatory review and approval. 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 clearance for implementation of the proposed modifications in safety & safety related systems is accorded by AERB after satisfactory reviews in its multi-tier review system. 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.

iii. Regulatory inspections

AERB conducts regulatory inspections of NPPs to check compliance to regulatory requirements. The report of the RI with inspection findings & their categorization is prepared and forwarded to the licensee for taking corrective actions. Licensee is required to submit an action taken report on the deficiencies brought out during the inspection within a specified time frame. These action taken reports are reviewed in AERB for disposition and need for enforcement action if any. AERB maintains a database for effective follow up, safety review and closure of all inspections findings. The regulatory inspection teams are authorized to take on-the-spot enforcement actions in consultation with AERB headquarters in cases of extreme non-compliances.

In addition to the routine/planned regulatory inspections, AERB SOTs at NPP Sites where NPPs under construction/commissioning are co-located with the operating NPPs, provide continuous on-site regulatory coverage and report their observations to AERB on daily basis. The important observations are reviewed at AERB and followed-up appropriately in safety review or regulatory inspections. For other operating NPPs where AERB SOTs are not deployed, AERB conducts additional routine/planned as well as unannounced regulatory inspections.

iv. Radiological Safety Status

AERB has specified the requirement of instituting a Radiation Protection Programme at all NPPs, based on which the NPPs prepare their radiation protection manuals. AERB approves these manuals and checks compliance to the same during regulatory inspections. AERB gets periodic reports on the radiological safety status of NPPs from Radiological Safety Officer (RSO) of the plant and the environment monitoring from the ESL at each NPP site. AERB reviews these reports along with the response of NPP management on the same.

v. 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 a minimum as practicable in terms of activity and volume. AERB issues the authorisation for release / transfer of radioactive waste from all the NPPs under the Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987. These authorisations are valid for five years and are renewed based on the reviews/assessments carried out during renewal of licence for operation of NPPs.

vi. Emergency Preparedness

Periodic exercises for plant, site and off-site emergency are carried out according to the prescribed frequency. The reports of these exercises are reviewed in AERB. Various state and central agencies participate in the offsite emergency exercises. AERB also deputes its representatives as observers to oversee the conduct of the off-site emergency exercise. Emergency Preparedness and Response plans are periodically updated based on the changes in organisation, infrastructure and site conditions. In the wake of accident at Fukushima Daiichi NPPs, a comprehensive review of the emergency preparedness and response plans, infrastructure required and the roles & responsibilities of the agencies involved in emergency response was carried out. The details are given in Article-16.

vii. Training and qualification of operating staff and management personnel of NPPs

The Technical Specification specifies the qualification requirements for licensed operating staff manning the control room of NPPs. The curricula of different licensed positions are prepared by utility and vetted by AERB. The operating staff undergoes the licensing process comprising of classroom training, on the job training & its assessment through questionnaire (checklist), walk through, simulator training and are interviewed by the Licensing Committee for operating personnel constituted by AERB. The licence is granted after successful completion of the process and the licence is valid for three years. For re-licensing, the candidate needs to undergo retraining & re-assessment by the same process. Similarly, AERB evaluates the personnel in the management positions through a Committee constituted by AERB for Licensing of the Station Management Personnel. Only the personnel having sufficient experience in operation & maintenance of NPPs are considered for senior management positions. The details of the training & qualification programme are given in Article-11.

14.2 VERIFICATION OF SAFETY

14.2.1 Regulatory Requirements for Verification of Safety by the Licensee

AERB Safety Codes on design of NPPs, AERB/NPP-PHWR/SC/D (Rev.1) 2009 for PHWRs and AERB/NPP-LWR/SC/D, 2015 for LWRs, require that a comprehensive safety assessment shall be carried out to confirm that the design, as used for construction and as built, meets the safety requirements set out at the beginning of the design process and the utility shall ensure that an independent verification of design and the safety assessment is performed by an independent group, separate from that carrying out the design, before it is submitted to the AERB.

AERB Safety Code on 'Nuclear Power Plant Operation', (AERB/NPP/SC/O, Rev.1, 2009) establishes requirements related to operation of NPPs and several safety guides issued under this Code, describe and make available methods to implement specific requirements of the Code. The code requires establishment of management programmes related to operation review and audit with the aim of ensuring that an appropriate safety consciousness and safety culture prevails. In accordance with the requirements, an elaborate verification programme is established at NPPs and adequacy of the programme is periodically monitored. Audits are conducted by plant management and also the utility headquarters to verify that the safety verification programmes are being followed at the plant.

14.2.2 Programmes for Continued Verification of Safety

The important elements of effective management for safe operation of a NPP are given in AERB Safety Guide on 'Management of Nuclear Power Plants' (AERB/SG/O-9). As per the regulatory requirements, the plant management is required to establish the following programmes before a licence for operation is issued:

i. Surveillance Programme - The surveillance programme for safety systems and safety related systems is 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 Structures, Systems, and Components (SSCs) important to safety. The guidelines for surveillance programmes are given in AERB Safety Guide AERB/SG/O-8 on 'Surveillance of Items Important to Safety in Nuclear Power Plants'.

ii. In-service Inspection Programme - As per this programme, SSCs are inspected for possible deterioration in safety margins and their acceptability for continued operation of the plant and corrective measures are taken as necessary. SSCs important to safety of the plant are identified in the In-service Inspection manual of NPPs, which gives (a) areas and scope of inspection (b) frequency of inspection (c) method of inspection and (d) the acceptance criteria. The guidelines for in-service programme are given in AERB Safety Guide AERB/NPP/SG/O-2 on 'In-service Inspection of Nuclear Power Plants'.

iii. Maintenance Programme - The maintenance programme is put in place to ensure that (i) safety status of the plant is not adversely affected due to ageing, deterioration, degradation or defects of plant structures, systems or components since commencement of operation and (ii) their functional reliability is maintained in accordance with the design assumptions and intent over the operational life span of the plant. The NPP prepares a preventive maintenance schedule for systems, structures and components. The preventive maintenance includes surveillance and verification, periodic preventive maintenance and predictive maintenance. In addition, system for trend monitoring of the important equipment is used for predictive maintenance. The guidelines for maintenance programmes are given in AERB Safety Guide AERB/SG/O-7 on Maintenance of Nuclear Power Plants.

iv. Establishment of programme related to life management - This programme is used to obtain information on behaviour of the SSCs, as identified for ageing management purpose, under reactor environment and to undertake necessary studies/experiments with respect to their residual life assessment. The guidelines for life management are given in AERB Safety Guide AERB/NPP/SG/O-14 on Life Management of Nuclear Power Plants.

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

vi. Programme to update Probabilistic Safety Assessment - The programme for collection of plant specific failure data at NPPs is established for evaluation of reliability of safety systems. These data are judiciously used to update the results of PSA studies. The PSAs are required to be updated taking into account of design/procedural modifications and component failure data. The PSA results are presented as a part of periodic safety review (PSR). The proposals for design modifications or revision in technical specifications are supported by the results of PSA studies, whenever required.

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

14.2.3 Regulatory review and control

AERB exercises regulatory control over the nuclear power plants following a system of safety supervision, inspection and enforcement and periodic assessment for renewal of Licence. Through these, AERB verifies that the NPPs comply with the above mentioned programmes throughout their lifetime.

i. Continuous Safety Supervision

The safety supervision during operation includes continual monitoring and assessment of operational and safety performance, radiological safety, maintenance and in-service inspection activities and the results thereof through review of performance reports, reports on radiological safety aspects, event reports etc. required to be submitted by the utility.

ii. Regulatory Inspection

The regulatory inspections of NPPs are carried out during all stages of consenting to verify compliance to the regulatory requirements. During regulatory inspection, documented evidences for compliance to the regulatory requirements are examined and certain plant activities are observed by AERB. The regulatory inspections are carried out as per the guidelines given in AERB safety guide on 'Regulatory Inspection and Enforcement in Nuclear and Radiation Facilities' (AERB/SG/G-4). The provisions of this guide are elaborated in AERB safety manual on Regulatory Inspections, (AERB/NPP/SM/G-1) and the procedures developed under Integrated Management System of AERB. Depending upon the requirements, AERB carries out periodic regulatory inspections as well as special/unannounced inspections with specific objectives as deemed necessary.

During construction and commissioning stages, the frequency of regulatory inspections depends on the progress of activities at the site and may vary from twice in a year to four times in a year depending on the consenting stage of the project. In addition to routine regulatory inspections, AERB also identifies important activities during construction and commissioning as hold points for which AERB deputes its experts to observe these activities.

The inspection programme is supplemented by the continuous regulatory presence of AERB SOTs at four multi-unit NPP sites where in addition to operating units, construction/commissioning of new NPPs is also taking place viz. Kalpakkam, Kudankulam, Rawatbhata, and Kakrapar.

During operation stage, the frequency of regulatory inspections may vary from five to eight per year in NPPs where SOTs are not posted and three to four times a year where SOTs are posted. (also refer section 7.2.3.2). Special regulatory inspections are carried out subsequent to an event if necessary depending on the safety significance, and/or after major modifications in the plant and form the basis for considering clearance for restart of the unit. In NPPs, where SOTs are not deployed, unannounced inspections are also carried out.

Following aspects are covered during a typical regulatory inspection of an operating NPP.

- Operation, Maintenance and Quality Assurance Programme.
- Adherence to the technical specification for operation including surveillance requirements

- Compliance to various regulatory recommendations and licensing conditions.
- Adequacy of licensed staff at NPPs
- Performance of safety related systems.
- Radiation safety and ALARA practices.
- Emergency Preparedness
- Industrial and Fire Safety

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

In addition to the above, regulatory inspections of physical protection systems for security aspects affecting safety of NPPs are also carried out once in a year.

iii. Enforcement

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

a. A written directive for satisfactory rectification of the deficiency or deviation detected during inspection;
b. Written directive to applicant/licensee for improvement within a reasonable time frame;
c. Orders to curtail or stop activity;
d. Modification, suspension or revocation of licence; and
e. Initiate legal proceedings under provisions of the Atomic Energy Act, 1962.

During safety review of nuclear power projects and related construction activities, few written directives for improvement of construction safety practices within a reasonable time frame were given. All these enforcement requirements were complied with by the utility to the satisfaction of AERB.

14.3 OPERATIONAL EXPERIENCE FEEDBACK PROGRAMME

AERB as well as utility have a structured system for reviewing external as well as internal OE pertaining to operating NPPs. The programme includes systematic collection of information, screening, review, dissemination and finally monitoring the implementation of the review recommendations. For reviewing international operating experience, IRS reports as well as other relevant information on international developments are screened and a group of experts review the screened reports. Screening guidelines have been developed to implement a graded approach in operating experience utilisation. Review reports are prepared encapsulating the highlights. Events which demand further review are selected for discussion under operating experience programme. The operating experience programme including the special safety reviews following major events (described earlier) provide opportunities for learning lessons and safety enhancements.

The lessons learnt for safety enhancements in NPPs and improvement of regulatory practices are implemented in regulatory activities, such as design review, regulatory inspections & licensing process also, for meeting the complete intent of operating experience.

14.3.1 Special Safety Assessments following accident at Fukushima Daiichi NPPs

Subsequent to the accident at Fukushima Daiichi NPPs, NPCIL conducted an immediate review to assess available capabilities to deal with the extreme external events by considering extended blackout and loss of ultimate heat sink provided in the existing design. AERB conducted an independent detailed review of plant specific design aspects with respect to functioning of safety systems and components and requirements for further enhancement of safety provisions in the case of extreme external events including combination of related events. The outcomes of these reviews were reported in detail in the National Reports for 2nd Extraordinary Meeting and Sixth & Seventh Review Meetings of Contracting Parties.

The status of upgrades identified during these reviews is given in Article-6. The regulatory response in the aftermath of accident at Fukushima Daiichi NPPs towards safety assessment and follow up of safety enhancement measures in Indian NPPs were also peer reviewed as part of the IRRS mission.

14.3.2 Safety Assessment of Indian NPPs in view of incidents of pressure tube leak at KAPS

KAPS-1&2 units had experienced events of heavy water leak from pressure tubes on March 11, 2016 and July 01, 2015 respectively. Preliminary investigations to establish the root cause of the events were described in National Report to 7th Review Meeting of CNS.

During the last three years, detailed investigations were carried out to establish the root cause of these events. The root cause has been identified as the presence of unlisted impurities of hydrocarbons in carbon dioxide gas used in AGMS which resulted in localized corrosion under reactor conditions. Details are covered in Article-6.

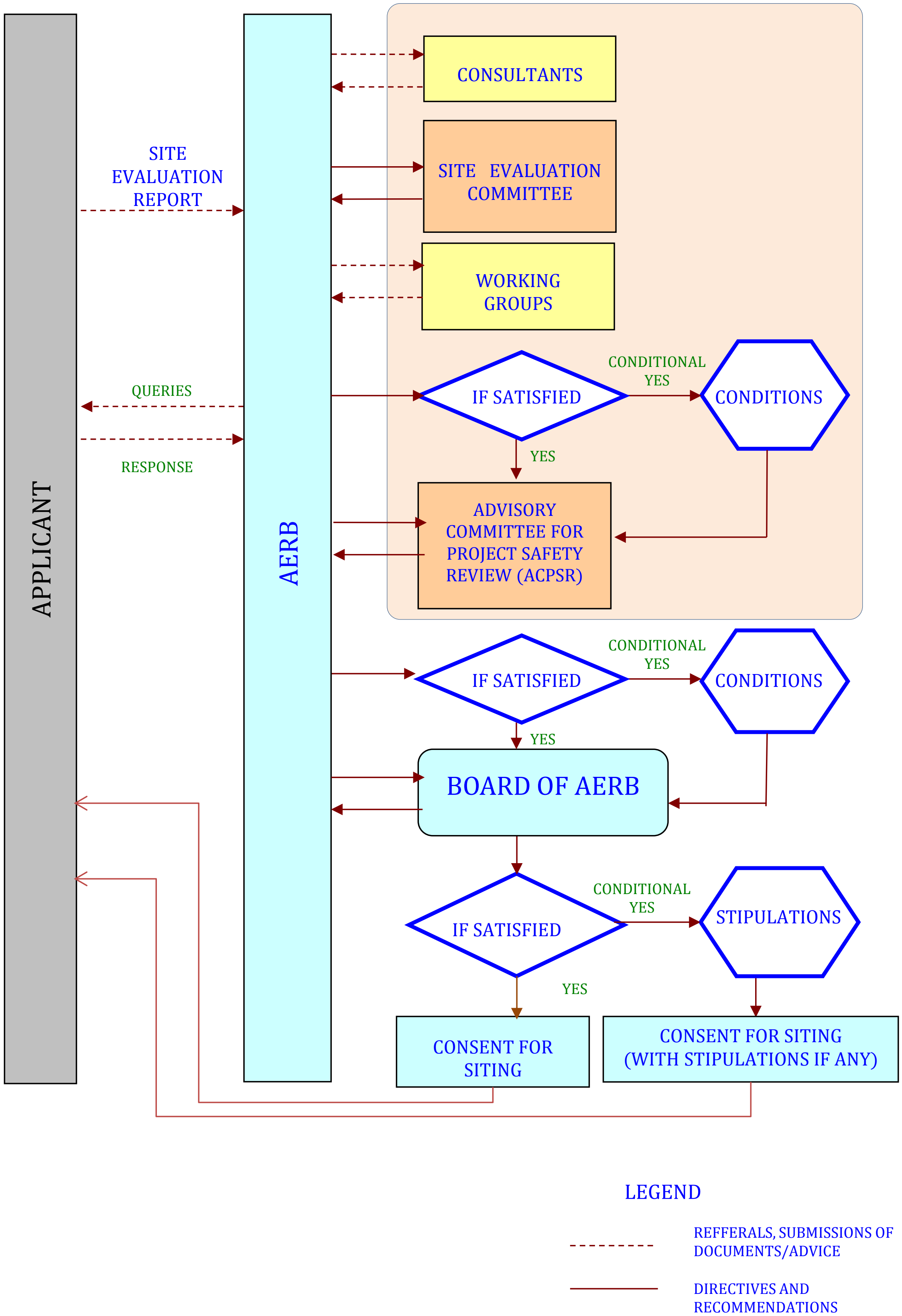
The investigation findings were reviewed in AERB. The events have brought into focus the importance of AGMS gas specifications. Based on the review outcomes, corrective measures have been implemented at all operating PHWRs which include strengthening of specifications & quality checks of AGMS gas and enhanced surveillance & monitoring of AGMS. The scope of in-service inspection programme of coolant channels has been strengthened for all operating PHWRs by including a requirement of periodic inspection for localized corrosion spots on outer surface of pressure tubes. The capability of AGMS was also analysed and found to be adequate to meet the design intent. Also, the operational mode of AGMS was modified to further enhance its sensitivity in NAPS-1&2 and KAPS-1&2, in line with the configuration in subsequent PHWRs.

14.4 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

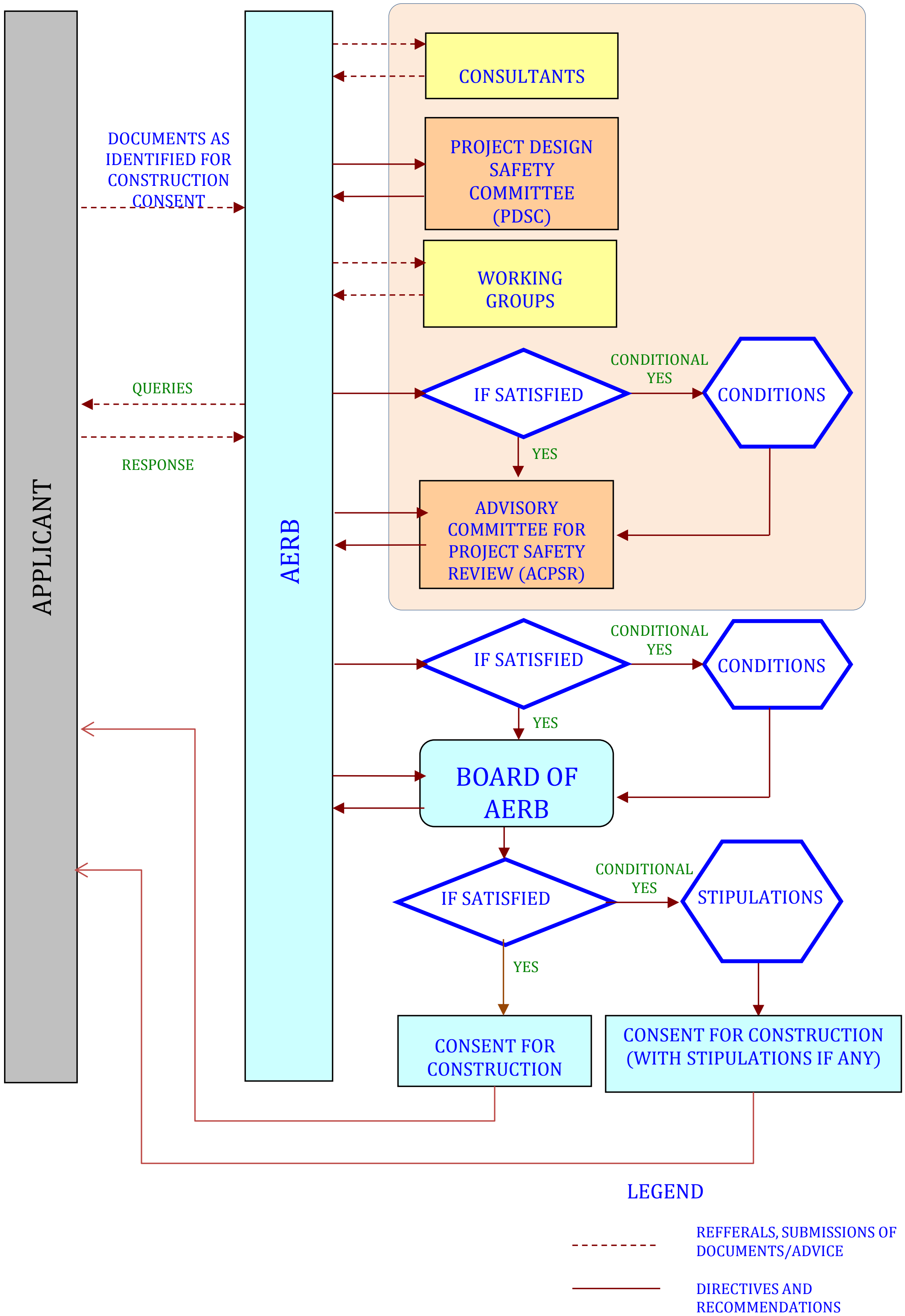
The consenting process established in the country ensures that comprehensive and systematic safety assessments are carried out during siting, construction, commissioning and operation. Changes that take place in the design during construction and commissioning are reflected in the FSAR, which forms one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

The regulatory system in India already incorporates the necessary mechanisms which ensure that the review processes for new and existing NPPs take account of evolution in technology, regulatory practices and lessons learned from operating experience. The review and verification mechanisms of the licensee and the regulatory body help India in addressing the Vienna Declaration on Nuclear Safety.

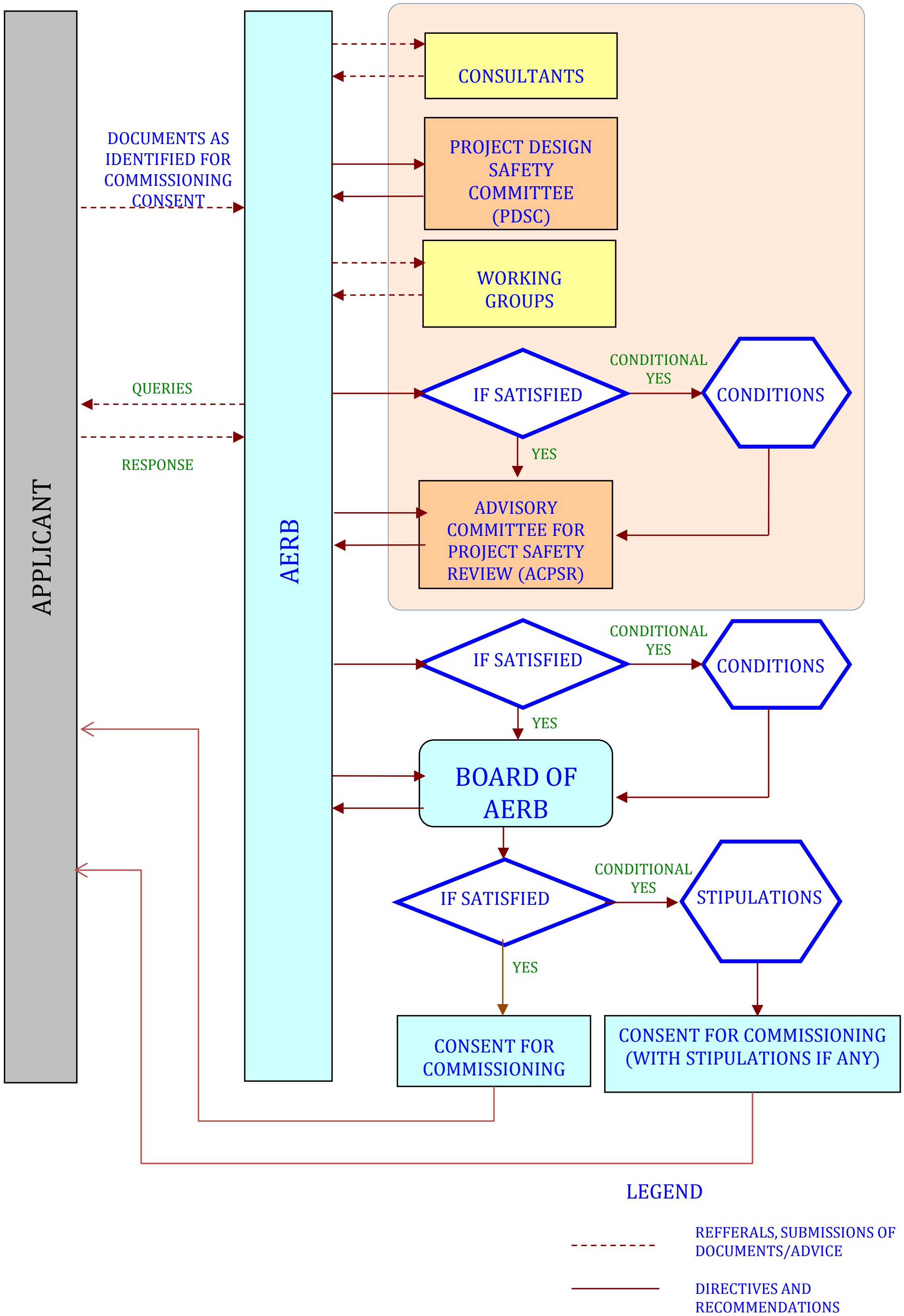
Annex 14-1: Scheme for Consent for Siting



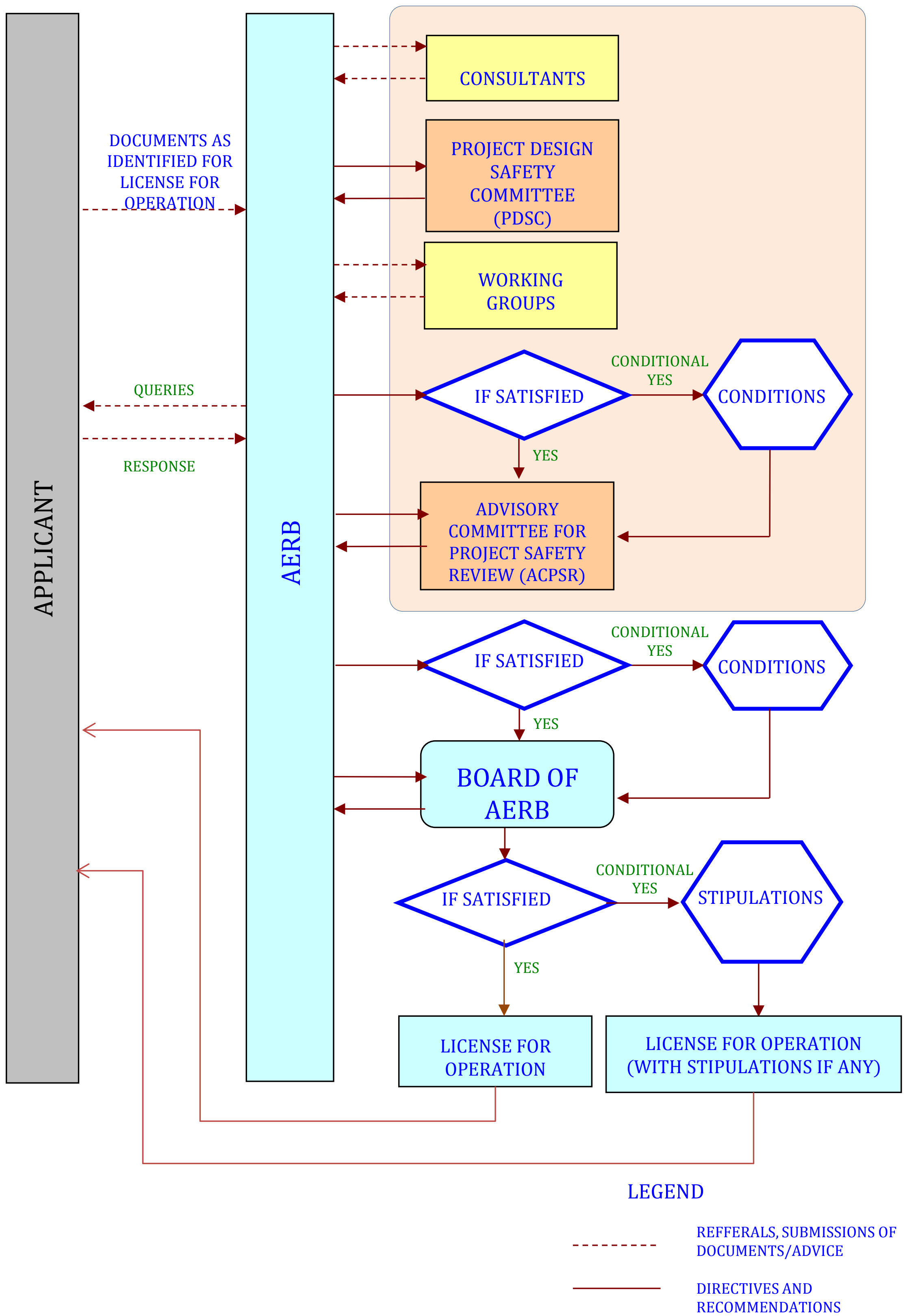
Annex 14-2: Scheme for Consent for Construction



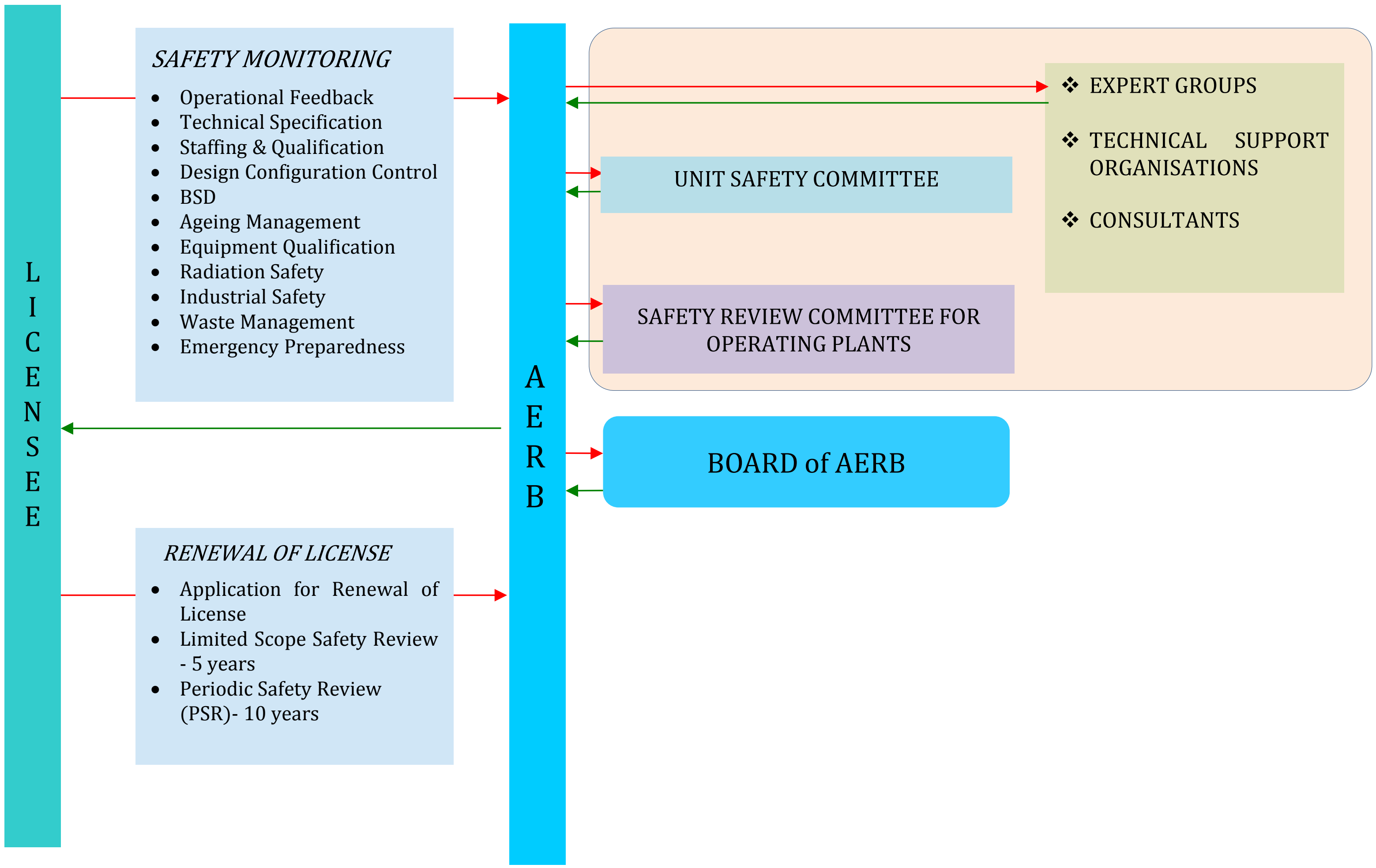
Annex 14-3: Scheme for Consent for Commissioning



Annex 14-4: Scheme for Consent for Initial Operation



Annex 14-5: Safety Review during Operation



ARTICLE 15: RADIATION PROTECTION

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

15.0 GENERAL

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

15.1 REGULATORY REQUIREMENTS RELATED TO RADIATION PROTECTION

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

i) AERB Safety code on 'Radiation Protection for Nuclear Fuel Cycle Facilities' (AERB/NF/SC/RP, 2012) covers radiation safety aspects specified in Atomic Energy (Radiation Protection) Rules, 2004 as applicable to the nuclear facilities.

   This safety code specifies the basic requirements for radiation safety of the occupational workers, members of the public and the environment. This code specifies the radiation protection requirements to be addressed in siting, design, construction, commissioning and operation of nuclear power plants. The requirements on radiation exposure control, discharge of radioactive effluents, radioactive waste monitoring, environmental monitoring, emergency preparedness, decommissioning and remediation are also addressed. The code also covers the roles and responsibilities of the consentee/ licensee, the Radiological Safety Officer (RSO) and occupational workers, and the quality assurance programme of radiation protection aspects.

   During preparation of this safety code, the safety requirements / guidelines provided in the IAEA documents, ICRP (ICRP 103, 2007) and the operational experience were considered.

ii) The Safety Code on 'Site Evaluation for Nuclear Facilities' (AERB/NF/SC/S (Rev1), 2014) spells out the requirements to be met during siting of nuclear facilities for assuring safety including radiological safety. The code has been developed on the basis of relevant IAEA documents on Site Evaluation for Nuclear Facilities: Safety requirements. The code specifies the requirement of dose assessment, pathways and parameters to be used for dose assessment and dose criteria for various plant states as basis for plant design, for the site, among others.

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

The Safety Code on Design for Safety in Light Water Reactors (AERB/NPP-LWR/SC/D 2015) lays down the minimum requirements for ensuring adequate safety in design of Light water reactors including radiation protection aspects.

Among other things, both these codes stipulate the provisions to be made in design to ensure adherence to ALARA principles and means/ methods to be employed for radiation monitoring.

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

The Safety Guide on 'Radiation Protection during Operation of NPPs' (AERB/SG/O-5, 1999) provides guidelines for establishing an effective radiation protection programme. It focuses on the commitment of the Plant Management to follow the exposure control measures / ALARA exposure control during all operational states and accident conditions in the plant. Safety Manual on 'Radiation Protection for Nuclear Facilities' (AERB/SM/O-2 Rev.4, 2005) provides the technical and organisational aspects of occupational radiation exposure control under both normal and potential exposure conditions. Based on this each plant prepares its own "Radiation Protection Procedures" relevant to its design and functioning.

v) The Safety Code on 'Management of Radioactive Waste' (AERB/NRF/SC/RW, 2007) lays down requirements to be met in the management of radioactive waste at nuclear and radiation facilities including radiation protection and environmental safety. The code requires establishment of predisposal management of radioactive waste.

The dose limits for exposure from ionizing radiation for occupational workers and the members of the public are prescribed by AERB in its Directive No.01/2011 under Rule 15 of the Atomic Energy (Radiation Protection) Rules, 2004. These dose limits are as follows:

Dose Limits for Occupational Workers

a. an effective dose of 20 mSv/yr averaged over five consecutive years (calculated on a sliding scale of five years);

b. an effective dose of 30 mSv in any year;

c. an equivalent dose to the lens of the eye of 150 mSv in a year;

d. an equivalent dose to the extremities (hands and feet) of 500 mSv in a year and

e. an equivalent dose to the skin of 500 mSv in a year;

f. limits given above apply to female workers also. However, once pregnancy is declared the equivalent dose limit to embryo/foetus shall be 1 mSv for the remainder of the pregnancy.

ICRP (ICRP 118, 2012 and IAEA GSR Part-3, 2014) had recommended an equivalent dose limit to the lens of the eye as 20 mSv per year averaged over five consecutive years (100 mSv in 5 years) and of 50 mSv in any single year. AERB is in the process of collecting inputs from NPPs on eye lens dose during various activities for revising and implementing the regulatory dose limits for eye lens. Currently, eye lens dosimeters have been deployed in NPPs in activities having potential for eye lens exposure on trial basis for collecting data.

Dose Limits for members of public

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

15.2 RADIATION PROTECTION PROGRAMME AT NPPs

15.2.1 Design Phase

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

At the design stage, adequate provisions for radiation protection are made to keep radiation levels in plant areas below design levels. Ventilation system is designed in such a way that the airborne contamination is maintained below 1DAC in full time occupancy areas of the plant. Occupancy factors are also taken into consideration in the design of ventilation and shielding for the accessible areas of the plant. The shielding shall be such that the dose rate in full time occupancy areas does not exceed 1 μSv/hr. The NPP is also designed to comply with the specifications on radiation levels in plant areas, maximum radiation dose rates in control room and outside reactor building during accident conditions. It also has an elaborate radiation monitoring system to enable verification of design intent. Radiation Monitoring System consists of area radiation monitors, process monitors, ventilation duct monitors, environmental monitors and effluent monitors. These monitors are connected to a Radiation Data Acquisition System (RADAS) which gives history, trend and instantaneous readings of the monitors and displays their alarm state in plant control room and the shift health physicist's office.

Based on the operating experience, many design modifications for exposure control have been incorporated progressively in the Indian NPPs. Some of the design changes such as water filled Calandria Vault Cooling system, CO_2 based Annulus Gas Monitoring system, valve-less PHT system, use of sub-micron filters in PHT system, use of canned rotor pumps in moderator system, reduction of equipment/components in moderator and PHT systems, use of cobalt-free alloys in in-core components and relocation of some of the equipment e.g. vapour recovery dryers, end shield cooling heat exchangers etc. from Reactor Building to reactor auxiliary building have resulted in significant reduction in exposures.

Pre-Operational survey which includes monitoring of external radiation levels, assessment of radioactivity in water, air, soil and other environmental matrices, meteorological conditions, dietary habits of public etc. is carried out for a sufficiently long time during siting stage of NPP. This baseline data is subsequently used as a datum for radiological impact assessment due to NPP operation.

15.2.2 Operation Phase

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

- Organisational structure of the health physics unit at the NPP,
- Area/zone classification of plant areas and access control ,
- Exposure control scheme and work procedures,
- Area radiation monitoring and surveys,

- Environmental radiological surveillance and monitoring,
- Determination of external and internal doses,
- Decontamination procedures and methods ,
- Control, handling, storage and transport of radioactive materials including radioactive wastes,
- Control and monitoring of radioactive liquid and gaseous releases,
- Equipment for personnel protection,
- Training/retraining of personnel including temporary workers in radiation protection and emergency procedures,
- Health surveillance of radiation workers,
- Documentation of data on radiological conditions of the plant, personnel exposures and effluent discharges
- Training and qualification of health physics personnel, and
- QA programme.

i. Radiation Protection Organisation

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

ii. Infrastructure and Manpower

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

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

iii. Exposure control and implementation of ALARA

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

a) All NPPs have ALARA committees at station level and sectional level. These committees periodically review the plant radiological conditions and exposure status. The committees also review all dose intensive jobs planned at the facility and their recommendations are incorporated in the job planning. In addition, periodic ALARA reviews are conducted at the NPPs to identify areas for dose reduction and to implement corrective actions.

b) The operating experience on radiological events at NPPs in India and in other countries is reviewed and the lessons learned are communicated to all concerned station personnel. In addition, Station Operation Review Committee (SORC) also reviews the radiation exposure control.

c) Collective Dose budgeting

d) Restricting the external exposure by means of shielding, remote operation, source control, rehearsing the work on mock ups and minimizing the exposure time;

e) Minimising the internal exposures by source control

f) Periodic review of radioactive work practices

g) Periodic training of radiation workers on Radiation protection aspects

iv. Observance of dose limits

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

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

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

The external exposure of radiation worker is determined using TLDs, and for day to day dose control purpose Electronic Personnel Dosimeters with preset alarm facility are used. In areas of high or non-uniform radiation fields, additional dosimetry devices such as extremity badges (for hands or fingers) and head badges are used for exposure control purpose. Neutron monitoring badges and direct reading neutron dosimeters as prescribed by the health physics unit are used wherever applicable. Evaluation of the committed effective dose of all radiation workers due to tritium uptake in PHWRs is carried out by routine and non-routine bioassay sampling. Workers are also subjected to routine whole body counting for assessment of internal contamination.

A computerized dose data management system and National Occupational Dose Registry System is used in NPPs for effective dose monitoring and dose control of radiation workers. Networking of Radiation Monitors for obtaining radiation levels on real time basis is provided in the control room and the Health Physics office.

Around 15,300 persons were monitored annually during 2016-2018. The average annual dose of the monitored persons is 1.32 mSv. No radiation worker received the radiation dose above the annual regulatory dose limit of 30 mSv/year in the last three years.

15.3 CONTROL OF RADIOACTIVE EFFLUENTS

i. Method of Disposal and Monitoring

Gaseous wastes from reactor building are filtered using pre-filters and HEPA filters and discharged after monitoring, through ventilation exhaust stack. Whenever the effluent releases as monitored at final discharge points are below the minimum significant level of measurement, the average and total releases for a particular period are arrived by taking measurements in individual streams coming from active areas i.e. monitoring/sampling of individual exhaust streams is resorted. The release rate and integrated releases of different radionuclides are monitored and accounted for to demonstrate that the releases are within the authorized limits and are kept ALARA.

The radioactive liquid wastes generated in a NPP are segregated, filtered and conditioned as per procedure and diluted to comply with the discharge limits for aquatic environment. The activity is monitored at the point of discharge and accounted on a daily basis. If activity is not detected at main discharge point, then samples are taken from the disposal tank (prior to dilution) and analyzed in the laboratory for tritium and gross beta-gamma activity. The lab results along with the dilution flow are used to compute the activity discharged. In case, no activity is detected in the lab measurement, the Minimum Detectable Limit (MDL) of the counting system is used for arriving at the releases. AERB has prescribed limits on annual volume and activity of discharge, daily discharges and activity concentration at the point of discharge from each NPP and are site specific.

The radioactive solid wastes generated from NPP operation are disposed off in brick lined earthen trenches, RCC vaults or steel lined tile holes, depending on radioactivity content and radiation levels. These disposal modes are located in Near Surface Disposal Facility (NSDF) within the exclusion zone of NPP and disposal is carried out as per the guidance given in AERB/NRF/SG/RW-4, 2006.

The details on radioactive waste management are covered in the Article 19.

ii. Authorized Limits of Discharge

The discharge of radioactive waste from an NPP is governed by the Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987. It is mandatory for a NPP to obtain authorization under these rules from the Competent Authority for disposal of radioactive wastes and file a return annually to AERB indicating the actual quantity of radioactive waste discharged.

The regulatory limits (authorized limits) of radioactive effluents are based on the apportionment of effective dose limit of 1 mSv per year to the public arising from nuclear facilities at a site due to normal operation (including anticipated operational occurrences), considering all the routes of discharges and significant radionuclides in each route of discharge. There is also a requirement of maintaining sufficient 'dose reserve', while apportioning the doses among nuclear facilities at a site, to factor the future requirements.

The derived limits of effluent discharge corresponding to the dose apportioned for the facility for different radionuclides are established taking into account the site-specific parameters, design of NPP and the operating experience, following the ALARA principle. These limits are included in the Technical Specification for Operation of the NPPs

iii. Discharge constraints

Discharge constraints are set at a much lower value than the authorized limits to achieve effluent releases at ALARA level. These discharge constraints are usually set at 50-65% of authorized discharge limits taking into cognizance differences in NPP system design. The operating data shows that releases from NPPs have been a small fraction of the specified release limits.

15.4 ENVIRONMENTAL MONITORING

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

The basic objective of environmental monitoring and surveillance programme is to assess the radiological impact of the NPP and demonstrate compliance with the radiation exposure limits set for the members of the public by AERB. This is achieved by carrying out radiological surveillance of the environment by professionals of ESLs. The ESLs are part of BARC and are independent of the utilities and submit periodic reports to AERB on radiological information and the results of environmental surveillance around the NPP.

The ESL continues its monitoring and surveillance programme during the operation phase of the NPP. The samples for analysis are selected on the basis of potential pathways of exposure. Areas up to a distance of 30 km are covered under the environmental surveillance programme. From the radioactivity level in the environmental matrices, intake parameters and dose conversion factors, the population dose is evaluated**.** The annual effective dose to the representative person of the public in the vicinity of the NPPs is estimated to be around 5 μSv, 40 μSv and 30 μSv for Tarapur, Rawatbhata and Kalpakkam respectively, the three sites having old NPP units and 0.1 to 2 μSv for other NPP sites.

Indian Environmental Radiation Monitoring Network (IERMON) has been established across the country for online detection of nuclear emergency. The network currently has about 470 monitoring systems across the India. IERMON provides:

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

15.5 RADIOLOGICAL PROTECTION OF THE PUBLIC

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

The sources contributing to generation of radioactive solid, liquid and gaseous wastes and their discharge to the environment are examined with respect to minimisation of waste at the source at the design stage itself. The effluent discharges are continuously monitored and restricted within the authorized limits. In addition to the authorized limits of discharge AERB has prescribed "Discharge Constraints" at which the licensee is required to review the situation and report to AERB on the corrective actions planned. The dose to the public resulting from these releases is assessed and if necessary, appropriate design measures to reduce the discharge are introduced. The annual effective dose to the representative person in public domain at various distances is assessed by using radioactive liquid and gaseous discharges as well as radioactivity concentration in various environmental matrices around NPPs. The radiation level in the public domain of NPP site and discharges from NPPs are included in the annual report of AERB and placed on public website.

15.6 REGULATORY REVIEW AND CONTROL ACTIVITIES

AERB enforces control on radiation protection aspects of NPPs through

i. Review of Radiation protection aspects during Project Stage

During the review of Preliminary Safety Analysis Report (PSAR) of the NPP at the project stage, aspects of radiation protection such as equipment layout, zoning, shielding, material selection etc. are covered. This ensures that during the subsequent operational stage of the NPP, exposure to occupational worker for operational and maintenance jobs are limited.

ii. Collective Radiation Dose Budgeting

Annually the collective dose budget is prepared by each NPP based on the jobs that are likely to be executed and collective dose consumed in the previous years as well as the existing radiological condition in the plant. The aim of the exercise is to minimize the collective dose in line with ALARA principle. AERB carries out review and approval of the budget. The review is based on past experience of similar jobs and maintains parity between similar NPPs. Further on quarterly basis adherence to the budget is also reviewed so that the planned activities for the year are carried out within the budget. The unplanned activities, which were not part of the collective dose budget, are carried out based on the principles of ALARA. Collective dose consumed in unplanned activities is also reviewed by AERB.

iii. Review of Radiological Safety Aspects

Routine quarterly and annual reports on radiological safety aspects are prepared jointly by the RSO of the NPP and Directorate of HS&E at HQ of utility. Subsequently, it is reviewed at station level in SORC. This report is further reviewed at NPC-SRC for operations at HQ and submitted to AERB for review. Annual ESL reports of off-site environmental monitoring and micro meteorological monitoring around NPP site are reviewed by AERB. NPPs' position on important observations, if any, is obtained by AERB.

iv. Regulatory Inspection

AERB carries out regulatory inspection of all NPPs to verify the compliance with the safety requirements and to check radiological status. During the inspection, environmental monitoring data, effluent discharge data, radioactive waste disposal data and quality assurance programme in Radiation Protection are checked. Additionally, AERB also conducts regulatory inspections during Biennial Shutdown (BSD)/ Refueling Shutdown (RSD) of NPPs to ascertain compliance with radiation protection procedures.

v. Review of Radiation Exposure to Occupational Workers

Radiation exposure to the occupational workers is controlled by ensuring compliance with the dose limits prescribed by AERB. The radiation exposure to the occupational workers is periodically reviewed by AERB based on the health physics reports. The exposure cases exceeding the regulatory constraints/ limits are primarily investigated by the exposure investigation committee at each NPP and subsequently reviewed by AERB.

15.7 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

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

ARTICLE 16: EMERGENCY PREPAREDNESS

1. Each Contracting Party shall take the appropriate steps to ensure that there are onsite and off-site emergency plans that are routinely tested for nuclear installations and cover the activities to be carried out in the event of an emergency.
2. 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.
3. 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.
4. Contracting Parties which do not have a nuclear installation on their territory, insofar as they are likely to be affected in the event of a radiological emergency at a nuclear installation in the vicinity, shall take the appropriate steps for the preparation and testing of emergency plans for their territory that cover the activities to be carried out in the event of such an emergency.

16.0 GENERAL

Nuclear Power Plants (NPPs) in India are designed, constructed, commissioned and operated in conformity with relevant nuclear safety requirements. These requirements ensure an adequate margin of safety so that NPPs can be operated without undue radiological risks to the plant personnel, public and environment. Notwithstanding these, it is necessary to develop Emergency Preparedness and Response (EPR) plans, as a measure of abundant caution. EPR plan has been an essential requirement for operation of NPPs in India from the very beginning of nuclear power programme. These plans are prepared in accordance with the national laws and regulations and deal with effective management of any eventuality with a potential to pose an undue radiological risk to the plant personnel, public and the environment. The Plant Management, District Authorities, State Government, AERB, National Disaster Management Authority (NDMA) and National Disaster Response Force (NDRF) have a significant role in preparedness and response to emergencies.

16.1 NATIONAL LAWS, REGULATIONS AND REQUIREMENTS

The national legislative requirement for the use of atomic energy is governed by Atomic Energy Act, 1962. Atomic Energy (Radiation Protection) Rules, 2004 prescribe the rules for implementation of the radiation protection related provisions of this Act. The Rule No. 32 prescribes the directives in case of accidents and the Rule No. 33 prescribes the requirement for emergency preparedness. Government of India has also enacted 'Disaster Management Act, 2005' which provides for effective management of disasters including accidents at NPPs which can result in a radiological emergency in the public domain. Based on these laws and regulations, specific requirements with respect to emergency preparedness in NPPs have been formulated by AERB.

The national framework with respect to preparedness & response to emergencies is given in the National Disaster Management Plan issued in year 2016 under the provisions of Disaster Management Act, 2005. This plan covers management of various disasters, including nuclear & radiological emergencies. The plan identifies Ministry of Home Affairs in the Central Government as overall coordinator for emergencies and Department of Atomic Energy (DAE) as the nodal department for technical support and coordination during management of nuclear or radiological emergencies. This plan assigns distinct functional responsibilities to various local, state and central authorities with respect to emergency preparedness and response. As per this plan, AERB has the responsibility to prepare safety and regulatory documents for all nuclear/ radiological applications, transport, safe custody, waste handling, personal safety, medical aspects etc.

The constitution order of AERB (1983) also assigns it the responsibility for review of the emergency preparedness plans of Nuclear Facilities. In order to fulfil these responsibilities, AERB has published necessary guidelines for preparation of emergency preparedness and response plans for Nuclear Installations.

The regulatory requirements and guidance for preparing and maintaining emergency response plans for plant and site emergency are given in the AERB Safety Guidelines 'Preparation of Site Emergency Plans for Nuclear Installation' (AERB/SG/EP-1, 1999). The requirements & guidance for off-site emergency preparedness and response are given in AERB Safety Guidelines on 'Preparation of Off-Site Emergency Preparedness and Response Plans for Nuclear Emergency' (AERB/SG/EP-2, 1999). In the year 2014, AERB issued Safety Guidelines on 'Criteria for Planning, Preparedness and Response for Nuclear or Radiological Emergency' (AERB/NRF/SG/EP-5, 2014 (Rev. 1)) which is in line with IAEA safety guide GS-G-2 (2011). This safety guideline provides the criteria for establishing an emergency preparedness and response plan to deal with nuclear and radiological emergencies.

In addition to the above safety guidelines, aspects related with emergency preparedness and response are also covered in the following AERB safety documents,

- The Safety Code on 'Regulation of Nuclear and Radiation Facilities' (AERB/SC/G, 2000) stipulates the minimum safety related requirements including that for emergency preparedness to be met by a nuclear or radiation facility to qualify for the issue of regulatory consent at every stage. Prior to issuance of licence for operation of an NPP, AERB ensures that the approved emergency preparedness plans are in place and are tested.
- The Safety Code on 'Safety in Nuclear Power Plant Operation' (AERB/SC/O, 2008) stipulates the requirement for development of an emergency preparedness plan and maintenance of a high degree of emergency preparedness by the licensee. The emergency preparedness programme shall provide reasonable assurance that, in the event of an emergency situation, appropriate measures will be taken to mitigate the consequences. This programme has to be in force before commencement of operation.
- The Safety Code on 'Radiation Protection for Nuclear Fuel Cycle Facilities' (AERB/NF/SC/RP, 2012) stipulates the requirements for providing adequate assurance for radiation safety of the occupational workers, members of the public and the environment against undue exposure to ionising radiation. It also specifies the requirements for establishing emergency preparedness programme and roles and responsibilities of various agencies.
- The Safety Guide on 'Role of the Regulatory Body with Respect to Emergency Response and Preparedness at Nuclear and Radiation Facilities' (AERB/SG/G-5, 2000) describes the role of AERB with respect to 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 AERB's review and approval process of emergency preparedness and response plans formulated by nuclear and radiation facilities and review of reports on emergency exercises carried out to assess the adequacy of response plans and associated preparedness.
- The Safety Guide on 'Preparedness of the Plant Management for Handling Emergencies at NPPs' (AERB/SG/O-6, 2000) supplements the Safety Code on 'NPP Operation' (AERB/NPP/SC/O, Rev.1, 2008). It covers the important considerations relevant to the preparation and implementation of EPR plans by the Plant Management.

16.1.1 Revision of regulatory documents on EPR

AERB is currently in the process of consolidating & revising its requirements and guidance for EPR, which presently are addressed in a number of documents and were developed in different timelines over many years. As a step towards holistic revision, the existing requirements are being consolidated/updated through a dedicated safety code and safety guides for management of nuclear and radiological emergencies. Safety code and guides for EPR are being developed taking into account existing EPR requirements, developments including the change in approach to public protection during emergency conditions as elaborated in ICRP publications, IAEA General Safety Requirements (IAEA GSR Part-7), lessons learned from the accident at Fukushima Daiichi NPP & subsequent safety reviews of Indian NPPs and guidance available nationally &internationally.

These new regulatory documents (code and guides) are being prepared following a bottom-up approach. Necessary supporting documents on areas including development of Emergency Action Levels (EALs), development of protection strategy, conduct of emergency exercise and template for EPR plans of NPPs have been developed. The understanding established in these supporting documents is also used in a graded manner in formulating the regulatory requirements and guidance.

Recently, AERB has approved the template for preparation of off-site EPR plans of NPPs. The template in addition to incorporating the current national framework and command & control for emergency response, elaborates on the various aspects that are to be addressed in the EPR plan in line with the expectations of the regulatory documents under revision/preparation. AERB has issued directives to NPPs to prepare their off-site EPR plans based on the template and other supporting documents developed by AERB until the regulatory documents on EPR (code & guide) are published.

Currently the draft Safety Code on Management of Nuclear and Radiological Emergencies has been prepared and, is in advanced stage of review. The Safety Guide on management of nuclear emergencies in NPPs is being drafted.

16.1.2 NATIONAL ARRANGEMENTS

The important agencies/authorities identified in the National Disaster Management Plan, 2016 with respect to preparedness and response for nuclear and radiological emergencies are as below:

i. National Level

The national agencies such as National Disaster Management Authority (NDMA), National Crisis Management Committee (NCMC) and the response organisations have role in management of all types of disasters including nuclear & radiological emergency, which is as follows:

National Disaster Management Authority (NDMA) - NDMA, the apex body is headed by the Prime Minister of India and has the responsibility for laying down policies, plans and guidelines for disaster management in the country. It also coordinates the implementation of the policy and plans for disaster management.

National Crisis Management Committee (NCMC) - NCMC, under the Cabinet Secretary, is mandated to co-ordinate and monitor the response to crisis situations, which includes nuclear and radiological emergencies. NCMC consists of 14 union secretaries of concerned ministries. NCMC provides effective co-ordination and implementation of response and relief measures in the wake of disasters. It will be supported by the Crisis Management Groups (CMG) of the Central Nodal Ministries and assisted by NEC as may be necessary. The Secretary, NDMA is a permanent invitee to NCMC.

National Executive Committee (NEC)– NEC is the executive committee mandated to assist the NDMA in the discharge of its functions and also ensure compliance of the directions issued by the Central Government. NEC prepares the National Plan for Disaster Management based on the National Policy on Disaster Management and monitors the implementation of guidelines issued by NDMA. NEC also coordinates the response in the event of any emergency.

National Disaster Response Force (NDRF) - NDRF is a specialized force constituted under DM Act, 2005, for disaster response. This is a multi- disciplinary, multi-skill, high-tech force. Twelve battalions have been equipped and trained for handling natural disasters including eight battalions for dealing with nuclear/radiological emergencies.

Crisis Management Group (CMG), DAE - Department of Atomic Energy (DAE) is the nodal agency in the country for providing technical expertise / guidelines for managing nuclear and radiological emergencies. For this purpose, a Crisis Management Group (CMG) has been established in DAE since 1987. CMG-DAE comprises of senior officials drawn from various DAE units and AERB. It is empowered to mobilize the resources of other DAE facilities, if required.

In the event of Off-Site Emergency, CMG-DAE is activated and the NCMC contact point is intimated. CMG-DAE provides necessary co-ordination between local authorities in the affected area(s), the NDMA and NCMC, and arranges necessary technical support for effectively handling the situation and reducing radiation exposure to the public. CMG provides advice and assistance in the areas of radiation measurement, radiation protection and medical assistance in the affected area. The Emergency Control Room (ECR) located at DAE Headquarter, Mumbai & at NPCIL, Headquarter, Mumbai functions 24 x 7 and ensures communication and co-ordination between all relevant agencies.

Technical Support Organisation (TSO) - Director, Health, Safety & Environment (HS&E) Group, BARC who is the ex-officio Emergency Response Director (ERD) of DAE is the lead co-coordinator for providing the radiation measurement, monitoring and protection services to the CMG, DAE. A network of twenty-five radiation Emergency Response Centres (ERCs) equipped with adequate radiation measuring and personnel protective equipment and trained Emergency Response Teams (ERTs) have been established by DAE in different parts of the country to respond to nuclear and radiation emergency situations. ERD has Standard Operating Procedures (SOPs) for coordinating various actions. During nuclear and radiological emergency situation, the ERC closest to the site of the incident, will be activated.

The HS&E group, BARC has established Indian Environmental Radiation Monitoring Network (IERMON) at various parts of the country and with central monitoring station located in Mumbai. IERMON provides online environmental radiation information during both normal and emergency situations.

Environment Survey Laboratory (ESL) - Well-equipped Environment Survey Laboratories (ESLs) are established near nuclear power plant sites, by BARC (TSO), well before the commissioning of the plant and continues to remain functional during the operational phase of NPP. During nuclear emergency, ESL undertakes environmental surveillance outside the exclusion boundary for monitoring any change in environmental radiation levels. It also provides information on meteorological data such as wind speed, wind direction etc. It undertakes extensive environmental sampling and radiation surveillance in the affected sectors to facilitate decisions regarding protective measures to be implemented in the public domain. It also provides predictive dose (based on source term and meteorological conditions) to the Site Emergency Director. These ESLs are integral part of the response organisations at each NPP site.

Atomic Energy Regulatory Board (AERB) - AERB lays down the requirements and provides guidance for preparation of EPR plans. AERB reviews and approves plant, site and offsite emergency preparedness & response plans of NPPs. The off-site emergency plans of the local authorities are reviewed by AERB before being approved by the district authority/state authority. AERB ensures EPR plans are in place prior to the operation of NPP and are periodically updated and that the plans are tested through periodic exercises as prescribed by its codes and guides and participates, as an observer, in the exercises.

During nuclear emergency phase, AERB monitors and keeps itself informed about the emergency situation. It reviews & assesses the emergency situation, and if required, provides appropriate regulatory support and technical advice to the response agencies, as necessary.

AERB also informs the public and government on the safety significance of events and actions being taken. For this purpose, AERB maintains its own Nuclear and Radiation Emergency Monitoring Centre (NREMC) which is equipped with adequate communication facility and capability to independently assess the emergency situation (see section 16.4.1). The activities carried out by AERB during an emergency situation are not a part of ongoing response actions carried out by the various response agencies.

During the existing exposure situation, AERB reviews and advises follow up actions to minimize exposures to protect the public, lays down criteria for re-entry into plant areas and affected places and reviews resumption of operations or decommissioning of the facility.

ii. State Level

State Disaster Management Authority (SDMA)- The State Disaster Management Authority (SDMA) headed by the Chief Minister of the State as Chairperson lays down policies and plans for Disaster Management in the State. It approves the State Plan in accordance with the guidelines laid down by NDMA, coordinates the implementation of the State Plan, recommends provision of funds for mitigation and preparedness measures and reviews the developmental plans of the different departments of the State to ensure integration of prevention, preparedness and mitigation measures.

State Executive Committee (SEC) - Each State Government constitutes a State Executive Committee (SEC) to assist the SDMA in the performance of its functions. The SEC headed by the Chief Secretary to the State Government, coordinates and monitors the implementation of the National Policy, the National Plan and the State Plan. The SEC also provides information to the NDMA relating to different aspects of Disaster Management.

iii. District Level

District Disaster Management Authority (DDMA) is the overall in-charge for the management of off-site emergency. DDMA acts as the planning, coordinating and implementing body for management of all types of disasters at district level including nuclear/radiological emergency in public domain (offsite emergency). DDMA is headed by the District Magistrate, District Collector (DC), Dy. Commissioner as the case may be.

All the decisions related to management of emergency in public domain are taken and executed by the Responsible Officer (Head of DDMA) at the District level. As the authority at the district level, he takes all necessary measures for emergency management in accordance with the policies, guidelines and plans laid down by SDMA, NDMA & AERB. The DDMA also ensures that the guidelines for prevention, mitigation, preparedness and response measures laid down by AERB, NDMA and SDMA are followed by all departments of the State Government at the district level and the local authorities in the district. In an emergency situation, the district authority on receipt of notification, initiates prompt response actions to protect public and responders based on technical inputs from SED and ERD (for the respective phases of emergency). Thus, the DDMA coordinates with all responsible agencies such as NPP, SDMA, CMG-DAE, NDMA, AERB and NDRF.

iv. Roles and Responsibilities of the Operating Organisation

In an emergency situation, the licensee reviews the plant status and assesses the actual or projected releases from the plant to identify and classify the emergency category. Plant, Site and Off-site emergencies are declared by Licensee / SED. Emergency communication are sent promptly to district authority (District Collector)) and other concerned organisations including AERB, CMG-DAE and NPCIL HQ. Site Emergency Director (SED) provides technical inputs and assistance during early phase of off-site emergency to district authority and recommends on implementation of protective actions and other response actions. During Intermediate and Late phase of off-site emergencies, DAE Emergency Response Director

(ERD) (member of CMG-DAE) provides technical inputs and assistance to district authority and recommends on implementation of protective actions and other response actions.

16.2 EMERGENCY PREPAREDNESS AND RESPONSE PLANS

Successful demonstration of EPR plans is a mandatory requirement for issuing licence for operation of NPPs. AERB ensures that necessary EPR plans are in place and they are successfully demonstrated before issuing regulatory consent for First Approach to Criticality. AERB evaluates all the elements of the EPR plans such as identification of emergency, classification, decision making, notification, communication, projected dose assessment and ensures that these plans are being periodically revised. The regulatory oversight during plant operation assures that the provisions and procedures to implement these plans are maintained up-to-date and tested periodically. EPR plans cover all emergency situations envisaged so that a graded response consistent with the gravity of the situation can be ensured.

AERB reviews and approves plant, site and off-site EPR plans of NPPs. The off-site EPR plan for response action in public domain is prepared by the local authorities and maintained as part of District Disaster Management Plan (DDMP). The plan is reviewed by AERB prior to the approval by responsible authorities at State level. District authorities in consultation with SED conduct off-site emergency exercises periodically at all NPP sites. In these exercises observers from other organisations such as AERB, Crisis Management Group-Department of Atomic Energy (CMG-DAE), NDMA, and NPCIL HQ also participate to check response of different emergency response groups as specified in approved EPR plans. During the above exercises, resources and facilities are assessed for adequacy. Further, Nuclear and Radiological Emergency Monitoring Centre (NREMC) at AERB is also activated to monitor these exercises.

Main features of the emergency preparedness and response plan are as follows:

16.2.1 Protective Actions

The planning and implementation of protective actions are broadly based on justification and optimisation of radiation exposure such that there is a net positive benefit to the exposed population. Protection strategies are evolved by simultaneously considering all exposure pathways and all relevant protective actions rather than acting on levels for individual protective actions. To comply with a planned reference level in an emergency exposure situation, protection strategies are evolved which is a combination of different protective actions like sheltering, iodine thyroid blocking, food control, evacuation, etc.

The Generic criteria and operational criteria have been established and included in the site specific EPR plans of NPPs and are being used for implementation of protective actions. Reference levels are used to plan protective measures commensurate with the phase of emergency and are also used as a tool in the optimisation of the protection strategy and also serve as a benchmark for retrospective assessment of the effectiveness of the protective actions and the protection strategy.

16.2.2 Emergency Planning Zones and Distances

Emergency planning zones and distances are established for emergency preparedness and response. The requirement and guidance for these zones and distances are provided in AERB Safety Codes AERB/SC/G, AERB/NF/SC/S (Rev.1), AERB/NPP/SC/O, AERB/NRF/SG/EP-5, AERB Safety Code (draft) on 'Management of Emergency in Nuclear and Radiation Facilities' and AERB Safety Guides (draft) on 'Management of Emergency in Nuclear facilities' for drawing up the emergency preparedness and response plans for NPPs. For effective implementation of protective actions, the area around the site is divided into zones viz. Precautionary Action Zone (PAZ) and Urgent Protective Action Planning Zone (UPZ). The area is further extended in the downwind direction as Extended Planning Distance (EPD) and Ingestion and Commodities Planning Distance (ICPD) for implementing protective actions. For the purpose of emergency preparedness, sizes of the zones & distances are based on hazard analysis.

16.2.3 Classification of Emergencies

In accordance with the severity of the potential consequences, emergency situations are graded as Plant Emergency, Site emergency and Off-site emergency. Emergency Action Levels (EALs) are used for identification, classification and declaration of plant, site and off-site emergency. These EALs are the specific plant parameters and conditions established based on hazard analysis and included in site specific EPR plans.

i. Plant Emergency

It is an emergency condition identified by EALs, in which the radiological/other consequences are confined within the plant or a section of the plant. The Plant Emergency Director (Station Director) is identified as the responsible person for the declaration and termination of a plant emergency.

ii. Site Emergency

It is an emergency condition identified by EALs, in which the radiological consequences are confined to the exclusion zone of the site. Site Emergency Director (SED) is the responsible person for the declaration and termination of a site emergency. Site Emergency Response Committee (SERC) advises SED. For twin unit site, Station Director and for multi-unit site, Site Director is identified as SED.

iii. Off-Site Emergency

It is an emergency condition resulting in an actual release, or substantial probability of a release, requiring implementation of urgent protective actions beyond the site boundary (exclusion zone) in the public domain. Site Emergency Director (SED) is responsible for declaration of off-site emergency. Off-Site Responsible Officer, who is a district authority, is responsible for implementation of protective actions in the public domain. Site Emergency Director (SED), Emergency Response Director (ERD)and Crisis Management Group-Department of Atomic Energy (CMG-DAE) provide technical inputs and assistance to district authority and recommends on implementation of protective actions and other response actions at various phases of emergency.

16.2.4 Features of On-Site EPR Plan

The Plant Management establishes and maintains the necessary emergency resources and procedures for implementation of On-Site EPR plan (i.e. Plant and Site EPR plans). The On-Site EPR plan includes criteria for declaration of emergency, duties and responsibilities of relevant key personnel, infrastructure for emergency response, mock exercises, and training of plant personnel & public authorities. Main elements of On-site EPR plan are detailed below:

16.2.4.1 Roles and Responsibilities for On-Site Emergency Response

For management of on-site emergency in an effective manner, senior officers of the NPPs are identified and various response teams/groups are formed. These teams/groups are responsible for specific actions such as advisory, services, damage control, search, rescue, radiation monitoring, medical response, transportation, environmental survey etc. For effective coordination between these response teams, a Site Emergency Committee is constituted with heads/ responsible persons from various sections of the plant. Site Director / Station Director is the head of the Site Emergency Committee. The duties and responsibilities of key personnel are well defined in the Site EPR plan.

16.2.4.2 Criteria for declaration and termination of emergency

Plant/ Site emergency is declared if the Emergency Action Levels (EALs) are reached. EALs are pre-determined, plant or site-specific, observable threshold for an Initiating Condition (IC) that, when met or exceeded, places the plant in a given emergency classification level. EALs are based on a variety of criteria including instrument readings and plant status based on indications; observable events; results of calculations and analyses; and the occurrence of natural phenomena.

The plant/site emergency is terminated after ensuring that the following conditions are met:

i. The plant condition is under control.

ii. The sources of incident causing emergency within the plant have been located and confined/ restricted.

iii. Effluent releases from the plant are within acceptable limits

16.2.4.3 Infrastructure for On-Site Emergency Response

The infrastructure available for conducting various emergency response actions in a systematic, coordinated, and effective manner is as follows:

i. Plant Control Room

In case of plant emergency, the plant control room is identified as the centre to handle emergency operations. Further, in case of site emergency, the plant control room provides firsthand information about the emergency situation to the Site Emergency Response Committee (SERC). If for some reason, the main control room becomes uninhabitable, the status of plant can be monitored from the backup control room located in the plant.

ii. Site Emergency Control Centre (SECC)

Presently an Emergency Control Centre (ECC) for Site Emergency is suitably located away from the plant but within the site, for use by the Site Emergency Committee to direct emergency actions. Further, it is used for coordinating with off-site emergency authorities, so that control room staff is not distracted from performing control room operations. This facility houses emergency equipment centre, treatment area, personnel decontamination area and has sufficient space to accommodate SERC members, rescue teams, health physics staff, emergency maintenance unit staff, stores and industrial safety group. It is equipped with communication systems, public address system, emergency equipment/instruments, standard operating and emergency procedures, design basis reports, P&I diagrams, maps of EPZ, potassium iodate tablets, iso-dose curves etc. for undertaking emergency response actions.

iii. Communication System

The NPPs have diverse communication systems which are available for emergency purpose. Direct communication link is available between the emergency control centre, fire station and plant control room for communication within the plant. In addition, during on-site emergencies NPCIL/Utility Headquarters, CMG-DAE, AERB and District Authorities with Off-Site/local government are required to be kept informed for which, NPPs have redundant and independent communication system in place. The contact details of the identified key personnel are maintained and updated from time to time by the NPPs. Siren and announcement system with adequate number of points for warning the plant personnel are available. The declaration and termination of emergency is done though this system. Communication system includes wireless, telephone, radio sets, satellite communication and electronic mail facilities which are tested daily to ensure their availability. These systems are available for use at all times.

iv. Emergency Equipment and Protective Facilities

Various equipment required for emergency management are kept available in the NPP. To protect the plant personnel essential facilities such as plant assembly areas, emergency shelters, first-aid centre, treatment areas, de-contamination kits, prophylactics, respirators, ambulance etc. are provided within the site area. In addition, for monitoring the radiological conditions, the required number and type of radiation monitoring instruments are available.

16.2.5 Features of Off-Site EPR Plan

The offsite emergency plan includes details about site characteristics, procedures for declaration of emergency, duties and responsibilities of relevant key personnel, infrastructure for emergency response, requirements for exercises, and training of plant personnel & public authorities / Local Government. Main elements of off-site EPR plan are as detailed below:

16.2.5.1 Site Characteristics

The site characteristics includes description of the site location, nuclear installations, various major components of the facility(s), nature of materials handled, processes involved and hazard category. This broadly covers the demographic location of the site indicating the state, district and taluka level division with relevant detailed map, location with respect to nearest natural and manmade features such as rivers, lakes, dams, railway station, State and National Highway with relevant detailed maps, details of nearby installations like factories, oil/gas pipelines, defense installations, airports and other vital installations. Demographic characteristics of the site include population distribution within the emergency planning zone (EPZ) and distance, transient population, population density, population centres and special groups, if any. In addition, arrangements for evacuation taking into consideration the condition of main and alternate routes, shelter points, adverse weather condition, and traffic congestion etc. are covered.

16.2.5.2 Offsite Emergency Response Framework

The offsite emergency response framework includes emergency handling organisations at the facility and the organisations at district, state and national level. For emergency situation in Early phase, Intermediate phase and Late phase, the role and responsibility of various stake holders of site organisation and offsite organisations are detailed in the EPR plan.

16.2.5.3 Roles and Responsibilities for Off-Site Emergency Response

EPR plans, wherein the roles and responsibilities of various agencies are defined, have evolved over the years for the existing NPPs. District Disaster Management Committee (DDMC) headed by the Divisional Commissioner /District Magistrate / Collector of the District is the Responsible Officer (RO) and having officials of the district organisation as the members. DDMC will function from the District Emergency Operation Centre (EOC). RO ensures implementation of protective measures such as, sheltering, distribution of prophylactics, evacuation, providing civil amenities and maintaining law and order.

The national framework and roles and responsibilities of each agency are elaborated in section 16.1.2.

16.2.5.4 Criteria for Declaration and Termination of Emergency

The criteria for identification, classification and declaration of emergency are predefined emergency action levels (EALs) that relate to abnormal conditions in the facility, releases of radioactive material, environmental measurements and other observable indications. The accidents in nuclear installation detected by plant and process parameters i.e. EALs forms the basis to declare an offsite emergency. The protective actions are implemented based on the generic criteria.

As part of emergency preparedness plan it is also ensured that arrangements are in place for the termination of a nuclear or radiological emergency. The termination of a nuclear or radiological emergency is done based on a formal decision that is made public and includes prior consultation with all stake holders, as appropriate. Both radiological consequences and non-radiological consequences are considered in deciding on the termination of an emergency.

The off-site emergency is terminated after ensuring that the specified criteria, including the following are met:

(a) The plant is under control and the sources of radiation within the plant have been identified and controlled

(b) Justified protective actions have been taken to reduce the target dose towards 20 mSv per year

(c) Confirmation that the source of exposure is fully characterized for normal living of members of the public

(d) Arrangements for managing the existing exposure situation are in-place.

16.2.5.5 Infrastructure for Off-Site Emergency Response

The infrastructure for implementing the emergency response actions in a systematic, coordinated, and effective manner is as follows:

i. Off-site Emergency Support Centre

An off-site Emergency Support Centre is located outside the exclusion zone of NPP. This is used during off-site emergency having the following as minimum functions:

a) Coordination with on-site response team;

b) Coordination of monitoring, sampling and analysis;

c) Recommending response actions;

d) Providing input for decision making with respect to protective actions in the public domain;

e) Providing information to nodal department and regulatory body on evolving emergency situation

The Off-Site Emergency Support Centre has redundant and independent communication systems for communication with NPCIL Headquarters, CMG-DAE, AERB and other concerned authorities/agencies. Emergency Control Rooms (ECRs) of CMG-DAE are maintained at Mumbai at two different locations. These ECRs are equipped with wireless, telephone, facsimile, satellite communication and electronic mail facilities which are tested daily to ensure their availability.

ii. Emergency Operation Centre

The off-site emergency response is carried out by the public authorities from the District Emergency Operation Centre. The centre has the following functions:

a) Receiving input from NPP/DAE, for carrying out response actions including information on radiological status;

b) Taking response actions (initiate and direct) in public domain and providing operational support to the response personnel.

c) Providing necessary public information.

iii. Assessment Facilities

The facilities required to assess the nature and severity of an incident and its impact on the environment are available at the NPP Site. These include plant parameters (EALs), Decision Support System (DSS), dose projection models, environmental survey vehicles, radiation survey and contamination monitors, dosimeters, meteorological data loggers, iso-dose curves, air samplers, maps, standard operating procedures, design basis reports, process & instrumentation diagrams.

iv. Radiation Monitoring during Emergency

Detailed procedures and the required capability for radiation monitoring of the affected population and area during an emergency are available at the Environmental Survey Laboratory (ESL) attached to each NPP site. Meteorological information and model predictions to determine the geographical area likely to be affected by the release of radioactive material, provided by ESL, is utilised to identify the monitoring and sampling locations. Projected dose / Radiological data required for taking decision on implementation of protective actions with reference to corresponding Operational Interventional Levels (OILs) related with Generic Criteria (GC) are established.

v. Emergency Equipment and Protective Facilities

For protection of the plant personnel, site personnel and members of public during emergency situation, sufficient inventory of equipment and facilities required for emergency management are kept available.

16.2.6 Training and Exercise

The required emergency preparedness is maintained by organising refresher training courses for site and off-site personnel at regular intervals. This includes conducting periodic exercises / rehearsals involving all concerned personnel of both site and off-site, updating plant emergency procedures 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 ready state.

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 organised for various Public Authorities. Public awareness programmes are organised for various public authorities and members of public for familiarization on radiation protection procedures and response actions during emergency.

Training programmes are also organised for National Disaster Response Force (NDRF) personnel in radiation protection procedures and response actions during nuclear and radiation emergency. The training is aimed at qualifying persons to act as trainers in their respective battalions. An arrangement has been put in place through which the training needs of personnel are identified by NDRF and special training and awareness programmes are arranged as necessary with support from BARC, NPCIL and AERB.

ii. Exercises

Exercises are conducted at regular intervals and all response organisations / concerned agencies take part. Exercises are used for the twin purposes: a) familiarize all the personnel concerned with the management and implementation of emergency measures b) assess the adequacy of EPR plans and improve them based on the feedback from exercises. It is also ensured that each Shift Crew of the plant 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 frequency of plant, site and offsite emergency exercises are once in three months, once in a year and once in two years respectively.

Mock decontamination of vehicle during off-site emergency exercise at Kakrapar site

Medical check-up of evacuees during off-site emergency exercise at Kakrapar site

In emergency exercises, hypothetical events resulting in off-site radiological implications are considered and efficacy decision making on identification and declaration of emergency condition, protective measures such as sheltering, distribution of prophylactics, sample evacuation is tested. Recently, exercises were also conceptualized and conducted, focusing on different aspects of emergency management; (a) Table top exercise emphasizing on decision making process and use of EALs; (b) Command and Control Exercise for testing command and control functions to ensure a well-coordinated operational framework. Based on the feedback from review of the exercise results, improvements in the infrastructure and other facilities are initiated, if necessary. Compliance to these aspects is further verified by AERB.

16.2.7 Revision of EPR Plans

The off-site EPR plans are being revised in line with the identified roles and responsibilities of the respective response organisations (utility & local authorities). The off-site EPR plan covering response action in the public domain is prepared by local authorities in coordination with the NPP, and the plan covering the responsibility of the utility is prepared by the utility; with both having necessary framework and interface.

In line with the above, templates for preparation of respective off-site EPR plan was prepared and issued to the district authorities and NPPs by respective agencies (NDMA to District authorities and NPCIL-HQ to NPPs). The template for offsite plan of NPPs was reviewed and approved by AERB. The template includes a revised overall response framework for off-site emergency to ensure an effective and coordinated response. This has been evolved through consultation among utility, CMG-DAE, NDMA and AERB. The template also coves various aspects of EPR plans including, classification, declaration and notification of emergency, protection strategy with focus on doing more good than harm, public communication, infrastructure for decision making, emergency exercises, comprehensive list of procedures for implementation of the emergency response plans, operational control and responsibility for personal protection of external services when they are at the facility, among others.

Following the directive from AERB (refer Section 16.1.1), NPPs have started revising the EPR plans including development of plant specific EALs and protection strategy based on the approved template.

16.3 IMPLEMENTATION OF OFF-SITE EMERGENCY MEASURES

The emergency measures consist of actions with respect to identification, classification, declaration and notification of emergency; assessment of emergency situation; corrective actions; mitigation actions; protective actions and control of contamination. These are detailed in the Off-site EPR plan and are described below:

16.3.1 Emergency Response Actions

The general sequence of response actions during an emergency:

i. Identification, Classification and Declaration of emergency

At the incipient stage of an accident, based on the adverse plant parameters and conditions (EALs), plant emergency is declared by Plant Emergency Director (Station Director) as part of the EPR plan. If the event further escalates and the EAL(s) for site emergency is/are met, Site Emergency Director (SED) declares the Site Emergency. At this stage, the off-site Responsible

Officer (RO) in the local authority is alerted about the possible escalation of Site Emergency in to Off-Site Emergency and if the situation further worsens, SED declares Off-Site emergency.

ii. Assessment Action during Emergency

The assessment of the plant conditions and likely radiological releases are made to enable planning of corrective actions and timely implementation of protective measures. The information used for assessment is based on plant parameters available in the main control room, Decision Support System (DSS), dose projection models, radiation surveys, environmental surveys and meteorological data among others. Each NPP has established facilities to continuously monitor the wind and weather conditions and to obtain dose projections in the public domain that could form the basis for determining the suitable protective measures. Provisions are also available for establishing the source term by actual measurement. In addition, the information from the Indian Environmental Radiation Monitoring Network (IERMON) is used for assessment of radiation levels in the public domain.

iii. Co-ordination among various agencies

On receiving the information of Offsite emergency from Station Management, CMG-DAE is activated. While the offsite emergency director initiates actions as per action plan for handling the emergency in public domain, the CMG will continue to provide necessary coordination between local authorities in the affected areas, the NDMA and National Crisis Management Committee (NCMC) and will provide necessary technical support and directions to the authorities responsible till the emergency conditions are terminated. On the prevailing situation at incident site, the information to the media and other agencies are given by Information and Media Officer appointed by District Collector.

iv. Mitigatory / Corrective Actions

These actions are taken to mitigate / correct the plant abnormal situation and to bring the plant under control. Various corrective actions are taken in accordance with the Emergency Operating Procedures and AMG actions existing in the plant.

v. Protective Actions

These are actions taken to mitigate the consequences of a radiological event and to protect site personnel, members of public and livestock from radiation. On the time scale these protective actions are planned as Precautionary Urgent protective Actions (PUA), Urgent Protective Actions (UPA) and Early Protective Actions (EPA). These include sheltering, iodine thyroid blocking, control on consumption of contaminated foodstuff and evacuation. It is essential to ensure that the response measures would reduce the overall impact on public to a level significantly lower than what it would be in the absence of such measures. It is ensured that implementation of protective actions is justified (doing more good than harm). The EPR plan gives details of the protective measures, generic criteria and operational criteria approved by AERB for initiating protective measures to limit radiation exposures.

Evacuation is an extreme measure taken after evaluating the risks and benefits of the protective action in terms of the projected/received dose. If the projected dose in the affected zone continues to exist beyond reference levels, then relocating the affected population is resorted to.

The generic criteria (projected dose) greater than 100 mSv/y is used for justified protective actions. Reference levels are used for optimisation of the protection strategy and also serve as a benchmark for retrospective assessment of the effectiveness of the protective actions and the protection strategy.

vi. Contamination Control

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

16.3.2 Assistance to Affected Personnel

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

i. First-aid

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

ii. Decontamination

Monitoring the contamination and carrying out decontamination of personnel, equipment, facilities and areas in the public domain is the responsibility of the District authorities. DAE is responsible for providing necessary technical support for carrying out decontamination.

iii. Transportation

All necessary resources for transport are mobilized within the plant in the shortest possible time in case of a site emergency to undertake evacuation of non-essential staff. This is done under the supervision of plant management. Organising the transport for evacuees in the affected sectors in the public domain is the responsibility of public authorities.

iv. Medical Treatment

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

The responsibility for treatment of affected persons in the public domain rests with the District Health Authority. However, any guidance needed in the treatment of radiation injuries will be provided by experts of the medical division of the NPP and DAE.

16.4 REGULATORY REVIEW AND CONTROL

Appropriate laws, regulations and requirements regarding emergency preparedness as applicable to NPPs are in place and are being complied by NPPs. Adequate regulatory control is exercised by AERB through regulations, review/approval of EPR plans of the NPPs and observing the emergency exercises. The EPR plans are updated and maintained taking into account the change in regulation, experience gained, population, demographic conditions and infrastructure in the emergency planning zone. The implementation of emergency plans has to be demonstrated before criticality of the unit. For multi-unit site, the plant / site / offsite emergency plans are revised before issuing construction consent to a new facility.

Periodic Off-site emergency exercises are carried out as per the regulatory requirements and are witnessed by AERB observers to ensure that the emergency planning is adequate and its implementation is effective. Aspects related to emergency preparedness are checked during the regulatory inspections of the NPPs.

16.4.1 Nuclear and Radiological Emergency Monitoring Centre (NREMC)

During nuclear and radiological emergency situation, it is essential for AERB to obtain up-to-date information about the emergency situation in the NPP, radiological safety of the emergency workers, public & environment in a more formal and continuous basis. It reviews & assesses the emergency situation, and if required, provides appropriate regulatory support and advice to the relevant response agencies. AERB also informs the public and government on the safety significance of events and actions being taken. To facilitate this, AERB has established a Nuclear and Radiological Emergency Monitoring Centre (NREMC). The centre is equipped with various cells (Communication, Assessment, Analysis & Legal) along with necessary software and hardware infrastructure.

NREMC of AERB

The capabilities of NREMC include, emergency analysis, assessment of emergency response actions & protective actions and communication with all stakeholders. The software systems with on-line Decision Support System (DSS), source term and radioactivity release assessment, environmental monitoring data inputs, video conferencing with other emergency response agencies and trained & experienced personnel for NREMC have been established. The necessary plans for monitoring of emergency and the procedures for functioning of NREMC are in place. NREMC is also activated during the site and off-site emergency exercises conducted at various plants to test its mechanism for obtaining information for assessing the situation. Establishment and operation of NREMC is overseen by Directorate of Radiation Protection and Environment (DRP&E), which is a dedicated group having mandate (among others) to fulfil the regulatory functions related to emergency preparedness and response.

16.4.2 Enhancement of infrastructure for Emergency Preparedness & Response

To strengthen EPR, the enhancement of the infrastructure such as given below has been done.

i. On-Site Emergency Support Centres at NPPs

AERB had mandated the requirement for establishing the On-Site Emergency Support Centre (OESC) at all NPP sites. Accordingly, a centralized On-Site Emergency Support Centre common to all NPPs at a site is being constructed within the exclusion zone. This facility is designed to have the capability to withstand earthquake and flood of magnitudes larger than their respective design basis for the NPP. The building is designed with requisite shielding for protracted stay of response personnel. From this facility all actions required for controlling the plant parameters for accident management will be coordinated. The centre will be self-sufficient with following features:

- Resting provisions for the personnel along with food and drinking water facilities for seven days
- Availability of selected plant data from all NPPs at the site including onsite/offsite radiological data.
- Infrastructure such as diverse communication means, dedicated air-cooled diesel generators, dedicated survival ventilation system, first aid facilities etc.

- Radiological monitoring & protective equipment (dose monitoring devices, sufficient number of protective clothing etc.)

  Status of establishment of OESC is given in section 6.5.1 of Article-6.

ii. Decision Support System

Decision Support System (DSS) for nuclear emergencies is intended to provide comprehensive and timely information to emergency managers on an emergency situation arising from a nuclear accident. It has capability for estimation of release rates during accidents using real time environmental radiation data. Based on the released source term and weather conditions, DSS estimates the radionuclide concentration (in air and ground), the projected dose and exposure to public. These estimates are used to provide guidance for affected areas to take appropriate protective actions in the public domain to handle emergency. The results are displayed on a Geographical Information System (GIS) platform for visualization and appropriate actions to be taken by decision makers.

16.5 INFORMATION TO PUBLIC AND NEIGHBOURING COUNTRIES

16.5.1 Information to Public

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

During an emergency, the protective measures would be communicated to the public through mass media communication and local communication system such as megaphone etc. The communication to the public is implemented through the local and district authorities. A pre-designated Information Officer makes arrangements for the reception of media and information briefing.

16.5.2 Trans-boundary Implications

The neighbouring countries are at large distances from the location of operating NPPs and projects under construction. Although no trans boundary implications are expected, India being a contracting party to 'Convention on Early Notification of a Nuclear Accident' and 'Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency', CMG-DAE will notify to IAEA in case of any accident at Indian NPP. Export of food items will be subjected to thorough contamination checks and clearance in accordance with the international guidelines.

16.6 PARTICIPATION IN IAEA EMERGENCY EXERCISES

India is signatory under the Convention on Early Notification of Nuclear Accidents and Convention on Assistance in case of Nuclear Accident or Radiological Emergency. Under these Conventions, India actively participates in the Emergency exercises through CMG-DAE, the national contact point. In the last three years (April 2016 to March 2019), India participated in ConvEx exercises which includes ConvEx-1, ConvEx-2a, ConvEx-2b ,ConvEx-2c and ConvEx-3 exercises.

16.7 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

Appropriate laws, regulations and requirements regarding emergency preparedness and response as applicable to NPPs are in place and are being implemented through the established national framework. Adequate regulatory control is exercised by AERB through establishment and enforcement of requirements & guidelines. The regulations are being reviewed and revised to take account of the various developments in EPR including current national & international practices and the lessons learned from the emergency response subsequent to the accident at Fukushima Daiichi NPP.

Hence, India complies with the obligations of Article-16 of the Convention.

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ARTICLE 17: SITING

Each Contracting Party shall take the appropriate steps to ensure that appropriate procedures are established and implemented:

i. for evaluating all relevant site-related factors likely to affect the safety of a nuclear installation for its projected lifetime;

ii. for evaluating the likely safety impact of a proposed nuclear installation on individuals, society and the environment;

iii. for re-evaluating as necessary all relevant factors referred to in sub-paragraphs (i) and (ii) so as to ensure the continued safety acceptability of the nuclear installation;

iv. for consulting Contracting Parties in the vicinity of a proposed nuclear installation, insofar as they are likely to be affected by that installation and, upon request providing the necessary information to such Contracting Parties, in order to enable them to evaluate and make their own assessment of the likely safety impact on their territory of the nuclear installation.

17.0 GENERAL

In India, only the Central Government, or any authority or Corporation established by it or a Government Company can set up NPPs as per the present statutory provisions. The Government of India constitutes Standing Site Selection Committee (SSSC) which carries out first order assessment of the site and evaluates the suitability of the various sites proposed by concerned state governments taking into account various site related factors and prevailing regulatory requirements. Ready acceptance criteria, in terms of Screening Distance Value (SDV) of site from potential sources of external events which could jeopardize safety and for which no engineering solutions are available, are applied at site selection stage to shortlist the candidate sites. Based on the recommendation of the SSSC, the Central Government conveys in-principle approval of the site.

Setting up of NPPs requires environmental clearance from Ministry of Environment, Forests and Climate Change (MoEFCC), as per the requirement of Environmental Protection Act, 1986, other clearances from various Central and State level agencies like National Airport Authority, State Maritime Boards besides the other agencies mentioned in Article-7.

Utility is also required to obtain siting consent from AERB. The regulatory consent for siting involves review of the various site and plant related safety aspects. The mechanism of review is brought out in Article-14 on 'Assessment and Verification of Safety'. AERB Safety Code on 'site evaluation of nuclear facilities' (AERB/NF/SC/S, Rev.1, 2014) establishes the requirements for evaluation of a site from safety considerations. Some of the salient features of AERB/NF/SC/S (Rev.1) with respect to the lessons learnt from accident at Fukushima Daiichi NPP and the Vienna Declaration on Nuclear Safety include: revised dose criteria, considerations for exceedance of design basis, consideration for evolution of hazard with time, considerations for multi-unit/multi-facility sites, periodic re-evaluation of hazards, requirements regarding ultimate heat sink and requirements related to monitoring of hazards.

A site is considered acceptable, when all the site related issues have been satisfactorily resolved, thus giving assurance that the proposed NPP can be engineered, built and operated such that the risk to the public and the environment is within acceptable limits.

17.1 EVALUATION OF SITE RELATED FACTORS AFFECTING SAFETY

The basic factors that govern site evaluation of nuclear installation are:

i. Effects of external events on the installation
ii. Effects of the installation on site environment and population

iii. Factors affecting implementation of emergency measures in public domain

Utility prepares a site evaluation report covering the above aspects, including brief design information and overview of the proposed NPP. The information helps in evaluating the given site in relation to the type, capacity, number of units, etc. It also includes overall safety approach, dose estimates under various plant states, bases for emergency preparedness and offsite power supplies.

The regulatory review and assessment of Site Evaluation Report is carried out to determine the potential consequences of interaction between the plant and the site and the suitability of the site for the proposed plant from the point of view of safety. It also includes assessment of population data, availability of roads & access features for emergency response purposes and aspects on security measures with reference to site characteristics.

The effect of various site parameters on engineerability of the site in the context of external and human induced events is assessed.

17.1.1 Characterization of effect of site on plant

A site is evaluated for phenomena or combination of phenomena which have annual frequency of more than 10-7 per year. These phenomena are to be considered for detailed assessment and establishment of design basis of a particular event at the site. The foreseeable evolution of these events and their combinations related to the region, along with population growth and distribution that may have a bearing on safety and radiological impact are monitored, evaluated and periodically reviewed for a time period encompassing lifetime of the facility.

Design bases are established both for natural and human induced external events following AERB Safety Code on site evaluation of nuclear facilities and associated safety guides. The facilities are graded based on their hazard potential into four categories. For each category the mean annual frequency of exceedance for external natural events are specified. The design parameters for external events are derived by systematic assessment of hazard associated with the events, taking into consideration site-specific conditions and the data / information collected. Uncertainty analysis is also performed as part of evaluation of the hazard. For an external event (or combination of events) the choice of values of 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.

Requirements for design provisions against internal and external events are governed by the AERB safety code for design of nuclear power plants. Robust design of the plant ensures that it possesses sufficient safety margin to protect against site specific external natural events (earthquake, flood, extreme wind and temperature) beyond the design basis and to avoid cliff edge effects. Design provisions against external and internal events are detailed in Article-18.

Changes of hazard (both natural and human induced) with time over the lifetime of the facility is also postulated in evaluating design basis parameters for external events. The assessment takes into account the changes such as regional climate change associated with global climate change. An example of this consideration is the enhancement of precipitation corresponding to design basis level, which was done for one of the sites.

17.1.1.1 Site investigations

Natural phenomena, which may exist or can occur in the region of a proposed site are identified and classified as per their impact on plant safety. Design bases are derived for each credible event and credible combination of events by adopting appropriate methodologies. Historical records of the occurrences and severity of the natural phenomena are collected for the region. The data is analysed for reliability, accuracy and completeness. If data for a particular type of natural phenomenon are incomplete for the region, then data from other regions having similar characteristics are used for evaluation of the design basis event, with proper justification and conservatism.

Hazards due to earthquake induced ground motion are assessed for the site considering site seismicity and seismo-tectonics of the region along with specific site conditions. Data from geological, geophysical, seismological and geotechnical investigations are collected and analyzed. Information on all earthquakes including pre-historical, historical and instrumentally recorded earthquakes in the region 300 km around the site are collected, documented and considered. All seismically active structures and active faults in the region are identified. On the basis of geological, geophysical, geodetic or seismological data, a fault is classified as active or not active. If it cannot be established that a fault is not active, the same is considered as active in the seismo-tectonic evaluation. Geological and seismological investigations are conducted in four scales, regional (300km minimum), intermediate range (50km radius), local (5km radius) and site area (within plant boundary). Each set of study leads to progressively more detailed investigation resulting in large volume of data and information as it gets closer to site. No NPP is located in seismic zone-V defined as per national standard IS 1893. If there is an evidence of a capable fault within a distance of 5 km from the reactor centre, the site is deemed unacceptable. Micro-seismic measurements of the site region are conducted for at least 3 years after the site is selected for the purpose of site evaluation and are continued for an operating NPP. Calculation/derivation of hazard is done through a formalized approach, which for hazards such as seismic, includes national level expert elicitation.

Potentials for slope instability (land/rock slides), land erosion, collapse, subsidence or uplift of the site surface are assessed. Subsurface investigations are carried out to establish competency of the foundation medium. The ground water regime and its chemical properties are also studied. Liquefaction potential at the site is evaluated for the design basis vibratory ground motion with margins to account for extreme events.

Meteorological and climatological characteristics of site region are investigated to derive design basis parameters for the meteorological variables such as wind, precipitation, temperature and storm surges. Potential missile hazard associated with tropical cyclones is also considered.

The site is assessed for flooding potential due to natural causes such as run-off from precipitation, high tide, storm surge or from earthquake induced water waves (tsunamis and seiches) as per AERB Safety Guides on Design Basis Floods for Nuclear Power Plants on Inland & Coastal Sites (AERB/SG/S-6A&B). Floods and waves caused by failure of upstream dams/barrages or due to possibility of temporary blockage of rivers upstream/downstream caused by landslides are also assessed with respect to safety of the installation.

For coastal sites, studies are carried out to establish that there is no potential for shore instability that could affect safety. For inland sites, possible erosion of river banks and/or change of river course are given due consideration.

With regard to human induced external events, the site and surrounding region are examined for facilities and human activities that may affect the safety of the proposed nuclear facility, such as aircraft crash, chemical explosion and toxic gas release. Information concerning the frequency and severity of important human-induced events are collected.

The region is also investigated for any hazards that may result from industrial / radiation/ nuclear facilities located away from site as well as within the site boundary.

17.1.1.2 Assessment of site characteristics for projected operating period

Site characteristics and characteristics of natural environment in the site region, which may affect safety of the nuclear installation are investigated and assessed periodically for a time period encompassing the lifetime of the installation. Monitoring and investigation of site characteristics and natural environment is continued during the operating life as a part of periodic safety review. Effects of the combination of these hazards with ambient hydrological, hydro-geological and meteorological conditions as well as the relevant plant internal events is given due consideration.

17.1.2 Regulatory Review and Control

AERB requires that site evaluation report should be submitted for siting consent. AERB safety guide AERB/NPP&RR/SG/G-1(2007) on 'Consenting Process for Nuclear Power Plant and Research Reactor' gives the guidelines on the contents of the site evaluation report. Significant areas of review and assessment as per this AERB safety guide are as follows:

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

Regulatory review of application for siting consent is carried out through multi-tier review system of AERB (section 14.1.1.2 (ii)). Staff of AERB carries out regulatory inspections during siting stage and its findings are referred during the review of the application for siting consent.

The site is reviewed and assessed to determine the potential consequences of interaction between the plant and the site and suitability of the site for proposed plant from the point of view of safety. In general, the site assessment criteria is divided into three: rejection criteria, which deals with the issues which if observed at site calls for direct rejection of site; mandatory criteria, which requires existence of engineering solutions for the observed issues; and ready acceptance criteria, which are based on screening distance values. Table – 5 lists the issues that constitute the rejection and mandatory criteria. During site evaluation, focus is specifically on ruling out the existence of issues related to rejection criteria, and ensuring availability of engineering solutions for issues related to mandatory criteria.

Table 5 Rejection and mandatory criteria in site evaluation

	Hazard	**Criteria**
Direct rejection	Earthquake	Site in seismic Zone-V as per National Std IS 1893
	Earthquake	Existence of capable fault within 5 km of site
Rejection: In absence of reliable engineering solutions	Earthquake	Potential for soil liquefaction
	Earthquake/geological	Potential for slope instability
	Earthquake/geological	Potential for ground collapse/subsidence/uplift
	Geological	Formation of migratory sand dunes
	Geological	Volcanoes

The siting consent is issued for a limited period. During subsequent stages of construction, the status report on compliance with AERB's stipulations if any, made during the earlier stages is required to be submitted to AERB.

17.2 ASSESSMENT OF IMPACT OF NPP ON PUBLIC AND THE ENVIRONMENT

Assessment of impact of the NPP on public and the environment is carried out in compliance with the acts and rules described in Article– 7. Siting consent by AERB and siting clearance from Ministry of Environment, Forests and Climate Change (MoEFCC) are given after detailed assessment of impact of the NPP on environment.

17.2.1 Assessment of environmental impact by MoEFCC

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

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

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

17.2.2 Safety Assessment by AERB

The Atomic Energy (Radiation Protection) Rules, 2004 stipulates that the licensee shall ensure compliance with the dose limits, safe disposal of radioactive waste and other regulatory constraints specified by the competent authority by order under these rules.

Further, according to AERB Safety Code on 'Site Evaluation of Nuclear Facilities' (AERB/NF/SC/S, Rev.1), potential radiological exposure to public during operational states and accident conditions shall be assessed during the life cycle of the facility. It also requires that site specific parameters be used for a realistic estimation of the doses. Moreover, direct and indirect pathways by which public might receive radiation exposure due to radioactive materials released from the nuclear facility shall be identified and used in the estimation of radiological impact. The Code also specifies the dose criteria for normal operation and accident conditions (refer Table -6).

Table 6 Dose Criteria

Condition	Dose limit	Remarks
Normal Operation	Annual release limit from site <1.0 mSv/year	Sufficient dose reserve shall be ensured
Accident conditions:		
1. Design Basis Accident (DBA) (Initiating event with consequential failure and taking credit of safety systems considering single failure criteria)	Design target for effective dose < 20.0 mSv/ year	No need for offsite countermeasures (i.e. prophylaxis, food control, shelter or evacuation) involving public, beyond exclusion zone.
2. Design Extension Condition (DEC) without core melt (multiple failure situations and rare external events)	Design target for effective dose (Same as DBA)	• No necessity of protective measures in terms of sheltering or evacuation for people living beyond Exclusion Zone. • Required control on agriculture or food banning to be limited to a small area and to one crop
3. Design Extension Condition with core melt (Severe Accident)	--	• No permanent relocation of population. • The need for offsite interventions to be limited in area and time

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

i. Meteorological data:

A programme of meteorological measurements is initiated at the site before start of construction of NPP and continues till its decommissioning. Based on the requirements of AERB/NF/SC/S (Rev.1), meteorological data is collected for a minimum period of one year and examined during site evaluation. This includes

- Assessment of inversion conditions,
- Atmospheric stability,
- Humidity,
- Rainfall and
- Hourly data for wind speeds, wind directions and calms.

In case of sites situated in river valleys, bowls and uneven topography, additional data is generated and appropriate model is used to assess the dilution factor, if found necessary. If sufficient site-specific data is not available, data from a region with similar characteristics is used for initial assessment, with appropriate justification.

ii. Hydrological data:

The hydrological characteristics of the region including location and relevant characteristics of water bodies, water control and intake structures, water use, etc. are collected. In case of inland sites, site specific data generated includes dispersion characteristics of water bodies, pick-up of radioactivity by sediment and biota, transfer mechanisms of radionuclides in hydrosphere and identification of exposure pathways for the significant radionuclides.

iii. Hydrogeological data:

A description of the hydrogeology of the region is developed covering characteristics of sub surface strata and aquifers, water table contours, their variations, water use, etc.

iv. Demographic and land use data:

Information on population distribution (existing and projected), including permanent residents, transient and seasonal population are collected up to a radius of 30 km and updated during each periodic safety review during life time of the nuclear power plant. The uses of land and water is characterised in order to assess radiological impact of the nuclear facility on the region and also for the purpose of preparing emergency plans. The investigation covers land and water bodies up to a distance of 30 km that are used by the population or may serve as a habitat for organisms in the food chain.

Effects of the plant on environment that could warrant specific design or operational requirements are radioactive effluents (liquid and gaseous), radiation exposure of the public from these effluents and other environmental pollutants. This is assessed for normal operation, anticipated operational occurrences and accident conditions, taking into account dispersion patterns, public water supply, milk and food consumption, and radioecology. As per the requirements of AERB/NF/SC/S (Rev.1), Radiological Impact Assessment (RIA) for dose evaluation considers all radiation exposure pathways including inhalation and ingestion routes. Dose criteria is given in Table -6.

The requirements and criteria with respect to radiation protection and emergency measures, as per the requirements of AERB/NF/SC/S (Rev.1), are implemented as follows:

a) An exclusion zone is established around the plant, as specified by AERB and this area is kept under the exclusive control of Plant Management. Public habitation in this area is prohibited. Further, a natural growth zone around the exclusion zone is established and influx of population to this zone is controlled by administrative measures by respective State Governments.
b) An Emergency Planning Zone (EPZ) of 16 km radial distance (from reactor centre) around an NPP is established for the emergency management purpose. In order to establish the baseline radiological and environmental data and for the purpose of continuous environmental surveillance, a zone of 30km radius around the NPP is designated as Radiological Surveillance Zone (RSZ). 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 in EPZ and RSZ.

17.2.3 Monitoring of characteristics that affect RIA

Data collected by various national institutes and accredited agencies using state of the art technology are used for monitoring and assessment by the utility. This monitoring commences at least three years before commissioning of the first facility and continues till decommissioning. The Environmental Survey Laboratory is established at every NPP site much before commencement of operation, for conducting the pre-operational studies and continued meteorological surveillance.

17.3 RE-EVALUATION OF SITE RELATED FACTORS

AERB Safety Code, AERB/NF/SC/S (Rev.1)specifies requirements related to re-evaluation of site related factors during the lifetime of NPPs. The safety code requires that site characteristics shall be re-evaluated in case of the following:

a) Revision in safety regulation.
b) Occurrence of any external event/meteorological phenomena resulting in corresponding design parameters potentially higher than the ones considered originally.
c) Any deviation from the approved type/capacity of facility, and/or when more nuclear facilities are added.
d) Any expansion of activities around the site in future that may have an impact on safety of the facilities at the site.
e) Additional data and/or new information on relevant climatic change, that may necessitate revision of design basis parameter.
f) As part of periodic safety review (see 17.3.1)

In the past, such safety assessments called for upward revision of seismic & flood design basis parameters of TAPS-1&2, RAPS-1&2 & MAPS-1&2 and additional measures as found necessary were incorporated. Re-assessments related to flood hazard have been completed for NAPS–1&2 & KAPS–1&2.

The safety reviews carried out following the accident at Fukushima Daiichi NPPs have shown the inherent strengths in the design, operational and regulatory practices and requirements associated with the Indian NPPs. The strengthening measures identified and being implemented for the Indian NPPs are associated mainly with enhancing the resilience of the plants to cope with extreme external events exceeding the design bases and to strengthen the provisions for mitigation of severe accidents.

17.3.1 Regulatory oversight of site re-evaluation

Review and re-evaluation of site related factors in the light of new knowledge from operating experience feedback, a major accident or the occurrence of extreme events is a continuing process in the Indian regulatory system.

The regulatory system in India has adopted the Periodic Safety Review (PSR) in which the following elements are comprehensively reviewed to determine the continued acceptability of the site safety status of nuclear installation:

- Changes in use of land areas around the site and population in the surroundings
- Site characteristics, particularly flood and seismic and other human activities, which may pose a hazard, and
- Local meteorological conditions

In addition, special safety reviews are undertaken following major events / developments details of which are given in Articles-6 and 14.

17.4 CONSULTATION WITH OTHER CONTRACTING PARTIES

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

17.5 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

The Site Selection for locating an NPP is carried out by the Central Government. The utility carries out detailed site investigations and prepares Site Evaluation Report and Environmental Impact Assessment Report for independent evaluation by AERB and MoEFCC 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 licence 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, India complies with the obligations of Article-17 of the Convention.

The regulatory requirements with respect to siting and design of NPPs in India are consistent with the Vienna Declaration on Nuclear Safety.

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ARTICLE 18: DESIGN AND CONSTRUCTION

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

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

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

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

18.0 GENERAL

National laws, regulations and requirements for setting up a NPP are summarised in Article 7: Legislative and Regulatory Framework. AERB safety code on 'Regulation of Nuclear and Radiation Facilities' AERB/SC/G: 2000 and Safety Guide AERB/NPP&RR/SG/G-1: 2007 on 'Consenting Process for Nuclear Power Plant and Research Reactor' identify various consenting stages. The consenting process for locating and operating NPP in India is summarised in Article 14: Assessment and Verification of Safety.

AERB has published safety codes specifying safety requirements for design of NPPs. The safety code for 'design of PHWR based NPPs' AERB/NPP-PHWR/SC/D (2009, revision in advance stage) and safety code for 'design of LWR based NPPs' AERB/NPP-LWR/SC/D (2015) provide mandatory requirements for design of NPPs. These safety codes are developed based on latest international standards including that of IAEA as well as national and international experience. The Safety codes contain both general requirements which are technology neutral like implementation of defence in depth, safety analysis, concept of single failure, management of safety etc., as well as specific requirements which are technology specific like systems specific requirements of shutdown system, ventilation system etc. The general requirements are utilised for review of different technology based NPPs as well. In addition to this, AERB has used a document developed by it titled 'Safety Criteria for Design of Fast Breeder Reactors' for design review of PFBR.AERB is in the process of developing Safety Code on Design of Sodium Cooled Fast Reactor based NPPs.

AERB safety code on Quality Assurance specifies requirements for overall quality assurance programme for constituent phases, viz. design, manufacturing, construction, commissioning, operation and decommissioning of NPPs. Details on the utility's safety management system for ensuring quality requirements during design, fabrication, construction etc. are brought out in Article-13: Quality Assurance.

18.1 IMPLEMENTATION OF DEFENCE IN DEPTH

Application of concept of defence in depth in design of NPPs is one of the requirements of AERB and has been specified in its design safety codes.

The concept is implemented in the reactor design by means of five structured levels of protection which act in succession. In case of failure of one level the subsequent level comes into action. Each level is provided with a set of systems or design features to ensure prevention of degradation, its detection & control and mitigation, if prevention fails.

Implementation of defence in depth philosophy requires that the design of SSCs of NPP is conservative with sufficient margins and their construction is of high quality to prevent deviation from normal operation and failure of items important to safety. Design includes equipment to identify and take control of any routine operational disturbances including possible human errors during operation to detect and control deviations from normal operation states to prevent anticipated operational occurrences (AOOs) from escalating to accident conditions. These two levels together render operation of plant safe. Postulating that there could be variety of possible failures in the normal operating systems i.e. Postulated Initiating Events (PIEs), third level of defence ensures the plant remains in safe state by activating specific safety systems. This level includes provision of multiple safety systems supplementing the normal operational features of the plant so that the effect of any such failure is mitigated within the plant. The general principles implemented in design of these safety systems are 'conservatism', 'independence', 'redundancy', 'diversity, 'physical separation', 'reliability' and, as far as possible, 'fail-safe'. Multiple failures beyond design basis may render the plant into design extension condition (DEC). The fourth level of defence is for mitigating the consequences of multiple failures by incorporating provisions for additional safety systems/features and complementary safety features in the design. These systems/features further extend safety by mitigating consequences of accidents without core melt and accidents with core melt so that the radioactivity released to environment remains within limits and meets the acceptance criteria.

The probability of severe accident that may lead to large radioactive releases becomes very low after implementing all the aforementioned levels of defence. Design extension conditions that could lead to large or early releases of radioactivity are required to be practically eliminated. The fifth level of defence is for mitigating the radiological consequences of an accident and it is implemented through off-site emergency preparedness.

Following principles are adopted to ensure that structures, systems and components having bearing on nuclear safety are designed to meet stringent performance and reliability requirements,

i. Quality requirements for design, fabrication, construction and inspection of systems commensurate with their importance to safety.

ii. The safety related equipment inside the containment building are designed to perform the desired function under the environment conditions expected in the event of postulated design basis accident.

iii. Physical and functional separation is ensured between process systems and safety systems to the extent practicable. This separation is also provided between different safety systems and between redundant components of a safety system. These features ensure that a single local event viz. fire, missile, pipe failure, will not result in multiple component/system failures and the functions required for safety of the reactor are not impaired due to common cause failures.

iv. Adequate redundancy is provided in the system such that the minimum safety function can be performed even in the event of failure of single active component in the system. In addition to 'single failure criteria' requirement, safety systems are also required to achieve specified unavailability targets, evaluation of which takes into account permissible down time of the equipment specified in the 'Technical Specifications for Operation'. Each channel in Reactor Control & Protection Systems is independent of other channels, with separate detectors, power supplies, amplifiers and relays. This arrangement ensures that safety function will be performed reliably and allows testing and maintenance of a control or protection channel without affecting reactor operation and safety.

v. To minimize the probability of unsafe failures, wherever possible, the logics and instrumentation circuits are designed such that in case they fail, they fail in the safe direction.

vi. Provisions are incorporated in design to ensure that active components in safety systems are testable.

vii. All support systems viz. electrical power supply, pneumatic supply & cooling water supply, necessary for satisfactory functioning of safety systems are from reliable sources such that single component failure does not jeopardize the minimum supply requirements.

viii. Comprehensive deterministic safety analyses and probabilistic safety assessments throughout the design process to ensure that all safety requirements on the design of the plant are met throughout all stages of the lifetime of the plant and to confirm that the design, as delivered, meets requirements for manufacture and for construction, and as built, as operated and as modified.

The safety requirement of radiation dose limits for member of public due to occurrence of a 'Design Basis Accident' or a 'Design Extension Condition without core melt' has been specified in the AERB code. It is also required that design should demonstrate that in case of a Design Basis Accident, there need not be any emergency countermeasures in the public domain. In case of design extension condition without core melt, limited counter measures in terms of food control may be acceptable. In case of design extension condition with core melt, design goal remains that emergency actions will be required for limited time and area. There should not be any situation which will call for permanent relocation of member of the public. This is consistent with the Vienna Declaration on Nuclear Safety.

The design of the plant also takes into consideration external events specific to a site. The external events are grouped into natural events and human-induced events. Natural events considered in the design are seismic events at the site and extreme meteorological phenomena such as heavy precipitation, floods, high winds, cyclones, tsunami etc. Human-induced events include hazards from toxic and explosive materials, blasting, aircraft impact etc. For each of the events, whose potential at the given site is known to exist, a design basis event is established. For a multi-unit/multi-facility site, consequences of external events are assessed considering their impact on all units/facilities at the site, including common cause failures. Such assessment also includes consequential effects due to incidences in one facility/unit on other facilities/units.

Two different intensities of earthquakes viz. Operating Basis Earthquake (OBE) and Safe Shutdown Earthquake (SSE) are considered for the seismic design of the plant. OBE represents the intensity of earthquake for which the plant is designed to remain functional during and after the event. SSE is that level of earthquake which produces the maximum vibratory ground motion, depending on the maximum earthquake potential of the site, for which certain structures, systems and components are designed to remain functional. These structures, systems and components are necessary to assure the integrity of the reactor coolant pressure boundary, the capability to shut down the reactor and maintain it in a safe shutdown condition, the capability to prevent the accident or to mitigate the consequences of accidents which could result in potential off-site exposures higher than the limits specified by the regulatory body and the capacity to remove residual heat.

Flooding in inland sites could be caused by heavy precipitation or by the release of large volumes of water due to failure of upstream dams under seismic disturbance or any other cause. The plants are designed for a design basis flood resulting from probable maximum precipitation with a mean recurrence interval of 10000 years. Flooding due to failures of upstream dam is also considered. Failures of dams located downstream may also affect availability of ultimate heat sink and are therefore considered in the design. For coastal sites, flooding due to cyclones, tsunami and wind waves are considered in the design.

A diverse and flexible accident response capability is provided in the design such that it would provide a backup to permanently installed plant equipment, that might be unavailable following certain extreme conditions (e.g. extreme natural phenomena such as earthquakes, flooding and high winds), and would supplement the equipment already available for responding to severe accidents. The approach includes design measures to provide multiple means of obtaining power and water needed to fulfil the key safety functions of maintaining core cooling, containment integrity, and spent fuel pool cooling.

Along with the above, additional safety margin are considered to ensure safety against the impact of cliff edge effect.

As a design improvement, seismic trip is implemented in all power plants where earlier it was not available.

External cooling water supply provision to steam generators was already available in all existing PHWRs. In addition to it, hook up points are provided in Primary Heat Transport System, Emergency Core Cooling System, Moderator System, End Shields Cooling System and Calandria Vault Cooling System for injecting external water. Water injection provisions to spent fuel storage pool of all PHWRs are provided. Important plant parameters are identified, which need to be monitored during a design extension condition. External power supply scheme from standalone air-cooled diesel generator has been implemented to monitor important plant parameters and for water injection pumps (in limited case) as safety enhancement.

For finalizing accident management measures, NPCIL had carried out a number of analyses of postulated severe accident scenarios for ascertaining the need for installing Containment Filtered Venting System (CFVS). This study indicated that owing to design features, some PHWR units of lower capacity and large containment volume, where containment pressure remains within the design basis for 7 days into the accident, do not need CFVS as this time is considered adequate to make alternate provisions for containment cooling. Requirement for CFVS was considered in remaining PHWR units and TAPS-1&2 (BWR). Subsequently, based on literature survey and available information on different designs, detailed design of the system was taken up in-house in NPCIL. The aim of the design was to ensure containment depressurisation during severe accident and to achieve decontamination factor more than that considered in the radiological release assessment. Towards this, the design was validated on a scaled model by conducting experiments simulating different conditions as expected in the accident in different PHWRs and TAPS-1&2 containments. As requirement of CFVS operation is much later into the accident progression, valving in of the system is envisaged to be manual and for facilitating manual action, system is adequately shielded and instrumented. CFVS is designed considering seismic and design basis flood level requirements. After completion of design, testing, qualification and regulatory review, CFVS has been installed in TAPS 1&2. Installation of CFVS in PHWRs is in progress. In KKNPP, due to provisions of core catcher and diverse cooling, the amount of non-condensable gas release is insignificant and do not pose any threat to the containment. During the severe accident event progression, the containment pressure can be brought down by various containment cooling provisions such as re-establishing the existing safety systems or connecting the additional diverse accident management systems. Therefore, Containment venting provision is not envisaged.

Hydrogen management in PHWRs is envisaged through Passive Catalytic Recombiner Devices (PCRDs) and means to promote intermixing of containment atmospheres. The PCRDs were developed indigenously and a large number of experiments were conducted in hydrogen recombiner test facility at R&D Centre, Tarapur for its qualification. This included dry tests (0.5% to 3.5% hydrogen concentration) and in the presence of steam (0.5% to 10% hydrogen concentration). After finalization of design, its functional testing, qualification and regulatory review, bulk production of PCRDs is in progress. PCRDs are being installed in NPPs in a phased manner.

For KKNPP, Passive Autocatalytic Recombiners (PARs) were part of the original design. The reactors at KKNPP have built-in systems for handling design extension conditions with core melt. Subsequent to the re-assessment following the accident at Fukushima Daiichi NPP, onsite storage of water (seismically qualified) along with hook up provisions for water injection to reactor coolant system, steam generators and fuel pool cooling system were implemented as a measure of abundant caution. In addition, additional mobile power source needed for monitoring and accident management have been provided.

For TAPS 1&2, hook up points for external water injection to reactor pressure vessel, emergency condenser, containment spray and fuel pool cooling system were provided. Further, inerting of containment has been refurbished and provision for post-accident containment venting has been implemented.

All the safety up-grades identified based on the safety reviews carried out following the accident at Fukushima Daiichi NPP have been made as a part of the design for the reactors under construction and commissioning.

In the NPPs that are already under operation, comparison is made with the current standards as a part of Periodic Safety Review (PSR), and it is determined whether the safe operation of the plant could be further enhanced by means of safety improvements that are practicably reasonable. Details of PSR are covered in Article 14.

18.1.1 Regulatory Review and Control activities

The regulatory review process at AERB includes review of the submitted information against the safety requirements specified in its safety codes. The application of concept of Defence In Depth (DID) in design of NPP is one such requirement. The review and assessment process is performed by AERB based on the information submitted by the applicant to demonstrate the implementation of concept of DID in the design of proposed NPP. The analysis of this information enables AERB to make decision on the acceptability of the plant in terms of safety during normal operations and AOOs, Design Basis Accidents and DEC, that have potential to cause exposure to the workers or the public.

The prerequisite for issue of consent for construction is the review of design safety of the proposed NPP. Details of the process is covered in Article-14.

The evaluation takes into account operating experience feedback from similar NPPs, new developments and experimental results.

In carrying out review and assessment of design prior to issue of consent for construction, AERB determines that the proposed design of NPP meets the safety requirements as specified in the AERB Safety Codes. Review and assessment by AERB also includes consideration of the applicant's organisation and management to ensure that the proposed construction will meet the quality requirements as envisaged in the design. 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 utilities for design, procurement, fabrication, construction, commissioning and operation. It is the responsibility of utilities to ensure that the vendors employed by it for carrying out different activities follow a QA programme commensurate with the safety requirements.

Basis of Acceptance (BOA) documents, (the documents to confirm that the components are manufactured, tested and qualified in compliance to the design requirements), for identified safety related components/equipment and First-Of-A-Kind (FOAK) systems are prepared by utility and submitted to AERB for review and acceptance.

To ensure design implementation and adherence to appropriate QA during construction, Regulatory Inspections are carried out by AERB. The frequency of regulatory inspections depends on the progress of activities at the site and may vary from twice in a year to four times in a year depending on the consenting stage of the project. In addition to routine regulatory inspection, AERB also identifies certain critical activities during construction as hold points for conducting Special Inspections or for deputing additional experts in the respective areas to observe these activities.

AERB has also implemented event reporting system viz. Significant Event/Change Reporting Criteria (SECRC) during construction and commissioning of NPP.

18.2 INCORPORATION OF PROVEN TECHNOLOGY

As per regulatory requirement, structures, systems and components (SSCs) important to safety for a nuclear power plant should be designed, fabricated, inspected and constructed in accordance with the applicable codes and standards. All the regulatory requirements specified in the different AERB Codes and other regulatory documents are complied with. If the design, construction, manufacture, inspection and maintenance of civil structures, mechanical, electrical, Instrumentation & Control equipment and systems are done by using the international codes & standards, it should be acceptable to AERB. SSCs important to safety of a nuclear power plant should preferably be of a design that has previously been used in equivalent applications. SSCs of high quality standard must be used for all safety related applications. Technology that has been qualified and tested previously should be applied. NPP designers should identify codes and standards to be used for designing of items important to safety and evaluate them to determine their applicability, adequacy and sufficiency. It is required to be demonstrated that the quality of design is commensurate with the associated safety function.

When a new design or feature is introduced or there is a departure from an established engineering practice, safety is to be demonstrated by means of appropriate supporting research programmes, performance tests with specific acceptance criteria, or utilising the operating experience from other relevant applications.All these systems are adequately tested during commissioning to verify that the expected behaviour is achieved. Performance of the new design/equipment is monitored while in service to verify that the behaviour of the system/equipment is as per design.

Proven and conservative design measures with well-established engineering practices are adopted in safety system design for design basis accidents. Additional safety systems/features for preventing and/or mitigating the consequences of design extension conditions leading to accidents situations without core melt, are designed with proven engineering practice using diversified principle. Complementary safety features for mitigating the consequences of any core melt scenario are designed based on practical approach backed up by research and development.

The equipment important to safety are qualified to operate in the environment expected under accident conditions. SSCs required to perform necessary functions during earthquake are qualified by testing/analysis to demonstrate their pressure boundary integrity or structural integrity for two levels of earthquake i.e. OBE & SSE, depending on the seismic categorization. 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. Codes are validated with both benchmark classical problems and experimental tests and results.

Computer codes are used for safety analysis during normal operation and accident conditions. Codes for studying thermal hydraulics, core physics, neutronics, high temperature phenomena and core concrete interaction during severe accidents, fuel behaviour and radioactivity release, containment behaviour, etc. have been developed. These codes are developed in-house and are benchmarked with results of experiments conducted at national and international laboratories, by participating in standard problem exercises of IAEA, coordinated research programmes of IAEA and technical exchange programmes.

Design and implementation of computer based systems has matured over last several years and with current state of technology. It has been possible to develop computer based systems for carrying out functions important to safety in nuclear power plants and also to demonstrate their fitness-for-purpose. In nuclear power plants, both new and old, computer based instrumentation and control (I&C) systems are used increasingly both in safety related applications, such as some functions of the process control and monitoring systems, as well as in safety critical applications, such as reactor protection or actuation of engineered safety systems. Since analogue equipment are becoming obsolete in earlier designed reactors, digital equipment are offering a practical replacement for the same. The digital instrumentation and control equipment are now extensively used in the newly built reactors in India. For qualification of digital technology for use in NPPs, an elaborate software development lifecycle process and Independent Verification & Validation process (IV&V) has been implemented.

The increasing use of digital/software I&C systems for safety critical applications pose certain issues from the regulatory perspective such as consideration of Common Cause Failure (CCF) of software based systems, regulatory acceptance of commercially available digital I&C systems and interface between safety & security aspects of digital I&C systems. The AERB safety guide on 'Computer Based Systems of PHWRs' (AERB/NPP-PHWR/SG/D-25, 2010) is presently being revised to address the above aspects as well as to consider the latest IAEA safety standards.

18.2.1 R&D Facilities for Assuring Safety of NPPs

BARC, IGCAR, other national R&D facilities including NPCIL in-house facilities provide R&D support for the nuclear power programme. The overall programme is aimed to enhance the safety margins of the current reactors, establishment of improved safety features of the proposed reactor designs and perform adequate testing for all FOAK systems to demonstrate its performance. Several R&D set ups are operational and mock up facilities are being constructed from time to time to satisfy the latest safety requirements of NPP.

BARC is presently involved in the following key activities as a part of R&D efforts related to NPP safety:

- Evaluation of fracture and fatigue properties of reactor structural materials using miniature specimen testing
- Development of special purpose machines and tools for ISI of PHWR pressure tubes and calandria tubes.
- Development of an integrated severe accident code PRABHAVINI for PHWRs
- Development of CFD code PINAK for Molten Fuel Coolant Interaction specific to PHWRs
- Adaptation of code ASTEC for PHWR severe accident analysis for CESAM project and development of models for Passive Autocatalytic Recombiners
- Experiments to establish analytical model DBHUPA for analysing PHWR debris bed heat-up.
- Large Scale Molten Material Coolant Interaction experimentation for PHWR
- Technical assessment of Calandria behaviour under Severe Accident for PHWR
- Experimental program on Severe Accident Management Guidelines validation for PHWRs for in-Calandria and ex-Calandria flooding.
- Generic containment benchmarks and alternate TMI benchmark exercises under SARNET programme to improve the understanding of severe accident code ASTEC
- Experiments on ultimate load capacity of containment using BARC containment model (BARCOM) facility
- Experiments on AHWR Thermal-hydraulic Test (ATTF) facility with full height simulation including the Fuel Rod Cluster Simulator (FRCS) at higher power levels.
- Experiments for design validation for AHWR core catcher and CFVS

IGCAR is involved in R&D activities related to fast reactor technology. Some of the key R&D activities of IGCAR are:

- A 100 MWt test reactor of loop type powered by metal fuel is conceptualized as successor to FBTR.
- The conceptual design of FBR1&2 is finalised with enhanced safety features approaching the safety criteria for GEN IV reactors.
- Neutron attenuation experiments are conducted in KAMINI reactor with different hydrogenous materials to generate data which will be used for shielding design and validation of computer codes.
- Technology development of seamless primary coolant pipes is carried out with the focus on reducing weld joint related defects and increase in reliability.
- A facility for testing of large diameter bearings under various thermal conditions has been commissioned and experiments are under progress for qualification of indigenously developed bearing.
- A Sweep Arm Scanner (SAS) is being developed as a modified carrier mechanism for ultrasonic transducers to inspect and map complete core of future reactors.
- Experiments are under progress towards developing Temperature Sensitive Magnetic Switch (TSMS) as an add-on passive device to shut down system.
- Development of Under Sodium Ultrasonic Scanner (USUSS) for scanning reactor internals, which can work above 200°C, is under progress.
- R&D on Molten Fuel Coolant Interaction (MFCI) during severe accident and post-accident heat removal are under progress.
- An aqueous scrubber system using submerged gravel bed is under development for sodium aerosol cleaning.
- RISHI (Research facility for Irradiation studies in Sodium at High temperature) loop is under sodium testing prior to testing in FBTR.
- R&D on ballooning behaviour of clad tubes under high temperature/pressure conditions is in progress in the RABITS (Rupture And Ballooning In TubeS) facility.
- Online Nuclear Emergency Response Decision Support System (ONERS) has been established.
- Facility for IVR studies is being setup.

NPCIL is involved in R&D activities related to 700 MWe PHWR based NPP. Some of the key activities are:

- Experiments for qualification of PCRD
- Experiments have been conducted for arriving at optimal spray nozzle design & spray ring header configuration for Reactor Building (RB) Containment Spray system with full scale facility at KAPS colony and facilities at IIT-Bombay. Iodine scrubbing experiments have been conducted. These have been successfully presented to AERB towards RB containment dome erection clearance.
- 700 MWe Fuelling Machine Test Facility is established and both Fuelling Machine Heads of KAPP-3 are tested with low temperature, high pressure operations. Full primary temperature & pressure tests are being carried out.
- A dedicated test facility to test indigenously manufactured Primary Coolant Pumps of 700 MWe reactors is being set up at R&D centre, Tarapur.

Apart from the above, AERB has its own Safety Research Institute (SRI) set up at Kalpakkam, Tamil Nadu. Some of the R&D activities undertaken are:

- Reactor safety studies (Deterministic and probabilistic approach)
- Consequence analysis and Atmospheric dispersion modelling
- Remote Sensing and Geographic Information System Applications
- Development of Simulation tools to predict flood inundation patterns
- Degradation of toxic organic pollutants from liquid waste

18.2.2 Regulatory Review and Control activities

AERB reviews the design of the plant with respect to applicable codes and standards. Applicability of the industrial code used for design, classification of SSCs, fitness for use, seismic categorization, loading of SSC as per design, etc. are thoroughly reviewed. Proven industrial codes for design, proven engineering practices, quality assurance programme, manufacturing practices, erection and commissioning procedures are reviewed to see compliance to regulatory requirement. Though proven technologies are preferred but innovative and first of a kind systems (FOAK) are also accepted. For innovative and first of a kind system, design and working principles are thoroughly reviewed. Utility is needed to submit necessary technical documents substantiating the design. It is also required that performance of the system is demonstrated in scaled model/mock up facility. During commissioning, detailed tests are needed to be carried out to demonstrate the capability of the system to perform intended function in an integrated manner.

Presently the R&D facilities at BARC, IGCAR, CSRP, IITs etc. are supporting AERB for verification of new design features considered in the plant design. Further, SRI carries out research activities in areas of regulatory interest. Design details of specific test facilities, testing methodology, test procedure, acceptance criteria, test results, etc. are reviewed by AERB at appropriate times. Performance tests are witnessed by AERB as and when required. However, the final acceptance of the systems is based on the established safety review process in AERB.

Pre-consenting review of conceptual design of Indian Pressurised Water Reactor

BARC jointly with NPCIL is working for finalizing the design of Indian Pressurised Water Reactor (IPWR). IPWR is an indigenous PWR design with a power rating of 900 MWe with advanced safety features, including passive safety systems. R&D activities are in progress and a major focus area is development of improved computational tools for reactor core design and safety analysis. Engineering developments required for manufacturing of reactor components and for experimental design & safety validation studies are also being carried out. AERB has carried out a pre-consenting review of conceptual design of IPWR.

18.3 DESIGN FOR RELIABLE, STABLE AND MANAGEABLE OPERATION

AERB has established the requirement for NPP design for reliable, stable and manageable operation. These include:

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

- Extensive automation of safety actions based on plant parameters without needing human intervention.
- Continuance of safety function based on plant parameter without operator intervention in the initial period.

Established design codes are used for designing systems incorporating sufficient margin to serve for entire life time of the plant. Reliable equipment and component are normally used in the design for which sufficient operating experience is available. Limiting condition for operation, limiting safety system setting and safety limits are specified for defining the safe operating envelope. The plant is operated strictly adhering to written procedures and Technical Specification for Operation. Operators of the plant are imparted theoretical and practical training including training in full scope simulator for normal, off normal and accident conditions. Periodic refresher training is also imparted to the operator and evaluation of the effectiveness of training is done.

In the plant, provision is made for periodic monitoring, testing, sampling and inspection to assess ageing mechanism predicted at the design stage and to help identify unanticipated behaviour of the plant or degradation that might occur in service. Required data is generated for these equipment for ageing management and estimation of their residual life.

In cases where the design life of equipment/ component is less than the design life of the plant, and mid-term in-situ replacement of the equipment is warranted, adequate provision is made in the design particularly for the in-core equipment, to facilitate such replacements.

A qualification programme for equipment/ component important to safety is implemented to verify that they are capable of performing their intended functions when necessary, and in the prevailing environmental conditions, throughout their design life, with due account taken of plant conditions during maintenance and testing.

Configuration control mechanism is established to record all necessary changes made in the plant during operation. Periodic safety review of the plant is carried out to assess the fitness for use and to incorporate necessary safety upgrades considering the current safety requirements and practices. Necessary safety reviews are carried out whenever required.

18.3.1 Regulatory Review and Control Activities

Safety requirements in regulatory document specify that, for the indigenously designed NPPs, design organisation supplies adequate information towards safe, reliable and manageable operation and maintenance of the plant. Design organisation also support subsequent plant modifications and provides assistance for preparation of administrative and operational procedures.

In case of NPPs of external design, it is required that responsible organisation establishes a formal system within its management for ensuring the safety of the plant design throughout the lifetime of the NPP. This includes arrangements with external organisations for assignment of tasks where detailed specialized knowledge is not available with the design authority. These external organisations including original designers (vendors) are required for maintaining their specialized knowledge of design and sharing the same with the design authority within the responsible organisation during the lifetime of the plant.

The implementation of the requirements for human factors / human machine interface is addressed in detail in Article 12: Human Factors. The regulatory requirements specify that the aspects of design, having implications on operability, shall be reviewed by the utility. The merits in developing such a methodology include acceptance of the design by the utility for ensuring proper operation, maintainability, layout, inspection etc. in the new designs. AERB ensures compliance to this requirement during the safety review for construction consent.

18.4 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

The stage wise consenting process of AERB ensures that the safety in design is comprehensively reviewed prior to issuance of consent for construction. The regulatory review and assessment determines that in the design of NPP, proper emphasis is placed on prevention of accident as well as on its mitigation. Design extension conditions that could lead to large or early releases of radioactivity are required to be practically eliminated. The defence in depth principle is as per the intent elaborated in the regulatory documents. All NPPs including those under design and construction have undergone a special review following accident at Fukushima Daiichi NPP and enhancements as required to cater to extreme external events have been incorporated in the design. 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 consideration among others in the design of NPPs. The objective of design has been to ensure safe, reliable, stable and easily manageable operation of the plant. Therefore India complies with the obligations of Article-18 of the Convention.

The regulatory requirements with respect to siting and design of NPPs in India are consistent with the Vienna Declaration on Nuclear Safety.

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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 organisations and regulatory bodies;

viii. the generation of radioactive waste resulting from the operation of a nuclear installation is kept to the minimum practicable for the process concerned, both in activity and in volume, and any necessary treatment and storage of spent fuel and waste directly related to the operation and on the same site as that of the nuclear installation take into consideration conditioning and disposal.

19.0 GENERAL

The requirements for licensing of NPPs for operation emanate from the Atomic Energy Act, 1962 and rules framed thereunder. National laws pertaining to NPP are given in detail in Article 7: Legislative and Regulatory Framework. Based on these requirements, the system of licensing, inspection and enforcement has been established. AERB safety code on regulation of Nuclear and Radiation Facilities (AERB/SC/G) and AERB Safety Guide on 'Consenting Process for Nuclear Power Plant and Research Reactor' (AERB/NPP&RR/SG/G-1) establish the entire licensing process for NPPs. The review, assessment and verification associated with licensing of NPPs is summarised in Article-14: Assessment and Verification of Safety. Further, AERB safety code on 'Nuclear Power Plant Operation', (AERB/NPP/SC/O, Rev. 1) establishes requirements related to operation of NPPs and several safety guides issued under this Code describe and make available methods to implement specific requirements of the Code.

19.1 INITIAL AUTHORIZATION

As required by AERB/SC/G, AERB completes the review of Preliminary Safety Analysis Report (PSAR) submitted by the licensee, prior to issuance of consent for construction. At this stage, a large part of the review and assessment effort is directed to the safety analysis of design for various postulated scenarios within the design basis and design extension conditions. The review and assessment process considers whether the applicant's list of Postulated Initiating Events (PIEs) is complete and acceptable as the basis for the safety analysis. AERB determines that the PIEs, type of analytical considerations and assumptions are in conformance with applicable safety guides. Further, the engineering systems are qualified to meet the functional requirement for which they were designed, under all situations considering environmental conditions, ageing etc. AERB safety guide AERB/NPP-PHWR/SG/D-19 (2018) on deterministic safety analysis and AERB/NPP/SG/G-9 (2017) on contents and format of the safety analysis reports provide guidance on safety analysis to be carried out and preparation of the safety analysis reports. Review of safety analysis is covered in Article-14: Assessment and Verification of Safety.

On completion of construction, Regulatory clearance for commissioning of NPPs is sought by the licensee as per AERB/NPP&RR/SG/G-1 and AERB Safety Guide on 'Commissioning of PHWR based NPPs' (AERB/SG/O-4) & AERB Safety Guide on 'Commissioning of PWR based NPPs' (AERB/NPP-PWR/SG/O-4 C).

There are three major phases of commissioning of NPPs namely; (i) Phase-A: pre-operational tests, (ii) Phase-B: Initial fuel loading, pre-critical tests, First Approach to Criticality and low power tests and (iii) Phase-C: Power ascension tests

Before start of commissioning activities, utility prepares a comprehensive programme for the commissioning of plant components & systems as per the requirements of AERB/NPP/SC/O and submits the same for review and acceptance by AERB.

The commencement of operation of an NPP begins with initial fuel loading and approach to the first criticality. At this stage, utility demonstrates to AERB its preparedness to commence operation of the NPP. This requires completion of all activities with requisite approvals, pertaining to the following:

a. Final as built drawings for the plant SSCs and Final Safety Analysis Report.

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 programme for their operation.

d. Pre-Service Inspection (PSI).

e. Establishment of organisation for plant operation, training, qualification & licensing of the operating personnel, as per AERB requirement.

f. Technical Specification for Operation specifying operational limits and conditions.

g. Operating instructions and procedures for commissioning and operation of the plant including emergency operating procedures.

h. Establishment of physical protection system and Nuclear Security Aspects.

i. Radiation protection programme.

j. Emergency Preparedness and Response Plans.

k. Waste management programme.

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.

In the light of lessons learned from the accident at Fukushima Daiichi NPPs, following aspects are given special attention:

- Implementation of safety upgrades in reactors as well as spent fuel storage pool
- Establishment of surveillance and testing programmes and limiting conditions of operation relevant to these upgrades
- Establishment of plant-specific accident management programme and training to NPP operators
- Demonstration of design safety through analysis taking into account of severe accident scenarios and radiological acceptance criteria specified in AERB/NF/SC/S (Rev.1, 2014)

- Upgradation of infrastructure for emergency preparedness and response plans

Before issuing licence 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 is resolved to the satisfaction of AERB. 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 basis documents for operation of the unit.

The review and assessment by AERB also includes consideration of the applicant's organisation, management, procedures and safety & security culture, which have a bearing on the safety of 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. The typical organisation for plant operation established at an Indian NPP is given in Annex 19-1.

19.2 OPERATIONAL LIMITS AND CONDITIONS

The licensee prepares the Technical Specifications for operation before approach to first criticality, based on the inputs from the design and safety analysis. AERB safety guide on 'Operational Limits and Conditions for Nuclear Power Plants' (AERB/SG/O-3) provide guidelines for preparation of this document, which is submitted to AERB for review and approval. Adherence to Technical Specifications during operation is mandatory. A Technical Audit Engineer at the Station independently verifies compliance with all the clauses of Technical Specifications and reports to station management. The compliance with the requirements specified in Technical Specification is further verified through regulatory inspections by verifying station's records as well as through direct observations.

The Technical Specification document is issued in two parts. Part A contains the technical specifications and station policy clauses, bringing out the mandatory requirements to be adhered to during operation. Part-B is explanatory in nature and contains the bases for arriving at different conditions/requirements in technical specifications for operation.

Technical Specifications (Part-A) consists of following sections:

i. Safety Limits

ii. Limiting Safety System Settings (LSSS)

iii. Limiting Conditions for Operation (LCO)

iv. Surveillance Requirements

v. Administrative Requirements

If a change in any section of the Technical Specification becomes necessary, based either on operating experience or new findings consequent to changes in safety analysis, the same is submitted to AERB for review and approval.

19.3 PROCEDURES FOR OPERATION, MAINTENANCE, INSPECTION & TESTING

The safety code on 'Nuclear Power Plant Operation', (AERB/NPP/SC/O, Rev. 1) requires that all the activities in the NPP be carried out as per the well laid down operating procedures. The procedures should be prepared, tested and approved as per the standard guidelines developed for the same. Based on these guidelines, the plant management prepares various procedures for commissioning and operation of all systems, maintenance, inspection, testing, and surveillance requirements. The procedures also include conditions dealing with plant under normal operation and anticipated operational occurrences as well as appropriate actions for accident conditions. These documents are normally prepared by plant personnel in co-operation with the designers and suppliers. The Plant Management ensures that the aspects of Quality assurance are duly considered in the preparation, review and approval of these procedures. All the approved procedures are available to the users on plant local area network and hard copies are maintained in main and supplementary/back-up control room.

19.4 PROCEDURES FOR RESPONDING TO OPERATIONAL OCCURRENCES & ACCIDENTS

All NPPs have procedures for handling various anticipated operation transients and accident conditions. These procedures are commonly called Emergency Operating Procedures (EOPs). These EOPs are unique to each station and independent of other stations. In addition to the above, several station-specific administrative procedures are also prepared, which include shift change over procedure, station work permit procedure, radiation protection procedure, engineering change procedure, temporary change control procedure, etc.

NPCIL HQ has developed generic technical basis document for Accident Management Guidelines (AMG) of PHWRs based NPPs. This generic technical basis document has been prepared considering the guidelines given in IAEA Safety Guide (IAEA-NS-G 2.15): 'Severe Accident Management Programme for Nuclear Power Plant'. The document also contains guidelines for dealing with postulated accident conditions in spent fuel storage pools. The generic technical basis document has been reviewed by AERB. Based on this document, the following station-specific accident management guidelines have been prepared for all NPPs:

- Severe accident prevention guidelines
  - injection of water into steam generators
  - injection of water into primary heat transport system
- Severe accident mitigation guidelines
  - maintaining calandria heat sink by injecting water to calandria
  - maintaining calandria vault heat sink by injecting water to calandria vault
  - controlling reactor building conditions
- Severe accident ultimate guidelines
  - reduction of containment pressure
  - reduction of containment atmosphere flammability/hydrogen concentration
  - mitigation of fission products release

The station-specific accident management guidelines also cover the transition criteria from EOPs to accident management guidelines. The qualified / licensed operating staffs at all the stations have undergone training on the transition criteria and the accident management guidelines. Their re-training frequency is set at once in three years. As part of long term measures, various hardware provisions/additional equipment required for these accident management guidelines are under implementation at all Indian NPPs. Passive Catalytic Recombiner Devices (PCRD) are being installed for hydrogen management inside containment building in a phased manner. The design of Containment Filtered Venting System (CFVS) has been finalized after due testing and regulatory review is also completed. CFVS has been installed at TAPS-1&2 (BWR units) and installation of CFVS in PHWR based NPPs is in progress.

The technical basis documents for TAPS-1&2 and KKNPP-1&2 have been reviewed and accepted by AERB. The accident management guidelines based on these technical basis documents have been put in place at TAPS-1&2 and KKNPP-1&2.

Apart from these, there are site-specific procedures for conducting site-emergency exercise and handling the off-site power failure situations, which involves multiple units/ facilities at the site.

India has adopted twin unit concept for establishment of nuclear power plants in the country. Each twin unit station has both units essentially similar in design. A site having multiple nuclear power stations also follows the same concept of twin unit station with adequate physical separation between them. However, each site has a centralized waste management facility, a centralized emergency equipment centre, a centralized emergency control centre and a centralized fire station, which takes care of the needs of each station/facility located at the site. In view of the non-sharing of safety systems among the multiple stations at a site and ability to implement emergency operating procedures and accident management guidelines for each unit, the safety concern related to multi-unit/multi-facility sites, as appropriate, are addressed. AERB verifies the availability of EOPs & AMGs during regulatory inspections. AERB also verifies the aspects related to surveillance requirements specified for the equipment/provisions for accident management. Additionally, AERB checks the aspects related to operator training on accident management as part of licensing of operators (also refer section 11.2.3.2).

19.5 ENGINEERING AND TECHNICAL SUPPORT

NPCIL manages all the presently operating NPPs through the Directorate of Operation set up at its Head Quarters at Mumbai. This Directorate provides leadership for the stations to continually improve and sustain high levels of safe and reliable operation. It provides organisational structures, policies, processes and programmes to establish high standards for station operation and foster strong safety culture. It monitors and assesses the stations, assists in arranging resources and services for resolving the performance and regulatory issues of the stations.

The Directorate of Operation also derives support from other technical groups at Headquarters, which include Directorate of Technical (comprising of directorates of Engineering, Reactor Safety & Analysis, Health Safety & Environment, Technology Development and Procurement) and Directorate of Quality Assurance. These groups at headquarters also provide Design, Engineering and Technical support to units under construction and commissioning. NPCIL also enters into memoranda of understanding with Research and Development and academic institutions so as to avail additional engineering and technical support as and when required.

Directorate of Technology Development, NPCIL provides technical support to all NPPs in the area of Remote handling techniques and tool development, optimisation of NPP construction time, residual life assessment of SSCs, application oriented projects to provide timely solutions to the problems emanating from operating NPPs/project under construction, experiment oriented projects for validating new designs and in-house developed computer models/codes.

Electronic systems R&D group concentrates mainly on development of electronics and computer based controls and instrumentation. The laboratory facilities for electronics and computer based systems are established at NPCIL headquarters, Mumbai.

At NPP 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. Based on the special safety assessment subsequent to the accident at Fukushima Daiichi NPP, a centralized On-Site Emergency Support Centre (OESC) common to all NPPs at a site is envisaged to be constructed within the exclusion zone (Please refer section 6.5).

In NPCIL, engineering and technology services are maintained centrally under headquarters control and in addition every nuclear station has its own engineering and technical support section at the respective station to deal with day to day operational issues. Headquarter extends these central resources to stations on receipt of 'Engineering Assistance Request' from stations. In addition, as required human resources can be made available from HQ as well as other stations. For specialized jobs, services from consultants are also availed.

The engineering and technical support to NPPs in case of accident has been identified in the station specific documents on accident management guidelines. In the case of accident, initial response is from NPP personnel, for which training programme exists covering accidents within design basis and design extension conditions. Technical support to the affected NPP is also provided from NPCIL headquarters, for which a control room is established. From this control room, required technical support can be provided as NPCIL has personnel having experience in design, operation and safety analysis. In addition, as per the established EPR framework, the Department of Atomic Energy will also provide support as required by the NPP in managing the accident (details given in Article-16).

19.6 REPORTING OF EVENTS SIGNIFICANT TO SAFETY

AERB Safety Code on 'Regulation of Nuclear and Radiation Facilities', AERB/SC/G specifies the reporting obligations of the Plant Management. AERB/SG/O-13 on 'Operational Safety Experience Feedback on Nuclear Power Plants' issued under the Safety Code on NPP Operation provides guidance for reporting events to regulatory body. The detailed reporting criteria for the events are provided in the Technical Specifications for Operation.

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). 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 following three stages:

i. Prompt Notification

   Prompt Notification in the prescribed format is sent within 24 hours of the occurrence of the event, including the provisional INES rating.

ii. Significant Event Report

   A detailed significant event report (SER) in a prescribed format, including the INES rating, for SER is submitted within a period of 20 days from the date of occurrence of the event.

iii. Event Closing Notification Report

   Event Closing Notification Report (ECNR) in a prescribed format is submitted for those significant events for which root cause could not be established within 20 days (reporting time for significant event report). ECNR indicates completion of all investigations pertaining to the event.

Number of significant events at operating NPPs during the years 2016, 2017 and 2018 were 39 (36 events were below INES rating scale, 2 events of INES rating 1 & 1 event of INES rating 2), 37 (36 events were below INES rating scale, 1 event of INES rating 1), 32 (all events were below INES rating scale) respectively.

The information on events rated at Level – 1&2 on INES is given under Article – 6.

All the SERs, including the INES rating, are reviewed by AERB and recommendations are addressed in a time bound manner.

Apart from the reporting requirements of operational events, licensee has established a Low Level Event (LLE) programme since year 2005 as a performance improvement programme by identifying and trending minor issues including issues related to safety culture. Stations send the quarterly reports on LLEs to Operations Directorate at NPCIL headquarters, where all the LLE reports are reviewed and generic issues related to all the stations are identified and suitable action is proposed to address the same. The awareness created at stations has resulted in increased reporting of LLEs. The periodic review of LLEs is helping stations in identifying & addressing the generic issues in stations.

A system for reporting Extraordinary Nuclear Events has been established in order to meet the requirements under the Civil Liability for Nuclear Damage (CLND) Act, 2010.

19.7 OPERATING EXPERIENCE FEEDBACK SYSTEM

AERB recognizes operating experience as input for 'Continual Safety Improvement' and has established regulatory requirement for a structured Operating Experience (OE) programme at NPPs. AERB safety code on operation (AERB/SC/O) specifies the requirement for establishing operating experience feedback system at NPPs. AERB Safety Guide AERB/SG/O-13 on 'Operational Safety Experience Feedback on Nuclear Power Plants' provides guidance and procedure for establishing an Operating Safety Experience Feedback (OSEF) system based on national / international experience on management of safety related operational experience in NPPs. The OSEF system at NPPs and at NPCIL complies with the guidelines given in the safety guide.

NPCIL obtains reports of international events through IAEA-IRS, WANO, COG etc. The reports on international events as well as reports on national events are reviewed at headquarters and applicable reports are sent to stations.

The organisational structure at NPP level ensures that both national and international events are systematically analyzed through Operating Experience Review Committee (OERC) and appropriate actions are taken to prevent the occurrence of similar events in Indian NPPs. Station OERC comprises of members from Technical Services, Operation, Maintenance, Health Physics, Training and other relevant sections. The observations of this Committee are further reviewed in Station Operation Review Committee (SORC) for identification of safety related actions.

The system ensures that events taking place at one NPP are communicated to other NPPs in India. The system also ensures that the information on events and corrective actions at one NPP is disseminated to other NPPs. Further, management of various NPPs interacts with each other at different levels. At these meetings, the information on various modifications to equipment and procedures is exchanged. These exchange meetings are held periodically.

At corporate level a 'Flash Report' is issued by Directorate of Operations at NPCIL headquarters to all the stations for quick dissemination of information pertaining to the occurrence of an event in any plant. In addition, an 'Operational Experience Feedback Report' is also issued by headquarters on those events which have significant learning points for all the other stations of NPCIL.

In addition to the reporting of events significant to safety (refer section 19.6), the plant management is also required to submit routine reports such as periodic performance reports, inspection & testing reports, reports on radiological safety status, environmental surveillance reports, waste management reports, minutes of Station Operation Review Committee (SORC) and other miscellaneous reports to AERB. The functioning of the operating experience feedback setup at the plant and the corrective actions taken in response to internal and external operating experience is monitored by AERB through the reports received from licensee and during regulatory inspections. Actions taken by licensee based on internal and external operating experience are also reviewed during renewal of licence for operation every five years.

AERB has an independent OE programme that utilises the information obtained from national operating experience (Nuclear Power Plants /Projects), national regulatory processes such as licensing, regulatory inspection, safety review &enforcement and national workshops, seminars and technical conferences. It also obtains operational and regulatory experience from IAEA incident reporting system, international peer reviews (CNS, IRRS, OSART), bi-lateral & multi-lateral co-operations with other regulatory agencies and regulator's forums.

The programme also plays a pivotal role in exchanging safety significant experience / information among different regulatory core processes (i.e. licensing, regulatory inspection, safety review and enforcement) and for the development of safety regulations. The overall structure of AERB OE programme along with various OE inputs & OE outputs is depicted in the figure below.

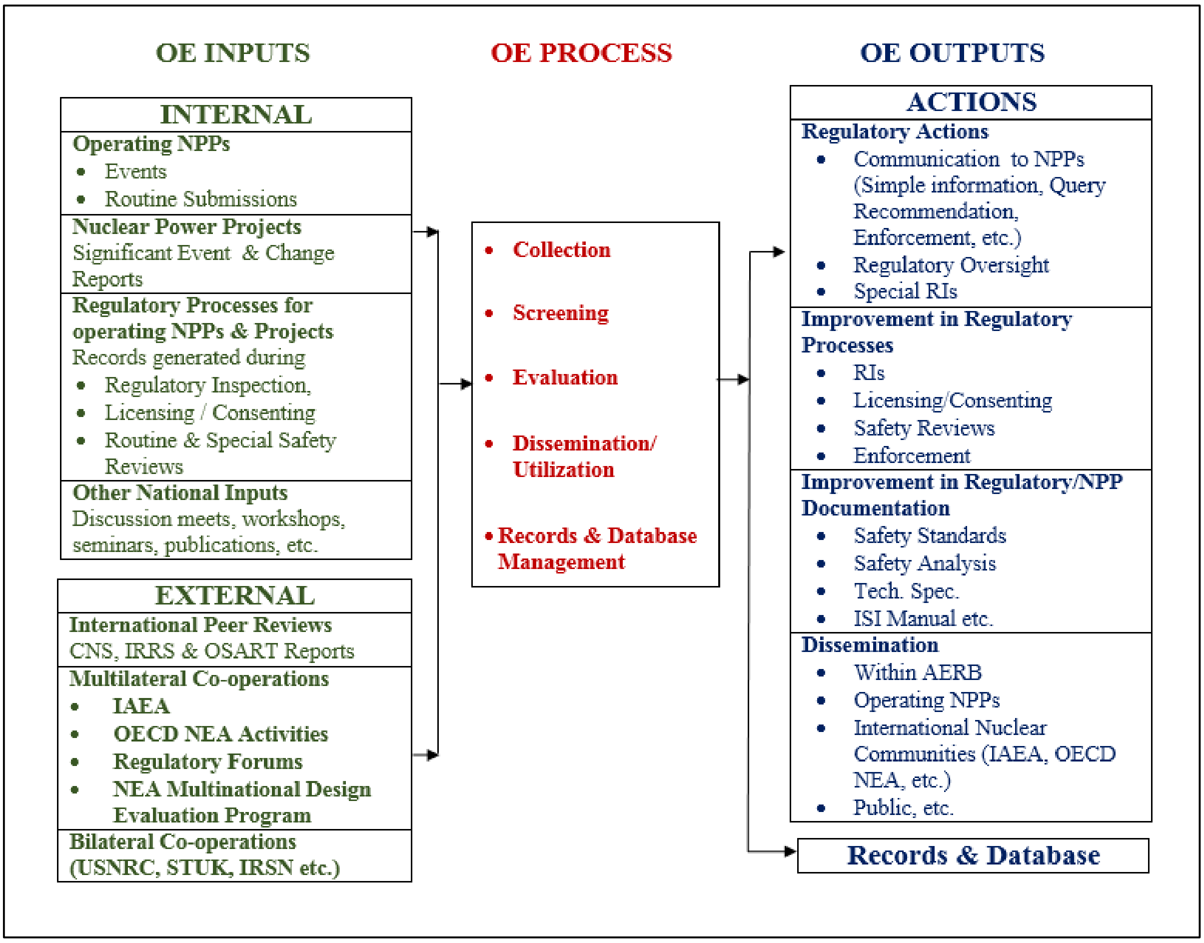

Figure 8 Structure of AERB OE programme

India shares OE of Indian NPPs through various international platforms like IAEA-IRS, WANO, COG, IAEA-INES and various regulator and operator forums.

19.8 MANAGEMENT OF SPENT FUEL AND RADIOACTIVE WASTE

19.8.1 Spent Fuel Storage

India's nuclear power programme is based on a closed fuel cycle, as brought out in section 1.3 (Introduction). The on-site storage of spent fuel is in the water filled storage bay provided at each NPP. The storage bays are typically 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 at the NPP site. All such additional storage facilities are subject to regulatory review and clearance.

19.8.2 Radioactive Waste Management

Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987 specifies the requirement for obtaining authorization for safe disposal of radioactive waste arising out of operation of NPP. Further, AERB Safety Code on Management of Radioactive Waste, AERB/NRF/SC/RW, 2007, establishes the requirements, which need to be fulfilled for safe management of solid, liquid and gaseous radioactive waste. 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. The requirements specified in the safety code include among others, minimisation of waste generation; categorization, storage, management, disposal of wastes and environmental surveillance. AERB has published safety guides on various aspects regarding management of radioactive wastes.

The operation and maintenance of nuclear power station results in the generation of radioactive gaseous, liquid and solid Low and Intermediate Level Waste (LILW) which are required to be monitored, treated/conditioned and safely disposed off to the environment. To meet this objective and also to limit the discharges below the prescribed limits during all operational states, Waste Management Plants (WMPs) are provided at all NPPs prior to the commencement of operation, which are co-located within the plant boundary. The WMP has necessary engineered systems and administrative procedures to exercise control on release of activity into the environment, as per the regulatory requirements. The waste management design philosophy is based on the principle of ALARA (As Low As Reasonably Achievable) taking the economic and social factors into consideration. Three principles governing the management of radioactive wastes are (i) dilution and dispersal of low level wastes, (ii) delay, decay and dispersal of waste containing short lived radio nuclides and (iii) concentration and containment of high active wastes containing long lived radio nuclides after conditioning. Keeping the waste generation to the minimum practicable is essential objective of radioactive waste management. Waste minimisation refers to both a) waste generation by operational & maintenance activities of plant and b) secondary waste resulting from predisposal management of Radioactive Waste.

Gaseous wastes generated mainly from equipment vent, purging and exhaust ventilation system are filtered and discharged through stack.

Liquid wastes generated from Indian NPPs are of low level which are segregated at source based on specific activity and chemical nature for ease of appropriate treatment. Specific or combination of treatments such as filtration, ion exchange process, chemical treatment and evaporation are provided followed by monitoring, dilution and discharge.

Environmental survey laboratories are established near all NPP sites for carrying out environment surveillance around the NPPs. The results of the environmental survey activities are monitored by AERB. Feedback from the surveys carried out in the past, show that the radiological impact due to releases from NPPs are negligible. For detail, refer section 15.4.

Solid wastes such as spent ion exchange resins, filters, sludge, cotton wastes, unusable mops, plastic sheets, hand gloves, shoe covers, etc. are segregated at source based on physical nature and surface dose rate. Treatments provided include immobilisation with polymer/ cement, shredding, compaction and incineration. Suitably designed engineered modules like trenches, vaults and tile holes of Near Surface Disposal Facility (NSDF) are provided for the disposal of conditioned solid wastes. NSDF is also covered by environmental surveillance programme. Safety assessment studies, waste assaying and waste accounting systems are in place as a part of solid waste management programme.

Efforts are also being made towards addressing the objective of near-zero discharges in the latest NPPs.

The authorization for safe disposal of radioactive wastes specifies the limits on volume and activity of radioactive wastes that can be transferred/disposed, which is arrived at based on the NPP design& operating experience of similar NPPs, following the regulatory requirements. Adherence to the specified requirements and the terms of the authorization is verified by AERB through regular reviews & inspections during the authorization period. These authorizations are renewed periodically (once in five years), based on review & assessment of safety aspects related to waste management performance during the previous authorization period. This process is also connected with the renewal of licence of the NPP.

19.9 LONG TERM OPERATION

All NPPs in India are required to establish a programme for life management as per the requirement specified in AERB safety code for Operation (AERB/SC/O). The guidance for this is detailed in AERB safety guide on Life management of NPPs (AERB/SG/O-14), including the issues of (i) residual life assessment and (ii) safety upgrades towards addressing the current safety standards/practices. Through a comprehensive Ageing management Programme (AMP), baseline data, operational history data and maintenance data for the SSCs are collected during the operation phase of NPPs. Effects of various operating conditions and degradation mechanisms on SSCs are studied. On the basis of such assessment, specified conditions of components are monitored to determine the degradation in safety margin of components and the residual life of components are assessed.

AERB has instituted a mechanism wherein an NPP can seek renewal of operating licence based on safety review. AERB issues licence for operation of NPP for a specified period of 5 years based on safety review and assessment of the application for renewal of licence. In addition, every 10 years, Periodic Safety Review (PSR) is carried out by licensee and the PSR report is submitted to AERB for review in accordance with the guidelines given in AERB safety guide AERB/SG/O-12.

During the PSR review, safety assessment of NPPs is carried out considering the cumulative effects of plant ageing and irradiation damage, results of In-Service Inspection (ISI), system modifications, operational experience feedback status and performance of safety systems and safety support systems, revisions in applicable safety standards, technical developments, manpower training, radiological protection practices, deterministic and probabilistic safety analysis, hazard analysis, plant management structure, etc. These PSRs, carried out regularly over the lifetime of the NPPs facilitate evaluation of the NPP vis-à-vis the current requirements / practices. Based on these reviews necessary safety enhancements are identified and implemented. This also facilitates addressing the Vienna Declaration on Nuclear Safety for the operating NPPs.

The regulatory approach followed for operation of NPPs in India allows the plant to continue operation as long as it meets the regulatory requirements and satisfies the safety case. As the plants get older, the ageing aspects receive increasing attention during various safety reviews including PSRs.

19.10 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

AERB Safety Code on Regulation of Nuclear and Radiation Facilities (AERB/SC/G) requires submission of the FSAR and Technical Specifications for Operation, incorporating the experiences from commissioning process. The licensing process in India ensures a comprehensive review of the safety analysis and safety management system to ensure that the commissioning and operation of NPP is carried out in a safe and reliable manner. Operation of NPP is carried out within the operating limits and conditions specified in the Technical Specifications for Operations. In addition to the organisational set-up in accordance with the Technical specifications, an effective operating experience feedback mechanism has been set-up both at utility and AERB to ensure that both internal and external operating and regulatory experience is reviewed and appropriate corrective actions as applicable are taken at Indian NPPs as well as the projects under construction. Therefore, India complies with the obligations of the Article-19 of the Convention.

The operational practices of the NPPs and the system of periodic safety reviews along with the extensive operating experience feedback programme ensure continual safety improvements throughout the NPP operating life. This facilitates addressing the Vienna Declaration on Nuclear Safety with respect to the operating NPPs.

Annex 19-1: Typical Organisation at NPP

NPCIL has established a well-defined functional organisation for each station. A typical organisation chart is depicted in Annex 19-2 for reference. The functional responsibilities of various wings of the organisation to conduct safe, orderly and efficient operation of the station are described below:

STATION DIRECTOR (SD) is the Head of station management of NPP. 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 organisation for plant management. He is also responsible for ensuring that the requirements of AERB are complied with. He is also responsible for training, qualification and licensing of operating personnel, in accordance with the approved laid down procedures.

The SD ensures compliance with the technical specifications for operation, 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, systems and components.
- For ensuring that safety 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 (in case of twin unit site).
- 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, Training and Quality Assurance Superintendents assist him in this regard.

TECHNICAL SERVICES SUPERINTENDENT (TSS) is responsible for:

- Engineering assistance required to efficiently operate the station/systems at optimum performance level.
- Performing engineering/technical studies and reviews.
- Issuing of work plans for specific jobs during operation and shutdowns.
- Reactor Physics and fuel management.
- Chemistry control of the systems.
- Upkeep and arranging updating of all technical documents including all design manuals and drawings.

OPERATION SUPERINTENDENT (OS) is responsible for:

- Safe operation of station / systems as per approved objectives, procedures, policies and within the limits and conditions laid down in the Technical Specifications for Operation.
- Bringing to notice of Station Operation Review Committee (SORC) members deviations / deficiencies in the operation of the systems.

- Ensuring that shifts are manned efficiently by providing adequate trained and licensed manpower.
- Bringing to the notice of SD/ CS/ TSS, promptly all deviations of Technical Specifications for Operation and all unusual occurrences with full information along with his comments and recommendations.
- Arrange to convene SORC meeting at least once in a month and also as and when necessary.
- Upkeep and updating of operating manuals.

MAINTENANCE SUPERINTENDENT (MS) is responsible for:

- Planned preventive / breakdown maintenance in respect of mechanical, electrical, control and fuel handling equipment / systems.
- Maintenance of adequate spares and consumables.
- Modifications to systems after approval by concerned authorities.
- Civil and Service maintenance.

TRAINING SUPERINTENDENT (TS) is responsible for coordinating arrangements for:

- Training of station staff in radiation protection, first aid and emergency procedures, industrial safety & fire protection.
- Training / Qualification / Re-qualification of operation staff.
- Training / Qualification / Re-qualification of maintenance staff.
- Training / Qualification / Re-qualification of fuel handling staff.

SUPERINTENDENT (QA) Heads the Quality Assurance group and is responsible for:

- Station Quality Assurance.
- Technical Audit.
- QA documentation.
- Monitoring the implementation status of recommendations of AERB.
- Pre-Service & In-service inspections.

Radiological Safety Officer (RSO) is responsible for advising station management and staff on radiation protection. This includes advice on personnel exposure, radiation monitoring and surveys and for liaison with Waste Management Plant regarding discharges and management of radioactive wastes, equipment for radiation protection and emergency arrangements and environmental surveys within the boundary of the unit. He is responsible for making measurements and observations during normal operations as well as during abnormal occurrences in the area of radiation safety.

SHIFT CHARGE ENGINEER (SCE) is responsible for authorizing all operation and maintenance activities of the station on shift basis. He is delegated all powers given to the SD / CS to maintain reactor systems under safe condition during operation and shutdown of the reactor. He is responsible for safe start up, operation and shutdown of the reactor, turbo generator and auxiliaries. In the absence of SCE, Assistance Shift Charge Engineer (ASCE) discharges these responsibilities. Both SCE and ASCE hold licence 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 AERB. He also submits all safety related proposals for review to SORC, NPC-SRC and AERB for obtaining necessary approvals.

STATION OPERATION REVIEW COMMITTEE (SORC), headed by Station Director / Chief

Superintendent and having TSS, MS, OS, Superintendent (QA) and Radiological Safety Officer as members, is formed at each station. The committee,

- Reviews the station operations at regular intervals to detect potential safety issues at the station and recommends corrective actions.
- Reviews all proposed special / emergency operation, maintenance and test procedures and recommends revisions thereto as necessary.
- Reviews reactor shut downs initiated by safety system and recommends action to prevent recurrence of unwarranted shutdowns, where applicable.
- Reviews all proposed changes, Engineering Change Notices including modifications to approved procedures for plant systems / equipment 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
- Investigates promptly, all safety related unusual occurrences and instances involving deviations of technical specifications, station policies (as applicable).
- Investigates loss, misplacement or unauthorized use of radiation sources.
- Investigates incidents involving radioactive material during transportation within the controlled area of the station.
- Investigates incidents involving disabling injury preventing the person from working for a period of 24 hours or more. (Injuries of lesser significance are reviewed by Head, Fire & Industrial Safety).

TECHNICAL AUDIT ENGINEER is responsible for auditing and monitoring the compliance with the operating procedures, administrative procedures, surveillance test schedules, SORC recommendations, in-service inspection and Engineering Change Notices of all safety related systems. He also monitors deviations of the technical specifications & station policy, and follows up implementation of the decisions given by SORC and AERB from time to time.

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 over-exposures.
- To suggest further action in respect of work to be allocated to such over exposed persons.

Investigation by the committee is carried out within specified timeframe and the report is forwarded to AERB.

NPC-SRC (OPERATIONS) 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 (Operations). The recommendations made by this committee are incorporated before the proposal is forwarded to AERB.

Annex 19-2: Organisation Chart of a Typical Indian Nuclear Power Plant