सत्यमेव जयते

Government of India

NATIONAL REPORT

(Actions taken for Indian NPPs subsequent to Fukushima Nuclear Accident)

to

THE CONVENTION ON NUCLEAR SAFETY

Second Extraordinary Meeting of Contracting Parties, August 2012

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FOREWORD

The Government of India ratified the Convention on Nuclear Safety on March 31, 2005. This National Report is being submitted by India for review by the Contracting Parties to the 2nd extraordinary meeting of the Convention on Nuclear Safety (CNS) in accordance with article 23 of the convention.

This National Report was prepared in accordance with the "Guidance for National Reports" for 'Second CNS Extraordinary Meeting' prepared by the General Committee of the 5th Review Meeting of the convention. 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 NPP are covered in the national report. The report describes the safety reviews of Indian NPPs, carried out after Fukushima Nuclear Accident and further actions taken/planned based on the lessons learnt from Fukushima.

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CONTENTS

LIST OF ABBREVIATIONS

AEC	Atomic Energy Commission
AERB	Atomic Energy Regulatory Board
AERBSC-EE	AERB Safety Committee for External Events
ASN	Nuclear Safety Authority, France
BARC	Bhabha Atomic Research Centre
BHAVINI	Bhartiya Nabhikiya Vidyut Nigam Limited
BWR	Boiling Water Reactor
CNS	Convention on Nuclear Safety
COG	CANDU Owners Group
CRP	Coordinated Research Program
DBE	Design Basis Event
DBFL	Design Basis Flood Level
DBGM	Design Basis Ground Motion
DG/ EDG	Emergency Diesel Generator
DIL	Derived Intervention Level
EBIS	Emergency Boron Injection System
EBP	Extra Budgetary Project
ECCF	Emergency Control Centre Facility
ECCS	Emergency Core Cooling System
GCNEP	Global Centre for Nuclear Energy Partnership
IAEA	International Atomic Energy Agency
IGCAR	Indira Gandhi Centre for Atomic Research
IL	Intervention Level
INPO	Institute of Nuclear Power Operations U.S.A
IRRS	Integrated Regulatory Review Service
IRSN	Institute for Radiation Protection and Nuclear Safety (IRSN), France
IS	Indian Standard
ISSC	International Seismic Safety Centre
KAPP	Kakrapar Atomic Power Project
KAPS	Kakrapar Atomic Power Station
KGS	Kaiga Generating Station
KKNPP	Kudankulam Nuclear Power Project
LOCA	Loss of Coolant Accident
LWR	Light Water Reactor
MAPS	Madras Atomic Power Station
MDEP	Multinational Design Evaluation Programme
MSLB	Main Steam Line Break
NAPS	Narora Atomic Power Station

NDMA	National Disaster Management Authority
NDRF	National Disaster Response Force
NEA	Nuclear Energy Agency
NPCIL	Nuclear Power Corporation of India Ltd.
OSART	Operational Safety Review Team
PFBR	Prototype Fast Breeder Reactor
PHRS	Passive Heat Removal System
PHT	Primary Heat Transport
PHWR	Pressurized Heavy Water Reactor
PSR	Periodic Safety Review
QBIS	Quick Boron Injection System
RAPS	Rajasthan Atomic Power Station
RPV	Reactor Pressure Vessel
SAMG	Severe Accident Management Guidelines
SARCOP	Safety Review Committee for Operating Plants
SBO	Station Black Out
SFSB	Spent Fuel Storage Bay
SG	Steam Generator
SOER	Significant Operating Experience Report
SSAFF	Special Safety Assessments Following Fukushima
SSC	Structures Systems and Components
TAPS	Tarapur Atomic Power Station
TEPCO	Tokyo Electric Power Company
TMI	Three Mile Island
TSM	Technical Support Mission
UPS	Uninterrupted Power Supply
USNRC	United States Nuclear Regulatory Commission
WANO	World Association of Nuclear Operators

EXECUTIVE SUMMARY

Nuclear energy remains an important element in India's energy mix for sustaining rapid economic growth. With 20 operating power reactors, the installed nuclear capacity in the country is 4780 MWe. These reactors have been commissioned over last four decades, first one as early as 1969 and the latest in 2011. India ranks sixth among nations in terms of the number of nuclear power reactors in operation. As regards reactors under construction, India ranks third with seven reactors in different stages of construction. The construction work of two 1000 MWe LWRs at Kudankulam, being set up in technical cooperation with the Russian Federation is nearly complete. Commissioning activities in Unit-1 have reached an advanced stage and the unit is likely to be operational soon. The unit-2 is expected to follow thereafter. The 500 MWe Prototype Fast Breeder Reactor is also at an advanced stage of construction. Construction of four indigenously designed 700 MWe PHWRs, two each at existing sites of Kakrapar in Gujarat and Rawatbhata in Rajasthan has also started. In addition, large size water cooled reactors are planned under international civil nuclear cooperation. The nuclear power programme is being pursued with full regard to the safety of plant, people and the environment around the plants.

Immediately after the accident at Fukushima, Hon'ble Prime Minister of India reemphasized that safety of nuclear power plants is a matter of highest priority for the Government and called for safety audits of Indian Nuclear Power Plants (NPPs). Nuclear Power Corporation of India Ltd. (NPCIL), the utility, constituted separate task forces to review safety of NPPs depending on types of reactor designs and their vintages in India. These task forces reviewed safety of NPPs with postulated scenario of non-availability of offsite & onsite electric power and water supply sources. Plant Managements were asked to conduct walk downs and inspect all important provisions required to withstand flood and fire events. The reports of these task forces were made available on the NPCIL website (www.npcil.nic.in).

In parallel, the Safety Review Committee for Operating Plants (SARCOP), an apex committee of Atomic Energy Regulatory Board (AERB) for safety review of operating NPPs met on March 15, 2011 and took stock of the Fukushima accident. SARCOP observed that the events at Fukushima have posed a new challenge to nuclear safety, wherein the safety of the NPPs in case of severe external conditions and multiple failures needs reassessment. SARCOP asked NPCIL to carry out a comprehensive reassessment of safety against external events and available emergency mitigation measures at all Indian NPPs. The Board of AERB met on March 23, 2011 to take stock of the safety of Indian NPPs in the light of Fukushima accident. AERB constituted a high level committee of specialists to review and recommend safety upgrades as required to handle extreme external events of natural origin. The Committee was chaired by a former Chairman of AERB and it had experts from AERB, BARC, NPCIL as well as other national agencies including academic institutions specialising in the areas of seismicity

/earthquake, tsunami, cyclones, river flooding etc. The committee reviewed safety aspects considering its broad terms of reference as follows

i. Capability of Indian Nuclear Power Plants to withstand earthquakes and other external events such as tsunamis, cyclones, floods, etc.

ii. Adequacy of provisions available to ensure safety in case of such events, both within and beyond design basis.

The report of the committee is available on the website of AERB (www.aerb.gov.in). All recommendations of the high level committee have been accepted by AERB. Necessary steps have already been taken by AERB to ensure implementation of the recommendations appropriately in a time bound manner at all NPPs.

The findings of both AERB and NPCIL committees reconfirmed inherent strengths in design, practices and safety regulation. The NPPs in India can withstand currently defined design basis external events with sufficient margins available for beyond design basis external events, and their consequential events such as sustained loss of electrical supplies (Station Blackout, SBO) and normal heat sink.

The design of Tarapur Atomic Power Station (TAPS 1&2), a twin unit Boiling Water Reactor (BWR) supplied by General Electric, USA, incorporates passive Emergency Condensers for decay heat removal. The water inventory available in the secondary side of the emergency condenser is adequate to remove decay heat from the reactor core for about eight hours. The Emergency Condenser can be put in service even in case of a SBO.

Pressurised Heavy Water Reactors (PHWR) form the backbone of the current Indian nuclear power programme. In this design, cooling of the reactor core during shut down state can also be achieved by natural convection flow of reactor coolant through steam generators. In case of an SBO, water can be added to the secondary side of steam generators using backup provisions such as diesel engine driven pumps. The efficacy of this design feature got amply demonstrated during turbine hall fire incident at Narora unit-1 in 1993 when reactor core cooling could be successfully maintained for over 17 hours of SBO.

The heat load from irradiated fuel in spent fuel storage pools is much less in Indian NPPs in comparison to the corresponding heat load in NPPs at Fukushima. Also the water inventory in these pools is much larger in comparison to spent fuel storage pools at Fukushima NPPs. Consequently, for Indian NPPs, submergence of the fuel in the pool water is assured for a considerable period of time, exceeding seven days without any credit for operator action.

AERB and NPCIL committees also concluded that ‘the submarine faults capable of generating tsunamis are located at very large distances of more than 800km from the Indian

NPPs located on the sea coasts unlike the case of Fukushima. Thus the possibility of simultaneous occurrence of an earthquake and a tsunami in Indian NPPs is almost non-existent. Further, NPPs in coastal areas are designed taking into account tsunami, storm surges, wave run up, floods, tides etc.

Post Fukushima, AERB carried out special regulatory inspections of all NPPs to assess their capabilities and preparedness to deal with the situations arising out of extreme natural events as well as the events of SBO and unavailability of water through the designed sources. The inspections have shown that NPPs in India are adequately equipped to handle such situations. Additional arrangements being made by NPPs will be effective in enhancing safety functions in such situations.

All NPPs in India undergo Periodic Safety Reviews (PSR) every 10 years. Safety assessments performed during PSR takes into account improvements in safety standards and operating practices, cumulative effects of plant ageing, modifications, feedback of operating experience, safety analysis and development in science and technology. Through this process strengths and shortcomings of the NPP against current standards are identified. During PSR, reassessment of site parameters and plant design is also carried out. PSRs along with extensive operational experience feedback and feedback from special safety assessments of Indian NPPs, conducted subsequent to accidents at TMI (USA), Chernobyl (Former USSR) and incident of Narora fire in India, led to substantial safety upgrades in Indian NPPs. Comprehensive safety assessment of TAPS units was also carried out after 30 years of their operation. Required safety upgrades were implemented during the refuelling outages of individual units and in a simultaneous long shutdown of both the units during November 2005 to January 2006.

The sites for NPPs are evaluated based on criteria laid down in the AERB's 'Code of Practice on Safety in Nuclear Power Plant Siting'. The criteria, among others include foundation conditions, seismicity, meteorological conditions, flooding, distance from airports/air corridors, industries handling toxic/ explosive substances, access by road/rail/sea and availability of land and cooling water etc. Even though the requirements for siting and design of NPPs with respect to postulated design basis natural events are sufficiently conservative, the magnitude of natural events can occasionally be higher than what is considered in design. Therefore, additional provisions are being made to further enhance the safety level of all NPPs. Seismic signal based automatic reactor trip is presently provided in Indian NPPs at Narora and Kakrapar. Automatic reactor trip on seismic signal is being implemented in all reactor units. Onsite AC power sources such as air cooled diesel generators are being provided to take care of extreme natural events. Augmentation of existing provisions like hook-up arrangements for addition of cooling water from external sources for decay heat removal for extended period, increasing battery life for monitoring important parameters, augmentation of water inventory and additional measures for protection of equipment as necessary are under implementation. AERB will undertake inspections to check the compliance/status of implementation of various safety measures and modifications recommended by various committees.

Notwithstanding all the design provisions and mitigating measures, severe accident management has been considered and the guidelines to handle severe accident are being implemented.

Successful demonstration of emergency preparedness and response plans is a mandatory requirement for grant of license for operation of NPPs. These plans ensure that sufficient means exist to cope with an emergency situation. Subsequent to Fukushima accident, National Disaster Management Authority (NDMA), NPCIL and AERB took up review of existing Emergency Preparedness and Response plans at all NPPs to ascertain and evaluate the response and coordination among different agencies during offsite nuclear emergency. NDMA organised mock exercises at all NPPs and identified areas for improvements. Consultations have also been held with the concerned state governments on emergency preparedness plans. A beyond design basis external event may disable the facilities available at the NPP site for monitoring and control of important reactor parameters. An emergency response facility with adequate radiation shielding and qualified for postulated earthquake and flooding is planned at each NPP site. The facility will also have provisions for communication with relevant agencies and for obtaining information from all units at the site; as also for food, resting etc. for essential personnel for a period of about one week.

AERB formulates safety requirements for nuclear and radiation facilities in the country and has issued safety codes for regulation, siting, design, operation and quality assurance. During the preparation of the regulatory documents, the safety requirements given in IAEA documents and the regulatory agencies of other countries are also considered. Reviews carried out subsequent to Fukushima accident confirmed that the requirements given in AERB regulatory documents are sufficiently conservative. However, AERB will appropriately incorporate the lessons learnt from Fukushima in its regulatory documents.

AERB has been exercising effective regulatory control and following robust and transparent procedures to enforce its mandate in the institutions under its jurisdiction. Government of India has been considering further strengthening of the legal framework for regulation of safety in nuclear facilities. As a consequence, Government has introduced ‘Nuclear Safety Regulatory Authority (NSRA) Bill 2011’ to strengthen India’s nuclear safety regulatory framework by conferring statutory status to the regulatory body. With the promulgation of the Nuclear Safety Regulatory Authority (NSRA) Bill 2011, NSRA will subsume the activities of AERB. The bill is under discussion in the Parliament of India.

The organisations responsible for nuclear power and its regulation have been keeping abreast of the safety developments internationally. NPCIL remains connected and aligned to the nuclear industry worldwide to ensure that the best industry standards are emulated. It has technical co-operation with World Association of Nuclear Operators (WANO), CANDU Owner's Group (COG) and World Nuclear Association (WNA). First round of WANO Peer Review of all NPPs in India has been completed. The second round of WANO Peer Review is also completed for most of the NPPs. Government of India has taken an initiative to invite IAEA Operational Safety Review Team (OSART) mission for review of Rajasthan Atomic Power Station 3&4. The preparatory meeting between IAEA-NPCIL and AERB was held in April 2012 and OSART mission is planned in November 2012.

AERB staff also participates in many activities of IAEA and Nuclear Energy Agency (NEA). Senior AERB officials participate in the meetings of the regulatory forums like CANDU Senior Regulators and VVER Regulators Forum. Recently, AERB has also become a full member of Multinational Design Evaluation Programme (MDEP). AERB has bilateral arrangements with Nuclear Safety Authority (ASN) France, Radiation Safety Authority, Russia and Nuclear Regulatory Commission of USA (USNRC) under which exchange visits and discussions take place in areas of mutual interest. Another agreement on technical cooperation between AERB and Institute for Radiation Protection and Nuclear Safety (IRSN), France has also been signed for collaboration in the area of nuclear reactor safety. AERB has been associated with a number of international research projects covering the assessment of NPP sites with respect to external hazards and structural capacity prediction under earthquake and accident loads. Considering the importance of international cooperation in learning lessons from Fukushima and further enhancing safety, India has been participating in many related activities of IAEA and NEA and had bilateral discussions with USNRC and ASN France. Preparation and planning for an IAEA- Integrated Regulatory Review Service (IRRS) for peer review of the regulatory system is also in progress.

The brief summary above demonstrates that Indian NPPs are not likely to be affected by the kind of natural disasters as were experienced at Fukushima. None the less actions have been taken for implementing additional hardware provisions, developing procedures for dealing with such accidents, strengthening emergency preparedness & response and revising regulatory requirements. While the international interactions give assurance that the measures taken by India on the lessons from Fukushima are in line with the international approach, the decision to invite international peer reviews co-ordinated by IAEA will lead to further confirmation of safety and improvements in Indian NPPs and their regulation.

INTRODUCTION

1. 0 Overview of Nuclear Power Programme in India

Presently, there are 20 NPP units in operation in India, with an installed capacity of 4780 MWe. Seven more units with a capacity of 5300 MWe are under construction / commissioning. In addition, a number of new NPPs are planned to significantly increase the nuclear power base from the current levels. The list of NPPs in operation and under construction is given in Table-1 and Table-2 respectively.

The first NPP in the country, TAPS units 1&2, based on boiling water reactors (BWR), supplied by General Electric, USA, became operational in the year 1969. 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 the 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 presented in the Indian National Reports submitted to the 4^{th} and 5^{th} Review Meetings of CNS.

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

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 reactors of this standardised design were built, two each at Narora in Uttar Pradesh (NAPS 1&2) and Kakrapar in Gujarat (KAPS 1&2). These plants became operational through the 1990s. Subsequently eight more units of standardised 220 MWe PHWRs were built, four each at Kaiga in Karnataka (KGS units 1-4) and Rawatbhata in Rajasthan (RAPS units 3-6). Over and above the basic standardised 220 MWe PHWR, this design has more compact site layout and incorporated further improvements in safety features and containment.

In 1990s, India undertook the design and development of 540 MWe PHWR. Two reactors based on this design became operational in 2005-2006 at Tarapur (TAPS units 3&4). Evolving on the 540 MWe PHWR design, India has now developed a 700 MWe design with limited boiling in the coolant channels. The construction of four such units is under progress, at the Kakrapar and Rawatbhata sites.

In addition, India has setup two VVER based NPPs (2X1000 MWe), at Kudankulam (KK-1&2) in Tamilnadu, with the co-operation of Russian Federation. The commissioning activities have been started in KK-1 and construction of KK-2 is almost complete. These are being built, with an objective of faster increase in the nuclear power capacity. These reactors incorporate many advanced safety features both passive and active.

Currently a 500 MWe Prototype Fast Breeder Reactor (PFBR) is under construction at Kalpakkam. The PFBR is being built with the design and technology developed at the Indira Gandhi Centre for Atomic Research (IGCAR) and is the forerunner of the future fast breeder power reactors.

2.0 Organisational Structure for Atomic Energy

The organization structure for Atomic Energy in India is described in detail in the Indian National report to the 5th Review Meeting of CNS. The structure in brief is given below:

Atomic Energy Commission (AEC)

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

Atomic Energy Regulatory Board (AERB)

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

Department of Atomic Energy (DAE)

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.

Nuclear Power Corporation of India Limited (NPCIL) is engaged in design, construction, commissioning, operation and decommissioning of water cooled NPPs. Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI) is for setting up fast reactor based nuclear power plants.

3.0 Special Safety Assessments following Fukushima (SSAFF)

Subsequent to the accident at Fukushima NPPs, Japan on 11th March 2011, the Hon'ble Prime Minister of India ordered a fresh review of safety of NPPs with respect to external events.

3.1 Reviews by the Utility

NPCIL, the utility, 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. NPCIL constituted different task forces to make an assessment of safety of following broad categories of Indian NPPs,

- Boiling Water Reactors (BWR) (TAPS 1&2)
- Pressurized Heavy Water Reactors (PHWRs) at RAPS 1&2
- PHWRs at MAPS 1&2
- Standard PHWRs from NAPS onwards

The reports of the Task Forces were summarised in a document titled "Safety Evaluation of Indian NPPs Post Fukushima Incident" to provide an integrated assessment of strength of Indian NPPs to withstand extreme external events. Further two more task forces were constituted for VVERs and 700 MWe PHWRs under construction.

3.2 Reviews by AERB

AERB constituted a high level committee (AERBSC-EE) with national level experts in the areas of (i) design, safety analysis and NPP operation, and (ii) external events in the field of seismology, hydrology and earthquake engineering, to carry out a comprehensive review of capability of NPPs to deal with external events within and beyond design basis. The committee constituted specialist working groups for detailed review in the following major areas:

- External events in relation to the safety of NPPs
- Safety of Electrical, Control and Instrumentation systems against external events
- Safety of NPPs under prolonged Station Black Out (SBO) and loss of Ultimate Heat Sink
- Safety of spent fuel storage facilities at NPPs against external events
- Severe Accident Management provisions and guidelines (SAMG)

AERBSC-EE submitted its report in August 2011. AERB has also taken cognisance of the self-assessment carried out by the utility and the site specific focussed regulatory inspections.

3.3 Site specific special regulatory inspections

Operating Plants Safety Division (OPSD) of AERB carried out special regulatory inspections of all NPPs to assess the plant capability and the preparedness to deal with the situations arising out of the natural disasters such as flood, tsunami, earthquake etc as well as the events of SBO and multiple failures. A special regulatory checklist was prepared for these inspections. These inspections have been completed at all the sites. The findings from these inspections were consolidated for assessment of existing safety strengths and adequacy of planned measures. The inspections have shown that in all NPP sites, the safety related structures, systems and components identified to meet the safety functions have been seismically qualified w.r.t current regulatory requirements for design basis levels. Inspections also identified the additional strengthening measures required. Future regulatory inspections will check the compliance/status of implementation of various safety measures, modifications suggested by various committees of AERB.

3.4 Approach to Special Safety Assessments following Fukushima (SSAFF)

Robustness of the design provisions for handling the postulated initiating events within the design basis is a regulatory requirement and AERB ensures their availability and operability through its existing mechanisms for safety reviews, licensing and inspection & enforcement during siting, construction, commissioning and operation. These mechanisms were described in detail in Indian National Reports submitted to the 4^{th} and 5^{th} Review Meetings of CNS. Periodic Safety Review (PSR) of NPPs is carried out in accordance with the guidelines given in AERB safety guide AERB/SG/O-12. Safety assessments performed during PSR takes into account improvements in safety standards and operating practices, cumulative effects of plant ageing, modifications, feedback of operating experience, 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 is subjected to regulatory review process for satisfactory resolution of the shortcomings. PSR along with extensive operational experience feedback programme in Indian NPPs and findings of the special safety assessments of Indian NPPs conducted subsequent to accidents at TMI (USA), Chernobyl (Russia) and an incident of fire at Narora-1 (India) led to substantial safety upgrades in older NPPs and design of NPPs built later.

Taking cognizance of all the above inputs i.e self-assessment by utility, report of AERB SC-EE and the findings of focussed regulatory inspections, AERB's apex committee for operational safety review and enforcement (Safety Review Committee for Operating Plants, SARCOP) has taken steps for review and follow-up of safety enhancement measures at NPPs.

The approach adopted for these safety enhancement measures following Fukushima is outlined below:

– Re-confirmation of capability to withstand currently defined site specific design / review basis levels of external events for individual plants. This included revisiting the results of earlier PSRs and review of need for further strengthening, as necessary.

– Assessment of margins available for beyond the design / review bases levels of external events. The objective of such assessment was to rule out existence of cliff edges close to the design basis /review basis levels and assess NPP's capability to perform minimum safety functions in such situation.

– Enhancing the capability of the plants to perform the safety functions under extended SBO / extended loss of heat sink through the design provisions. Towards this, plants were asked to carry out safety assessment for extended SBO beyond 24 hours and assess the need for increasing the capability of existing provision for continued heat removal. The measures being incorporated based on the above assessments include,

  - Alternate provisions for core cooling and cooling of reactor components including identification / creation of alternate water sources and providing hookup points to transfer water for long term core cooling,
  - Provision of portable DGs / power packs
  - Battery operated devices for plant status monitoring
  - Additional hook up points for making up water to spent fuel storage pools

– Review and strengthening of severe accident management particularly with respect to:

  - Hydrogen Management
  - Reliable provision for containment venting
  - Availability of key parameters for monitoring even under most extreme conditions

– Adequacy of SAM programme following an extreme external event, with the possibility of destruction of assisting facilities, both inside the plant and the surroundings; and affecting multiple units.

– Creation of an emergency facility at each NPP site which should remain functional under extreme events including radiological, with adequate provisions of communication and having capacity for housing essential personnel for a minimum period of one week.

4.0 Structure of the Report

The overall assessment of safety of Indian NPPs carried out by the utility and the regulatory body following Fukushima Nuclear accident and the actions taken/planned based on the lessons learnt are described in the report. The report is organised in the following six sections

i. External Events
ii. Design
iii. Severe Accident Management and Recovery (Onsite)
iv. National Organisations
v. Emergency Preparedness and Response and Post-Accident Management (Offsite)
vi. International Cooperation

Actions by utility, regulatory body, national research institutes and Government of India are described under the relevant topics.

The structure and the contents of the report are presented in line with the guidelines prepared by the General Committee of the fifth Review Meeting of the Convention. As some of the technical sessions during the second extraordinary meeting will be conducted in parallel, to the extent feasible, each section of the report has been made self-standing. Therefore some duplication of information in the report is intentional.

Table – 1

NPPs in Operation as of May 2012

Station / Unit	Type	Gross Capacity (MWe)	Operator & Owner	Reactor Supplier	Commencement of Operation
KGS-1	PHWR	220	NPCIL/NPCIL	NPCIL	Nov-2000
KGS-2	PHWR	220			Mar-2000
KGS-3	PHWR	220			May-2007
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/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			March 2010
TAPS-1	BWR	160		GE, USA	Oct-1969
TAPS-2	BWR	160			Oct-1969
TAPS-3	PHWR	540		NPCIL	Aug-2006
TAPS-4	PHWR	540			Sep-2005

** Unit under shutdown since 2004.*

Table – 2

NPPs under Construction as of May 2012

Station/ Project	Type	Gross Capacity (MWe)	Operator & Owner	Reactor Supplier	Start of Construction
KK-1	PWR	1000	NPCIL/NPCIL	ASE, RUSSIA	Mar-2002
KK-2	PWR	1000	NPCIL/NPCIL		Mar-2002
PFBR	PFBR	500	BHAVINI	BHAVINI	Oct-2004
KAPP 3&4	PHWR	700 each	NPCIL/NPCIL	NPCIL	22-Nov-10
RAPP 7&8	PHWR	700 each	NPCIL/NPCIL	NPCIL	18-Jul-11

TOPIC-1: EXTERNAL EVENTS

1.0 Overview

1.1 General Features of Indian sub-continent

1.1.1 Geography

The Indian sub-continent is characterised by great diversity in its physical features. In the North, North-East and North-West of the subcontinent lie the Himalayan ranges. The great plain of India is formed by the Indus-Ganga-Brahmaputra Rivers originating in the Himalayan ranges. Rising from the plains and extending south is the great Indian peninsular plateau. The country lies entirely in the northern hemisphere and is surrounded by the Bay of Bengal in the East, the Arabian Sea in the West, and Indian Ocean to the South. India has coastline of about half the length of its land frontier.

1.1.2 Weather conditions & River Systems

India has tropical weather. It has large regional variations in its climate with monsoon rains in common. Annual rainfall varies from over 2000 mm in the Himalayan and part of the western peninsula, to hardly any rainfall in and around the Thar Desert located in the North Western region. Seasonal wind pattern exists with calm periods as well as high winds. Tropical cyclones visit the coastal lands, the east coast being more prone compared to the west coast.

The river systems in India may be classified as the Himalayan, the Deccan (Southern), the coastal and the inland drainage basin. The Himalayan Rivers are generally snow-fed and flow throughout the year. During the monsoon months (June to September), the Himalayas receive very heavy rainfall and the rivers carry the maximum amount of water, causing floods. The Deccan Rivers are generally rain-fed and, therefore, fluctuate greatly in volume. The coastal rivers, especially on the west coast, are short and have limited catchment areas.

1.1.3 Seismicity

The country is divided into four seismic zones designated as zone-II, III, IV and V as per the national standard (IS 1893: 2002) with associated broad seismic activity in terms of Modified Mercalli Intensities of VI or less, VII, VIII and IX respectively. The information on zoning is used for initial screening of NPP sites and a detailed evaluation is carried out based on AERB guidelines for estimation of design basis ground motion parameters.

1.2 Siting and External Events of Natural Origin

The natural external events of relevance for setting up a nuclear installation in India are

- Earthquakes
- Geotechnical hazards (landslides, liquefaction, ground subsidence)
- Meteorological conditions (wind, temperature, etc.).
- Floods (storms/cyclones/tsunami / upstream dam break/local rainfall)
- Shoreline and river bank erosion
- Scenarios like downstream dam break, tsunami draw down, excessive marine growth, etc resulting in loss of ultimate heat sink

Basic siting criterion for nuclear installations is to ensure that the site-installation interaction does not introduce radiological or other risks of unacceptable magnitude. Siting process involves three stages – selection, evaluation and definition of design basis related to external events. Important considerations in site selection of NPP are topography, geology, seismology, meteorology, accessibility, infrastructure, availability of power supply, transmission lines, cooling water and construction facilities. A large region is investigated to select one or more candidate sites on the basis of safety and other considerations. Rejection criteria, in terms of Screening Distance Value (SDV) of site from potential sources of external events which could jeopardize safety and for which no practical protection measures are available, are applied at site selection stage to shortlist the candidate sites. This is followed by a detailed evaluation of the candidate sites. Three basic requirements that govern siting of nuclear installation are:

- Effects of external events on the installation.
- Effects of the installation on site environment and population.
- Factors affecting implementation of emergency measures in public domain.

Details of these requirements for NPP are specified in AERB/SC/S, “Code of Practice on Safety in Nuclear Power Plant Siting” and related “Safety Guides” published by AERB. Safety standards published by International Atomic Energy Agency (IAEA) are also considered.

Site characteristics and characteristics of natural environment in the site region which may affect safety of the nuclear installation are investigated and assessed rigorously at the site evaluation stage for a projected 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. Hazards associated with external events are characterized in terms of parameters that can be used as design basis for the installation. Effects of the combination of these hazards with ambient hydrological, hydrogeological and meteorological conditions as well as the relevant plant internal events is given due consideration while deriving their design basis values. If evaluation indicates that the overall risk cannot be kept acceptably low by means of design features of the installation, engineering of the site or administrative procedures, the site is deemed unsuitable.

1.2.1 Earthquakes

Hazards due to earthquake induced ground motion are assessed for the site considering site seismicity and seismotectonics of the region along with specific site conditions. Data from geological, geophysical, seismological and geotechnical investigations are collected and analyzed. If adequate data for the site region are not available, data from sites with similar seismotectonics and seismic wave propagation path characteristics are used. 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. Microseismic measurements of the site region are conducted for at least 3 years after the site is selected for the purpose of site evaluation.

1.2.2 Geotechnical hazards and foundation strata

Potentials for slope instability (land/rock slides), land erosion, collapse, subsidence or uplift of the site surface are assessed. In case such potentials exist and no practical engineering solutions are available to mitigate their effects, the site is deemed unsuitable.

Adequate 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. If such potential exists, the site is rejected.

1.2.3 Meteorological events

Meteorological and climatological characteristics of site region are investigated to derive design basis parameters for the meteorological variables such as wind, precipitation, temperature, storm surges. Potential missile hazard associated with tropical cyclones is also considered.

1.2.4 Flooding and loss of ultimate heat sink

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) to determine whether safety of the installation is affected. 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 the safety of the installation. Possibility of failure of downstream dam/barrage, temporary blockage of rivers, depletion of a reservoir and excessive marine organism vis-à-vis loss of heat sink functions for a NPP is scrutinized. Availability of alternate heat sink is also an important consideration.

1.2.5 Shoreline and river bank erosion

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.

1.2.6 Impact of NPP on site and emergency planning

Details of site characteristics affecting dispersion of radioactive materials are collected. Meteorological measurement is initiated and carried out at the site at least 3 years in advance of commissioning of the installation. Investigations and measurements of surface hydrology of the site region are carried out to determine dilution and dispersion characteristics of water bodies. Hydrogeological data for subsurface water movement are collected to assess potential impact of ground water contamination.

Population distribution data in the site region from the most recent census including their dietary habits, and use of land and water bodies are collected to assess potential effects of the nuclear installation and prepare plans for implementation of emergency measures under accident conditions. Ambient radioactivity of the atmosphere, hydrosphere, lithosphere and biota in the site region is assessed prior to commissioning so as to be able to determine the effects of the installation. The data also serve as a baseline in future investigations.

There is a mandatory requirement for an exclusion zone around the NPP which is under the exclusive control of the plant management wherein public habitation is prohibited. The current regulatory requirements call for establishing exclusion zone of minimum 1km around NPP. In the vicinity of the exclusion zone, activities that may impact safety of NPPs and neighbouring population including those that may cause large influx of population are regulated. Emergency planning zone around Indian NPPs extends up to a radius of 16 km.

1.2.7 Periodic safety review of external events

The estimates of design basis parameters of the plant corresponding to external events could change due to advancement of state of the art knowledge used for estimation of parameters, occurrence of natural events exceeding the scenarios considered, revision of regulatory requirements, etc. At the time of the 10 yearly Periodic Safety Review (PSR), the following elements are comprehensively reviewed to determine the continued acceptability of the 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, which may pose a hazard, and
– Local meteorological conditions.

Over the years, need was identified to re-visit the safety aspects related to external events like earthquake and flood due to upward revision of the design basis parameters used for design of TAPS 1&2, RAPS 1&2 and MAPS 1&2. Safety assessments of these NPPs were carried out and additional measures as found necessary were incorporated.

2.0 Activities Performed by the Operator and National Institutes

2.a Overview of actions taken/planned by NPP operator

Subsequent to the accident at Fukushima Nuclear Power Plant in Japan, NPCIL initiated safety assessment of Indian NPPs considering the preliminary lessons learnt from the accident. As part of the periodic safety review, the older generation NPPs had been evaluated with respect to latest site specific seismic design parameters and were strengthened based on the evaluation findings. The plant specific information generated from this activity is used as a ready input during estimation of seismic margins. Preliminary estimates made based on the insight gained from these activities indicate that for the plants constructed subsequent to 1990, a seismic margin of two to three times of design value is available. The exercise for detailed evaluation of margins is planned. Similarly, the R&D studies undertaken subsequent to the 2004 Indian Ocean tsunami have provided good insight into the tsunami phenomena around Indian coast and would be providing valuable inputs for evaluation of tsunami hazard at NPP sites. Readiness of the MAPS units in case of a tsunami got tested during the recent April 11, 2012 Sumatra earthquake and the subsequent tsunami warning.

2.a.1 Assessment of seismic margins

Assessment of seismic margins consists of two parts (i) defining the earthquake level and (ii) estimations of reserve strength margin available w.r.t this earthquake level. Work on seismic margin assessment is in progress. As a separate research exercise, national experts are also working on possibility of defining the level of a beyond design basis earthquake event.

2.a.2 Seismic re-evaluation of older generation nuclear power plants

In India 14 out of 20 operating Nuclear Power Plants (NPPs) (viz. NAPS-1&2, KAPS-1&2, KAIGA-1,2,3&4, RAPS-3,4,5&6 and TAPS-3&4) had been seismically qualified using state of the art techniques to define the seismic ground motion and then by conducting seismic analysis and testing as applicable.

The six older generation plants (viz. TAPS-1&2, RAPS-1&2 and MAPS-1&2) were seismically designed following the standards prevailing at the time of their construction but not with the rigour of the current design practice. These plants have been seismically re-evaluated in the years 2003, 2006 and 2008 respectively following the methodologies as per the IAEA Safety Series -28.The structures, systems and equipment, required for shut down of the plant, decay heat removal and containment of activity, were seismically re-evaluated. All the safety related civil structures qualified for earthquake resistance and corresponding to High Confidence of Low Probability of Failure (HCLPF) values were estimated. The mechanical, electrical, instrumentation & control equipment and Masonry walls which are not reinforced were qualified using the Generic Implementation Procedure (GIP) given in the document DOE/EH0545 titled "Seismic Evaluation Procedure for equipment in US DOE facility". The seismic walk downs revealed need for additional strengthening in some of the SSCs, which were retrofitted / replaced to increase their seismic resistance.

2.a.3 Current methodology for external flooding design basis

The grade level for NPP is decided based on the combinations of phenomena that can maximize flood water level at NPP. These are decided based on guidelines given in AERB safety guides AERB/SG/S-6A and AERB/SG/S-6B respectively for inland and coastal sites.

For inland sites the design basis flood level is based on following

(i) Dam failure caused by Safe Shutdown Earthquake (SSE) , coincident with peak of 25 years flood.

(ii) Dam failure caused by Operating Basis Earthquake (OBE) coincident with peak of flood caused by one-half Probable Maximum Precipitation (PMP), which corresponds to a rainfall of 1000 years.

(iii) Inadvertent opening of all gates on an upstream dam coincident with peak of flood caused by one half PMP.

(iv) Probable Maximum Flood (PMF) due to PMP.

(v) Inadvertent opening of all low-level outlets in an upstream dam coincident with peak of flood caused by one-half PMP.

Case (i) and (ii) are to be considered if the upstream dam cannot be qualified to the same level of seismicity for which the NPP is designed.

The PMF for site is determined based on probabilistic or deterministic approach. The probabilistic approach involves determining the flood having mean recurrence interval of 1000 years. The deterministic approach involves identifying the maximum storm which has occurred in the vicinity of the site. This storm is suitably modified so as to give the maximum run off at the site.

For coastal sites the estimation of maximum water level is based on summation of astronomical high tide and wave height due either to storm or tsunami and their respective wave run-up.

The grade level of the site is decided based on maximum water level due to above conditions. If site cannot be graded to this level, suitable engineering measures are designed so that the water level does not jeopardise the safety of NPP.

2.a.4 Wind effects on structures

The wind speed considered for design corresponds to a return period of 1000 years. The velocities are further modified to take into account the height and class of structures and wind loads are calculated accordingly.

2.a.5 Temperature effects on structures

The ambient temperature effects for thermal loads on civil structures are based on the extreme temperature of 100 year return period. Solar radiation effects have also been considered.

2.a.6 R & D Activities related to Tsunami

The tsunami generated on December 26, 2004 due to Sumatra earthquake of magnitude 9.3 resulted in inundation of various coastal regions of India. In view of this, a need was felt for detailed evaluation of the present and future coastal nuclear sites for arriving at the flood hazard due to design / extreme event tsunami. Specific requirements for the evaluation of the coastal nuclear sites were identified and a National Round Robin Analysis was coordinated for this assessment. Round robin analysis included code benchmarking and analysis procedure evaluation. Kalpakkam site was chosen as the first site for the study. Participants from research, academic and technical organizations carried out detailed computation of inundation reach and wave run up for Kalpakkam site, which were shown to have reasonable comparison with the post tsunami measurements carried out after the Sumatra-2004 tsunami event. The results of this study have been further utilized for tsunami hazard evaluation of coastal nuclear plants in India. It was found that the Indian R& D programme is equipped to predict the impact of extreme external events with reasonable assurance.

The tsunami generated due to Sumatra earthquake is well studied and reported, however, the Makran event, which may affect western coast of India, has uncertainties due to lack of historical data. For the Makran event, Tarapur site has been chosen for detailed inundation and run-up study as a second problem. The results of the evaluation were presented to a panel of experts and discussed in a special workshop for extreme tsunami events with focus on

Fukushima tsunami during SMiRT-21 conference. In addition, for exchange of the insights gained from external flooding incidents for flood hazard assessment among member states, two IAEA workshops were organized in 2005 and 2010 at Kalpakkam.

2.a.7 Sumatra earthquake of April 11, 2012 and Tsunami Warning

During the recent Sumatra earthquake event of April 11, 2012, Indian National Centre for Ocean Information Services (INCOIS) issued its first bulletin within eight minutes ie.1416 hours IST. This earthquake with magnitude 8.5 had the capability to generate a tsunami.

The information regarding earthquake and Tsunami alert was received in MAPS Control Room immediately. In response to this, precautionary measures as per the operating procedures were initiated and readiness of all systems to handle probable Tsunami was ensured. Senior plant management personnel assembled in Control Room in a short period of time to provide assistance to Control Room staff.

Some of the measures initiated were as follows:-

- Standby DG (at higher elevation) was started and kept operating.
- All diesel operated fire water pumps were tested and ensured to be in poised state.
- Mobile fire water pumps were tested and ensured available along with fire tenders which were kept full.
- On-site water storage capacities were ensured available.
- Walk-down was conducted in plant and doors/shutters and other openings which could cause water ingress in plant areas were ensured closed and sealed.
- Preparations were made to shutdown the plants in case of requirement.
- Continuous communication was maintained between Control Room, State Authorities and Tsunami monitoring agencies to assess the situation.

In addition to the above, the Technical Support Centre at NPCIL Headquarter was also activated to monitor the situation and advise station. All senior management personnel at NPCIL Headquarters assembled at Technical Support Centre and provided necessary support to the station.

During the earthquake, all the systems for the identification of location of earthquake, estimation of tsunami arrival time and height, dissemination of messages through various means, as well as bottom pressure recorders and tidal gauges to record sea level changes managed under the National Warning System have performed as envisaged.

2.b. Schedules and milestones to complete the operator's activities

2.b.1 Assessment of seismic margins

As part of Periodic Safety Review, seismic re-evaluation was carried out for older NPPs (TAPS 1&2, RAPS 1&2 and MAPS 1&2). Analysis results show that margins are available over and above the design basis. All important SSCs related to shutdown, decay heat removal and containment functions were included in the revaluations.

For all NPPs from NAPS onwards, preliminary assessment carried out indicates that SSCs required for accomplishing safety functions, are capable of withstanding earthquake with margins of the order of two to three times above SSE (return period of 10000 years).

2.b.2 Assessment of beyond design basis flood and other meteorological hazards

At all NPPs, grade level is kept sufficiently above the design basis flood level. Post Fukushima, re assessment of elevations of important equipment and systems was carried out to assess their operability and to identify the cliff edge effect if any, above design basis flood level. Equipment vulnerable to flood are made flood proof with leak tight doors and protection bunds. The recent estimates at one of the costal site suggest that the postulated flood level may undergo upward revision. Considering this, diesel generator, fire water pumps, diesel driven feed pumps and external water injection points have been located above the re-evaluated flood level. All other stations have sufficient margins above DBFL and external water injection schemes are located well above the DBFL.

Interim guidelines regarding meteorological hazards have been proposed as part of AERBSC-EE committee report and these will be addressed adequately.

2.b.3 Assessment of tsunami hazards

The submarine faults capable of generating tsunamis are located at very large distances of more than 800 km from the Indian coast. Thus, unlike in the Fukushima case, the possibility of simultaneous occurrence of an earthquake and a tsunami at Indian coastal NPPs, is almost non-existent. The lead time available between earthquake and flooding can be utilized to bring operating units to safe shutdown states. In all coastal NPPs, tsunami early warning system is made operational.

Post 2004 Indian Ocean Tsunami, Tsunami hazard assessment with mathematical tools complimented by local bathymetry data was carried out. Analysis was completed for all coastal stations. Analytical computer codes used are validated against 2004 Tsunami observed water levels and through benchmarking. NPCIL also participated in national level round robin exercise to validate the computer code against 2004 Tsunami.

For costal sites located in the west coast, Tsunami analysis shows that magnitude of tsunami height is well below the present DBFL after considering the extreme earth quake. For costal sites located on the east coast, at one site, estimated levels are higher than the present DBFL and corrective actions already taken up as mentioned in the previous section.

2.c Results of utilities activities / further actions

Margins available for individual plants based on the preliminary analysis are made available in the NPCIL report available on the website of NPCIL. Detailed analysis for seismic margin assessment is planned.

3.0 Activities Performed by the Regulatory Body

Subsequent to the accident at Fukushima Nuclear Power Plant in Japan, Chairman AERB, constituted a High Level Committee (AERBSC-EE). The committee also had members from national institutions having expertise in the field of seismology, hydrology and earthquake engineering. A set of specialist working groups were formed by AERB-SC-EE for detailed review of plant specific designs with respect to functioning of safety systems and components and requirement for further enhancement of safety provisions in the case of external events, including combination of related events of maximum postulated intensity. The recommendations made by AERBSC-EE were sent to utility to submit plans and proposals for implementation of the recommendations.

To take into account the aspects such as advancement of state of the art, lessons learnt from related events across the globe, change in regulatory approaches followed by international bodies, etc., regulatory body carries out revision of its regulatory guidelines. The regulatory guidelines of AERB are being revisited considering the lessons learnt from Fukushima accident.

3.a Overview of Actions taken/planned by Regulatory Body

The AERB-SC-EE examined the current methodologies for estimation of design basis external events and design approaches followed for NPPs. Possible interim measures for evaluating extreme natural events beyond design basis and guidelines for arriving at the site specific estimates for safety margin assessment were also examined considering physical bounds of the underlying parameters as currently understood and the inherent uncertainties. Important observations and recommendations of the committee and regulatory actions are as follows:

3.a.1 Regulatory Review Findings

3.a.1.1 Earthquake

i. Design basis for Safe Shutdown Earthquake (SSE)

Assessment of seismicity and related hazards constitute a major part of the siting criteria for NPPs. A NPP is not located in seismic zone V, which is the zone of high seismicity in India as per the seismic design code published by the Bureau of Indian Standards (IS:1893-2002). Sites prone to ground failure phenomena during seismic events are also rejected. If there is an evidence of a seismic capable fault within 5 km of a site, the site is deemed unacceptable.

Conservatively formulated regulatory norms exist for seismic design to ensure that safety related SSCs of a NPP are capable of withstanding, with margins, the effects of vibratory ground motion arising from the strongest earthquake derived from site specific studies.

For estimation of ground motion corresponding to safe shutdown earthquake (SSE) level, the probable maximum earthquake potential of each seismogenic source (fault) is estimated. This also takes into account the maximized value of historical/recorded seismicity attributable to the fault. The source point of this maximized earthquake on the fault is brought nearest to the site and for this magnitude and distance combination, earthquake acceleration is determined. The exercise is repeated for all faults surrounding the site and the maximum of accelerations thus derived is adopted as design basis SSE level acceleration. The spectral shape is derived conservatively considering an ensemble of past earthquake records on geo-seismically similar regions and local site soil/rock conditions. Detailed guidelines for derivation of design basis ground motion are given in AERB guide AERB/SG/S-11 (1990).

The current method of estimating ground motion corresponding to SSE is found to be sufficiently conservative. However, certain limitations because of lack of sufficient and relevant earthquake data and other uncertainties regarding site tectonics were recognized. These aspects will be addressed while revising the AERB guide on seismicity.

ii. Beyond design basis earthquake event

The recent occurrence of earthquake events like Niigataken Chuetsu-oki Earthquake in 2007 and the Great East Japan Earthquake in 2011 have indicated the possibility of NPPs being subjected to ground motions beyond their design values. In recent times peninsular India also experienced earthquakes larger than the regional estimates of the maximum magnitude e.g. Latur earthquake of 1994 and Koyna earthquake of 1967. One suitable approach to evaluate the capability of the NPP to withstand ground motion beyond the design values is the estimation of seismic margins utilising as-built information. Work has been initiated in this regard.

Estimation of earthquake vibratory ground motion strongly depends on site data and the associated uncertainties. Since most of the NPPs are sited in stable continental region of India with sparse seismicity compared to Himalayan region, defining an extreme beyond design basis earthquake event for the purpose of siting and design of NPPs is a challenging task. As a separate R&D exercise, national experts are also working to define the possible level of beyond design basis earthquake event by exploring the possibilities such as postulating level of expected extreme acceleration/intensity of shaking at site, guided by the regional seismicity and local soil/rock site conditions, irrespective of earthquake source location, and scaling up earthquake hazard evaluated for SSE to a possible extreme value considering regional seismicity and past earthquake data.

3.a.1.2 Flood

i. Design basis flood

The current regulation allows use of probabilistic or deterministic approach for arriving at the design basis flood level (DBFL) for NPP sites. While following probabilistic approach, 1000 years mean recurrence interval of the causative parameter is considered. While following deterministic approach, the biggest historical storm in the region is transported to the site area and is oriented in such a way that it maximizes the flood in the river or storm surge in the sea. The DBFL estimation is generally carried out by specialised governmental agencies.

For inland sites, flooding could occur on account of overflowing of an adjoining river/lake, upstream dam break or intense precipitation in the surrounding region. Guidelines for evaluation of probable maximum precipitation and flooding due to probable maximum flood or failure of water control structures are covered in AERB/SG/S-6A. The assessment also takes into account possible combination of events such as associated flood along with seismically induced dam break, flood with concurrent accidental opening of gates, etc. If the site is on the bank of an inland water body such as a reservoir or lake, the effect of seiches is also considered. In addition, adequacy of site surface drainage to cater to intense precipitation has to be verified.

For a coastal site, the flooding hazards include those caused by cyclonic storms, tsunamis and local intense precipitation. Guidelines for evaluation of flooding due to cyclonic storms in coastal sites are covered in AERB/SG/S-6B. Values of the maximum tide, storm surge and wave run-up are added to arrive at the most conservative estimate of flood level above a defined reference level, generally mean sea level.

Tsunami heights are specified in AERB/SG/S-11 (1990) based on the historical data. These tsunami heights are superimposed on the maximum astronomical tide and are then added to the wave run-up to arrive at the DBFL. With the experience of the 2004 Indian Ocean tsunami, AERB stipulates a more rigorous treatment of tsunami potential for coastal NPP locations based on the maximum potential tsunami genic sources around the Indian coast. The submarine faults capable of generating tsunamis are located at very large distances of more than

800km from the Indian NPPs located on the sea coast. Thus the possibility of simultaneous occurrence of an earthquake and a tsunami in Indian NPPs is almost non-existent.

Design basis external flood had been derived for recent NPP sites considering the requirements specified in the AERB safety guides stated above. Adequacy of flood protection aspects of older plants form part of periodic safety reviews (PSR).

The existing guidelines and procedures for estimation of DBFL are found to be appropriate except that for tsunami heights. Utility is asked to carryout detailed site specific analyses using a validated numerical model to arrive at refined estimates of tsunami run-ups under all possible combinations and variations of source parameters. The evaluation will include refined near-shore data. For a multi-facility site, plant specific modifications like protection walls may cause modification of impact of phenomenon on the neighbouring areas. The utility was also asked to conduct analysis that ascertains the impact on all facilities before implementing any protection measures. In some locations, shore line bathymetry may be such that it causes amplifications in wave amplitudes. The existing postulates of tsunami heights may need revision based on the outcome of R&D activities brought out in 2.a.6.

ii. Beyond design basis flood

Interim guidelines for quantification of beyond design basis flood level for safety margin assessment of NPPs are as follows:

- In case of flooding caused due to dam break, a conservative upper bound analysis (in terms of postulated size, and time for development of break) is suggested for beyond design basis event of dam break along with a rainfall/flood of 100 year return period.

- The volume/flow considered for design basis flood conditions in Inland sites suggested to be increased by 15% to arrive at a first order estimate of flood levels for inland sites as well as for carrying out the capacity assessment of site drainage corresponding to beyond design basis flood event.

- Considering available data for past storms, it is recommended that a pressure drop of 100 millibar, associated wind speed of 300 kmph for east coast and 240 kmph for west coast and a radius of 50 km would be taken as an upper bound value for the postulated beyond design basis cyclonic storm. The translational speed of storm is suggested as 40 kmph. The total height of the wave shall be summation of (i) maximum tide height, (ii) storm surge height, (iii) wave set up and (iv) wind induced wave run-up.

– For assessment of extreme tsunami event, all physically possible combinations and variations of tsunamigenic source parameters and accurate near shore data including the effect of built environment around the site, were suggested.

It was asked to use a validated model considering all possible combinations of causative phenomena in the detailed site specific analyses to estimate flood water levels. While assessing inland sites, a scenario involving combination of earthquake and flood due to dam break were suggested.

3.a.1.3 Other Meteorological Hazards

For the purpose of design of NPPs, wind and temperature constitute major meteorological parameters that can have an impact on design.

i. Design basis wind

Majority of structures in an NPP have lateral dimensions comparable to their heights and lateral forces due to earthquake generally govern the design. However, in slender structures like stack, wind could govern. NPP structures are designed for severe wind corresponding to a return period of 1000 years. The extreme wind corresponding to a return period of 10000 years is used to assess whether wind induced missiles could be generated at an NPP site and if so their effects on items important to safety are evaluated. Wind velocities are calculated following probabilistic approaches with site specific data and/or following code of practice for wind loads published by Bureau of Indian standards (IS:875 (part-3)-1987).

The current guidelines and procedures for estimation of design basis wind speed are considered adequate.

ii. Beyond design basis wind and temperature

The specialist working group of AERBSC-EE recommended interim guidelines to define a beyond design basis wind speed considering past data on extreme wind, which corresponds to 1000 year return period wind increased by 50% and rounded off to the nearest 10m/s speed. Procedure for obtaining site specific values on these parameters are given in IS:875, which will be used for further assessment of safety margins.

For safety evaluation w.r.t beyond design basis temperature, mean plus two standard deviations for higher values and mean minus two standard deviations for lower values corresponding to 1000 year mean return period, may be considered.

3.a.2 Actions taken/planned by Regulatory Body

3.a.2.1 Revision of AERB Code on Siting of Nuclear Power Plants

AERB had published a code on siting of nuclear power plants in 1990. Revision of this code was on anvil at the time of occurrence of the Fukushima accident. AERB decided to incorporate the lessons learned from Fukushima into this code. Some of the important provisions in light of the Fukushima accidents include emergency preparedness program accounting for common cause accidents and possible site isolation, need for additional margins and assessment of cliff edge effects in respect of meteorological and hydrological events, uncertainty analysis in hazard evaluation due to external events, periodic safety review of site characteristics and emergency measures at operating NPP sites, continuous monitoring and periodic safety review considering foreseeable evolution of natural and human induced events, re-visit of return periods of some natural events viz. earthquake and flooding, etc.

3.a.2.2 Revision of AERB guide on seismic studies

Revision of the AERB guide on ‘Seismic Studies and Design Basis Ground Motion for Nuclear Power Plant Sites’ is contemplated in line with the recommendations of the AERBSC-EE. Development of guidelines for consideration of extreme natural events and their consequential effects including design provisions for enhanced safety margins beyond design basis is also contemplated.

3.a.2.3 Actions taken in NPPs under construction and operation

Special regulatory inspections were conducted for all operating stations with respect to their capability to cope with the situations arising out of the natural disasters such as flood, tsunami, earthquake etc as well as the events of SBO and multiple failures. Plant specific weak links, if any, have been identified for design improvement or retrofitting.

Utility was asked to submit plans and proposals for implementation of the recommendations of the AERB committee report. Proposals for immediate improvement at the older plants (TAPS-1&2 & MAPS-1&2) have been received and these are being deliberated with respect to their adequacy and suitability for implementation.

AERB also issued directives to all plants under construction and/or at various stages of review to demonstrate how safety of these plants is ensured under the extreme external events scenario. The utilities responses are being reviewed in the project safety review committees of AERB.

In case of two ongoing projects (RAPP-7&8 and KAPP-3&4) utility has submitted early estimates of seismic margins available in safety related civil structures beyond SSE. Preliminary estimate for civil structures indicates that a minimum margin of 2.0 exists, over the design basis ground motion for SSE. AERB asked utility to carry out a detailed study considering ductile detailing for seismic resistance and the supporting capability of the structures to maintain functionality of the equipment.

3.b Schedules and milestones for regulatory body's activities

The work on revision of AERB Safety Code on Siting of Nuclear Power Plants is already in progress and expected to be completed by 2013 and the expected time for revision of AERB guide on seismic studies and design basis ground motion for NPP sites is about three years.

The review of the submissions by the utility related to external events and available margins is ongoing in a progressive manner.

3.c Conclusions of the regulatory body regarding operators activities.

The regulatory body is undertaking the review of the submissions made by the utility.

4.0 Summary Table

S.No	Activity	Activities by the Operator (Item 2.a) Activity - Taken? - Ongoing? - Planned?	(Item 2.b) Schedule Or Milestones for Planned Activities	(Item 2.c) Results Available - Yes? - No?	Activities by the Regulator (Item 3.a) Activity - Taken? - Ongoing? - Planned?	(Item 3.b) Schedule Or Milestones for Planned Activities	(Item 3.c) Conclusion Available - Yes? - No?
TOPIC 1 – EXTERNAL EVENTS							
1.	Special regulatory Inspections				Taken	March 2012	Yes
2.	Review of Safety of Indian NPPs against external events of natural origin and recommend action plan	Taken	2011	Yes	Taken	2011	Yes
3.	Seismic re-evaluation of older NPPs (TAPS-1&2, RAPS-1&2 and MAPS-1&2) based on updated design basis	Taken	2003 TAPS-1&2 2006 RAPS-1&2 2008 MAPS-1&2	Yes	Taken	Completed	Yes
4.	Evaluation of site safety against	Ongoing	2014	No	Planned	2015	No

S.No	Activity	Activities by the Operator			Activities by the Regulator		
		(Item 2.a) Activity - Taken? - Ongoing? - Planned?	(Item 2.b) Schedule Or Milestones for Planned Activities	(Item 2.c) Results Available - Yes? - No?	(Item 3.a) Activity - Taken? - Ongoing? - Planned?	(Item 3.b) Schedule Or Milestones for Planned Activities	(Item 3.c) Conclusion Available - Yes? - No?
	Beyond design basis floods and wind						
5.	R&D activities for Indian NPPs for tsunami events and to define the possible level of beyond design basis earthquake	Ongoing	2013	------	Ongoing	Mid 2014	------
6.	Evaluation of seismic margins.	Planned	2015	No	Planned	2015	No
7.	Revision of AERB safety code on siting of NPPs.	-----	------	-----	Ongoing	2013	-------
8.	Revision of AERB safety guide 'seismic studies and design basis ground motion for NPPs'.	------	------	------	Planned	2015	-------

TOPIC-2: DESIGN

1.0 Overview of post Fukushima design review performed for Indian NPPs

The first NPP in the country, TAPS units 1&2, based on boiling water reactors (BWR), supplied by General Electric, USA, became operational in the year 1969. Thereafter the mainstay of India's nuclear power programme has been the PHWR. 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 Tamilnadu, with indigenous efforts. Of these four units, presently RAPS unit-2 and MAPS units 1&2 are operational and have undergone extensive safety upgrades during en-masse coolant channel replacement and/or en-masse feeder replacement.

Subsequently, India developed a standardised design of 220 MWe PHWRs. This 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 pool. In 1990s, India undertook the design and development of 540 MWe PHWR. Two reactors based on this design became operational in 2005-2006 at Tarapur (TAPS units 3&4). India has now developed a 700 MWe design with limited boiling in the coolant channels. The construction of four such units is under progress at the Kakrapar and Rawatbhata sites.

In addition, India has setup two VVER based NPPs (2X1000 MWe), at Kudankulam (KK-1&2) in Tamilnadu, with the co-operation of Russian Federation.

Subsequent to the accident at Fukushima NPPs, the Government immediately ordered review of capability of Indian NPPs to withstand severe natural events. AERB setup a high level committee for comprehensive review of capability of NPPs to deal with external events within and beyond design basis. Utility was asked to undertake self-assessment of safety against prolonged SBO and loss of heat sink due to external hazards. The safety review and assessment methods adopted by AERB and NPCIL complement each other to constitute the Special Safety Assessment Following Fukushima (SSAFF) approach which has been successful in addressing the safety challenges posed by Fukushima.

AERB's apex committee for operational safety review (Safety Review Committee for Operating Plants, SARCOP) has taken cognizance of the report of AERBSC-EE and its specialist working groups, NPCIL's action plans and the findings of focused inspections, and is taking steps for further assessments and follow up of implementation of the recommended safety enhancements at the NPPs.

1.1 Design of Indian PHWR

PHWRs form the back bone of the current nuclear power programme in India. The Indian standard PHWRs incorporate certain design features which give them strengths in prevention and mitigation of accidents. These reactors are provided with two diverse fast acting shut down systems and double containment with passive suppression pool to limit containment pressure. The reactor core is surrounded by large volume of moderator heavy water in Calandria. Further the Calandria is surrounded by a water filled vault. These additional water inventories add to the capability of decay heal removal in accident situations.

Indian PHWRs have certain advantages in respect of shutting down the reactor and maintaining long term guaranteed shutdown state. The shutoff rods, which are part of primary shutdown system, are inserted into the low pressure moderator system. Also the passive and diverse fast acting secondary shutdown system acts by way of liquid poison injection into the moderator region. In addition, to achieve long term sub-criticality, there is also a provision for addition of liquid poison directly into the moderator.

With respect to core cooling capability under SBO, the Indian PHWRs have some distinct advantages. Decay heat removal in these reactors can be sustained by natural convection flow of the reactor coolant through Steam Generators (SGs) as they are located at much higher elevation with respect to reactor core. Heat from the SGs is removed by boiling of water in the secondary side of SG and the steam so produced is discharged to the atmosphere. The design of the steam discharge system incorporates provision of 10% atmospheric discharge valves that are designed to be fail safe to open. It is possible to cool down these reactor system / SGs at a faster rate (crash cool down), without any adverse implications from the point of view of core reactivity and structural integrity. This provides an added advantage in providing make up water to SGs at low pressure and continued removal of decay heat. Design provisions already exist for injecting water to the SGs by diesel engine driven fire water pumps, without any need for electric power. The water inventory available at site for this purpose, without any replenishment, is generally sufficient to achieve cooling for more than a week.

The standard Indian PHWRs have double containment with large volume and have passive pressure suppression facility. Containment systems are not shared among reactors at the same site. Also provisions for filtered venting are provided to avoid re-pressurisation of containment following a design basis accident.

The Spent Fuel Storage Bay (SFSB) is located in a separate building outside reactor building, at elevations below ground, and is seismically qualified. The pools are designed to store spent fuel for 10 years of reactor operation and one full core fuel discharge from the reactor. The heat load from irradiated fuel from PHWRs is less owing to lower burn up. Also there is no risk of any re-criticality, due to use of natural uranium fuel. Submergence of the fuel in the pool water is assured for a time period of at least one week under SBO conditions, even with the most conservative assumptions on the quantum of decay heat from the stored fuel and without taking any credit for operator action.

1.2 Design of BWRs at Tarapur (TAPS 1&2)

TAPS -1 & 2 reactors are twin unit first generation BWRs supplied by GE, US. The reactors started commercial operation in the year 1969. The rated power initially was 210 MWe. This was de-rated to 160 MWe in the year 1984, when the secondary steam generators had to be taken out of service, due to frequent tube leaks.

The design of TAPS 1&2 provides passive emergency condenser (EC) for decay heat removal. The water inventory available on the secondary side of the EC is adequate to provide decay heat removal from the reactor core for 8 hours. The EC can be put in service even in case of a station black out. The plant configuration allows the EC to be taken in service even in situations, where no power supply (including station DC batteries) is available.

The containment of TAPS 1&2 consists of drywells, suppression pools and a large volume pressure relief chamber (common chamber). As compared to typical Mark-I BWR containments, this design provides a much higher free space and volume to power ratio (around 10 times). This provides ability to accommodate larger amount of non-condensable gases and as a result, the pressure increase inside the TAPS containment is expected to be lower, consequently reducing the leakages.

A comprehensive safety review was conducted for TAPS-1&2 in the year 2005, which included review of Station operating performance, safety analysis, ageing assessment & management, structural integrity and seismic re-evaluation; against current safety standards and practices. Based on this review the plant underwent significant upgrades, which included augmentation of emergency power supply systems, relocation of essential electrical equipment (EDGs, station batteries) to a higher elevation, segregation of power and control cables for safety related systems, addition of supplementary control room, augmentation of emergency feed water supply to the reactors, unit wise segregation of important shared systems, up-gradation of fire protection systems, etc., for enhancing the safety levels. Based on seismic re-evaluation, seismic upgrades were also carried out. The details of the safety assessments and upgrades were presented in the Indian National reports submitted to the 4th and 5th Review Meetings of CNS.

1.3 Safety enhancements in the past

Robustness of the design provisions for handling the postulated initiating events within the design basis is a regulatory requirement and AERB monitors their availability and operability through existing licensing and inspection mechanisms. Renewal of operating licenses is based on Periodic Safety Reviews (PSR). Review during PSR involves comparison with the current safety requirements / practices. Ageing of important structures, systems and components and its management also form an important part of the reviews during PSR. Such reviews along with extensive operational experience feedback and feedback from special safety assessments of Indian NPPs (conducted subsequent to accidents at TMI (USA), Chernobyl (Former USSR) and incident of Narora fire in India, lead to substantial safety up-gradations in the past in Indian NPPs. In this context it may be noted that two more events viz Flooding at KAPS and the tsunami at MAPS in 2004, lead to thorough review of safety of Indian NPPs with respect to external hazards. Significant safety enhancements implemented in the three older NPPs namely RAPS-2, MAPS 1&2 and TAPS 1&2 are given below,

RAPS-2

- Installation of two additional SBO diesel generators (air-cooled) at higher elevation above review basis flood level.
- Provision for connection of fire tenders for additional back up for core cooling.
- Provision for make-up to dousing tank using fire tenders to enable continued water injection to SGs.
- Additional air accumulators for supplying instrument air to essential loads in RB
- Identification of water sources in case of downstream side dam break
- Segregation of power and control cables for safety related loads
- Up-grades in fire protection systems
- Addition of supplementary control room
- Seismic re-evaluation and upgrades

MAPS 1&2

- Installing additional diesel generator at 2 m above grade level.
- Re-location of UPS system to higher elevation
- Diesel driven air compressor at higher level
- Dedicated pump for transfer of deaerator water to SGs (Emergency Boiler Feed Pumps)
- Two diesel driven fire pumps located at 2.m above grade level.
- Construction of Tsunami protection wall
- Installation of Tsunami warning system
- Additional air accumulators for supplying instrument air to essential loads in RB
- Segregation of power and control cables for safety related loads
- Up-gradation of fire protection systems
- Addition of Supplementary Control Room

– Seismic re-evaluation and upgrades

Majority of these safety improvements were implemented in the PHWR units at RAPS 2 and MAPS 1&2, during the long shutdowns of these units for en-masse coolant channel replacement.

Major improvements implemented at TAPS 1&2 were:

- Addition of 3 X 100 % seismically qualified, physically separated DGs located at higher elevation, in place of the original 3 X 50 % capacity DGs
- Additional SBO Diesel Generator
- Additional battery banks at higher elevation
- Introduction of additional unit start-up transformer
- Additional reliable level monitoring for the RPV, covering the entire core region.
- Unit wise segregation of residual heat removal systems.
- Incorporation of a dedicated fuel pool cooling system.
- Augmentation of Emergency feed to reactor coolant system.
- Unit wise segregation of Emergency Power supply for safety systems
- Physical separation of cables for redundant trains of safety systems
- Seismic re-evaluation w.r.t latest revised ground spectra of TAPS site and subsequent strengthening

Majority of these safety improvements were implemented in TAPS 1&2 during the long shutdown of these units in 2005-06 specifically for this purpose following the comprehensive safety assessment.

2.0 Activities performed by the Utilities

Subsequent to the accident at Fukushima Nuclear Power Plant in Japan on March 11, 2011, NPCIL had initiated an immediate safety assessment of Indian NPPs as early as 15th March 2011. The main focus was to review the design features of Indian reactors to ensure core cooling in extreme circumstances caused by external events, as happened during the Fukushima accident. For this purpose, NPCIL constituted four separate taskforces, taking into account the differences in design of various operating NPPs, which broadly fall in four categories.

- Boiling Water Reactors (BWR) (TAPS 1&2)
- Pressurized Heavy Water Reactors (PHWRs) at RAPS 1&2
- PHWRs at MAPS 1&2
- Standard PHWRs From NAPS onwards

Taskforces were also formed for plants under construction.

The Safety Review Committee for Operating Plants (SARCOP), the apex committee of AERB for operational safety review and enforcement directed the NPPs to undertake self-assessment of safety against prolonged SBO and loss of heat sink due to external hazards. These immediate reviews by NPCIL considered the safety of NPPs under complete loss of electric power together with complete unavailability of water from designated water resources through the designed route and to recommend, if necessary, measures for survivability of safety functions under such conditions.

The utility made a quick check of the strengths and adequacy of design pathways in view of the Fukushima accident and also made a check on the availability of water supply pathways, under severe external events beyond design basis. The review findings are described in the subsequent sections.

2.a Overview of actions taken/planned by the NPP operator

Indian PHWR is the standardized, indigenously designed, developed and implemented progressively at NAPS1&2, KAPS1&2, KGS1-4, RAPS-3-6 and TAPP3&4. Of these, NAPS 1&2, KAPS 1&2, KGS 1-4 and RAPS 3-6 are 220 MWe reactors, at inland sites. TAPP 3&4 are 540 MWe units at coastal site. These plants are designed for a set of site specific levels of external events including flood, fire and earthquake. The external event parameters used for design of the NPPs were subjected to thorough review and acceptance by AERB prior to construction. In the case of older plants, TAPS 1 &2, RAPS 1&2 and MAPS1 &2, assessment with respect to site specific external event parameters was carried our as part of the periodic safety reviews and/or special safety reviews undertaken in the past. Based on these reviews, certain up-gradations were carried out in the past. These were in the form of seismic re-evaluation & strengthening and relocation / addition of certain important equipment at higher elevations to ensure availability of safety functions in case of external flood.

Fire incident at NAPS-1 resulting in total loss of power (off site and on site) for several hours (about 17 hours) was safely handled on the strength of design provisions and appropriate operator actions. The valuable feedback arising from this event and events like the flooding incident at KAPS and Tsunami at MAPS led to strengthening of design provisions by addressing the issues related to common cause failures with respect to power supplies, pathways for cooling water supplies and strengthening the availability of heat sinks.

All the plant grade levels are higher than the design basis flood levels for the respective plants. Emergency power supplies are located above the design flood levels at all the plants. At RAPS-2 and MAPS-1&2, where the diesel generators were not above the revised reference flood level (Review Basis Flood Level), one diesel generator was provided at higher elevation during the last plant up-gradation.

The earthquake design of all the reactors in India are typically for 0.2g acceleration during SSE condition (for NAPS it is 0.3g). The preliminary assessment carried out post Fukushima has shown that the SSCs have good margins over and above the design/review basis earthquake.

During their reviews the NPCIL Taskforces carried out assessment of existing provisions and enhancements required for addressing the lessons learned from the Fukushima accident. The review findings have been subjected to detailed assessment based on analysis inputs, engineering viability and regulatory requirements.

As was mentioned in the overview, in addition to the self-assessment by the utility, review and assessments were also undertaken by AERB at various levels namely the AERB High level Committee, focused planned inspections and review by the SARCOP and other safety committees under the regular mechanism of safety supervision. The safety enhancements identified as a result of all these efforts where necessary measures fall in the purview of the utility are described in the subsequent paragraphs.

The recommendations that are common to all the types of NPCIL reactors are brought out below,

- Provision of automatic reactor trip on seismic event at all plants except where it is already available (NAPS & KAPS)
- Additional options for Power sources for cooling
    - Additional diesel operated pumps and/or diesel operated fire tenders to enable water addition to the different systems based on the need.
    - Additional diesel driven electric generators (air cooled and not requiring external cooling) to cater to minimum power needs.
- Water sources
    - Qualifying existing water storages/tanks in the plants for necessary earthquake resistance
    - Augmentation of on-site water sources for decay heat removal
    - Provision of boreholes at suitable locations to further augment water supply.
- Enhancing containment performance
    - Strengthen hydrogen management provisions in containment
    - Review of containment venting provisions
- Additional Battery operated devices to monitor important plant parameters
- Alternate water make up provisions for SGs, reactor coolant and other important systems and spent fuel pool during extended station blackout

- Review of Emergency Operating Procedures for external events and retraining of operators

In addition to the applicable common recommendations made above, additional specific recommendations for the TAPS 1&2 station are

- Enhanced flood protection measures for SBO DG to ensure operability during beyond design flood.
- Provision of hook up points for alternate means for injecting water to RPV through multiple routes, shell side of emergency condenser and containment spray system from outside RB
- Provision for high point vent for the reactor pressure vessel to depressurize the vessel
- Alternate provisions for replenishment of water in spent fuel pool inside the Reactor Building and Away From Reactor (AFR) storage facility

2.b. Schedules and milestones to complete the operator's activities

The identified measures for enhancement of safety against external hazards were scheduled for implementation taking into account feasibility, need for assessments/analysis/development, engineering & procurement and planned outages. Considering the number of activities identified measures were categorised into short term, medium term and long term, with respect to time frame for implementation, as brought out below:

Short term measures

- External hook up points for addition of water to Steam Generator, PHT, Endshield, Calandria, Calandria vault 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

Medium term measures

- Introduction of seismic trip where it does not exist
- Provision of additional backup DGs (air cooled mobile/fixed at higher elevation)
- Strengthening provision for monitoring of critical parameter 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 augmentation of onsite water storage, wherever required

Long term measures

- Enhancing Severe Accident Management programme
- Strengthening hydrogen management provisions
- Provision for venting of containment
- Creation of an emergency response facility capable of withstanding severe flood, cyclone & earthquake etc.

In addition to the above generic measures at all plants the following specific actions have been implemented/planned at the older NPPs at RAPS-2, MAPS 1&2 and TAPS 1&2. In these plants the flood level which was originally considered for design got revised in the subsequent PSR. Though necessary upgrades were implemented as part of PSR for meeting the review basis flood levels, the acceptance was essentially aimed at capability to perform safety functions adequately. During the post Fukushima reviews it was recognised that there is a need for improving the reliability for performing safety functions and its defence in depth at the review basis level. Similar approach was also adopted for review from seismic considerations. Certain plant specific upgrades were identified with this objective.

For RAPS-2 the flood level got revised from originally considered flood level of 354.2m (design basis) to the current review basis flood level of 359.6m considering upstream dam failure. Following the present reviews the additional actions envisaged are as below,

- Relocation of hook-up points above review basis flood level.
- Additional air compressor at higher elevation for supplying instrument air to critical valves and dampers
- Seismic strengthening of identified water storage tanks.

For MAPS 1&2 the flood level got revised from originally considered level of 8.96m (DBFL) to the current review basis flood level of 12.5m, in line with the subsequent assessments carried out. Plant grade level for MAPS 1&2 is 10.6m. Following the present reviews, the additional actions envisaged are as below,

- Construction of seismically qualified water storage tank along with diesel engine driven pumps at higher elevation to augment on-site water storage
- Additional UPS to supply power to vital instruments for monitoring important plant parameters under prolonged SBO.

For TAPS-1&2 the review basis flood level was revised from the original DBFL of 28.81m to 32m. The finished grade level is 31.39 m and the sea water pump el. is 29.3m. Additional measures planned for TAPS 1&2 are,

- Protection of Emergency diesel generators and ECCS pumps & valves against revised flood levels
- Provision for external hook points for adding water to RPV, Emergency Condenser and Spent Fuel Pools
- Alternate provision for decay heat removal (back up for the salt service water)

In addition to the above, based on the lesson learned from Fukushima, steps are being taken for implementation of nitrogen inerting of primary containment at TAPS 1&2.

All these plant specific measures for older NPPs are scheduled to be completed in the medium term.

2.c. Results of utilities activities / further actions.

Implementation of the identified measures is subject to the due process of regulatory review and clearances. The timeframe for implementation of the identified measures were also reviewed and accepted by the regulatory body. Implementation of the identified measures is given in Summary table (4.0) of this Topic

In areas where the requirements for enhancements are general in nature, the utility was asked to come up with approach papers with proposals on scope and criteria. After regulatory review and acceptance of the same, detailed engineering and implementation would be taken up. Accordingly the NPCIL is progressively submitting to AERB, the approach papers or proposals as applicable, on various enhancements for regulatory review and acceptance.

3.0 Activities performed by the Regulatory Body

Following the Fukushima accident, AERB directed NPPs to undertake self-assessment of safety against prolonged SBO and loss of heat sink due to external hazards. The immediate review by NPCIL considered the following:

- NPP safety under complete loss of electric power
- Safety during complete unavailability of water through designed route
- Providing measures for survivability under such conditions

By end of March 2011, NPCIL submitted a preliminary report on the self-assessment, titled “Safety Evaluation of Indian NPPs Post Fukushima Incident”. This report provided an integrated assessment of strength of Indian NPPs to withstand severe external events and specific recommendations applicable to various plants for further enhancement of safety.

As mentioned earlier, Chairman AERB constituted an independent High Level Committee (AERB-SC-EE) with national level experts in the areas of (i) design, safety analysis and NPP operation, and (ii) external events – seismic science, hydrodynamics and earthquake engineering. Also a number of working groups with specialists in the subject areas were formed for detailed review of plant specific design aspects with respect to functioning of safety systems and components and requirement for further enhancement of safety provisions in the case of severe external events, including combination of related events. Detailed review by the individual working groups covered the following areas:

- External events in relation to the safety NPPs
- Safety of Electrical, Control and Instrumentation systems against external events
- Safety of NPPs under prolonged Station Black Out (SBO) and loss of Ultimate Heat Sink
- Safety of spent fuel storage facilities at NPPs against external events
- Severe Accident Management provisions and guidelines

The review by the working groups aimed at assessing the following aspects in the specified subject areas:

- Safe shutdown of the reactor and maintaining in guaranteed shutdown state,
- Adequate cooling of the reactor core on a sustained basis,
- Ensuring containment function, and
- Availability of important plant parameters

The working groups completed their initial round of reviews in July 2011. The reports on these reviews and the utility's self-assessment report were inputs to the assessment by AERB SC-EE. The committee completed its assessment and submitted its report in August 2011. AERB accepted the recommendations of the AERBSC-EE and asked NPCIL to formulate the approach and action plan for their implementation, as relevant for the NPPs.

Accordingly NPCIL has submitted a consolidated action plan for implementation of the recommendations of the AERBSC-EE and the safety enhancements identified based on the outcome of the self-assessment in December 2011.

While the high level committee of AERB has completed its assessments in generic areas, the specialist working groups were asked to continue their reviews with respect to plant specific aspects including the need for enhancement.

In parallel, as a separate exercise, AERB undertook focused regulatory inspections of all NPPs in a phased manner to examine the plant capability and the preparedness to deal with the situations arising out of the natural disasters such as flood, tsunami, earthquake etc as well as the events of extended SBO and multiple failures. A special regulatory inspection checklist has been prepared for these inspections. These inspections have been completed at all the sites.

Taking cognizance of all the above inputs, the AERB's apex committee for operational safety review and enforcement, SARCOP has taken steps for review and follow-up of safety enhancements at various NPPs.

Similar actions are in progress for incorporation of the lessons learnt from the reviews, for the plants under construction by the respective Project Safety Review Committees, which are responsible for safety review for licensing of the projects (Some of the key aspects of review of safety aspects of the plants under construction are included in this report, as part of the section on Severe Accident Management and Recovery).

Additionally AERB has undertaken a review of its existing safety documents to identify the need for revision of the existing requirements/guidance or need for development of any additional requirement/documents.

3.a Overview of Actions taken/planned by Regulatory Body

Use of operating experience feedback for enhancing safety of NPPs has all along been accorded high importance in India. Lessons learned from Three Mile Island and Chernobyl accidents and other events in NPPs in India and abroad, as also from new knowledge gained through research have been appropriately used for design and procedural improvements to enhance safety of Indian NPPs. Previous experiences of such extensive safety review following the Three Mile Island and Chernobyl accidents shows that the detailed experience feedback based on analysis of data from the Fukushima accident will take much longer time. Hence, the approach followed during design review for safety of Indian NPPs in the light of the Fukushima accident is to be viewed in this context.

The review of Indian NPPs conducted as a part of Special Safety Assessment following Fukushima was comprised of self-assessment by the Utility and independent review and assessment by the Regulatory Body. These reviews and assessments were done through a multi-tier mechanism as follows,

- Review at station level (unit wise) through questionnaire, walk through and inspections.
- Next level of assessment by specialist committees (task forces or working groups).
- Final review and assessment by apex committees with wide range of participations from various stake holders.

The regulatory approach adopted by AERB with respect to siting and design of NPPs is well established and requires consideration of site specific inputs with respect to external events in the design basis. This aspect is periodically re-assessed during the periodic safety review (PSR) for any subsequent change in the magnitude of the external events.

The regulatory requirements for NPPs in India include consideration of station blackout as part of the design. This requirement came about essentially due to the consideration for lower grid stability prevailing in India in the earlier days. The requirements in this respect include onsite storage of fuel for EDG and water that can be used for 7 days (seismic design), besides the requirement that the utility has to demonstrate the availability of water resource for 30 days. The aspects related to this are included in AERB safety code on siting (AERB/SC/S) and AERB safety guide on 'Design Basis Events for Pressurised Heavy Water Reactor' (AERB/SG/D-5) and 'Ultimate Heat Sink and Associated Systems in Pressurised Heavy Water Reactor' (AERB/SG/D-15).

The approach adopted for the post Fukushima review in India (SAAFF) is outlined in the Introduction. In accordance with the SAAFF approach, in the area of design, the review covered the following aspects.

- Re-confirmation of capability to withstand currently defined site specific design / review basis levels of external events for individual plants. This included revisiting the results of earlier PSRs and review of need for further strengthening, as necessary.

- Assessment of margins available for beyond the design / review bases levels of external events. The objective of such assessment was to rule out existence of cliff edges close to the design basis /review basis levels and assess NPP's capability to perform minimum safety functions in such situation.

- Enhancing the capability of the plants to perform the safety functions under extended SBO / extended loss of heat sink through the design provisions. Towards this, plants were asked to carry out safety assessment for extended SBO beyond 24 hours and assess the need for increasing the capability of existing provision for continued heat removal through thermo-siphoning. The measures being incorporated based on the above assessments include

  - Alternate provisions for core cooling and cooling of reactor components including identification / creation of alternate water sources and providing hookup points to transfer water for long term core cooling,
  - Provision of portable DGs / power packs
  - Battery operated devices for plant status monitoring
  - Additional hook up points for making up water to spent fuel storage pools

The above provisions were intended to be capable of being deployed / used under adverse environmental conditions.

3.b. Schedules and milestones for regulatory body's activities

As mentioned in the earlier sections, AERB has carried out safety review of NPPs in India with respect to the lessons learned from the Fukushima accident and the need for further enhancements; through the AERB High Level Committee and its specialist Groups and the site specific focussed regulatory inspections. AERB has also taken cognisance of the self-assessment carried out by the utility. The plant specific safety enhancements are being finalised based on these.

Towards implementation of these measures, AERB has initiated requisite regulatory review and safety clearances for implementation of the measures at site. It may be noted that the enhancement measures are planned to be implemented in a phased manner, as brought out in section 2.b of this chapter. Accordingly, AERB is carrying out review of submissions from the utility in the form of (i) plant modification proposals involving introduction of additional systems / equipment and (ii) approach papers for addressing the long term measures, in phases.

AERB will be following up implementation of the safety enhancement measures in the plants as per the agreed schedules, through regulatory inspections and compliance reports from the utility.

The reviews undertaken for addressing the lessons learned from the Fukushima accident indicated the need for revisiting some of the existing provisions in the regulatory / safety documents of AERB, to examine the need for any revision. The issues that are identified so far in this regard, with respect to design of NPPs are,

- Need for safety margins w.r.t external events
- Assessment of vulnerability to cliff edge effects
- Provision for handling extended loss of power and extended loss of heat sink
- Review and strengthening of severe accident management provisions and guidelines
  - Impact of extreme external events w.r.to damage of assisting facilities and affecting multiple units
  - Hardening of systems for severe accident management
  - Monitoring of important parameters
- Safety classification and qualification aspects of the structures and systems for severe accident/extreme events
- Issue of sharing of systems for severe accident / extreme events and provisions for handling SBO & loss of Ultimate Heat Sink
- Any additional requirements that may arise from further lessons arising out of the Fukushima accident.

AERB is planning to take up this review through its existing framework for development of safety documents, in a phased manner. In this activity, inputs will also be taken from the ongoing revisions in the IAEA Safety Standards.

3.c Conclusions of the regulatory body regarding operators activities.

The utility has made significant efforts for assessment of safety of the NPPs based on the lessons learned from Fukushima. AERB has taken cognisance of the assessment of the utility, while conducting its own safety assessment. The safety enhancements that are being implemented address the consolidated outcome of assessments by both the utility and AERB.

AERB has reviewed the approach proposed by the utility for implementation of the identified safety enhancements, including the time frame proposed. The safety enhancement measures that were already implemented and the ones being pursued conform to the schedules mutually agreed between the utility and AERB.

The review and assessments conducted following Fukushima accident has shown that with the existing design features and the upgrades done in the past, the NPPs in India have significant strengths. Implementation of the short term measures would further strengthen the ability of the plants to cope with the effects of prolonged SBO and loss of heat sink.

With the implementation of remaining planned measures, together with the measures being taken towards severe accident management programme would result in enhanced capability of the NPPs for prevention and mitigation of accidents and thereby further reducing the possibility of any off-site impacts.

4.0 Summary Table

S.No	Activity	Activities by the Operator			Activities by the Regulator		
		(Item 2.a) **Activity** **- Taken?** **- Ongoing?** **- Planned?**	**(Item 2.b)** **Schedule Or Milestones for Planned Activities**	**(Item 2.c)** **Results Available** **-Yes?** **- No?**	**(Item 3.a)** **Activity** **- Taken?** **- Ongoing?** **- Planned?**	**(Item 3.b)** **Schedule Or Milestones for Planned Activities**	**(Item 3.c)** **Conclusion Available** **-Yes?** **- No?**
TOPIC-2 - DESIGN							
1.	Self-assessment of safety of NPPs by the utility and review	Taken	Completed	Yes	Taken (action by AERB included scoping of self-assessment)	Completed	Yes
2.	Consideration of utility's self assessment in the review by AERB high level committee	Taken (providing necessary details to facilitate assessment by AERB High level committee)	Completed	Yes	Taken	Completed	Yes

S.No	Activity	Activities by the Operator			Activities by the Regulator		
		(Item 2.a) Activity - Taken? - Ongoing? - Planned?	(Item 2.b) Schedule Or Milestones for Planned Activities	(Item 2.c) Results Available -Yes? - No?	(Item 3.a) Activity - Taken? - Ongoing? - Planned?	(Item 3.b) Schedule Or Milestones for Planned Activities	(Item 3.c) Conclusion Available -Yes? - No?
3.	Detailed plant specific assessment of identified areas by the specialist working groups of AERB High Level Committee	Taken (action by the utility include providing necessary details to facilitate plant specific assessment)	Completed	Yes	Ongoing	Initial Assessment completed – July 2011.	Yes
						Final Assessment 2012	--
4.	Focussed Regulatory inspections by AERB	Taken	Completed	Yes	Taken	Completed	Yes
5.	Identification of short term safety enhancement measures	Taken	Completed	Yes	Taken (review and acceptance)	Completed	Yes
6.	Implementation of Short term measures	Ongoing	2013	No	Ongoing (issuing necessary clearances and subsequent verification)	2014	No
7.	Identification of Medium term safety enhancement measures	Taken	Completed	Yes	Ongoing (review and acceptance)	2012	No

S.No	Activity	Activities by the Operator			Activities by the Regulator		
		(Item 2.a) **Activity** **- Taken?** **- Ongoing?** **- Planned?**	**(Item 2.b)** **Schedule Or Milestones for Planned Activities**	**(Item 2.c)** **Results Available** **-Yes?** **- No?**	**(Item 3.a)** **Activity** **- Taken?** **- Ongoing?** **- Planned?**	**(Item 3.b)** **Schedule Or Milestones for Planned Activities**	**(Item 3.c)** **Conclusion Available** **-Yes?** **- No?**
8.	Implementation of Medium term measures	Planned	2014	No	Planned (issue necessary clearances and subsequent follow-up)	2015	No
9.	Identification of Long term safety enhancement measures – approach paper and conceptual design	Ongoing	2013	No	Planned (review and acceptance)	2013	No
10.	Detailed design and implementation of Long term measures	Planned	2015	No	Planned (issue necessary clearances and subsequent verification)	2015	No
11.	Identification of regulatory requirements/ documents for revision	-----	-----	-----	Ongoing	2013	No

TOPIC-3: SEVERE ACCIDENT MANAGEMENT AND RECOVERY (ONSITE)

1.0 Overview

AERB Safety Code on "Design of Pressurized Heavy Water Reactor Based NPPs" (AERB/NPP-PHWR/SC/D (Rev.1), 2009 requires that the behaviour of plant under specified beyond design bases accidents including severe accidents should be addressed. These requirements include:

(i) Important event sequences that may lead to severe accidents shall be identified using a combination of probabilistic methods, deterministic methods and sound engineering judgment.

(ii) These event sequences shall then be reviewed against identified set of criteria aimed at determining which severe accidents should be addressed in the design.

(iii) Potential design or procedural changes that could either reduce the likelihood of these selected events or mitigate their consequences, should these selected events occur, shall be evaluated, and shall be implemented.

(iv) Consideration shall be given to the plant's full design capabilities, including the possible use of some systems (i.e. safety and non-safety systems) beyond their originally intended function and anticipated operating conditions, and the use of additional temporary systems to return the potential accident conditions to a controlled state and/or to mitigate the consequences, provided that it can be shown that the systems are able to function in the expected environmental conditions.

(v) For multi-unit plants, consideration shall be given to the use of available means and/or support from other units, provided that the safe operation of other units is not compromised.

(vi) Accident management procedures shall be established, taking into account representative and dominant severe accident scenarios.

Severe accident management features and guidelines are being implemented in line with the above requirements, as reported in 4th and 5th review meetings of the contracting parties of the convention.

Accident at Fukushima Daiichi nuclear power station has highlighted importance of external events of natural origin as a potential initiator of severe accident. Use of operating experience feedback for enhancing safety of Indian NPPs has all along been accorded high importance in the country. The lessons learned from previous severe accidents in the industry, Three Mile Island (USA) and Chernobyl (former USSR), have been appropriately used for design and procedural improvements to enhance safety of Indian NPPs. Post Fukushima Daiichi

NPP accident, the ongoing activities with respect to severe accident management for Indian NPPs were reviewed and lessons learned from this accident are suitably incorporated in the provisions to handle beyond design basis scenario, as well as for enhancing safety against external natural events. These reviews were carried out by review committees constituted by utility and the regulator. The recommendations made by these committees are now being pursued and those calling for backfits in NPPs have been taken up on priority.

The review carried out after Fukushima accident in Japan has confirmed inherent strengths of the design, practices and regulation followed in India, further re-confirmation or enhancements of safety is structured as below:

- Confirming capability to withstand currently defined design basis external events (Re-assessment)
- Assessing the margins available over and above these design basis in-order to ensure the functioning of SSCs during an external event of larger severity
- Introducing provisions for handling extended loss of power and extended loss of heat sink
- Severe accident management with respect to
  - Hydrogen management features
  - Provisions for maintaining containment integrity
  - Implementing severe accident management guidelines (SAMGs)
- Emergency planning and preparedness (covered in Topic 5 of this report)

Information with respect to severe accident management and recovery (on-site) is presented according to NPP designs, as categorized below.

S.No.	NPP Design	NPP Units
1	Pressurized Heavy Water Reactor	Rajasthan Atomic Power Station (RAPS-2) Rajasthan Atomic Power Station (RAPS-3&4, RAPS-5&6) Madras Atomic Power Station (MAPS-1&2) Narora Atomic Power Station (NAPS-1&2) Kakrapar Atomic Power Station (KAPS-1&2) Kaiga Generating Station (KGS-1&-2, KGS-3&4) Tarapur Atomic Power Station (TAPS-3&4) Kakrapar Atomic Power Project (KAPP-3&4) Rajasthan Atomic Power Project (RAPP-7&8)
2.	Boiling Water Reactor	Tarapur Atomic Power Station (TAPS-1&2)
3.	Pressurized Water Reactor	Kudankulam Atomic Power Project (KKNPP-1&2)

2.0 Activities by the Operator and National Research Institutes

2.a. Overview of actions taken/planned by NPP operator

Immediately after Fukushima Daiichi accident, NPCIL constituted different committees for design wise review of operating and under construction NPPs. The review focused on the following aspects related to ensuring fundamental safety functions.

(i) Assessing NPP capabilities to handle non availability of (a) motive power (b) designed water supply routes.
(ii) Augmentation of measures and infrastructure facilities to mitigate the situation.
(iii) Safety assessment of stored spent fuel.

Based on this review**,** emphasis is placed on protecting and augmenting onsite power supplies and water storage; thereby strengthening preventive component of accident management. Aspects related to severe accidents prevention and mitigation are elaborated further as follows:

2.a.1 Pressurized Heavy Water Reactor (PHWR) Units

Standard Indian PHWRs have certain advantages which make accident progression slower, viz.

- The steam generators are located above the core and as such decay heat can be removed passively by thermo siphoning of the primary system and boiling of water in the SG with water available in steam generators. Indian PHWRs have provision for supplying water to depressurized steam generators by diesel engine driven pumps, which do not require station power supplies. Steam discharge valves are provided such that the steam generator can be depressurised even in case of complete loss of power and compressed air.
- Secondly, the core is always surrounded by large quantity of low temperature and low pressure water in calandria and calandria vault. These inventories significantly delay progression of severe accidents and thereby provide time to intervene and take corrective actions. These inherent heat sinks come into picture only when primary heat sink through steam generators or shutdown cooling system becomes unavailable.

Notwithstanding inherent advantages of PHWRs with respect to accident progression, additional provisions for severe accidents management are being introduced in these units.

Potentially, a severe accident in PHWRs could result from

– Accident sequence initiated as loss of coolant accident (LOCA), followed by simultaneous or sequential loss of ECCS and moderator heat sink.
– Prolonged loss of offsite and on site power supplies (i.e. extended and unmitigated station black out)

Provisions corresponding to level-1 of defence in depth as incorporated in the design ensure that possibility of such an accident is remote and provisions at level-2 and level-3 ensure that such accidents can be safely mitigated, thereby avoiding their progression into severe accident domain.

Large water inventory in the spent fuel storage pools makes heat up of spent fuel, a slow process, in the event of loss of cooling. The slow rate of heat up of spent fuel bay water also provides ample time to put in place mitigation measures.

2.a.1.1 Severe Accident Prevention Features

Following modifications are being made to strengthen preventive aspect of accident management:

(i) Improving availability of onsite power supply

This is being achieved by ensuring availability of onsite emergency diesel generators under external natural events. For this available margins for onsite power supply with respect to earthquake and external flood are evaluated and necessary upgrading in the following form is contemplated.

– Providing back up emergency diesel generator at a higher location, where normal emergency diesel generator location is assessed to be vulnerable from the point of view of external natural events.
– Providing a smaller / mobile diesel generator, which can be utilized to power essential loads and charge station batteries for obtaining plant information and emergency lighting.

(ii) Improving steam generator heat sink

Improved availability of steam generator heat sink for maintaining thermo syphoning mode of decay heat removal is being achieved by

– As mentioned earlier, Indian PHWRs design incorporate provision of supplying water into steam generators by diesel engine driven pumps; which are independent of station power supplies. These diesel engine pumps are being further secured against external flood; and also margins for these pumps with respect to earthquake is evaluated.

- In selected units, additional diesel engine operated pumps are being installed at location secured from external flood to transfer deaerator storage tank inventory to steam generators.
- In some units provision exists to transfer deaerator storage tank inventory to steam generators by gravity.
- Provisions are being made to provide hook-up connections outside reactor buildings, through which water can be supplied to steam generators and end shields either by mobile pump or fire tenders. These connections would be kept isolated in normal operation through valves and spectacle flanges. The design of these connections is being qualified for maximum anticipated earthquake and flood at the site. These provisions will take care of extended loss of power supply scenario.
- The under construction 700 MWe units have a design feature of passively removing decay heat from steam generators by recirculating steam generator inventory through condensers located at elevation higher than steam generators. Water inventory to secondary side of these condensers can be replenished from outside reactor building. With this replenishment of inventory, steam generator heat sink can be maintained for extended duration. In addition, as backup, provision of supplying water to steam generators by diesel engine driven pumps is retained.

(iii) Improving onsite water storage.

Standard Indian PHWRs have onsite water storage sufficient for seven days of residual heat removal in case of loss of offsite power supply. This water storage is designed to be available against earthquake and external flood. In case of station black out this inventory when used only for replenishing steam generator heat sink can cater decay heat removal for about a month. Following improvements are being made for improving onsite water storage.

- Based on station specific review, onsite water inventory is being augmented wherever strengthening is considered necessary.
- Water sources at or near stations are identified, from where water can be transported with fire tenders.

(iv) Hook up to Primary Heat Transport System/ Emergency Core Cooling System (ECCS)

Indian PHWRs have provision to supply water into ECCS by fire water system, in case long term recirculation part of the system is not successful or develops some problem during the mission period. This provision is reviewed and necessary strengthening is done.

A provision to inject water into Primary Heat Transport (PHT) system is being made to be used in extended station blackout. With this provision issue of making up leakages to keep PHT system in solid state gets addressed. This water supply arrangement is from outside reactor building without utilizing station power supplies. i.e. by diesel engine operated pumps/ fire tenders.

2.a.1.2 Severe Accident Mitigation Features

In the unlikely situation of preventing accident progression, there could be potential of core damage. To mitigate accident sequences involving significant core damage, following measures are being made.

(i) Injection of water in calandria

Indian PHWRs have a large quantity of low pressure and low temperature heavy water inventory surrounding the core. Under beyond design basis accidents, this inventory acts as a heat sink and provides decay heat removal capability for several hours. Being a low pressure system, simple means can be employed to replenish this inventory thereby increasing autonomy of this heat sink and preventing significant core damage. For this purpose hook-up connections are made and are brought outside reactor building. From these connections water can be supplied to calandria either by connecting mobile pump or fire tenders. Replenishing water into calandria provides continuous heat rejection from the core and maintain core integrity or keep core materials within calandria depending upon the time when action is credited to refill the calandria. The design of this arrangement is qualified for maximum anticipated earthquake and flood at site.

(ii) Injection of water in calandria vault

Surrounding the calandria is another large inventory of water in the calandria vault, which is also available at low pressure and temperature. Thus this inventory provides a back up to water inventory in calandria and provides another retarding barrier in case calandria barrier for limiting accident progression could not be maintained. Provisions are made to supply water into calandria vault by hook-up connections that are brought outside reactor building. This connection is kept normally isolated through valves and spectacle flange. From this connection water can be supplied to calandria vault either by connecting mobile pump or fire tenders. By introducing water in calandria vault

- External cooling can be maintained for calandria and thus core or core material can be kept confined within calandria.
- Even in case of calandria breach, core material can be kept cooled and molten core concrete interaction can be avoided.

2.a.1.3 Spent Fuel Safety

The spent fuel storage pools for Indian NPPs are designed for SSE conditions and are located above design basis flood level for the site. Post Fukushima Daiichi accident, spent fuel storage pools were re-evaluated for finding out margin over SSE level of earthquake. One important feature that new Indian PHWR units employ is tank-in-tank design. In this design spent fuel pool (inner tank) is surrounded by another tank in such a way that any leakage past the spent fuel storage pool will get collected in the inter space between two tanks. This outer tank therefore provides another barrier to release of leaked water from the inner tank (spent fuel storage pool). The inter space dimension between the tanks is such that when filled, spent fuel bundles in the spent fuel storage pool (inner tank) would still have water cover over the stored fuel.

The spent fuel pools are designed to cater to 10 years of spent fuel inventory and one full core charge (emergency loading). It is estimated that in different stations, time taken for spent fuel pool temperature to reach 100°C varies from 2 days to 7 days for emergency loading. For normal heat loads these timings are still larger. The time for fuel exposure when radioactivity release from spent fuel could be of concern varies from 11 days to 40 days depending upon pool dimensions. From the above estimates it is noted that sufficient time is available to augment water to spent fuel storage pools in case cooling to spent fuel pool cannot be restored.

For supplying water to spent fuel storage pools, arrangements are made through which water can be supplied from outside the building. Water injection through this path does not require station power supplies and water can be provided through mobile pump or fire tenders. In addition measurement of spent fuel pool water level, temperature and area radiation fields is further strengthened.

2.a.1.4 Containment Integrity and Safety

With implementation of severe accident prevention and mitigation features, containment pressurization can be avoided. In case of prolonged station blackout (without any intervention), containment pressure remains below the ultimate load bearing capacity for about 3.5 days. For maintaining integrity and enhancing safety of containment, following improvements are under discussion and being finalized for implementation.

– Provision of hydrogen management by passive autocatalytic recombiners.
– Provision of filtered venting of containment.

The hydrogen recombiner test facility has been commissioned at R&D Centre at Tarapur. Initial tests with and without recombiners are completed upto 2% hydrogen concentration. The next phase will include tests in which performance of passive hydrogen recombiners will be evaluated, in steps upto 4 % of hydrogen concentration without steam and upto 10% of hydrogen concentration with steam in the test vessel.

The preliminary analysis for hydrogen source terms is available and based on obtained hydrogen removal rate, number of passive autocatalytic recombiners will be fixed and incorporated in NPPs. Discussions are also underway with foreign vendors for supplying hydrogen recombiners.

2.a.2 Boiling Water Reactor (BWR) Units

TAPS 1&2 BWR units are being operated at 160 MWe as against the original rating of 210 MWe. As mentioned in the national report for the 4th review meeting of the convention, this operation at lower power was necessitated due to tube leakages in secondary steam generators and their subsequent isolation. This lowering of reactor power and having water inventory in the system corresponding to 210 MWe makes progression of accident slower. In addition, TAPS-1&2 units have an emergency (isolation) condenser located above their respective reactor pressure vessels. This feature makes decay heat removal possible, passively, for few hours and after that this mode can be continued by introducing water in the secondary side of emergency condenser. As reported in the national reports for 4th and 5th review meeting of the convention, these units had undergone a detailed safety reassessment and a number of upgrades were implemented in these units during November 2005 to January 2006.

TAPS 1&2 units are also being provided with automatic reactor trip on seismic event. In TAPS 1&2 which is a coastal station, a tsunami early warning system is made available. The submarine faults capable of generating tsunamis at TAPS 1&2 are located at large distances, and therefore the possibility of simultaneous occurrence of an earthquake and a tsunami at these units is almost non-existent.

Potentially severe accident progression in TAPS 1&2 could result from

(i) Accident sequence of LOCA simultaneous with loss of emergency core cooling.
(ii) Prolonged loss of offsite and onsite power supplies (i.e. extended and unmitigated station blackout). For TAPS-1&2, it is pertinent to note that in addition to emergency diesel generators; these units have one additional diesel generator, providing another barrier against station blackout.

2.a.2.1 Severe Accident Prevention Features

For TAPS 1&2 also, measures are introduced which can prevent accident progression into severe accidents. These provisions include

(i) Strengthening availability of on-site power supply

This is being achieved by

- Improving protection of emergency diesel generators against external flooding.
- Providing a small capacity air cooled diesel generator for operating emergency make up pumps, charging batteries and facilitating emergency lighting.

(ii) Making up water to safety related SSCs

Provisions for makeup water to following are provided through hookup points outside reactor building. These points are qualified for maximum anticipated earthquake and flood level at site. Water through these provisions can be provided by mobile pumps or fire tenders, which also addresses extended loss of station power supplies.

- Emergency condenser.
- Reactor pressure vessel.

(iii) Improving onsite water storage.

TAPS 1&2 have on site water storage which is adequate for about 30 days of decay heat removal. This inventory is available in an underground tank, capability of which is reassessed for earthquake at station.

2.a.2.2 Severe Accident Mitigation Features

To mitigate accident sequences involving significant core damage, following provisions are being made, in addition to external water injection into reactor pressure vessel.

- Provision of hydrogen management by passive autocatalytic recombiners.
- Additional venting scheme to provide venting of drywell, suppression pool and common chamber.

2.a.2.3 Spent Fuel Safety

The spent fuel storage at TAPS-1&2 is within the reactor building and also at a facility away from reactor, for long term storage. As decay heat of stored fuel in the away from reactor facility is lower and on account of large water inventory, it is evaluated that there is no much concern of heat up of this pool water. For spent fuel stored inside reactor building, it is estimated that it takes 4 days and 1 day of time for water temperature to reach 100°C for normal and emergency heat load respectively. The timings for these two cases for fuel exposure are 30 days and 7 days respectively. While these estimates indicate that sufficient time is available before radioactivity release from spent fuel is of concern; provisions are made to supply water to spent fuel pools from outside reactor building. Water to spent fuel pools can be supplied either by diesel engine operated pumps or fire tenders. In addition, provisions for measurement of spent fuel pool water level, temperature and area radiation levels are being strengthened.

2.a.2.4 Containment Integrity and Safety

For enhancing integrity and safety of containment, following improvements are under discussion and being finalized for implementation.

- Inerting of the primary containment
- Provision of hydrogen management by passive autocatalytic recombiners.
- Provision of filtered venting of containment

2.a.3 Pressurized Water Reactor (PWR) Units

India is constructing two PWR units (Kudamkulam Nuclear Power Plant 1 & 2 – KKNPP 1&2). The design of these units is based on VVER-1000 model V-412. Besides the inherent safety features of PWRs namely negative power coefficient and negative void coefficient, several engineered safety features are incorporated to strengthen the design at defence in depth levels 3 and 4.

2.a.3.1 Existing provisions for ensuring safety functions

i. Mitigation of Anticipated Transient Without Scram (ATWS)

In order to mitigate ATWS, two safety systems viz. Quick Boron Injection System (QBIS) and Emergency Boron Injection System (EBIS) are provided. QBIS is a passive system connected to each of the four reactor coolant system loops. EBIS, a high pressure injection by pumps, is also connected to each of the four loops.

ii. Decay Heat Removal

Residual heat removal function during unavailability of offsite power supply is performed by reliable DG powered auxiliary feed pump in combination with steam discharge valves. At the next level of defence, a dedicated system known as SG Emergency Cool Down (SG ECD) system, powered by emergency DGs, configured in 4x100% independent trains has been provided. The steam from the SGs passes to the process condenser of SG Emergency Cool

Down system where it is cooled by intermediate cooling water and the condensate is pumped back to the SG. Thus the decay heat removal from reactor core takes place in closed loop in case of loss of off-site power avoiding loss of water inventory expected in other designs or old VVER reactors where steam is dumped to the atmosphere.

Decay heat removal below 130^{o}C is accomplished by 4x100% Residual Heat Removal system powered by emergency DGs.

For SBO, a Passive Heat Removal System (PHRS) has been provided. This system removes decay heat through secondary circuit via SG and PHRS Heat exchangers which are cooled by atmospheric air and does not require any AC power supply. When the decay heat removal through steam dump valve to condenser or steam dump valve to atmosphere is not possible due to unavailability of AC power or closure of main steam isolation valve, the PHRS system removes the decay heat by condensing the steam in PHRS Heat exchangers and returning back to SG.

Prolonged SBO can be handled by PHRS without the need for any makeup. This is made possible by natural draught air cooling and large water quantities in ECCS first stage and second stage accumulators to take care of leakages and shrinkages of reactor coolant system.

ECCS consists of 4x100% active systems powered by emergency DGs along with 4x33% accumulators configured in two stages. Borated water for safety injection is stored in the spent fuel pool located inside the containment.

2.a.3.2 Containment Safety Provisions

KK NPP is provided with a double containment. The inner containment is pre-stressed concrete and is lined with carbon steel. The outer containment is a RCC structure.

Containment spray system has been provided to reduce the pressure inside the containment during postulated LOCA or MSLB as well as to bind the volatile iodine during LOCA. Passive hydrogen recombiners are provided inside the containment to avoid deflagration and detonation during DBA/ BDBA scenarios.

A core catcher is provided to retain and cool corium for long term without re-criticality and also without causing formation of hydrogen. The design provides for emergency gas removal from reactor coolant system and core depressurization system to manage severe accident scenarios.

2.a.3.3 Spent Fuel Safety

The spent fuel storage at KKNPP is within the reactor building which has capacity for eight years of spent fuel and one full core unloading. In case of loss of offsite power supply, emergency DG powered fuel pond cooling system provides decay heat removal. In the case of SBO, it is estimated conservatively that for spent fuel storage at the end of 8 years including emergency full core load, a time period of about forty hours is available before fuel gets uncovered.

2.a.3.4 Envisaged Safety Enhancements

The following safety enhancements are envisaged

- Provision of onsite seismically qualified water storage to supply make up water to steam generators, reactor coolant system, spent fuel storage pools, by diesel driven pumps.
- Air cooled diesel generators to supply power to essential valves, plant parameters monitoring, lighting

2.a.4 General aspects of severe accident management

Some of the general aspects of severe accident management in Indian NPPs are as follows

2.a.4.1 Personnel Resources and Training

Indian NPP stations are twin unit modules. This concept applies to human resources also. Therefore, in case of multi-units getting affected, on-site emergency actions would be performed by personnel dedicated to two units. One of the positive aspect in this respect is the fact that core operating, maintenance, technical and support staff belongs to the utility and based on evaluation of situation, additional work force can be requisitioned from the staff residential colony, which is generally located less than 10 km from the NPP site. In addition, technical expertise from utility headquarters and Crisis Management Group of the Department of Atomic Energy is available for handling the situation.

The requirements for Technical Support Centre as part of severe accident management are seen vis-à-vis existing practice of on-site emergency management. It is assessed that with the existing framework, all requirements of Technical Support Centre are covered.

2.a.4.2 Adequacy of Procedures

Training for handling beyond design basis situations is included in severe accident management guidelines. The training module includes beyond design basis scenario, positive and negative impacts of suggested mitigating actions and appropriate consideration of human factors under accident condition.

The severe accident management guidelines document would include analysis for severe accident scenario and therefore would be used as a training material. The mode of training envisaged for severe accidents is classroom training, field walkdown and table top exercises.

2.a.4.3 Multi-Unit Events

Indian NPPs follow twin unit concept and in twin unit station safety related SSCs are in general unitized. Distance between twin unit stations is considerable and as such it is unlikely that event at one station could affect another station at the same site. The additional features that are being introduced for handling beyond design basis situations are also designed on per unit basis. The provision for on-site water inventory and motive power to supply water to the systems are made taking into account simultaneous requirement of two units. Therefore, in case of multi-unit event, mitigation actions could be performed and each unit can be handled safely. However, further review with respect to multi-unit events is continuing, and this will include issues arising out of deliberations at international level.

2.a.4.4 Availability of Equipment and Access

The hardware to mitigate accident progression from outside reactor building is designed to have margins over design basis earthquake and flood at site.

As part of severe accident management, availability of plant information is ensured through direct or indirect measurements and indications, through which plant state can be correlated. Multiple means are available to maintain communication, which include landline phones, mobile phones (of different operators), wireless sets and satellite communication system.

It is proposed to house equipment required for handling beyond design basis situations in the onsite emergency control centre (Refer topic-5 of the report) along with required plant and environmental radiation information with necessary documents. For all NPP sites, access is available from two different routes and this aspect is being included in emergency management plans.

2.b Schedules and milestones to complete the operator’s activities

The safety enhancements mentioned in 2.a above have been put up to AERB for review, and after regulatory concurrence, cleared proposals are being progressively implemented in ensuing biennial shutdown/ long shutdown of units. Some of the modifications, which have already been implemented, include the following

All Coastal NPPs

- Tsunami early warning system

TAPS 1&2

- External water injection provision to Isolation condenser secondary side
- External water injection provision to Reactor pressure vessel

TAPS- 3&4

- External water injection provision to PHT
- External water injection provision Steam Generators
- External water injection provision to End shields
- External water injection provision to Calandria Vault

KGS-1&2

- External water injection provision to PHT
- External water injection provision to End shields
- External water injection provision to Calandria Vault

KGS-3&4

- Portable DG sets

NAPS-1&2

- External water injection provision to PHT
- External water injection provision Steam Generators
- External water injection provision to End shields
- External water injection provision to Calandria Vault
- External water injection provision to Calandria

MAPS-1&2

- Portable DG sets
- Solar lighting
- UPS for battery charging

2.c Results of utilities activities / further actions.

Implementation of various accident prevention and mitigation measures is being taken up with due approval of the regulatory body. In addition, sever accident management guidelines utilising these provisions are under finalisation.

3.0 Activities by the Regulatory Body

The lessons learned from the Fukushima accident showed the need for closer look at the accident prevention and mitigation features in the NPP designs and the preparatory programmes for accident management.

As brought out in section 1.0 of this topic, AERB has specified requirements with respect to these aspects in the revised AERB codes on design and operation of NPPs (issued in 2009 and 2008 respectively). As reported in the National reports presented to the 4^{th} and 5^{th} review meetings of CNS, steps were already initiated for putting in place a systematic programme for severe accident management for the operating NPPs in India. This includes development of additional guidelines and measures required for strengthening the aspects related to severe accident management. Following the Fukushima accident, efforts are being put in with respect to (i) incorporating the lessons learned from Fukushima, particularly to identify the weak links in the existing provisions, (ii) emphasising the analytical and R&D efforts to address such weakness, (iii) translating the identified solutions to plant specific measures and (iv) incorporating the plant specific enhancement measures.

AERBSC-EE has examined aspects related to severe accidents, as part of the assessment of Indian NPPs following Fukushima. Also a specialist working group is reviewing the design specific and plant specific approaches towards implementation of systematic accident management programme.

3.a Overview of Actions taken/planned by Regulatory Body

Work towards enhancement of preventive measures as well as mitigation measures against severe accident sequences in NPPs were being pursued by AERB for quite some time. Substantial progress has already been made in the research and development activities in this regard that were undertaken by NPCIL as well as TSOs like BARC and IGCAR. Separately AERB has also conducted in-house studies as well as has sponsored several research projects to the academic institutions in some of the related areas.

Among the recent R&D projects that were dedicated towards managing hydrogen threat in containment and containment integrity are Hydrogen Recombiner Test Facility (HRTF) and containment model test facility (BARCOM) at Tarapur site.

AERB has been involved in the review of scoping aspects of the experiments and subsequently the results of these studies and experiments, in relation to the severe accidents. AERB has also been organising Discussion meets and Theme-Meetings for exchange of information and consolidation of the knowledge base on the issues related to severe accidents and accident management.

Subsequent to Fukushima accident in Japan, AERB-SC reviewed the aspects related to severe accident management. The specialist working group is presently examining the design specific and plant specific approaches towards implementation of systematic accident management programme and guidelines proposed by the utilities. In particular the working group is reviewing the following areas

- Enhancement of severe accident management provisions and guidelines
- Protection of calandria vault and reactor building raft concrete
- Prevention of criticality during different stages of accident progression
- Hydrogen management
- Habitability and functioning of control room/ supplementary control room and emergency management centres / shelters
- Impact of external events on the provisions and guidelines with respect to degradation of support infrastructure
- Common cause failure and other effects at multi-unit sites that may inhibit support from neighbouring units.

Outcome of the ongoing review of the utility's proposals will be used for further enhancement of the prevention and mitigation measures at the NPPs and for undertaking any additional developmental activity, as necessary.

3.b Schedules and milestones for regulatory body's activities

Based on the post Fukushima review and assessments done so far in the areas of Severe Accident Management, AERB has recommended that there is an urgent need to utilise the available outcome of R&D activities to strengthen severe accident management by providing additional design means both for operating and under construction plants and by procedural changes/guidelines and operator training. AERB has also recommended speedy implementation of severe accident management guidelines.

The approach adopted for the post Fukushima review in India (SAAFF) is outlined in the Introduction. In accordance with the SAAFF approach, in the area of severe accident, the additional measures cover the following aspects,

- Review and strengthening of severe accident management particularly with respect to:
    - Hydrogen Management
    - Reliable provision for containment venting
    - Availability of key parameters for monitoring even under most extreme condition

- Adequacy of SAM programme following an extreme external event, with the possibility of destruction of assisting facilities, both inside the plant and the surroundings; and affecting multiple units.
- Creation of an emergency facility at each NPP site which should remain functional under extreme events including radiological, with adequate provisions of communication and having capacity for housing essential personnel for a minimum period of one week.

– Enhancement of capability to treat large quantities of liquid waste that could be generated in case of an accident by means like transportable radioactive effluent treatment modules, which can be speedily deployed at any NPP site

AERB has asked the utility to prepare and submit relevant approach papers addressing the above recommendations. Accordingly the approach papers are being submitted by the utility progressively. AERB is reviewing these submissions for their acceptability, so that the utility can finalise the implementation details and schedules.

3.c Conclusions of the regulatory body regarding operators activities.

The reviews and assessments done post Fukushima have shown that significant strengths exist for prevention of severe accidents in the NPPs in India. The improvements incorporated in the past as part of the operating experience feedback programme following some of the events and accidents, have helped in strengthening the safety of NPPs against external events developing into severe accidents. However the lessons learned from Fukushima emphasises the need to give equal importance to accident mitigation capabilities. Recognising this aspect, AERB is pursuing speedier implementation of the enhancement measures identified through the ongoing analytical, experimental and R&D efforts, severe accident mitigation and management programme.

The Fukushima experience has also revealed that there could be certain weak areas in the present programme for accident mitigation. The present reviews have shortlisted such areas requiring strengthening in the context of Indian NPPs. The utility has initiated steps to address these areas, the outcome of which will further strengthen the accident mitigation capabilities, thereby further reducing the possibility of any off-site radiological impact.

4.0 Summary Table

S.No	Activity	Activities by the Operator			Activities by the Regulator		
		(Item 2.a) **Activity** **- Taken?** **- Ongoing?** **- Planned?**	**(Item 2.b)** **Schedule Or Milestones for Planned Activities**	**(Item 2.c)** **Results Available** **-Yes?** **- No?**	**(Item 3.a)** **Activity** **- Taken?** **- Ongoing?** **- Planned?**	**(Item 3.b)** **Schedule Or Milestones for Planned Activities**	**(Item 3.c)** **Conclusion Available** **-Yes?** **- No?**
TOPIC-3: SEVERE ACCIDENT MANAGEMENT AND RECOVERY (ONSITE)							
1.	Design and implementation of hardware/ means in PHWR and BWR units for preventing significant core damage	Ongoing.	Progressively in each unit. Likely completion for all units by 2013	Yes	Taken. Utility proposals reviewed	Completed	Yes. Proposals accepted.
2.	Design and implementation of hardware/ means in PHWR and BWR units for mitigating core damage	Ongoing.	Progressively in each unit. Likely completion for all units by 2013	Yes	Taken. Utility proposals reviewed	Completed	Yes. Proposals accepted.

S.No	Activity	Activities by the Operator			Activities by the Regulator		
		(Item 2.a) **Activity** **- Taken?** **- Ongoing?** **- Planned?**	**(Item 2.b)** **Schedule Or Milestones for Planned Activities**	**(Item 2.c)** **Results Available** **-Yes?** **- No?**	**(Item 3.a)** **Activity** **- Taken?** **- Ongoing?** **- Planned?**	**(Item 3.b)** **Schedule Or Milestones for Planned Activities**	**(Item 3.c)** **Conclusion Available** **-Yes?** **- No?**
3.	Providing hardware at PHWR and BWR units for hydrogen management and containment venting	Planned	2015	Yes	Planned. Will review utility proposals	2014	-
4.	Provisions for makeup water to spent fuel storage in PHWR and BWR units	Ongoing.	2013	Yes	Utility proposals reviewed	Completed	Yes Proposal accepted.
5.	Final SAMG document for PHWRs	Ongoing.	2013	Yes	Planned.	Mid 2014	-
6.	Final SAMG document for BWRs	Ongoing.	2014	Yes	Planned.	Mid 2015	-

TOPIC 4: NATIONAL ORGANISATIONS

1.0 Overview

The organisations for utilisation of atomic energy for power production and its regulation for safety are briefly described in section 2.0 (Organisational Structure for Atomic Energy) under Introduction. The details regarding these organisations were described in the Indian National Report to the 5th Review Meeting of the contracting Parties to the Convention on Nuclear Safety. The review of these organisations subsequent Fukushima accident identified the inherent strengths in the organisations. The utility has the capabilities for design, construction, commissioning, project execution, operation, ageing management and safety upgrades of the NPPs. AERB the regulatory body has a mature regulatory system and technical expertise for regulation. The regulatory requirements in India are in line with the requirements contained in the IAEA documents. Multi-tier safety review mechanisms both in utility and regulatory body ensure that no safety related aspect is overlooked. Periodic safety reviews every 10 years and brief review every five years for renewal of operations license, WANO peer reviews and effective operating experience sharing mechanisms ensure that the safety levels of the NPPs are as per the current safety standards and the NPPs follow the best industry practices. Decision has been taken to invite IAEA Operational Safety Review Team (OSART) mission to RAPS 3&4. Preparation and planning for an IAEA- Integrated Regulatory Review Service (IRRS) for peer review of the regulatory system is also in progress. A legislative bill to further strengthen the legal framework for regulation of safety in nuclear facilities has been introduced in the Parliament of India.

2.0 Activities Performed by Operator

2.a Overview of actions taken/planned by NPP operator

Over the years, NPCIL has acquired expertise in all the areas of nuclear power generation. These include design, construction, commissioning, project execution, operation, ageing management and safety upgrades. A complement of about 12000 highly trained and experienced employees support these function. The organisation has carried out some high end rehabilitation, retrofitting and safety up-gradation work, viz. En-masse coolant channel replacement in RAPS-2, MAPS-1&2, NAPS-1&2 and KAPS-1, En-masse feeder replacement work in RAPS-2, MAPS-1, NAPS-1&2 and KAPS-1, replacement of hair pin type heat exchangers of steam generators in MAPS-1&2, repair of end shield leak in RAPS-2 and KGS-3, repair of moderator inlet manifold in MAPS-1&2, etc. Safety upgrades in older NPP units to bring them at par with latest safety standards, viz. retrofitting of high pressure ECCS in RAPS-2, MAPS-1&2, strengthening of emergency AC power system under SBO condition / flooding condition in RAPS-2 and MAPS-1&2, strengthening of emergency AC power system in TAPS-1&2, etc were also carried out. These important tasks were carried out with completely indigenous efforts utilising in-house capabilities for development of tools and tackles, their fabrication and deployment in field. NPCIL also seeks technical support from R&D organisations including BARC, IGCAR, leading technical institutions and various universities. The support ranges from development of sophisticated tools, carrying out important inspections on the reactor components, post irradiated examination, metallurgical analysis, development of codes, safety analysis, etc.

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

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

The organizational structure at NPP level ensures that both national and international events are systematically analyzed and appropriate actions are taken to prevent the occurrence of similar events in Indian NPPs. A committee comprising of members from Technical Services, Operation, Maintenance, Health Physics, Training and other relevant sections is responsible for the review of these events. The observations of this committee are further reviewed in Station Operation Review Committee (SORC) for finalization of recommendations. The system ensures that events taking place at one NPP are communicated to other NPPs in India. The system also ensures that the information on events and corrective actions at one NPP is disseminated to other NPPs. Further, management of various NPPs interacts with each other at different levels. At these meetings, the information on various modifications to equipment and procedures is exchanged. These exchange meetings are held periodically.

First round of WANO Peer Review of all NPPs has been completed. The second round of WANO Peer Review is also completed for most of the plants.

The post Fukushima reviews indicate that the existing organisational setup within the utility both at the plant level and headquarters is adequate to ensure safety of plant, public and environment and as such no changes are contemplated at present. Decision has been made to invite IAEA OSART mission. The organisational aspects related to emergency preparedness are brought out in the Topic: 5 (Emergency Preparedness and Response and Post Accident Management (Offsite)).

2.a.1 Addressing Public Concern in relation to Safety of NPPs

DAE and NPCIL have been addressing public concerns related to safety of NPPs on a top priority and have enhanced the public outreach programme. Public is kept informed about important activities and milestones achieved at NPPs through press releases. Immediately after Fukushima accident, NPCIL organized national level press conference to dispel apprehensions about safety of Indian NPPs. The situation at Fukushima was regularly updated on NPCIL web site. Findings of safety audit of Indian NPPs carried out after Fukushima accident were put on NPCIL website.

NPCIL is setting up pavilions in local, national and international exhibitions about nuclear power to directly communicate with the public, industry experts and students. NPCIL has set up country's first ever nuclear gallery, "Hall of Nuclear Power", a permanent exhibition at Nehru Science Centre, Mumbai. It is planned to set up 11 more such centers across the country. NPCIL is encouraging visits of students, media personnel and general public to NPPs. Public can request visit to Indian NPPs through NPCIL web site. Presentations and interactive sessions are held at engineering colleges across the country covering various aspects of nuclear energy including design, safety and decay heat removal.

NPCIL is having partnership with Department of Science and Technology, Government of India to enhance public outreach at national level. Professional agencies are roped in to organize various public awareness activities at grass route level across the nation to allay fear about nuclear energy. Services of professional advertising agencies are hired to conceptualize, design and develop creative pull outs, promotional films and other useful information in a lucid way to make people understand about various aspects of nuclear energy. Special meetings with theme of radiation and cancer are organized in different parts of the country with active participation of specialist doctors on cancer treatment to dispel fear of relationship between cancer cases and radiation from NPPs.

Short films about nuclear energy are being screened at multiplexes and theatres across the country. NPCIL is collaborating with TV Channels for producing short films on nuclear power.

Information about benefits and safety of nuclear power and its environmental friendliness is disseminated through animated comic films/ comic books/ pamphlets and pictorial material in different regional languages.

2.b Schedules and milestones to complete the operator's activities;

WANO Peer Review of Indian NPPs is an ongoing process and each NPP undergoes WANO peer review every four years and a follow up mission is organised every two years. IAEA-OSART mission for RAPS 3&4 is scheduled for completion in November 2012.

3.0 Activities Performed by Regulatory Body

3.a Overview of Actions taken/planned by Regulatory Body

In India, all activities related to atomic energy including those for electricity generation through nuclear power are governed by the Atomic Energy Act – 1962 as amended from time to time and the rules made thereunder. Atomic Energy Regulatory Board (AERB), the regulatory body constituted under the provisions of the act frame policies, lay down safety standards & requirements and monitor & enforces all the safety provisions. AERB reports to the Atomic Energy Commission (AEC), the apex body of the Central Government for atomic energy that provides direction on policies related to atomic energy. AERB exercises the regulatory control over the activities related to nuclear and radiation facilities including the nuclear power plants (NPPs) through the consenting and regulatory inspection & enforcement processes.

Regulatory requirements related to safety in nuclear power plants are given in AERB safety codes. The regulatory programme setup by AERB also has built-in feature to continually improve safety by comparing with current safety standard and implementing planned safety upgrade measures.

AERB activities are conducted as per the Safety Code, AERB/SC/G, on "Regulation of Nuclear and Radiation Facilities" and various guides issued under it. These documents give in detail the consenting process, obligations of the consentee, conduct of regulatory review & assessment, inspection regime & enforcement provisions for the nuclear power plants, Research reactors, other nuclear fuel cycle facilities and radiation facilities. AERB has developed a Quality Assurance programme through which activities of each division are assessed for conformance to the prescribed procedures. In recognition of this programme, AERB has obtained ISO 9001:2008 certifications for its activities pertaining to consenting, inspection and development of safety documents.

Actions have been initiated to further strengthen the legal framework for regulation of safety in nuclear and radiation facilities and also to prepare for IAEA-IRRS mission.

3.a.1 AERB actions to reassure Public regarding Safety of NPPs

Soon after receiving the information on the great eastern Japan earthquake and the tsunami of March 11, 2011 and their impact on the NPPs located at Fukushima, the staff of AERB has been following the developments at the affected NPPs. Subsequently AERB constituted a monitoring cell, for closely following the accident, both from the technical and radiological perspective. The cell regularly monitored the related developments in Japan and radiological conditions in India and kept the public informed through the AERB website. AERB also made press releases aimed at addressing the concerns of the public on the website of AERB and AERB newsletters. The other initiatives included interviews to TV and print media regarding Fukushima accident and also the measures adopted for ensuring safety at the Indian NPPs.

As the post Fukushima safety review of Indian NPPs was in progress, AERB provided press releases on the progress of the reviews. AERB has also received queries from many quarters regarding the steps it had taken to ensure safety of the NPPs. The queries were from the Legislators, Media and members of Public. AERB responded to all such queries promptly and in a comprehensive manner.

After the High level committee (AERBSC-EE) submitted its report on safety review of Indian NPPs, AERB gave wide publicity to the review findings through press releases and briefings. The report of the high level committee was also placed on the website of AERB. AERB has also taken steps to utilize the scientific and technical forums outside the nuclear industry, seminars / conferences in various universities and academic institutes, for delivering talks / lectures / presentation on the post Fukushima assessments and safety enhancement of NPPs.

3.a.2 Nuclear Safety Regulatory Authority Bill, 2011

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 details regarding the functional independence of AERB and the regulatory framework were presented in our earlier national reports submitted to the 4th and 5th review meetings of the convention.

Government of India has been considering further strengthening of the legal framework for regulation of safety in nuclear facilities. As a consequence, Government has introduced the ‘Nuclear Safety Regulatory Authority (NSRA) Bill 2011’ to strengthen India’s nuclear safety regulatory framework by conferring statutory status to regulatory body. With the promulgation of the Nuclear Safety Regulatory Authority (NSRA) Bill 2011, NSRA will subsume the activities of AERB. The legislative bill is under discussion in the Parliament.

3.a.3 IRRS mission

AERB is planning to host Integrated Regulatory Review Services (IRRS) mission. In this regard AERB is in the process of carrying out self-assessment.

3.b. Schedules and milestones for regulatory body's activities

Preparation and planning for an IAEA- Integrated Regulatory Review Service (IRRS) for peer review of the regulatory system is in progress. A legislative bill to further strengthen the legal framework for regulation of safety in nuclear facilities has been introduced in the Parliament of India.

3.c. Conclusions of the regulatory body regarding operators activities

AERB reviews the 'organisational and administration' and 'Operational Experience Feedback' as safety factors during renewal of operation license based on PSR. AERB is of the view that the organisational setup and the operating experience feedback programmes at NPPs are strong. The safety concerns are identified and resolved in a timely manner.

4.0 Summary Table

Activity	Activities by the Operator			Activities by the Regulator		
	(Item 2.a) Activity - Taken? - Ongoing? - Planned?	(Item 2.b) Schedule Or Milestones for Planned Activities	(Item 2.c) Results Available -Yes? - No?	(Item 3.a) Activity - Taken? - Ongoing? - Planned?	(Item 3.b) Schedule Or Milestones for Planned Activities	(Item 3.c) Conclusion Available -Yes? - No?
TOPIC 4 – NATIONAL ORGANISATIONS						
'Nuclear Safety Regulatory Authority (NSRA) Bill 2011'	---	---	---	On going	---	---

TOPIC 5: EMERGENCY PREPAREDNESS AND RESPONSE AND POST ACCIDENT MANAGEMENT (OFFSITE)

1.0 Overview

Nuclear Power Plants (NPP) 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 and members of the public. Notwithstanding these, it is necessary to have emergency response plans for effective management of any eventuality with a potential to result in undue radiological risk to the plant personnel, public and the environment.

Successful demonstration of emergency preparedness and response plans is a mandatory requirement for granting license for operation of NPPs. These plans ensure that sufficient means exist to cope with an emergency and meet the regulatory requirements. NPP Management accordingly establishes and maintains the necessary emergency resources and procedures by having Plant and Site emergency preparedness plan. District Authorities have plan for off-site emergencies. The roles, responsibilities and action plans for various agencies required to act during an emergency are detailed in these plans.

AERB evaluates the procedures for emergency detection, classification and decision making as also those for notification, communication, dose calculation and assessment. Necessary training is imparted to the personnel in implementing the action plans. Main features of the emergency preparedness plans were described in the Indian National report to fifth review meeting of CNS (Article 16).

1.1 National Laws, Regulations and Requirements

Emergency preparedness plan has been an essential requirement for operation of nuclear power plants in India from the very beginning of nuclear power programme. Specific requirements with respect to emergency preparedness in NPPs have been formulated by AERB in various Safety Codes and Guides.

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

2.0 Activities Performed by Operator, State and National Agencies

2.a. Overview of actions taken/planned by NPP operator

Considering the severity of the situation at Fukushima resulting from extreme natural events leading to loss of operational and safety systems in Fukushima Dai-ichi plants, comprehensive review for assessing the readiness of Indian NPPs for dealing with such extreme events was carried out. The assessments indicated robustness of the design and margins available over and above the design basis for natural events. Some of the incidents at Indian NPPs like prolonged loss of power supplies at Narora (1993), flood incident at Kakrapara (1994) and Tsunami at MAPS (2004) were managed successfully with existing provisions. However, to further enhance the safety levels and improve defence- in-depth, additional station specific provisions have been worked out and are under implementation as already brought out in earlier sections of the report.

The adequacy of emergency preparedness programme at each NPP is evaluated by conducting periodic exercises involving all concerned personnel. In these exercises, site personnel, district authorities, representatives from AERB, NDMA and local representatives participate as required. The frequency of plant, site and offsite emergency exercises are once in three months, once in a year and once in two years respectively. Periodic review and updating of plant emergency procedures is carried out based on observations made during such emergency exercises. The infrastructure required for emergency preparedness programme is maintained by each facility. The required emergency preparedness is maintained by organizing refresher training courses for site and off-site personnel at regular intervals.

The management of on site emergency, is the responsibility of NPP management and the Management of Off-site Nuclear Emergencies is the responsibility of District and State Authorities. Offsite nuclear emergency management includes well established coordination with clear roles and responsibilities of agencies.

2.a.1 Review and Revision of Emergency Preparedness Plans

To ascertain and evaluate the response and coordination among different agencies during offsite nuclear emergency, National Disaster Management Authority (NDMA), NPCIL and AERB took up review of existing Emergency Preparedness and Response plans at all NPP sites. Subsequent to Fukushima accident, NDMA organised mock exercises at all the Nuclear Power Plants (NPPs) and identified areas for improvements which mainly relate to the improvements in facilities and infrastructure for better implementation of various countermeasures. While an independent review of the emergency preparedness plans has provided reasonable assurance of the adequacy of existing provisions, further work has been taken up in following areas:

- Revision of offsite emergency plans based on the results of exercises conducted by NDMA
- To integrate important elements of the Incident Response System in the existing emergency preparedness plans

2.a.2 Training of Disaster Management personnel

The Disaster Management Act has mandated the constitution of a Specialist Response Force for handling disaster. This Force functions under the National Disaster Management Authority which has been vested with its control, direction and general superintendence. This is a multi-disciplinary, multi-skilled, high-tech force for all types of disasters capable of deployment by air, water and land routes. Ten battalions have been equipped and trained for natural disasters including four battalions in combating nuclear disasters. Training programmes have been organised for training of National Disaster Response Force (NDRF) personnel in radiation protection procedures. The training is also 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 programmes are arranged as necessary with support from BARC, NPCIL and AERB.

2.a.3 Considerations for multi unit sites.

India has adopted twin unit concept for establishment of nuclear power plants in the country. Each site thus has twin unit station with both units essentially similar in design. A site having multiple nuclear power stations also follows the same concept with adequate physical separation between them. Within the station, the two units are independent of each other. The complement of man-power in a shift adequately caters to the requirement of each unit and for all core functions, only regular employees are deployed. Station Instructions are in place to shutdown a unit in case of emergency at other unit. For multi station sites, site director is designated under whose control all site emergencies are handled. Each station has an independent management and organisation for operation. Each of the Station Director is in command for handling plant / unit emergencies. The common systems such as fire station, ambulance, vehicle management are ensured to be adequate for handling multi-unit emergency.

2.a.4 Establishment / Upgrading of the Emergency Control Centre Facility.

An emergency control centre has been a part of the onsite / offsite emergency handling infrastructure at each site. The centre provides a convenient location onsite for assembly of emergency committee personnel for handling and directing emergency response onsite and to also provide technical support to offsite public authorities. The centre is well equipped with all the necessary documents, communication system, equipment and other facilities to support intended function to be performed from this centre.

A beyond design basis external event, as experienced at Fukushima, Japan may disable the facilities available at the NPP site. It may also result in physical isolation of the site such that it may not be possible to receive outside help for a considerable period of time. A feasibility study has been undertaken to upgrade the Emergency Control Centre Facility (ECCF) to ensure that it remains functional under extreme natural events postulated for a particular site. The study would also consider need for any further upgrades in power supply arrangement, ventilation, plant parameter display and other emergency handling provisions.

2.b. Schedules and milestones to complete the operator's activities;

Review & revision of existing off-site Emergency Preparedness and response plans at nuclear power plants based on conduct of exercise & experience of Fukushima is expected to be completed by March 2013.

Approach paper to upgrade ECCF will be finalized after the feasibility study. The proposal is expected to be finalized by 2012.

2.c Results of utilities activities / further actions.

Mock exercises involving all stakeholders at various NPP sites were completed and the inputs were generated for revision of the emergency preparedness and response plans. Review of existing off-site Emergency Preparedness and Response plans at NPPs is being done. Training on emergency preparedness and response to nuclear emergency was completed for the specialised response teams of NDRF & District officials. Feasibility study is being done for finalizing the proposal to upgrade ECCF.

3.0 Activities Performed by the Regulatory Body

3.a Overview of Actions taken/planned by Regulatory Body

Off-site emergency preparedness plan is an essential requirement for operation of nuclear power plants in India from the very beginning of nuclear power programme. Specific requirements with respect to emergency preparedness in NPPs have been formulated by AERB in various Safety Codes and Guides. AERB through its regulatory mechanism ensures the preparedness of the emergency management organisation at each site.

After the Fukushima accident, resulting out of severe multiple natural events leading to loss of operational and safety systems in Fukushima Dai-ichi plants, AERB has undertaken comprehensive review for assessing the readiness of Indian NPPs for dealing with such extreme events. AERB has initiated actions in collaboration with the licensee, research organisations, national, regional and local authorities to strengthen the emergency preparedness and response of all the response organisations. These measures include review of existing Emergency Preparedness and Response plans at all NPPs, review of regulatory guides on Emergency Preparedness and Response and improvements in facilities & infrastructure for better implementation of various countermeasures.

3.a.1 Review of Intervention levels during emergencies.

The Intervention Levels (ILs) and Derived Intervention Levels (DILs) applicable for initiating countermeasures in case of offsite emergencies are prescribed in AERB/SG/HS-1. Intervention Levels in this guide are formulated using the graded approach such that exposure to individuals from all pathways is well below the (i) thresholds for deterministic (non-stochastic) effects in high risk area (ii) risk of stochastic health effects to individuals in the medium risk area and (iii) the overall incidence of stochastic effects in the exposed population is also limited in low risk area. For practical application, DILs are expressed in terms of quantities that are directly measurable, i.e., exposure rate from ground deposited activity and activity concentration in food stuff and water. The ILs and DILs recommended in this Guide are integrated into the off-site emergency response plans, prepared for the various NPPs in India.

The revision of this guide initiated prior to Fukushima accident will also consider the inputs from the reviews post Fukushima. Other AERB safety guides relevant to emergency preparedness and response are also identified for the revision and are in the process of revision.

3.a.2 Review and Revision of Emergency Preparedness and Response Plan

To review / revision of off-site emergency preparedness and response plan of Indian NPPs based on experience of Fukushima nuclear accident, AERB organised a discussion meet involving NPCIL, BARC, AERB, District Authorities and NDMA. The discussion included topics related to experience of Fukushima nuclear accident, radiological evaluation at Indian NPPs following postulated emergency situations, decision support systems, communication setup, off-site emergency planning and role & responsibilities of various agencies. The meet also discussed R&D programme for supporting the Nuclear and Radiological Emergency preparedness and response system, Incident Response System for off-site emergency and observations from recent off-site emergency exercises conducted at Indian NPPs. The meet identified required actions to enhance emergency preparedness. These included (i) Review of existing AERB safety guidelines AERB/SG/EP-2 on "preparation of off-site emergency preparedness plans for nuclear installations" (ii) Capacity building of the off-site emergency response organisations and (iii) Redundancy in communication system under extreme natural events.

3.a.3 Monitoring Cell in AERB

Following the Fukushima nuclear accident, a monitoring cell was constituted at AERB to monitor the nuclear emergency events and to keep close vigil on the radiation and contamination levels in India after Fukushima accident. Monitoring cell monitored the post Fukushima events, coordinated with DAE , BARC and IGCAR and collected information on radiation levels and contamination levels in air, water, soil and food material in India, for transmission to government and guidance of the general population.

To review the nuclear and radiological emergency situation in the country in future and advise Chairman, AERB on the subject, a Nuclear and Radiological Emergency monitoring cell in AERB is planned which can be activated in a short notice.

3.a.4 Participation in the IAEA ConvEx-2b Exercise:

India participates in the Emergency Exercises conducted by the IAEA Incident and Emergency Centre (IEC). India participated in the ConvEx-2b (Convention Exercise -2b) emergency exercise conducted by the IEC on April 13, 2011 under the Emergency Notification and Assistance Convention (ENAC) through DAE – Emergency Control Room (ECR). Emergency response organizations involving NPCIL, AERB, BARC, CMG (Crisis Management Group) of DAE participated in the exercise. The purpose of the exercise was to gain the experience with the relevant procedures and tools used to communicate with the IAEA IEC in an emergency through USIE (Unified System for Information Exchange in Incidents and Emergencies) website.

The exercise began with the 1st message from IEC describing the scenario happened in the reporting country.. Exercise was conducted for about five hours, during which IEC sent out series of messages describing the progression site emergency and then general emergency. This information was used to create and submit messages to IEC using appropriate forms thorough fax and web communication.

3.b. Schedules and milestones for regulatory body's activities

Review of existing off-site Emergency Preparedness and Response plans at NPPs based on conduct of exercise and experience of Fukushima is expected to be completed by 2013. Review and approval of proposal to upgrade ECCF at each NPP site is expected to be completed by 2012.

Establishment of monitoring cell at AERB for monitoring & assessment of nuclear and radiation emergency and to advice Chairman, AERB is expected to be completed by 2013. Revision of regulatory guide on "Intervention Levels and Derived Intervention levels for Offsite Radiation Emergency is expected to be completed by 2013.

3.c. Conclusions of the regulatory body regarding operators activities

Following the Fukushima accident utility, district authorities and NDMA have carried out offsite emergency exercises at all NPP sites and identified areas for improvements. The mechanisms to handle offsite nuclear emergency situations exists and trained NDRF teams are available for nuclear emergencies for performing the required task.

4.0 Summary Table

S.No	Activity	Activities by the Operator			Activities by the Regulator		
		(Item 2.a) Activity - Taken? - Ongoing? - Planned?	(Item 2.b) Schedule Or Milestones for Planned Activities	(Item 2.c) Results Available -Yes? - No?	(Item 3.a) Activity - Taken? - Ongoing? - Planned?	(Item 3.b) Schedule Or Milestones for Planned Activities	(Item 3.c) Conclusion Available -Yes? - No?
TOPIC 5 - EMERGENCY PREPAREDNESS AND RESPONSE AND POST ACCIDENT MANAGEMENT (OFFSITE)							
1.	Conduct of mock exercises involving all stakeholders at various NPP sites to review the emergency preparedness and response plans.	Taken .	Completed	Yes	Taken	Completed	Yes
2.	Review and revision of existing off-site Emergency Preparedness and response plans at nuclear power plants based on experience of	Ongoing (Review committee formed for one site involving	2013	No	Planned	2013	No

S.No	Activity	Activities by the Operator			Activities by the Regulator		
		(Item 2.a) **Activity** **- Taken?** **- Ongoing?** **- Planned?**	**(Item 2.b)** **Schedule Or Milestones for Planned Activities**	**(Item 2.c)** **Results Available** **-Yes?** **- No?**	**(Item 3.a)** **Activity** **- Taken?** **- Ongoing?** **- Planned?**	**(Item 3.b)** **Schedule Or Milestones for Planned Activities**	**(Item 3.c)** **Conclusion Available** **-Yes?** **- No?**
	Fukushima	operator, regulator, NDMA & TSO)					
3.	Approach paper to upgrade Emergency Control Centre Facility (ECCF)	Ongoing	2012	No	Planned	2012	No
4.	Training for emergency preparedness and response to nuclear emergency (Training to NDRF & District officials)	Taken	Completed	---	Taken	Completed	---
5.	Establishment of monitoring cell in AERB to advice Chairman, AERB	---	---	---	Planned	2013	---
6.	To revise regulatory guides related to intervention levels and Offsite emergency preparedness plans				On-going	2014	

TOPIC-6: INTERNATIONAL COOPERATION

1.0 Overview

During the ministerial conference on Nuclear Safety Vienna 2011, India expressed its appreciation for the initiative taken by Director General IAEA, to organise the Global Conference on Nuclear Safety following the Fukushima accident and called for strengthening the international cooperation mechanisms to enhance public confidence in nuclear power generation.

India has been actively participating in the IAEA activities related to safety of nuclear power plants. India has also taken up participation in the activities in the various working groups and committees of NEA. AERB has also become a full member of Multinational Design Evaluation Programme (MDEP). Indian experts have participated in the various international meetings presenting the reviews carried out in India following the Fukushima accident and also the measures implemented and proposed to be implemented. A decision has been made to invite IAEA missions namely, Operational Safety Review Team (OSART). Preparations for Integrated Regulatory Review Service (IRRS) for peer review of the regulatory system have been started.

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. As described earlier under Topic 5 on Emergency Preparedness and Response and Post-Accident Management (Off-Site), India has developed National Disaster Response Force (NDRF) which has battalions for handling various types of disasters, some of them are specially trained to handle nuclear emergencies.

The Department of Atomic Energy, Government of India is setting up Global Centre for Nuclear Energy Partnership (GCNEP) in the state of Haryana near New Delhi, to pursue studies in the field of Advance Nuclear Energy Systems, Nuclear Security, Radiological Safety and Applications of Radioisotopes and Radiation Technologies. In this context, memoranda of understanding (MOUs) are already signed with USA, Russian Federation and with the IAEA. Some other countries have also expressed interest in this initiative.

2.0 Activities of the operator and national organisations

2.a Overview of actions taken/planned by NPP operator

NPCIL has policy of remaining connected and aligned to the nuclear industry worldwide to ensure that best industry standards are emulated, safety and reliability of plants is improved on continuous basis and isolation is avoided. NPCIL has technical co-operation with the following international organizations:

– World Association of Nuclear Operators (WANO)
– CANDU Owner's Group (COG)
– World Nuclear Association (WNA)

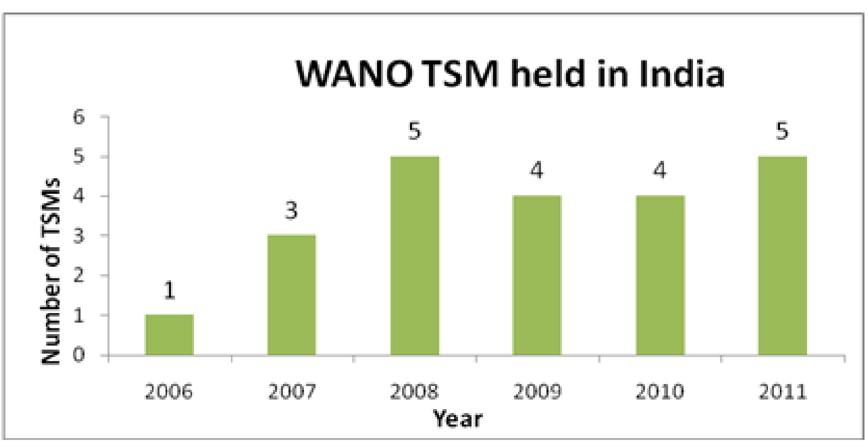
NPCIL has significantly benefited by participating in various programmes conducted by these international organizations. NPCIL has also provided the services of its experts to these organizations.

2.a.1 Cooperation with WANO

NPCIL is one of the founding members of WANO and has been actively participating in all its programmes like Operating Experience sharing, Peer Review, Professional & Technical Development Programme (workshops, seminars) and Technical Support & Exchange of good practices, performance indicators, technical support missions. NPCIL also has a liaison officer at WANO Tokyo Centre.

i. WANO Technical Support Mission:

WANO Tokyo Centre has a programme "Technical Support Mission (TSM)" to assist its members to address Areas for Improvements (AFIs) identified in the WANO Peer Reviews. NPCIL has so far organized 22 WANO TSMs to learn from best international practices so as to address the AFIs identified in the WANO peer reviews and to fine tune and improve its existing programme and practices. Some of the WANO TSM hosted by NPCIL were 'Capturing and Analysing Low Level Events, Improving human performance through optimized control room design, Task observation and coaching, Human performance and root cause analysis, Outage and work management, Managing ageing of the plant equipment, Conduct of error free operations with application of error reduction tools, Single point vulnerability, etc. Generally about 30 selected senior and middle level engineers from stations, projects and NPCIL Headquaters participated in each of the TSM. Experts in the specific field of the TSM are arranged by WANO.



ii. Performance Indicator Programme:

NPCIL has been sharing performance indicators data with WANO every quarter using its Performance Indicators Data Acquisition System. The world median and best quartile values of WANO performance indicators are used to benchmark performance of Indian NPPs and setting targets for ensuring continuous improvement.

iii. Good Practices and Guidelines:

WANO periodically develops good practices from the members programme worldwide. WANO good practices and guidelines are reviewed at stations and head office and some of them have been used to develop Head Quarter Instructions (HQI), revision of operation and maintenance procedures and fine tuning of station programmes and practices. Some examples are HQI-0535 (Implementation of an effective self-assessment and corrective action programme at NPPs), HQI-0540 (Implementation of Operating Experience Programme at NPPs), HQI-0548 (Conduct of pre-job briefing and post job debrief) and HQI-0550 (Human performance enhancement programme at NPPs).

iv. 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 NPP operation, safety and reliability.

v. Technical Exchange Visits:

This programme provides an opportunity for exchange visits between various NPPs 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 cooperation between host plant and visiting plant. Under this programme, NPCIL team of experts has over the years visited several NPPs in countries like South Korea, Argentina, China, Ukraine, Romania, Russia and Canada.

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

2.a.2 Cooperation with CANDU Owners Group (COG)

NPCIL has been a member of COG since 1989 and participates in its information exchange programme. NPCIL persons have been provided access to secured COG website under confidentiality agreement and therefore have access to operating experience information /

documents. A COG satellite server has also been installed at NPCIL, Mumbai which replicates data from main server periodically. This has enabled large number of NPCIL engineers to access COG website.

Post Fukushima, a Candu Industry Team (CIT) was constituted with members from many PHWR operating utilities including NPCIL. In the meeting various common issues were identified for further deliberations, such as enhancing core cooling capability, enhancing emergency power supply, hydrogen mitigation, etc. The meeting is held through video conference.

Recently, NPCIL has started participating in COG Weekly Screening Meeting held through video conference. This is a process of quick dissemination of operating experience information.

2.a.3 Cooperation with World Nuclear Association (WNA)

WNA is a global organization that seeks to promote the peaceful worldwide use of nuclear power as a sustainable energy resource. WNA is associated with nuclear power generation and all aspects of the nuclear fuel cycle, including mining, conversion, enrichment, fuel fabrication, plant manufacture, transport and the safe disposition of spent fuel. NPCIL became a member of WNA in 2002 along with two other organizations under Department of Atomic Energy; Nuclear Fuel Complex and 'Atomic Minerals Directorate for Exploration & Research'.

NPCIL has participation in each to the following three Working Groups of WNA.

- Event Definition and Analysis Working Group
- Nuclear Fuel Working Group
- Waste Management and Decommissioning Working Group

Post Fukushima, WNA has supported industry in providing authentic information through its member's website, which was found very useful.

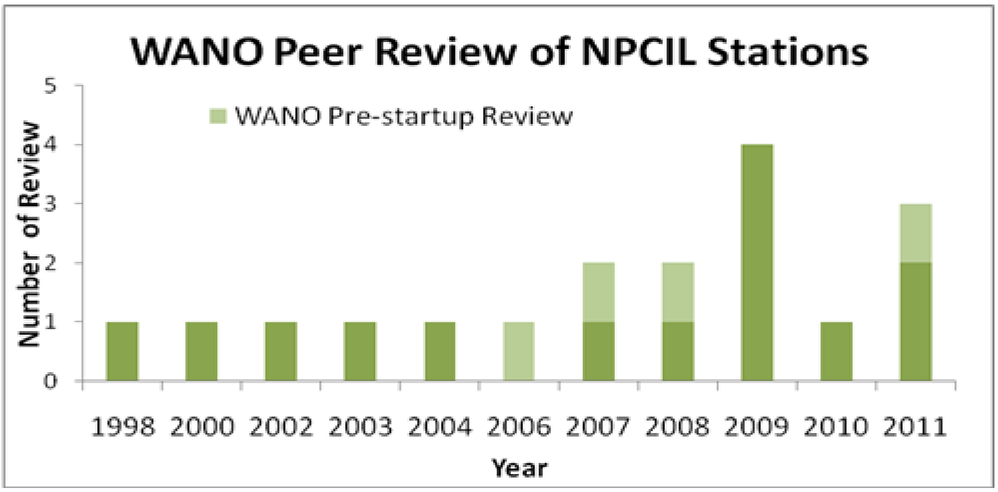
2.a.4 International Peer Reviews

NPCIL is committed to international peer review programme of all its NPPs. First international WANO Peer Review team was invited in 1998 to one of its plants. Since then, first round of WANO Peer Review of all its plants has been completed. The second round of WANO Peer Review is also completed for most of its plants.

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 four construction plants of NPCIL has been completed including KKNPP.

NPCIL has a team of about 75 engineers who have undergone Standard Peer Review Training conducted by WANO. NPCIL has provided the services of about 40 reviewers so far to WANO to support its Peer Review programme.

The bar chart shown below is an indicative of WANO Peer Review and Pre-Start-up Review of NPCIL plants since its first peer review in 1998.



NPCIL being an active member of WANO has also readily agreed to recommendations of a high level commission appointed by WANO Governing board for setting up future directions to strengthen WANO in post Fukushima era. Peer review frequency will be increased and some of the additional areas will be included in peer reviews based on evolution of Fukushima accident.

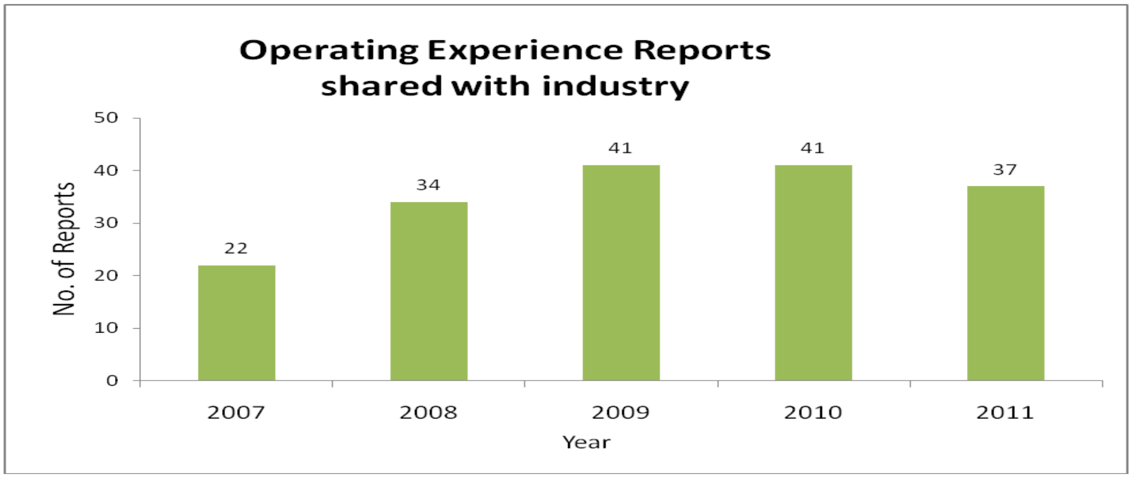
Government of India has taken an initiative to invite IAEA OSART mission for review of Rajasthan Atomic Power Station 3&4 of NPCIL. The preparatory meeting between IAEA-NPCIL and AERB was held in April 2012 and the OSART mission is planned for completion in November 2012.

2.a.5 Sharing International Operating Experience (OE)

NPCIL has been actively participating in operating experience programme of WANO, COG and other international organisations. About 200 senior and middle level officers in NPCIL stations, projects and HQ have been provided access to secured websites of WANO, COG and IAEA-IRS. This enables them to have quick access to operating experience information.

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. In addition, there is an Operating Experience Committee at corporate design office, which reviews events for which root cause is related to design. The implementation status of the OERC recommendations is regularly monitored.

NPCIL fulfils its international obligation of OE sharing by periodically sending the event reports of its plants to WANO. These reports bring out the root cause of the events and the lessons learnt. The number of events reported to WANO during the past five years is given below:



WANO has promptly issued Significant Operating Experience Reports (SOERs), related to Fukushima accident, Fuel pool safety and Near Term Actions to address an extended loss of all AC power. NPCIL has taken note of all such significant reports and has incorporated lessons learnt through its review process while revisiting safety of its plant and to assess the safety margins.

NPCIL has also joined the CANDU Industry Team (CIT) consisting of the representatives of all CANDU members and is involved in the review of various lessons learnt from Fukushima accident and the approach and methodology for addressing the same.

Immediately after Fukushima accident, NPCIL had activated a special Emergency Control Centre (ECC) at HQ, which functioned round the clock initially and thereafter, in day time for a few months. Latest information from WANO, IAEA, WNA NISA and TEPCO websites was obtained, analysed and disseminated to all concerned.

2.a.6 Participation of NPCIL in international forums post Fukushima

i. Workshop on lessons learnt from Fukushima

NPCIL representative participated in the workshop on “Lessons learnt from Fukushima Daiichi accident” organised by WANO Tokyo Centre and had direct interaction with company staff of TEPCO.

ii. Plant Managers Meeting

NPCIL representatives from each of its NPP site participated in WANO Tokyo Plant Managers Meeting held in December 2011. Representative from TEPCO presented the situations in Fukushima Daiichi NPP control room and emergency response capability at Japanese NPPs. All other WANO members made a presentation highlighting the safety enhancements in their respective plants.

iii. INPO CEO Conference and Fukushima Forum

NPCIL participated in INPO CEO Conference and Fukushima Forum held in USA. The participants shared, actions taken in their organisations, post Fukushima. TEPCO participants shared the event details and actions taken for prevention and mitigation, command and control, and communication during the accident.

2.a.7 International co-operation activities of national organisations

The Department of Atomic Energy, Government of India is setting up Global Centre for Nuclear Energy Partnership (GCNEP) in the state of Haryana near New Delhi, to pursue studies in the field of Advance Nuclear Energy Systems, Nuclear Security, Radiological Safety and Applications of Radioisotopes and Radiation Technologies. The objective of Center is to undertake studies for developing nuclear systems that are intrinsically safe and secure and proliferation resistant and address the residual risk using physical security measures. Setting up Global Centre for Nuclear Energy Partnership (GCNEP) is an initiative to enable India in establishing the leadership in the field of Nuclear Energy partnership through education, training, research and international seminar by Indian and international scientist on topical issues. The Centre will be engaged in the following activities:

- Training of Indian and international participants.
- International seminars, workshops, group discussions etc. by experts on topical issues like nuclear security, radiological safety.
- Research by Indian and visiting international scientists.
- Development and conduct of courses in association with interested countries and the IAEA.

– To impart training to security agencies and forces on application of physical protection system and response procedure, enhance physical security of nuclear facilities by developing and deploying most modern technological tools including information security, and to provide facilities for test and evaluation of sensors and systems used for physical security.

Memorandums of understanding (MOUs) are already signed with USA, Russia and with the IAEA. Some other countries have also expressed interest in this initiative.

2.b. Schedules and milestones to complete the operator's activities

WANO Peer Review of Indian NPPs is an ongoing process and each NPP undergoes WANO peer review every four years and a follow up mission is organised every two years. IAEA-OSART mission to RAPS 3&4 is planned for completion in November 2012.

3.0 Activities Performed by the Regulatory Body

3.a Overview of Actions taken/planned by Regulatory Body

AERB recognises the importance of international cooperation and collaboration in enhancing safety and regulation. AERB staff participates in many activities of IAEA and NEA. AERB also participates in the various regulatory forums like CANDU Senior Regulators and VVER Regulators Forum. AERB also has bilateral arrangements with ASN France, Radiation Safety Authority, Russia and USNRC under which exchange visits and discussions take place in areas of mutual interest.

AERB has been associated with a number of international research projects covering the assessment of NPP sites with respect to external hazards and structural capacity prediction under earthquake and accident loads. These activities are performed as part of Coordinated Research programs/extra budgetary programs of IAEA and safety research programs of USNRC.

International cooperation activities of AERB are as follows:

3.a.1 International Atomic Energy Agency (IAEA)

AERB has been participating in the activities of IAEA. The staff of AERB participates in the various Technical and Consultants meeting organised by IAEA for development of IAEA safety standards on a range of topics for fuel cycle activities, radiation facilities, transport of radioactive materials, handling of radioactive waste and illicit trafficking of radioactive materials. For most of these activities AERB has published its own safety codes, guides and standards for regulation of nuclear installations in the country. While preparing these documents

IAEA safety standards are extensively referred. IAEA safety standards are also used during various reviews conducted by AERB. India is represented in Commission on Safety Standards (CSS), Nuclear Safety Standards Committee (NUSSC), Radiation Safety Standards Committee (RASSC), Transport Safety Standards Committee (TRANSSC), Waste Safety Standards Committee (WASSC) of IAEA.

Following the Fukushima accident, staff of AERB has participated in the various meetings organised by IAEA and presented the reviews carried out by AERB after Fukushima, the actions taken / proposed to be taken. Top officials of AERB also participated in the IAEA ministerial conference 2011 and IAEA Fact Finding Mission to ascertain factual information and to identify initial lessons learned from the accident. Some of the other IAEA meetings included IAEA-IRS National Co-ordinators meeting where a full day discussions were held on measures taken by countries after the Fukushima accident. AERB is planning to host an integrated regulatory review service (IRRS) and is presently conducting self-assessment.

AERB staff has also been participating in some specific IAEA activities related to external events. The participation covered broadly two areas, viz., evaluation of seismic safety and assessment of flood hazards. AERB has been associated with IAEA CRP on "Safety Significance of Near Field Earthquakes", IAEA seismic EBP titled "Kashiwazaki-Kariwa Research Initiative for Seismic Margin Assessment" (KARISMA) and IAEA EBP on "Protection of nuclear power plants against tsunamis and post earthquake considerations in the external zone" (TiPEEZ). AERB has recently joined the activities of International Seismic Safety Centre (ISSC) of IAEA and is participating in four work areas viz., Seismic Safety Evaluation, Tsunami Hazards, Engineering Aspects of Protection against Sabotage and Site Evaluation and External Events Safety Assessment.

3.a.2 Nuclear Energy Agency

India has started participating in the activities of various working groups and committees of NEA. India has participated in Working Group on Operation Experience (WGOE), Working Group on Inspection Practices (WGIP), Working Group on the Regulation of New Reactors(WGRNR), Working Group on Risk Assessment (WGRisk), Senior level Task Group on Long Term Operation (STG on LTO) and Senior-level Task Group on the impacts from Fukushima Daiichi accident (STG Fukushima)

Recently AERB has also become a full member of Multinational Design Evaluation Programme (MDEP).

3.a.3 CANDU Senior Regulators Forum

AERB is a member of the forum for the CANDU Senior Regulators for exchange of information on issues specifically related to safety of PHWRs. The countries which are member of this forum are Argentina, Canada, China, India, Korea, Pakistan and Romania. The November 2011 meeting of the forum was held after Fukushima accident, actions taken by the regulatory bodies of all the participant countries were discussed. Some specific items like regulatory aspects/findings on periodic safety review, new build CANDU type reactors, refurbishments etc. were also discussed. The National Reports of the member countries of this forum was peer reviewed by the forum in a special meeting held in April 2012.

3.a.4 VVER Regulators Forum

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

3.a.5 Agreement with ASN and IRSN, France

AERB and Nuclear Safety Authority (ASN), France, discussed safety issues of mutual interest including emergency preparedness and management of post accidental situations and safety reviews carried out after Fukushima accident. A two day workshop was also conducted with safety experts from both the countries presenting the latest practices adopted by them. Both the countries have conducted such meetings and workshops in the past also under the Nuclear Safety Co-operation Arrangement between the two organizations that was signed in July 1999 and further renewed in 2005 and 2010.

Another agreement on technical cooperation between AERB and Institute for Radiation Protection and Nuclear Safety (IRSN), France was also signed for collaboration in the area of nuclear reactor safety covering areas such as exchange of staff, exchange of materials or software, joint studies and joint projects etc.

3.a.6 Radiation Safety Authority, Russia

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

3.a.7 United States Nuclear Regulatory Commission (USNRC)

A delegation from United States Nuclear Regulatory Commission (USNRC) led by Chairman, USNRC visited India during November 2011. The recommendations arising from review of Fukushima accident in India and USA were discussed during the meeting between AERB and USNRC delegation.

AERB also carried out Standard Problem Exercise (SPE) on "Performance of prestressed concrete containment vessels (PCCV) under severe accident conditions" .The activities of the SPE are divided into two phases. Phase-1 deals with examination of certain local effects, like liner concrete interaction, containment dilation effects on prestress etc. Phase – 2 deals with examination of methods to estimate leakage as a function of pressure and temperature and application of PCCV model for a pseudo time history and a time history representing SBO condition. The analysis provided detailed insight into the performance of containment structures in the beyond design basis condition, validity of the analytical models used and ultimate capacity of prestressed concrete containment structure. The methodology for estimation of leakage as a function of pressure and temperature was also developed by AERB.

3.b. Schedules and milestones for regulatory body's activities

International cooperation activities of AERB are part of an ongoing process. Bilateral and multilateral discussions in various regulatory forums are held as and when planned. Exchange visits and technical projects are also undertaken.

AERB is planning to host Integrated Regulatory Review Services (IRRS) mission.

3.c. Conclusions of the regulatory body regarding operators activities

AERB reviews Operational Experience Feedback process as one of the safety factors during renewal of operation license based on PSR. During review of this safety factor, AERB reviews the actions taken by utility on the international experience feedback and finds that the experience available from international organisations is appropriately utilised by the NPPs.

4.0 Summary Table

S.No	Activity	Activities by the Operator and National Organisations			Activities by the Regulator		
		(Item 2.a) Activity - Taken? - Ongoing? - Planned?	(Item 2.b) Schedule Or Milestones for Planned Activities	(Item 2.c) Results Available -Yes? - No?	(Item 3.a) Activity - Taken? - Ongoing? - Planned?	(Item 3.b) Schedule Or Milestones for Planned Activities	(Item 3.c) Conclusion Available -Yes? - No?
TOPIC 6: INTERNATIONAL COOPERATION							
1.	WANO Peer Review of Indian NPPs	Ongoing	Peer review of each NPP every 4 years and follow-up mission every two years	Yes			
2.	OSART mission of a Indian NPP	Planned	2012	No			
3.	IRRS mission				Planned		