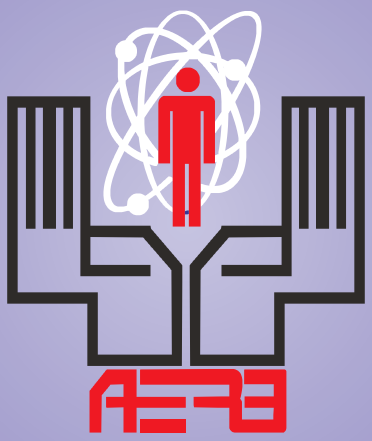
GOVERNMENT OF INDIA

ATOMIC ENERGY REGULATORY BOARD

ANNUAL REPORT
2009-2010



ATOMIC ENERGY REGULATORY BOARD

The Atomic Energy Regulatory Board (AERB) was constituted on November 15, 1983 with the consent of the President of India by exercising the powers conferred by Section 27 of the Atomic Energy Act, 1962 (33 of 1962) to carry out certain regulatory and safety functions under the Act. The regulatory authority of AERB is derived from the rules and notifications promulgated under the Atomic Energy Act, 1962 and the Environment Protection Act, 1986. The mission of the Board is to ensure that the use of ionizing radiation in India does not cause undue risk to health of people and the environment. Currently, the Board consists of Chairman, Vice-Chairman, three Members and a Secretary.

AERB is supported by the Safety Review Committee for Operating Plants (SARCOP), the Safety Review Committee for Applications of Radiation (SARCAR), Advisory Committees for Project Safety Review (ACPSRs), Advisory Committee on Radiological Safety (ACRS), Advisory Committee on Industrial and Fire Safety (ACIFS), Advisory Committee on Occupational Health (ACOH) and Advisory Committee on Nuclear Safety (ACNS). The ACPSRs recommend to AERB issuance of authorizations at different stages of projects of the Department of Atomic Energy (DAE), after reviewing the submissions made by the project authorities based on the recommendations of the associated Project Design Safety Committees.

SARCOP carries out safety surveillance and enforces safety stipulations in the operating units of the DAE. SARCAR recommends measures to enforce radiation safety in medical, industrial and research institutions, which use radiation and radioactive sources. AERB receives advice on development of safety codes and guides and on generic nuclear safety issues from ACNS. ACRS, ACIFS and ACOH advise AERB on safety matters relevant to their fields of specialization. The administrative and regulatory mechanisms in place ensure multi-tier review of all safety matters by experts in the relevant fields available nationwide. These experts come from reputed academic institutions, R&D organizations, industries and Governmental Agencies.

AERB has a Safety Research Institute (SRI) at Kalpakkam, which carries out research in various safety-related topics and organizes seminars, workshops and discussion meetings periodically.

AERB has seven technical divisions. Chairman, Vice-Chairman and Directors/Heads of Divisions and Director, SRI constitute the Executive Committee, which meets periodically and takes decisions on important matters related to the functioning of the organization. AERB enforces the following Rules issued under the Atomic Energy Act, 1962:

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

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ATOMIC ENERGY REGULATORY BOARD
NIYAMAK BHAVAN, ANUSHAKTI NAGAR
MUMBAI-400 094

Website : www.aerb.gov.in

THE FUNCTIONS OF THE ATOMIC ENERGY REGULATORY BOARD

- Develop safety policies in both radiation and industrial safety areas.
- Develop Safety Codes, Guides and Standards for siting, design, construction, commissioning, operation and decommissioning of different types of nuclear and radiation facilities.
- Grant consents for siting, construction, commissioning, operation and decommissioning, after an appropriate safety review and assessment, for establishment of nuclear and radiation facilities.
- Ensure compliance with the regulatory requirements prescribed by AERB during all stages of consenting through a system of review and assessment, regulatory inspection and enforcement.
- Prescribe the acceptance limits of radiation exposure to occupational workers and members of the public and acceptable limits of environmental releases of radioactive substances.
- Review the emergency preparedness plans for nuclear and radiation facilities and during transport of large radioactive sources, irradiated fuel and fissile material.
- Review the training program, qualifications and licensing policies for personnel of nuclear and radiation facilities and prescribe the syllabi for training of personnel in safety aspects at all levels.
- Take such steps as necessary to keep the public informed on major issues of radiological safety significance.
- Promote research and development efforts in the areas of safety.
- Maintain liaison with statutory bodies in the country as well as abroad regarding safety matters.

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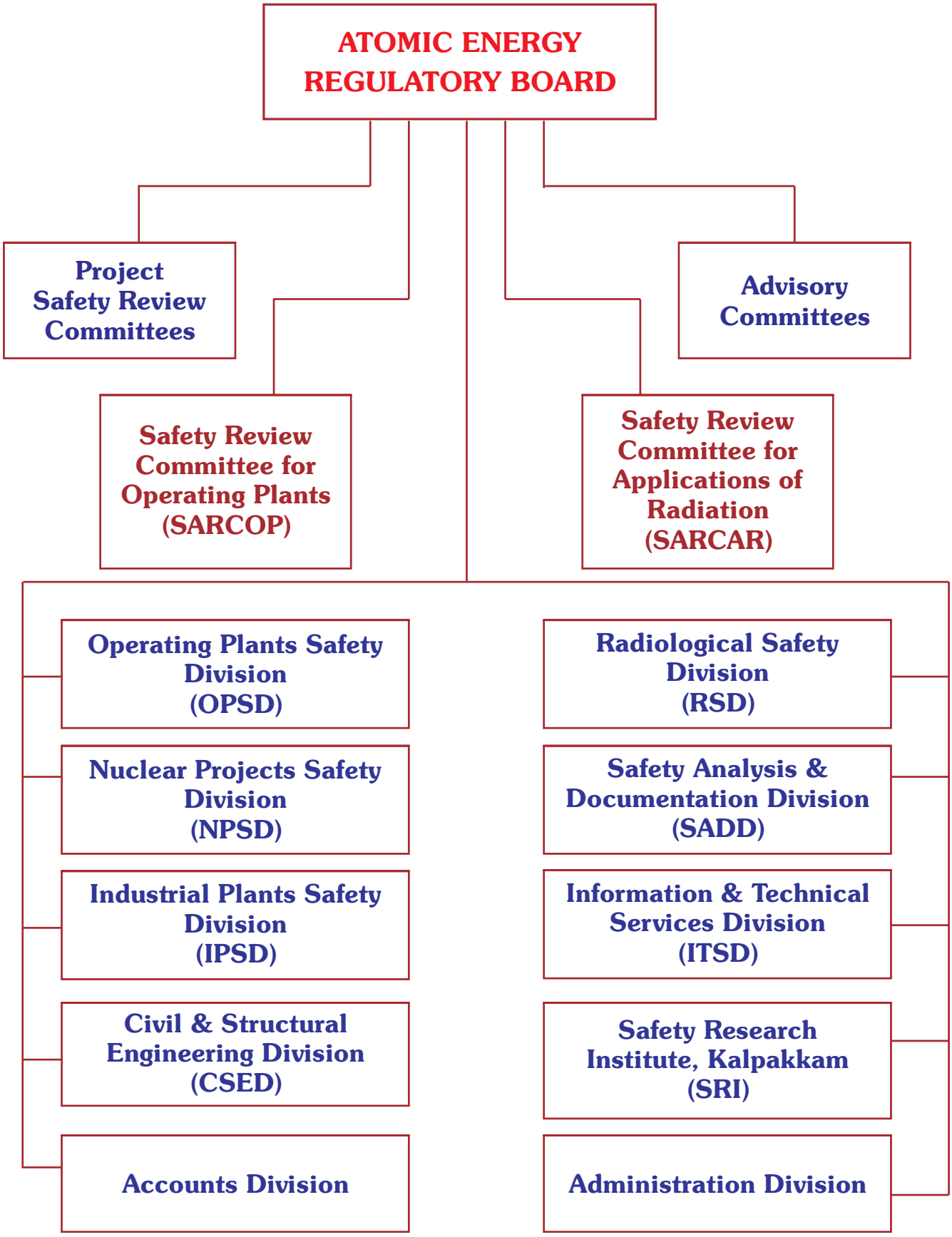
1.	Shri S. K. Sharma, AERB	…	Chairman (Up to January 13, 2010)
2.	Shri S. S. Bajaj, AERB	…	Chairman (Since January 14, 2010)
3.	Shri S. K. Chande Chairman, SARCOP, AERB	…	Member (Ex Officio)
4.	Dr. K. V. Raghavan INAE Distinguished Professor Indian Institute of Chemical Technology Hyderabad	...	Member
5.	Prof. J. B. Joshi DAE Homi Bhabha Distinguished Chairperson & Former Director University Institute of Chemical Technology University of Mumbai, Mumbai	…	Member
6.	Dr. K. A. Dinshaw Former Director Tata Memorial Centre, Mumbai	…	Member
7.	Dr. Om Pal Singh Director, Information and Technical Services Division, AERB	…	Secretary

1.2 ORGANISATION CHART OF AERB



1.3 SUMMARY

Appointment of Chairman, AERB

AERB witnessed a change in its leadership during the year. Shri S. S. Bajaj took over as the Chairman of the Atomic Energy Regulatory Board with effect from January 14, 2010 after Shri S.K. Sharma, outgoing Chairman, AERB relinquished the charge on expiry of his tenure on January 13, 2010. Shri Bajaj began his career with the Department of Atomic Energy (DAE) in 1969 after completing the training in 12th Batch of Bhabha Atomic Research Centre (BARC) Training School. He held several important responsibilities and contributed significantly in various capacities in the areas of nuclear and radiation safety. He retired as Senior Executive Director (Safety) from Nuclear Power Corporation of India Limited (NPCIL) in July 2007. Following this, he had been serving under Raja Ramanna Fellowship Scheme of DAE and advising various DAE units on safety issues. He is a recipient of the Indian Nuclear Society Award for outstanding achievement in Nuclear Technology and is a Fellow of the Indian National Academy of Engineering (INAE).

Shri S.K. Chande, Vice-Chairman, AERB welcoming New Chairman of AERB, Shri S. S. Bajaj, during the Executive Committee Meeting on January 12, 2010

Shri S. K. Chande, Vice-Chairman, AERB Felicitating Shri S.K. Sharma, Outgoing Chairman, AERB during Executive Committee Meeting on January 12, 2010

AERB carried out its functions with the support of its secretariat and specialist committees under the guidance of the Board. The Board met three times in Mumbai during the year: on May 15, 2009, October 22, 2009 and January 7, 2010. Some of the important clearances/approvals given by the Board are: First Approach to Criticality of RAPP-5 and RAPP-6, siting consent for KAPP-3&4, erection of major equipment for PFBR and the publication of the revised AERB Safety Code on 'Design of PHWR based NPPs'.

AERB Board Meeting in Progress in AERB
(L to R: Dr. Om Pal Singh, Shri S. K. Chande, Shri S. K. Sharma, Prof. J. B. Joshi, Dr. K. V. Raghavan and Dr. K. A. Dinshaw)

Safety Review of Nuclear Projects

AERB granted several clearances to RAPP-5&6 for various commissioning sub-phases from fuel loading in the reactor core to clearance for reactor operation up to 90% FP progressively as per established consenting process. RAPP-5 achieved first criticality on November 23, 2009 and it was synchronized to the power grid on December 22, 2009. RAPP-6 achieved first criticality on January 23, 2010 and it was synchronized to the power grid on March 28, 2010. AERB granted siting consent for KAPP-3&4 on May 25, 2009 and the excavation clearance on January 15, 2010. Safety review for the next sub-stage of construction, i.e., "First Pour of Concrete" is in progress. Safety review for siting consent for RAPP-7&8 is nearing completion.

Safety review of KK NPP-1&2 remained in progress. For these units, construction activities are nearing completion and commissioning activities are in progress. Regulatory review for siting stage for KK NPP-3 to 6 is nearing completion. For PFBR, AERB granted the clearance for last sub-stage of construction, i.e., 'Erection of Major Equipment'. Main vessel of the reactor has been lowered in the already erected safety vessel.

NPCIL is planning to install progressively 6 units of EPR type PWRs; each of 1650 MWe at Jaitapur on Western Coast of Maharashtra. Technical Assignment document for this project is under review by AERB.

Safety review of Demonstration Fast Reactor Fuel Reprocessing Plant (DFRP), Interim Fuel Storage Building (IFSB) for PFBR and Fast Reactor Fuel Cycle Facility (FRFCF) continued during the year.

A total of 15 regular and one special regulatory inspections were carried out for various projects, other than the monthly inspections on industrial safety aspects.

Safety Review of Operating NPPs and Research Reactors

All nuclear power plants and research reactors operated safely during the year. At the beginning of the year, RAPS-2, NAPS-2 and KAPS-1 were under long shutdown. After the completion of en-masse feeder replacement campaign of RAPS-2 and detailed review of submissions of NPCIL in connection with restart of the unit and the review of the performance of the plant at various stages, the stage-wise clearances were given for

operation of the unit up to full power. NAPS-2 and KAPS-1 continued to be under shutdown for en-masse coolant channels replacement campaign and other upgradation activities.

The report on Periodic Safety Review of RAPS-2 and Applications for Renewal of Authorisation of NAPS-1&2 and KAPS-1&2 were reviewed in detail. Based on these reviews, the authorisations for operation of RAPS-2, NAPS-1&2 and KAPS-1&2 were renewed up to August 2014, June 2013 and December 2010 respectively. TAPS-1&2 was granted clearance for construction of Additional Away From Reactor, an additional spent fuel storage facility at TAPS-1&2 site.

On November 24, 2009, an event involving radiation exposure of plant personnel due to consumption of tritium-contaminated drinking water occurred in KGS-1&2. The detailed investigations revealed that this was a malicious act and tritium-contaminated water was deliberately added to a drinking water cooler. After the review of this incident, all the nuclear power stations were asked to take adequate steps to prevent misuse of hazardous materials at the plants.

A total of 32 regulatory inspections were conducted for operating plants during January 2009 to March 2010.

During the year, there have been some changes in the Health Physics organization of the NPPs. Presently the Health Physics Units at all the NPPs are working under the Health and Safety group of NPCIL. Earlier these units were working under the Health Physics Division of BARC. In View of this change, AERB is taking steps to strengthen the regulatory controls related to radiological safety of NPPs through enhanced inspections and designation of Radiological Safety Officers (RSO) for all the NPPs.

Safety Review of Front-End Fuel Cycle Facilities and R&D Facilities

The consents issued for nuclear fuel cycle facilities include: commissioning of Technology Demonstration Plant (TDP) at Rashtriya Chemicals Fertilizer Ltd., Mumbai for recovery of rare metal from the wet phosphoric acid and production of sodium di-uranate, commissioning of Heavy Water Clean-Up (HEWAC) facility at HWP-Kota with hydrogen and de-mineralized water, Tri-Butyl Phosphate (TBP) at HWP-Baroda, Indus-2 with 2.5 GeV beam energy and 300 mA in steps of 100 mA beam current at RRCAT, Indore, Oxide Production Facility (OPF) & Sponge Production Facility (SPF) at Zirconium Complex, Pazhayakayal,Tamil Nadu, commissioning & operation of Versatile Solvent Production Plant (VSPP) at HWP-Talcher, Elemental Boron Plant (EBP) at HWP- Manuguru, construction of Zirconium Tetrachloride ($ZrCl_4$) facility at Zirconium Sponge Plant (ZSP), NFC, Hyderabad, and Licence for operation of 750 keV DC Accelerator at RRCAT, Indore.

A total of 42 regulatory inspections were carried out in nuclear facilities other than Nuclear Power Projects (NPP) sites.

Industrial Safety

There were four fatal accidents at construction sites of the DAE projects. These were at sites of Demonstration Fast Reactor Reprocessing Plant (DFRP), Kalpakkam, Kudankulam Nuclear Power Project, Kudankulam, RRCAT, Indore and Kakrapar Atomic Power Project 3&4, Kakrapar.

One major fire incident took place at Thermal Battery building of ECIL, Hyderabad that resulted in five fatalities due to burn injury.

These accidents were investigated and the required remedial measures were taken.

AERB strengthened regulatory inspections for industrial and fire safety aspects at projects. Job Hazard Analysis (JHA), preparation of safe working procedures and use of field check list on JHA were made mandatory for all hazardous works at sites.

A total of 28 monthly inspections and 16 regulatory inspections were carried out at construction sites of nuclear power projects and 13 quarterly inspections were carried out at construction sites of fuel cycle facilities.

Safety Surveillance of Radiation Facilities

Two medical cyclotrons and one industrial gamma radiation processing facilities were issued license for operation during the period April-March 2010. With this, there are now nine medical cyclotrons and fifteen industrial gamma radiation processing facilities in operation in India. Over 2740 licenses were issued for procurement of radiation sources and 452 authorizations were issued for export and disposal of sources. A total of 575 certificates of registration were issued to diagnostic X-ray installations. Regulatory Inspections were conducted in various radiation facilities and three unusual occurrences related to loss or misplacement of radiation sources were investigated. Seventeen permissions were issued for transport of radioactive material other than disposal. Six shipments were approved to be transported under special arrangement. Awareness programmes for regulatory requirements and radiation safety in fields of interventional radiology, nuclear medicine, planning of radiotherapy installations, dosimetry aspects for radiation processing facilities, radioactive contamination in steel products, safe handling of radioactive material, etc were conducted.

Radiological Incident in Delhi

In April 2010, an radiological incident occurred in metal scrap market in Mayapuri area of Delhi. The incident was caused by presence of radioactive material (cobalt-60) in metal scrap. The cobalt-60 source originated from an old gamma cell (made by Atomic Energy Canada Limited) which was un-authorizedly disposed off in scrap by one of the educational institutes of the Delhi University (DU). The incident resulted in radiation overexposure to seven persons. They were medically treated in hospitals of Delhi. Unfortunately one of them succumbed to death. Other six have been progressively discharged from the hospitals; the last one being discharged on 24th May 2010.

AERB, units of DAE, Crisis Management Group (CMG) of DAE and National Disaster Management Authority (NDMA) carried out detailed search and investigation in the affected area of Mayapuri and recovered all the radioactive sources. The contaminated patches of soil were decontaminated by removing the contaminated soil. The sources and the soil were sent to Narora Atomic Power station for safe and secure disposal.

The DU has decided to pay compensation to the victims. In view of the serious violation of the atomic energy rules for safe disposal of radioactive waste and radiation protection by DU, AERB issued a show cause notice to DU and directed to suspend the use of radioactive sources.

To prevent such incidents in future, awareness programs for scrap dealers of Mayapuri and other associated industries have been conducted. A campaign by AERB and UGC has been undertaken to bring awareness among educational and R&D institutes on safe handling and disposal of radioactive wastes. Detailed guidelines have been issued by NDMA to deal with such radiological emergencies and National Disaster Response Force, emergency control centres of CMG are well equipped to mitigate the consequences of such emergencies. A variety of equipment are being installed at various sea/air/land ports by the concerned agencies to prevent unauthorised entry of radioactive sources in the country.

Safety Documents and Safety Studies

Six new regulatory documents were published and 2 documents were translated in Hindi and published. Three documents are under revision and 11 under development. Safety studies were conducted in various Divisions of AERB, Mumbai and

Safety Research Institute, Kalpakkam in the areas of Event Analysis of PHWRs and VVER-1000, Probabilistic Safety Assessment, Reactor Physics, Radiological Safety and Environmental Safety.

International Cooperation

The AERB-RTN workshop was held at Scientific and Engineering Center for Nuclear Radiation Safety (SEC NRS), Moscow, Russia during March 22-24, 2010 to discuss commissioning experiences of VVER in recent past, safety review of Verification &Validation of digital Control & Instrumentation, safety review experiences of KK-NPP, regulatory inspections of NPP, etc.

A discussion meeting was held on February 1, 2010 between AERB senior officials and officials from USNRC to review the status of various programmes under the ongoing AERB-USNRC technical cooperation. AERB participated in the 16th Annual Meeting of the Forum of the State Nuclear Safety Authorities of the countries operating VVER type reactors held during July 7-9, 2009 in Bulgaria to exchange experience and information on VVER specific issues and practices. AERB officials participated in "International Collaborative Standard Problem Exercise on Comparison of Code Predictions of HWR Thermal Hydraulics with Experimental Data of Small Break Loss of Coolant Accident (SBLOCA)" and "Uncertainty Evaluation in Best Estimate Accident Analysis".

AERB participated in IAEA Programme for Seismic Margin Assessment Benchmark Study. AERB staff also participated in several activities of IAEA such as Incident Reporting System (IRS) and International Nuclear Event Scale (INES) based reporting system, Commission on Safety Standards, International Nuclear Safety Group and work related with development of Safety Standards.

Human Resource Development

Considering the expanding nuclear power programme and increasing use of radiation for societal benefits, appropriate steps were taken to augment and train the manpower of AERB. One refresher course and several technical talks were organized on various topics of interest. The orientation training of AERB Graduate Fellows from IIT-Bombay and IIT-Madras was organized with Human Resource Development Division, BARC. The training of newly inducted scientific officers from BARC training schools was organized with IGCAR, Kalpakkam and other organizations.

Awareness Programme

Workshops were organized on topics such as 'Awareness on Safety and Regulatory Requirements of Beach Sand Minerals Facilities', 'Gamma Ray Shielding' and 'Radiation Safety in Interventional Radiology including Catheterization Labs' and 'Regulatory Requirements in Radiotherapy Facilities'.

Public Information

AERB disseminated information on its major activities through Press Releases, Newsletters and Annual Report and by posting information on AERB website. Required measures were taken to implement the 'Right to Information Act-2005'. AERB started posting relevant AERB Safety Documents on the Website.

ISO Certification

AERB obtained ISO 9001:2000 certification in 2006 for Quality Management Systems (QMS) for its core activities related to Consenting, Regulatory Inspections and Development of Safety Documents for Nuclear and Radiation facilities. The same was renewed as ISO 9000:2008 in 2009. Necessary steps were taken to implement the QMS for continual improvement in the three regulatory processes of AERB.

CHAPTER 2

SAFETY SURVEILLANCE OF NUCLEAR FACILITIES

2.1 NUCLEAR POWER PROJECTS

2.1.1 Project Safety Review

AERB issued stage-wise clearances/permissions for commissioning of two 220 MWe PHWR Units at Rajasthan, i.e., RAPP-5 and RAPP-6 for reactor operation upto 90% FP. Commissioning of KGS-4 remained in progress. Siting consent was granted for locating first twin-unit station of indigenously designed 700 MWe PHWRs, KAPP-3&4 near the existing NPPs, KAPS-1&2. Excavation clearance for the project was also issued and was in progress since January 15, 2010. Safety review for 'First Pour of Concrete' clearance is in progress. Safety review for siting and excavation clearance for second twin-unit station of 700 MWe PHWRs, RAPP-7&8 proposed to be located at Rawatbhata, Rajasthan is in progress.

Major civil construction activities and erection of major equipment for KK NPP-1&2, each of 1000 MWe VVERs have almost been completed. Jobs such as, installation of C&I systems, laying of piping, ducts, cables etc. are in progress. Commissioning activities are also in progress. Safety review for siting of 4 additional units of 1000 MWe VVERs, KK NPP-3 to 6 near KK NPP-1&2 is nearing completion.

NPCIL is planning to install progressively 6 units of EPR, each of 1650 MWe PWR (vendor M/s. Areva, France) at Jaitapur site located on the western coast in Ratnagiri District, Maharashtra. Draft Technical Assignment (TA) document (Part-I Design and Safety Requirement) for Jaitapur NPP (JNPP) is under review.

Construction activities are in progress for indigenously designed liquid sodium cooled Proto type Fast Breeder Reactor (PFBR) of 500 MWe capacity. Clearance for 'Erection of Major Equipment' has been granted for PFBR. The safety review of three nuclear fuel cycle facilities, designed by IGCAR, namely, Demonstration Fast Reactor Fuel Reprocessing Plant (DFRP), Interim Fuel sub-assembly Storage Building (IFSB) and Fast Reactor Fuel Cycle Facility (FRFCF) continued during the year. Civil construction of IFSB has almost been completed

AERB has been following a well-established practice of multi-tier review process for safety review of nuclear projects starting from siting through commissioning stages. The Site Evaluation Committee (SEC), Project Design Safety Committee (PDSC), Civil Engineering Safety Committee (CESC) and associated Specialist Groups (SGs)/Working Groups (WGs)/Task Forces (TFs), carry out the first-tier review. In the case of KK-NPP, an in-house KK Co-ordination Group (KK-CG) along with SGs carried out the first-tier review. The corresponding Advisory Committee for Project Safety Review (ACPSR), which includes specialist members from the Ministry of Environment and Forests, Central Boilers Board, Central Electricity Authority and Educational Institutes, Experts retired from DAE units and officers from BARC, IGCAR, NPCIL and AERB perform the second-tier review.

The third-tier review is carried out by the Board of AERB. The safety review process is supplemented by periodic regulatory inspections as per the established practice for verifying compliance with the requirements recommended by the safety committees and those specified in various codes, standards and guides of AERB.

Table 2.1 lists the number of meetings held by various safety committees during the year. In addition, a large number of meetings of SGs, TFs and WGs constituted by PDSC/CESC/ACPSR/ AERB were held for in-depth review of specific aspects of the projects.

Table 2.1: Safety Review Committee Meetings of Power Projects

Project Safety Committee	Number of Meetings
ACPSR- PHWR	6
ACPSR- LWR	6
PDSC-KGS-3&4 and RAPP-5&6	16
PDSC-KAPP-3&4 and RAPP-7&8	14
SEC-700	5
PDSC-PFBR	4
PDSC-DFRP	5
PDSC-IFSB	1
PDSC-FRFCF	3
KK-CG	2
CESC	9

The status of safety review of various projects and some of important observations and recommendations made during the review process are given in the subsequent paragraphs:

(i) KGS-3&4 & RAPP-5&6

KGS-3&4 and RAPP-5&6 are "Repeat Designs" of KGS-1&2 and RAPS-3&4 respectively with certain differences mainly in plant layout and control & instrumentation systems. Safety review process for these projects continued mainly on topics related to commissioning phase activities; commissioning data results; operating experience feedback from similar type of reactors; significant event reports; Safety related modifications in the design; resolution of balance design issues; salient observations made during regulatory inspections; etc.

(ia) KGS-3&4

Clearance for operation of KGS-3 upto 90% FP has already been granted by AERB in the year 2007; the unit was operated upto 65% FP during the year as per instruction from NPCIL HQ.

KGS-4 is under commissioning. PHT system and Moderator System are kept under preservation and PSI of coolant channels has been completed. The balance commissioning activities of KGS-4, fuel loading onwards are expected to be completed by December 2010. The review of various commissioning activities is in progress.

(ib) RAPP-5&6

For RAPP-5, hot conditioning of PHT system, light water commissioning tests and 20 Te of HW addition for the moderator system were completed in the earlier years. Subsequent to completion of pre-requisite, reactor core was loaded with combination of Natural Uranium (NU) bundles and some Deeply Depleted Uranium (DDU) bundles in November 2009. The RAPP-5 achieved first criticality at 12.51h. on November 24, 2009 and was synchronized to the power grid for the first time on December 22, 2009. The unit was declared commercial on February 4, 2010. AERB has issued clearance for operation of the unit upto 90% FP.

For RAPP-6, Proof Test and Integrated Leakage Rate Test of primary containment were carried out and the test results were found satisfactory. Hot conditioning of PHT system and light water commissioning tests were performed in August 2009.

Fuel loading pattern in RAPP-6 remained the same as adopted for RAPP-5 and it was completed in December 2009. The RAPP-6 achieved first criticality at 21.53 h on January 23, 2010. The unit was synchronized to the power grid for the first time on March 28, 2010 and it was declared commercial on March 31, 2010. Based on review of the results of mandatory tests carried out at 50% FP, AERB has granted clearance for unit operation upto 90% FP on April 16, 2010.

Some of the salient observations/ recommendations made during the safety review of RAPP-5&6 are given below:

- In RAPP-5, gap between feeders to yoke for 26 nos. of feeders was found to be less than the intended gap after completion of erection works. This gap is required to avoid damage to feeder/yoke due to rubbing against each other. Based on study of this issue, it was inferred that minimum required would still be available for the worst case during reactor operation. Implication of this deviation during Operating Basis Earthquake (OBE) was analyzed and found acceptable from the consideration of safety. It was recommended that the gap between feeder & yoke be measured and survey should be done to check tell-tale mark, if any, of touching of feeders with yoke during biannual Shutdown.

- High neutron count rate (~ 3 times) was observed as compared to the predicted values during and after bulk heavy water addition to moderator system and first approach to criticality of RAPP-5. This aspect was studied in detail by AERB and NPCIL, based on recommendation of safety committee. Based on the study, reason for higher count rate was identified to the additional photo-neutron source caused by Thalium 208 (gamma energy 2.64 MeV). Thalium-208 is one of the daughter products in the decay chain of U-232 present in DDU bundles. The DDU bundles have been located in the central region of the reactor core for the first time in RAPP-5, close to start-up neutron detector locations in the central thimble.

- While RAPP-5 was under start up (Power < 0.1% FP), it tripped on pump room high pressure on Dec 23, 2009. Reactor containment got boxed up, shut-down systems operated and crash cool down got initiated as per the logic. Reason for pump room high pressure was traced to be shearing off 65 mm NB fire water (FW) feed line to a Steam Generator (SG). Reason for shearing of FW feed line and certain pipe supports was attributed to water hammer caused by hot water /steam backing up from SG to the FW feed lines to SGs. Investigations revealed passing of check valves and failure of flappers/ discs which led to entry of hot feed water in fire water pipes. There was no radioactivity release. 'Strap-on RTDs' have been incorporated on FW inlet lines to SGs with alarm in control room to indicate passing of check valves. Design of supports of FW feed lines to SGs were modified and qualified by analysis for withstanding higher temperature upto 265 °C. Based on AERB's recommendation, seismic qualification of firewater feedline was reviewed. The piping analysis was reviewed by AERB and found acceptable.

- During bulk heavy water addition to the moderator system in RAPP-6, mismatch in moderator levels as indicated by Computerised Operator Information System (COIS) and manometer was noticed, hence heavy water addition to the moderator system was suspended. Investigations had revealed rupture in 6% moderator level measurement SS tube (wide range) located in central thimble; the same was rectified. Safety Committee reiterated that quality assurance during construction/erection should be strengthened.

- NPCIL proposal for increasing coolant channel cold gap between front nut and yoke has been accepted for RAPP-5&6 based on detailed review by the Expert Group on Coolant Channel for the first five years of operation. These gaps are provided to accommodate thermal expansion and creep of the coolant channel. Increased gaps would reduce frequency of the adjustment of the gap and thus reduction in collective dose.

(ii) KK NPP-1&2

Civil construction of major building and structures and erection of major equipment for both the units were completed. Pre-Stressing of Primary Containment of both units was completed. All fuel assemblies for both Units-1&2 and a set of dummy fuel assemblies have been received at Site. The Refueling Machine of Unit-1 is erected and its commissioning is under progress. Commissioning of desalination plant and DM water plant is completed. Commissioning of electrical power supply system, Nuclear Steam Supply System (NSSS), compressed air system, chillers, etc. have been initiated.

The safety committees reviewed topics related to Commissioning, Emergency Preparedness Plan, Effect of Fire on Pre-Stressing Strands & Concrete, Testing of safety systems during commissioning, salient observations made during regulatory inspection, etc.

Some of the salient observations/ recommendations made during the safety review are given below:

- The earlier earmarked area for Solid Waste Storage/ Disposal is being changed considering future needs of KK-NPP-3 to 6. NPCIL has been requested to submit more details on this aspect covering new location, capacity, construction schedule, etc.

- High Density Poly Ethylene (HDPE) sheath is provided around pre-stressing cable strands. As per the results of accelerated ageing studies on HDPE, it is estimated that life of HDPE is ~ 60 years provided service temperature does not exceed 33oC. NPCIL has been asked to prepare and implement monitoring procedure during the operating life of the plant.

- In KK-NPP, each pre-stressing cable consists of 55 strands. Subsequent to the incident of fire at KK-NPP Unit-1, strands of some of the pre-stressing cables were identified for replacement. However a total of 5 strands could not be replaced during rethreading. Safety Committee asked NPCIL to study and submit the effect of reduced number of strands vis-à-vis containment strength aspects for review.

- It was informed that new cable routes have been created to take care of additional cables required for normal operation of the plant as these were not accounted in the earlier design. The subject topic is under review.

Kudankulam Nuclear Power Project (KKNPP) Units-1&2

(iii) PFBR

Civil construction activities and fabrication of major equipment and components are in progress. Works

PFBR Main Vessel being Lowered into Safety Vessel

on switchyard, erection of gas insulated breakers, 6.6KV switch gears etc. are in progress. Clearance for Erection of Major Equipment was issued on October 12, 2009 after satisfactory resolution of the identified issues. Main Vessel (MV) was lowered in the already erected Safety Vessel in the reactor vault. Alignment of MV is in progress.

Safety committee continued to discuss issues related to design and construction. Some of the salient observations/recommendations made during the safety review are given below:

- Space available around the Argon Buffer Tanks is very less and it could be quite difficult to carry out inspection/maintenance in these areas. BHAVINI has been asked to prepare detailed procedure to carry out these activities safely.

- Water accumulation in Neutron Detector Box (NDB) is not acceptable from safety point of view. The arrangements are made for periodical purging of the NDB and for measuring the dew point. The designers are asked to modify the system such that it is possible to physically check the thoroughness of the drain lines periodically.

- The designers are asked to estimate the dose to public through air route, provide basis for the dose apportionment between Liquid Waste Management Plant (LWMP) and Centralised Waste Management Facility (CWMF) and study feasibility/ operational aspects with regard to transferring of Category III waste from PFBR to CWMF through tankers.

(iv) KAPP-3&4

Site Evaluation Committee (SEC-700) had completed review of Application seeking Consent for Siting and associated submissions for KAPP-3&4 and submitted its Report in 2008. On satisfactory review of all the issues related, clearance for Siting of KAPP-3&4 was issued on May 25, 2009. AERB granted clearance for first sub-stage of construction, i.e. site excavation on January 15, 2010 after satisfactory completion of review of the NPCIL application and related submissions by PDSC and CESC. Safety review for the next sub-stage of construction, i.e. 'First Pour of Concrete' is in progress. Detailed design of the plant by NPCIL continued during the year.

Safety Committee reviewed various submissions related to design and construction which includes end shield design, leak tightness of containment, radiation zoning, adequacy of DG Sets, plant layout, internal flooding, common main control room for both units, non-consideration of drop load for design of civil structures, bulk shielding aspects, near surface disposal facility and salient issues emanated during regulatory inspections, etc.

Salient observations/recommendations made during the review process are given below:

- NPCIL proposed to provide 4x4000 KW capacity DG sets for each Unit. This was reviewed in detail w.r.t AERB, IEEE & NUREG requirements. AERB asked NPCIL to submit reliability of Class-III system under various Design Basis Events for review together with the offsite power reliability for the Site. In this context, NPCIL was also asked to carry out analysis to assess the heat removal capability of the system with fire water injection into end shields. Based on the review of these submissions, NPCIL proposal was accepted.

- NPCIL has proposed a common Main Control Room (MCR), which is a deviation from the earlier concept of unitized MCR in recently built PHWRs. After a detailed review of the various justifications provided by NPCIL, the safety committee noted that the overall layout of the common MCR meets all requirements of the safety codes/guides. Also, this deviation does not jeopardize any safety or human engineering aspect.

- The existing solid waste disposal facility for KAPS-1&2 is planned to be augmented for catering to KAPP-3&4 also. NPCIL was asked to make submissions addressing aspects such as, site specific data, secondary pathways to ingestion dose, emergency planning for failure of disposal facility, etc. for further review.

- NPCIL had proposed exclusion of load drop event in KAPP-3&4 in Reactor Building on use of single failure proof cranes and restricting the area of operation of crane. After review, NPCIL's proposal was accepted.

- Based on the observed tritium activity of a low magnitude in the bore hole samples at certain locations of the KAPP-3&4, Site was asked to establish proper monitoring procedures and radiation protection scheme as a precautionary measure prior to starting site excavation.

Meeting of PDSC-KAPP-3&4 (700 MWe PHWR) in Progress at AERB

(Dr. A. K. Ghosh, Chairman, PDSC-KAPP-3&4 and Shri K. J. Vakharwala, Member-Secretary, PDSC-KAPP-3&4 are seen in the Picture along with Other Members and Invitees)

- Plant lay-out was reviewed and suitable changes were incorporated in location of safety related structures/buildings to preclude possibility of radiation emergency arising due to the event of Low Trajectory Turbine Missile.
- NPCIL initially proposed to use active rock anchors for the Nuclear Building (NB) raft for avoiding uplift during seismic event. Subsequently, NPCIL revised the design of NB raft, with passive rock anchors, this was found acceptable to the Safety Committee.

(v) RAPP-7&8

NPCIL submitted an application on May 29, 2009 seeking clearance for locating 2 x 700 MWe PHWRs (RAPP-7&8). As part of pre-project activities, Phase-1 study related to preliminary geo-technical investigations involving bore-hole data assessment has been completed. Hydrological assessment related to inland flooding for arriving at the finished grade level for the main plant buildings has been evaluated based on CWPRS studies. The design of RAPP-7&8 would be similar to KAPP-3&4, except for site specific changes. Environmental Clearance from MoEF has been obtained.

Site Evaluation Committee for 700 MWe PHWR (SEC-700) has reviewed the Site Evaluation Report (SER), Design Basis Information (DBI), QA Manual for Siting, Environment Survey Laboratory (ESL) results on annual mean dose data for Site, tritium activity in bore wells located around Waste Management Centralised Facility (WMCF)/Solid Waste Management Facility (SWMF), Compliance status of stipulations/recommendations made by Advisory Committee for Site Evaluations (ACSE-RAPP-3 to 8) in the early nineties, Radiological Impact Assessment for DBA, etc. Safety review for siting consent is nearing completion.

NPCIL has also submitted an application seeking Clearance for Site Excavation for RAPP-7&8 in December 2009. Safety review of these submissions has also been taken up in parallel.

Some of the salient observations/ recommendations made during safety review process are given below:

- NPCIL was asked to submit compliance status to earlier AERB recommendations related to revision of Emergency Preparedness Plan covering H_2S emergency handling, over dimensional consignment transport survey report, availability of redundant source of start-up power, details of water requirement, power evacuation studies, etc.
- NPCIL submission on radiological impact analysis (RIA) addressed only air route. Revised RIA estimates considering aquatic & terrestrial routes were also asked to be submitted.
- Radiological Impact Assessment (RIA) done by NPCIL, for the governing of Design Basis Accident (DBA), indicates that the time available for invoking soft countermeasures at exclusion boundary would be adequate. The assessment was found acceptable and it is recommended that a refined RIA study taking into account improvements such as provision of metallic liner on primary containment towards reducing leakage rate, incorporation of containment spray system, etc. should be carried out for assessing the additional time period available for invoking counter measures under postulated accident conditions.
- Confirmation of absence of capable fault within 5 km radius from the plant is a requirement as per the Siting Code. In this regard, geological investigations made during 1989 – 90 were found to be inadequate. Hence, NPCIL arranged for fresh studies by GSI and it was conducted within 5 km radius of plant location. Results of these studies were discussed with the participation of five independent experts in the field of Geology & Geophysics (From AMD, ONGC, GSI, Institute of Seismological Research, MPSC). Based on the detailed deliberations, it has been inferred that there is no capable fault within 5 km radius. As per the recommendations of the Experts Micro-Earth Quake (MEQ) network would be installed at the Site by NPCIL by Oct, 2010.

(vi) KK NPP-3 to 6

NPCIL application seeking consent for locating 4 additional units each of 1000 MWe VVERs (KK NPP- 3 to 6), near KK NPP – 1&2 and associated submissions are under review by Site Evaluation Committee. Most of the issues emanating from the review have been satisfactorily resolved. NPCIL has been asked to submit details towards confirming that there is no capable seismic fault within 5 km radius of the proposed plant location.

(vii) Jaitapur Nuclear Power Project (JNPP)

NPCIL is planning to install 6 units of EPR, each of 1650 MWe PWR (Vendor M/s. Areva, France) at Jaitapur site on Western Coast in Maharashtra. Draft Technical Assignment (TA) document (Part–I: Design and Safety Requirement) for Jaitapur NPP (JNPP) is under review by specially constituted Working Group.

(viii) Demonstration Fast Reactor Fuel Reprocessing Facility (DFRP)

DFRP, a forerunner of the reprocessing facility FRFCF to close fuel cycle of PFBR, is being setup by IGCAR at Kalpakkam. It is divided into 2 concrete cell facilities called Head End Facility (HEF) and Process Plant Facility (PPF). Most of the construction, equipment installation and piping for the PPF had been completed at the time of construction of Kalpakkam Reprocessing Plant. Civil construction of HEF is now in progress.

The Safety Committee has reviewed the various submissions related to the Process, the Process Plant and equipment design, inactive solution management, re-conversion and analytical laboratories.

Some of the salient observations/ recommendations made during the safety review are given below:

- It was recommended that the Re-Conversion (RC) laboratory should have only one entry point through an air lock from radiation zoning point of view instead of two entry points provided in the design.
- All the process vessels in the RC laboratory will be located below the RC boxes and will be provided with a fume hood type enclosure. It was recommended that the area should have provision for maintaining sub-atmospheric pressure.
- It was recommended that criticality safety of the whole plant viz. various tanks, vessels, sumps, lines etc should be reviewed various stages of the process such as transfers of solutions from one tank to another, Pu concentration in individual tanks, instrumented controls on such transfers, transfers controlled by administrative controls etc.
- The designers have analyzed postulated fire incident in process cells and has inferred that such incident will not take place in the absence of source for ignition. The safety committee has recommended further study of this aspect.

(ix) Interim Fuel Subassembly Storage Building (IFSB)

Civil construction of IFSB is nearing completion. Procurement of various materials, instrument, preparations for erection of equipment, etc., are in progress.

The Safety Committee reviewed various topics such as organization structure, commissioning with dummy fuel pins, fire detection system and deliberated on the methodology for further review of the project and regulatory hold points.

(x) Fast Reactor Fuel Cycle Facility (FRFCF)

FRFCF is planned to reprocess the spent fuel of PFBR and to close the fuel cycle. Detailed design of the facility is in progress. IGCAR had submitted an application seeking construction clearance on February 28, 2007 and safety review is in progress.

The Safety Committee reviewed the proposal for the design basis seismic ground motion parameters for various civil structures of FRFCF in detail. Reports on estimation of Tsunami run-up at FRFCF site were also reviewed. IGCAR has carried out additional studies to estimate the effect of sea shore wall constructed at PFBR site, as per recommendation of Safety Committee. Increase in design basis flood level due to postulated event of Tsunami was noticed due to the said shore wall.

2.1.2 Consents/Clearances/ Permissions Issued

KGS-4

- Permission for draining light water from the moderator system (April 6, 2009).

RAPP-5

Clearance for

1. Initial fuel loading in the reactor core (Oct. 28, 2009).
2. HW filling in PHT system (Nov. 8, 2009).
3. Bulk HW addition to moderator system (Nov. 17, 2009).
4. First Approach to Criticality (Nov. 23, 2009).
5. Low Power Phase-B Physics Tests (Nov. 25, 2009).
6. Phase-C Commissioning (synchronization of TG set and operation of plant upto 50% FP) (Dec. 8, 2009).
7. Reactor operation up to 90% FP (February 5, 2010).

RAPP-6

Clearance for

1. Hot Conditioning and Light Water Commissioning (August 07, 2009).
2. Initial fuel loading in the reactor core (Dec. 10, 2009).
3. 20Te HW addition to moderator system (Dec. 10, 2009).
4. HW filling to PHT system of RAPP-6 (January 11, 2010).
5. Bulk Addition of HW to Moderator System (January 16, 2010).
6. First Approach to Criticality (January 23, 2010).
7. Low Power Phase-B Physics Tests (January 25, 2010).
8. Phase-C Commissioning (Synchronization of TG set and operation of Plant upto 50% of FP) (February 25, 2010).

PFBR

- Clearance for Erection of Major Equipment (October 9, 2009).

PFBR Argon Buffer Tank (ABT) being lowered into ABT cell

KAPP-3&4

- Siting Consent for locating two PHWR based NPP Units, each of 700 MWe capacity (May 25, 2009).
- Clearance for Site Excavation (January 15, 2010)

2.1.3 Regulatory Inspections of Nuclear Power Projects

AERB carried out Regulatory Inspections (RI) of the on-going nuclear power projects as a safety audit measure to ensure compliance with the AERB safety requirements and stipulations. The number of RI carried out for various projects is given in Table 2.2.

Table 2.2 :
Regulatory Inspections of Nuclear Power Projects

Site	No. of Inspections
KGS-4	1
RAPP-5&6	2
KK-NPP-1&2	3
PFBR	3
KAPP-3&4	2
RAPP-7&8	1
DFRP	1
IFSB	2
TOTAL	15

In addition, one Special RI of RAPP-5&6 was conducted during January 27-29, 2010. Security Inspections of RAPP-5 and RAPP-6 were carried out on September 30, 2009 and December 8, 2009 respectively prior to issue of clearance for initial fuel loading. AERB Observers were posted during commissioning sub-phases namely, during bulk HW addition to moderator system, First Approach to Criticality (FAC) and Phase-B physics tests of RAPP-5 and RAPP-6.

Some of the important observations/ recommendations made by RI teams are given below:

(i) KGS-4

- It was recommended that Site should ensure that QA internal audits of KGS-4 related activities are carried out in accordance with AERB requirements and approved procedures of NPCIL HQ / Site.
- It was noted that in recent past, in KGS-3, DG exciter windings and certain fuel injection nozzles have shown premature failures and presently DGs are tested monthly at 50% load for half an hour. DG exciters of same design are installed in KGS-4. Site was asked to carry out a comprehensive review of DG exciter failures along with designer and supplier. DGs should be tested periodically at 90-100% of the design rating for one hour.
- It was noted that jockey pump operates for 1.5 hrs and remains off only for half an hour. Site was asked to analyze the operating data to rule out any significant leakages from the system.
- Pitting marks were observed on E-face of some Coolant Channels in FMV (S) and in FMV (N). Site was asked to prepare and submit a consolidated report addressing root-cause for the corrosion marks and corrective actions.

(ii) RAPP-5&6

- In RAPP-5, problems related to laying of cables; viz., mix-up in control and power cable and safety and non-safety related cables, overflowing of cable trays etc. were observed which are deviations from the requirements of IEEE-384. Site confirmed that survey has been conducted for all cable trays and corrective measures were implemented.

- Boron concentration in different banks of Secondary Shutdown System was observed to be different. Site was asked to investigate the reason for large variation and comply with the Technical Specifications for Operations.

- Position indicating limit switches for the valves in the ECCS recirculation line were found to be improperly installed. Site was asked to conduct periodic survey of instrumentation system and take corrective actions, as necessary.

(iii) KK NPP-1&2

- Certain deficiencies (mixing of cables, absence of fire barrier, contact between cable trays and process pipelines etc.) violating IEEE-384 requirements related to cable layout were observed. Site was asked to take actions for rectification of such deficiencies.

- The core barrel axis shift with respect to axis of RPV was found to be more than the specified value. The Passport of RPV has been corrected by manufacturer to reflect these modifications. Site was asked to prepare a document reflecting the clarifications provided by the designers on the effect of shift and re-marking of the axis on RPV, etc. for future reference.

- The containment structures are instrumented with embedded sensors at different locations. Total 377 and 256 sensors were installed in Unit-1 and Unit-2 respectively as per design for monitoring containment behaviour during testing and through out the life of the plant. Some of the sensors are not in working condition. It was recommended that Site should propose a methodology and alternative solution prior to start of test on containment structure of KK-NPP Unit-1 and submit to AERB for review.

- A number of Expansion Bellows (EB) have been introduced in the pipings of the three trains of long term low pressure ECCS system and process water system as a design change. It was recommended that detailed design change note (DCN) for this should be made available and justification for not putting the EB in the 4th safety train is to be provided.

- In Reactor Building – 1, it was observed that the steam generator (SG) support concrete is chipped and reinforcement bars were exposed as the support was fouling during laying of main coolant system pipeline. However, the available gap between the pipeline and SG support was found insufficient to accommodate the pipeline insulation. Also, it was observed that there is less gap between SG and the newly erected metallic support platform. Site was asked to take remedial actions.

(iv) PFBR

- As per preservation procedure, inflatable seals are to be packed and sealed in polythene packets and stored at 25C in AC. room. It was found that polythene packets were not properly sealed and unconditioned air was entering the room. Site was asked to preserve the seals as per the preservation procedure. Also, Site was asked to ensure that all the SS pipes of sodium circuits are preserved properly from the saline atmosphere. The adequacy of storage method of surveillance coupons (Archive samples) of the Core Support Structure (CSS) and core catcher was asked to be checked for its acceptability as these samples need to be stored for the life time of the reactor.

- Site was asked to make permanent arrangement for SF_6 leak detection in 230 kV GIS building.

- Issues concerning quality assurance during construction were deliberated in CESC and it was decided that two tier special audit/inspections would be carried out for PFBR for nuclear island and connected buildings.

(v) KAPP-3&4

- Site informed that water for construction would be available from Moticher pond and the feeder canal and construction water supply would be arranged by the contractor. Site was asked to ensure that necessary clearance from Irrigation Department is obtained.

(vi) RAPP-7&8

- One large gorge of ~ 60-80 m deep and length of ~ 1 km (steep valley type with sharp ridges/shear zones) was seen traversing through the Exclusion Zone (EZ) at ~ 1.9 km distance from RAPP-7&8. Considering the type of this gorge, AERB asked the site to check whether this could be a manifestation of any surface fault.

- Site informed that the Labour colony for construction workers of RAPP-7&8 is proposed at 4.5km away from RB-7&8 in Tamlav village. Site was asked to ensure inclusion of labour colony habitants in off-site emergency exercises at RR Site.

(vii) DFRP

- As per inspection reports of floor lining alignment of active cells, achieved slopes are less than the required value. Site was asked to raise DCRs for the deviation and physically verify the effectiveness of slopes.

- Site was asked to carry out seismic evaluation of waste tank farm.

- Accumulation of radioactive material can take place in off-gas header in the fan room as the header is not terminated smoothly and thus could result in higher radiation levels in the fan room. Also electrical cables were found running beneath these headers which are potentially active. It was recommended to make the header termination smooth and to assess the choice of electrical cables used inside this room in the light of radiation field it can see.

- It was recommended to dig the bore wells around waste tank farm and analyze the ground water to establish base line data well before the commissioning of the plant.

(viii) IFSB

- Site was asked to make provision for manual power off on the hydraulic scissor lift (1 Te capacity) provided to receive/handle fuel pin magazine such that the lift operation can be stopped in case of an emergency like over drive of the platform due to struck drive control switch etc.

- The platform of hydraulic lift on which fuel pin magazine box will be loaded, does not have the mechanical locking/ doors arrangements to restrict pin box movement during transfer. Site was asked to provide mechanical stops on the hydraulic platform.

2.2 NUCLEAR POWER PLANTS AND RESEARCH REACTORS

2.2.1 Safety Review of Operating Plants

AERB carried out the safety review of operating NPPs and Research Reactors. The Safety Review Committee for Operating Plants (SARCOP), the apex committee for safety review of operating plants, held 23 meetings. The Unit Safety Committees (USC) established under SARCOP met a number of times to review safety related issues of individual plants in detail. The number of meetings conducted by various safety committees is given in Table 2.3.

Table 2.3 : Meetings of Safety Committees

Name of the Safety Committee	No. of Meetings during Jan 2009 to March 2010
SARCOP	23
TAPS-1& 2 Safety Committee	12
TAPS- 3 &4 Safety Committee	7
RAPS-MAPS Safety Committee	11
NAPS-KAPS Safety Committee	19
KGS-1to 4 and RAPS-3&4 Safety Committee	12
IGCAR Safety Committee	5
SARCOP-Standing Committee on Reactor Physics	7
SARCOP-Standing Committee on Control & Instrumentation	6
Expert Group on Coolant Channels	3

During the year, a number of applications from the utilities were reviewed and several authorizations/ clearances were issued. Important among them are:

1. Renewal of authorisation for operation of NAPS upto June 2013 (April 28, 2009).

2. Clearance for construction of Additional Away From Rector (AAFR) for spent fuel storage facility at TAPS-1&2 (June 5, 2009).

3. Renewal of authorisation for operation of RAPS–2 upto August 2014 based on periodic Safety Review (PSR) and permission for restart of the unit after en-masse feeder replacement campaign (August 20, 2009).

4. Renewal of authorisation for operation of KAPS-1&2 upto December 2010 (March 30, 2010).

Detailed review of the significant events / incidents that occurred in the Units was carried out. Important among these are:

1. Significant event of consumption of tritium-contaminated drinking water by some plant personnel of KGS-1&2 on November 24, 2009.

2. Events of pin-hole leaks in small diameter tubes connected to the Primary Heat Transport (PHT) system in three Indian Pressurised Heavy Water Reactors (PHWRs) namely MAPS-1, TAPS-3 and TAPS-4, resulting in spillage of heavy water.

The safety status of individual NPPs and research reactors is described below:

(i) TAPS-1&2 and TAPS-3&4

TAPS-1&2 and TAPS-3&4 operated safely during the year.

Clearance for construction of Additional Away From Reactor (AAFR) facility for storage of Spent Fuel of TAPS-1&2

TAPS site has an Away From Reactor (AFR) spent fuel storage facility for storing spent fuel discharged from TAPS-1&2 reactors. This facility was constructed in the year 1990 and designed for storage of 2000 spent fuel assemblies discharged from TAPS. It is now close to its full capacity. In order to provide additional storage space for spent fuel that would be generated during future operation of the reactors, NPCIL has proposed to construct an Additional Away From Reactor facility adjacent to the existing AFR. The capacity of the additional AFR would be for storage of 3500 fuel assemblies, which is sufficient for storage of spent fuel generated in about 35 years of operation of the units. Design of the new facility is generally similar to that of the existing facility. After detailed review of the Preliminary Safety Analysis Report (PSAR) and Application for Construction of the additional AFR facility, AERB granted clearance for construction of AAFR at TAPS-1&2 with validity upto December 31, 2010.

(ii) RAPS-1 to 4

RAPS-1 continues to be under shutdown with all the fuel removed from the core. RAPS-2 was synchronized to the grid on September 1, 2009 after a 26 months long shutdown for replacement of the feeders of primary heat transport system. RAPS-3 and RAPS-4 operated safely during the year.

Authorisation for Operation of RAPS-2

The authorisation for operation of RAPS-2 was valid till May 31, 2007. RAPS had submitted the Periodic Safety Review (PSR) report for RAPS-2 based on AERB Safety Guide on "Renewal of Authorisation for Operation of NPPs" (AERB/SG/O-12) and requested for renewal of authorisation. The preliminary review of the report in AERB had indicated that the performance of the station was generally satisfactory. However, additional submissions were required to address the issues related to revision of safety report, seismic re-evaluation, ageing management and equipment qualification. Pending the submission of these reports, replacement of PHT system feeders, inspections related to ageing management and retrofits related to seismic re-evaluation of the plant, the authorisation was extended initially upto November 2007. However, the unit was shut down for en-mass feeder replacement in July 2007.

During the outage of the unit for en-masse feeders replacement campaign, the required inspections related to ageing management and implementation of the retrofits related to seismic re-evaluation of the unit were carried out. Also, some modifications in safety systems were undertaken during this shutdown, such as:

- Provision of reactor trip on "No Primary Coolant Pump and Shutdown Cooling Pump Running".
- Deletion of isolation valve upstream of relief valve on Emergency Core Cooling System nitrogen / air accumulator.
- Provision of dedicated high pressure instrument air supply to reactor building main supply and exhaust dampers and personnel air lock from the instrument air bullet tank.
- Replacement of Indicating Alarm Meters of Channel Temperature Monitoring System of Installation–II by solid state temperature alarm units.
- Latching provision in logic circuit of fast cool down of PHT system on low inventory in the PHT system storage tank.
- Replacement of electromagnetic switches in 118 V AC control power supply of Auto Transfer Scheme by static switches.

RAPS-1&2 and NPCIL submitted the detailed reports related to inspections, ageing management, seismic re-evaluation, equipment qualification and revised safety analysis of RAPS-2. These submissions were reviewed in detail by the concerned Expert Group / Division of AERB, RAPS-MAPS Safety Committee and SARCOP. After the detailed review, SARCOP noted that RAPS-1&2 / NPCIL has satisfactorily addressed the issues related to PSR of RAPS-2. There is no immediate concern with regard to operation of the plant as brought out in the inspections related to ISI and Ageing Management. The program for Equipment Qualification is in place. Station has implemented the identified retrofits related to seismic re-evaluation. Based on the satisfactory condition of the plant, the authorisation for operation of the plant was renewed upto the end of August 2014.

Restart of RAPS-2 after En-masse Feeder Replacement Campaign

As mentioned earlier, RAPS-2 was under shutdown since July 2007 for en-masse replacement of PHT system feeders. Replacement of feeders was completed in June 2008. During this outage, inspections of major equipments / structures were undertaken for their health assessment. After completion of these activities, RAPS submitted various applications related to restart of the unit-2, viz., commissioning of major systems, fuel loading, first approach to criticality, low power physics measurements, synchronization of the unit to grid,

operation of the unit at high power and raising the power upto 100 % full power. These applications were reviewed in detail in SARCOP and other concerned safety committees. A regulatory inspection of the station was also carried out to check the preparedness for restart of the unit. Based on these reviews, permission was granted for restart of the unit. The stage wise clearances for raising the power up to 100 % full power were given after detailed review of performance at each stage.

(iii) MAPS-1&2

Both the Units operated safely during the year.

Use of Slightly Enriched Uranium Bundles in MAPS–2

In order to establish the programme for optimal utilization of the available uranium resources, NPCIL carried out assessments with regard to use of slightly enriched uranium (SEU) fuel bundles in 220 MWe PHWRs and submitted a proposal for trial irradiation of different types of SEU fuel bundles, viz., (i) 19 element 0.9 wt % U-235 enriched bundles, (ii) 22 element 1.1 wt % U-235 enriched bundles and (iii) 22 element bundle of enriched uranium (2.0 % U-235) & ThO2 in the ratio of 10: 90 wt/wt.. The NPCIL submissions were reviewed in detail by Standing Committee on Reactor Physics (SC-RP) and SARCOP. It was observed that with the large scale use of SEU bundles, as the enrichment goes up, the worth of shutdown systems decreases. This is attributed to reduction in thermal neutron flux for the same operating power. However, sub-criticality margins are still maintained for different shutdown conditions as well as accident scenarios. The evaluations showed that there will not be any problem for irradiation of the SEU bundles and therefore permission was granted for trial irradiation of the SEU bundles.

(iv) NAPS-1&2

NAPS-1 operated safely during the year. NAPS-2 continues to be under shutdown for En-Masse Replacement of Coolant Channels (EMCCR) since December 18, 2007.

Renewal of Authorisation for Operation of NAPS-1&2

The authorisation for operation of NAPS-1&2 was valid till June 30, 2008. Earlier, AERB had extended the authorisation for operation of NAPS upto the end of April 2009, as certain issues arising out of the review of the event of spurious actuation of Instrumented Relief Valve of PHT System in NAPS-1 wererequired to be addressed. To address these issues, NAPS implemented modifications that will give indications for better analysis of the event and assist operator in taking proper decisions during such events. Some of these include:

- Provision to monitor the time of opening of instrumented relief valve.
- Provision of a window annunciation to alert operator in case of failure of the standby server of Control room control System (CRCS).
- Indication in control room for position of bleed condenser level control valves.
- Modification in logic for box-up of bleed condenser.
- Modification in containment box-up logic.
- Modification in emergency operating procedure for the event involving inadvertent opening of instrumented relief valve of primary heat transport system.

Based on the satisfactory review of the above, the authorisation for operation of NAPS-1&2 was extended till the end of June 2013.

Visit of SARCOP to NAPS-1&2 Control Room
(Shri S. S. Bajaj, Chairman, AERB and Shri S. K. Chande, Chairman, SARCOP, are seen in discussion with other members and control room staff)

EMCCR in NAPS-2 and KAPS-1

NAPS-2 and KAPS-1 continue to be under shutdown for EMCCR campaign for replacement of the old Zircaloy-2 pressure tubes with two loose garter springs by coolant channels having pressure tubes of Zirconium-2.5% Niobium material, with four tight fit garter springs. The new coolant channels have a much longer life span as compared to the life span of the Zircaloy-2 channels, owing to lower hydrogen pick up during reactor operation and reduced possibility of movement of the garter spring spacers from their design locations. Taking advantage of this long shutdown, all the feeder pipes of the PHT system have also been replaced. Also, a number of upgradation jobs are being carried out, which will help in enhancing the safety and availability of the units. These activities and results of inspection of plant systems are being closely reviewed and monitored by a special review group of AERB. The units are expected to be ready for restart by September 2010.

(v) KAPS-1&2

KAPS-1 continues to be under shutdown since July 1, 2008 for EMCCR campaign as mentioned above. KAPS-2 operated safely during the year.

Rectification of light water seepage from the calandria vault of KAPS-1

Light water seepage from calandria vault of KAPS–1 was first observed in March 1998. AERB reviewed the status of this seepage periodically and observed that there was no immediate concern with regard to operation of the unit. However, AERB had asked KAPS to resolve this issue during the EMCCR campaign. NPCIL developed a special procedure for carrying out extensive remote inspection of calandria vault for identification of locations of leak. In this regard, a mock-up facility was also established to qualify the procedure for leak search. AERB reviewed the procedure and permitted to carry out leak search. The search indicated leaks at four locations inside the calandria vault. Two of the leaks were detected on lug plate bottom most bolting hole welded plug). The rectification of the leak, as per procedure established on the mock up was carried out from FM vault side by cutting a small portion of fueling machine side octagonal flange of end-shield.

The other two leaky locations are on the weld joint between 'end shield carbon steel ring on the calandria side' and 'Calandria Vault liner plate'. The procedure for repairing these leaks is being finalized. The trials are in progress.

Extension of Authorisation for Operation of KAPS

The authorisation for operation of KAPS-1&2 was valid till July 31, 2009. The application for renewal of authorisation for operation upto July 31, 2014 was reviewed in detail by AERB. The aspects reviewed included operational performance, significant events, radiological performance, status of in-service inspections of plant systems and environmental discharges. The reviews carried out indicated that the performance and safety status of both the units of KAPS has been satisfactory. However, it was noted that during the EMCCR outage, actions were in progress to address some of the issues such as revision of technical specifications for operation, modifications for facilitating online surveillance, installation of qualified fire doors/fire barriers, etc. A detailed review of these issues, including the implementation of modifications, would be taken up again before restart of the unit, which is expected by the end of September 2010. Considering the above, the authorisation for operation of the unit was extended upto the end of December 2010.

(vi) KGS-1&2 and KGS-3

KGS-1, 2&3 operated safely during the year.

Significant event of consumption of tritium-contaminated drinking water by some plant personnel

A significant event of consumption of tritium-contaminated water by some plant personnel from a drinking water cooler occurred in KGS 1&2 on November 24, 2009. This was noticed during the routine urine sample analysis of workers that is carried out regularly at all NPPs that use heavy water as moderator. The affected water cooler was isolated immediately. All other drinking water sources were found free of tritium contamination.

AERB deputed two of its officers to KGS who, along with the plant authorities, investigated the incident. Water tank of the affected cooler, like all other water coolers, was found to be locked. The samples taken from the inlet of the water cooler were found free of contamination. The cooler overflow line was rinsed with 5 ml of fresh water. The analysis of this water showed the presence of tritium activity. The investigations indicated that somebody had deliberately added a small quantity of tritiated heavy water to the cooler, through its overflow tube, possibly from a heavy water sampling vial.

The bioassay samples of all plant personnel were taken and analysed. The personnel found to have received tritium uptake above 2.5 times investigation levels (≥ 10 MBq/l) were referred to the hospital for administration of diuretics (under medical supervision) to quickly get rid of the tritium from the body. The affected persons were also subjected to whole body counting, which indicated that there was no internal contamination other than tritium. Examination of the affected Eighty six persons received tritium uptake above the investigation levels (≥4 MBq/l).

Individual dose of 14 persons exceeded the respective investigation level (monthly/ quarterly/yearly). Only two persons were having tritium in their body that could cause their cumulative annual radiation exposure to exceed the AERB specified limit of 30 milli-sievert (mSv). The expected doses to these individuals are 38.95-mSv and 33.95-mSv.

After the incident, station identified the possible sources of the tritiated heavy water which could have been used for contamination of the drinking water and took actions to control them to prevent such events. Similar actions were taken at other NPPs also.

(vii) RAPPCOF

RAPPCOF had undertaken a project for augmentation of Cobalt Handling Facility to facilitate processing of increased quantities of Co-60 and to fabricate sealed sources in their final form. AERB had granted permission for processing of one batch of Co-60 in this new facility on trial basis. Subsequently, the performance of the operation of this trial batch was

reviewed and permission was granted for regular operations at the facility.

Investigation of the reported high radiation exposure of four workers at RAPPCOF

During the processing of TLDs (device used for monitoring radiation dose to personnel), the exposure of four departmental workers at RAPPCOF for the month of February 2009 was found to be in the range of 129.65 mSv to 141.35 mSv. The monthly doses measured by the independent and redundant Electronic Personal Dosimeters (EPD) / alarm dosimeter were in the range of 0.21 to 1.08 mSv. AERB constituted a Committee for investigation of the event. The investigations revealed that the individuals under investigation were involved in routine activities during this period and therefore the exposure indicated by the TLDs was not in-line with the exposure expected. The detailed investigations indicated that the exposure recorded in the TLDs could be the result of some mischief, wherein the TLDs were deliberately exposed to a source of radiation.

The chromosomal aberration (CA) test done on these persons indicated absence of dicentrics in the case of three persons confirming that they had not received such exposures. For the fourth person, as the CA test indicated a small number of dicentrics, the possibility of him not receiving the exposure could not be ruled out. The experts in the field of dosimetry through CA test opined that the observed dicentrics are so low that no conclusion could be drawn on the basis of these observations. Under such conditions, only the circumstantial investigation should be considered for assigning of the dose to individual. Based on the opinion of the experts and the investigations carried out, AERB decided to assign the DRDs readings to these individuals. RAPPCOF was advised by AERB to take concrete steps to prevent misuse of TLDs and secure access to radioactive materials present at the site.

(viii) Indira Gandhi Centre for Atomic Research

Fast Breeder Test Reactor (FBTR)

The 15th irradiation campaign of FBTR that started on December 6, 2008 was completed on May 27, 2009, when the lead fuel sub-assembly attained the stipulated burn-up of 165 GWd/t. The performance of unit during the 15th irradiation campaign was satisfactory. The 16th irradiation campaign was started on December 25, 2009 to complete the Irradiation of PFBR test fuel Sub Assembly and to continue the irradiation of structural material (D-9). The core for 16th irradiation campaign had 49 fuel sub-assemblies including seven fresh subassemblies. During the start-up, the shutdown margin was observed to be lesser than the expected value. This involved a reactivity anomaly that exceeded technical specification limit. The operation of the reactor was suspended for further investigations. A Task Force, constituted by Director, Reactor Operation & Maintenance Group, IGCAR carried out detailed investigations involving rechecking refueling operations, the theoretical evaluations, experimental measurements and additional analytical evaluations of various aspects affecting core reactivity. Through the investigation and assessments of the Task Force, the source of the anomalies seen during the start-up of 16th campaign could be reasonably established. The report of the Task Force and the revised proposal for 16th campaign of FBTR were reviewed in detail by AERB and permission was granted for 16th irradiation campaign of the reactor.

KAMINI

KAMINI reactor remained operational for conducting various irradiation and neutron radiography experiments.

2.2.2 Regulatory Inspections

During the period of the report, a total of 32 inspections were undertaken of which 30 were scheduled inspections and two were special inspections.

A special inspection was carried out to observe the activities during the Integrated Leakage Rate Test at NAPS-1.

Another special inspection was conducted following the significant event of tritium uptake by personnel at KGS-1&2.

The observations made during the routine regulatory inspections are categorized as follows:

Category: I	Deviations from Technical Specifications and other regulatory requirements/ stipulations.
Category: II	Deficiencies and degradations in Systems/ Structures/Components of Safety and Safety Related systems and deficiencies in important procedures to meet the technical specifications & reporting criteria
Category: III	Shortcomings identified in the design of Safety, Safety related and Safety support systems, based on operating experience including generic deficiencies.
Category: IV	Procedural inadequacies.
Category: V	Observations on housekeeping and departure from good practices.

Category wise distribution of observations in different plants during the period January to December 2009 and January to March 2010 are given in Tables 2.4.a & 2.4.b respectively.

The data on regulatory inspections and licensing of operating personnel was earlier being reported on a calendar year basis. Henceforth this will be reported for the financial year (April-March). In view of this change, the present report includes data for the calendar year 2009 (tables 2.4a and 2.5 a) and for the period Jan-Mar 2010 (2.4 b & 2.5 b) separately.

Table 2.4.a: Categorization of Deficiencies Observed during Regulatory Inspections (January to December 2009)

Unit	Number of Inspections		Cat. I	Cat. II	Cat. III	Cat. IV	Cat. V	Total
	Planned	Special						
TAPS-1&2	2	0	0	3	1	18	48	70
TAPS-3&4	2	0	0	7	8	50	2	6
RAPS-1&2	2	0	0	3	6	48	2	59
RAPS-3&4	2	0	0	2	8	33	0	43
MAPS-1&2	2	0	0	1	8	62	3	74
NAPS-1&2	2	1	0	12	5	43	4	64
KAPS-1&2	2	0	0	12	6	35	7	60
KGS-1&2	2	1	0	6	7	36	10	59
KGS-3&4	2	0	0	6	2	28	17	53
RAPPCOF	1	0	0	0	0	0	0	0
FBTR & KAMINI	1	0	0	3	8	23	0	34
Radio Chemistry Lab	1	0	0	0	0	0	0	0
Radio Metallurgy	1	0	0	0	0	0	0	0
LEAD MINI CELL A,B,C	1	0	1	2	3	17	5	28
FRTG	1	0	0	0	0	0	0	0
Total	24	2	1	57	62	393	98	611

Table 2.4.b: Categorization of Deficiencies Observed During Regulatory Inspections (January to March 2010)

Unit	Number of Inspections		Cat. I	Cat. II	Cat. III	Cat. IV	Cat. V	Total
	Planned	Special						
MAPS-1&2	1	0	0	3	5	27	4	39
FBTR & KAMINI	1	0	0	0	0	0	0	0
RAPS-3&4	1	0	0	0	7	16	17	40
RAPS-1&2	1	0	0	1	3	34	0	38
KGS-1&2	1	0	1	0	0	5	15	21
KGS-3	1	0	0	1	3	22	3	29
Total	6	0	1	5	18	104	39	167

Some of the salient observations made during the Regulatory Inspections during January 2009 to March 2010 are as follows:

1) Modification in the Startup Procedure for ensuring the Availability of ECCS during Reactor Criticality- RAPS-3&4

As per the hot pressurization scheme of PHT system, the temperatures and pressures of the PHT system water are raised in steps in the regime so as to avoid brittle failure of the coolant channels. In view of the limited data available on strength of coolant channels, this scheme was followed in all NPPs as a conservative approach. The drawback of this scheme is that the Emergency Core Cooling System (ECCS) has to be kept in blocked condition during reactor start-up to prevent its actuation during raising of PHT system pressure. The revised analysis carried out by NPCIL has indicated that the pressure of the system can be increased to substantial levels at ambient conditions, without affecting the integrity of the coolant channels. In this regard, NPCIL had submitted a proposal for cold pressurization of PHT system. The cold pressurization of PHT system reduces the time for restart of the reactor and will also facilitates taking ECCS into service before making reactor critical. AERB had agreed to cold pressurization of PHT system in the reactors having Zirconium – 2.5 % Niobium (Zr-Nb) pressure tubes with closed annulus system. During the RI of RAPS-3&4, it was noted that the reactor start up procedure did not prevent the reactor being made critical with ECCS in blocked condition, even after implementation of cold pressurization scheme. NPCIL was asked to issue instructions to ensure that in such reactors, ECCS is taken into service before making reactor critical.

2) Design provision for Light Water Injection to PHT System in case of Blind LOCA in KAPS & NAPS

ECCS in PHWRs involve a high pressure heavy water injection phase followed by intermediate and low pressure light water injection. The light water injection is controlled by a 'conditioning signal' to ensure that it actuates only in case of generic LOCA (Loss of Coolant Accident) events. A design feature for manually actuating the light water injection under certain conditions is provided in the reactors built subsequent to KAPS. At NAPS and KAPS, such design provision does not exist. However, the system can be actuated by following certain administrative steps. During the RI of NAPS, it was observed that the written procedure for handling such condition was not available. Based on the recommendation of RI, an emergency operating procedure has been prepared for such condition. NAPS and KAPS have also been asked to make design provision in control room for actuation of light water injection into PHT system.

3) Reactor Building Containment Leak Test in RAPS-2

During the containment leak test in RAPS-2, the observed leak rates from main air lock, personnel air lock, and reactor building isolating dampers were well within the acceptable limits. However, the leak rate from containment was observed to be nearing the allowable limits. Station was asked to strengthen the integrity of the containment.

4) Observation regarding Fire Water System at RAPS-1&2

At RAPS-1&2, corrosion of the fire water system piping was observed at the entry / exit location of the buried section. A few of such pipe portions have been replaced with new pipes. The regular surveillance program of the station does not cover these piping. Station was asked to formulate a surveillance program for regular monitoring of the health of these pipes.

5) Use of Fire Water for Cooling Requirements

In RAPS-2, fire water was being used as main source of cooling water to some of the process systems, such as compressors cooling water system, lubrication water supply to condenser cooling water (CCW) pumps, etc., as the capacity of fire water system is able to cater to these auxiliary supplies also. However, as per design, the fire water system is not the main source of cooling water to the process system. Station has been asked to review the practice of using fire water for normal cooling requirements for process system in consultation with the designers.

6) Surveillance of the Logic for Reactor Set Back in TAPS-3&4

Liquid Zone Level Control is one of the systems used for reactor power regulation in TAPS-3&4. During the RI of TAPS-3&4, it was observed that the surveillance of the logic related to reactor set back on 'more than two liquid zone level control not available' is not specified in the Technical Specifications. Station was asked to implement a test scheme for this logic and include the surveillance requirement inthe Technical Specifications.

7) Modifications/Repairs in Supports of Emergency Fire Water Piping to Steam Generators in KGS-3&4

There was an event of reactor trip on pump room pressure high in RAPP-5 due to leak from fire water injection line to steam generator. The detailed investigations indicated that one of the contributors to the event was the improper layout and supports on this line. In this regard, NPCIL was asked to review the layout and supports of the piping at all NPPs. During the survey of the pipe routing and support installation for emergency fire water injection line to steam generator at KGS-3&4, it was

observed that at a few locations, pipe supports and pipe anchors do not conform to the design drawings. Station was asked to take necessary corrective actions to rectify these deficiencies.

2.2.3 Licensing of Operating Staff

The number of operating personnel, who were licensed from various nuclear power plants and nuclear power projects during the calendar year 2009, is tabulated in Table 2.5.a. In addition, for the operation of FBTR, one person was licensed for the position of Junior Shift Engineer and two persons were licensed for the position of Control Room Assistant / Field Supervisor. One person was licensed for the position of Shift In-charge, KAMINI. Also four persons were licensed for the position of Shift Engineer at CORAL, IGCAR.

Table – 2.5.a Licensing of Operating Staff (January-December 2009)

Plants	No. of Persons Licensed					Licensing Committee Meetings
	SCE	ASCE	ASCE(F)	CE	CE (F)	
TAPS-1&2	3	6	-	6	-	3
TAPS-3&4	-	6	3	9	1	2
RAPS-1&2	6	6	1	7	-	2
RAPS-3&4	7	11	2	16	5	3
RAPS-5&6	-	2	-	5	3	3
MAPS	3	5	-	4	-	2
NAPS	4	3	-	3	1	2
KAPS	-	2	3	6	2	2
KGS-1&2	4	3	2	10	2	2
KGS- 3&4	-	4	1	4	1	2
Total	27	48	12	70	15	23

The number of operating personnel, who were licensed from various nuclear power plants during the period January to March 2010, is tabulated in Table 2.5.b. In addition to these, one Senior Shift Engineer (Level-II), one Junior Shift Engineer (Level-III) and three Control room Assistants / Field Supervisors (Level-IV) were licensed / re-licensed for FBTR operations and one person was licensed / re-licensed as Shift In-charge, KAMINI.

Table – 2.5.b Licensing of Operating Staff (January-March 2010)

Plants	No. of Persons Licensed					Licensing Committee Meetings
	SCE	ASCE	ASCE(F)	CE	CE (F)	
RAPS-1&2	3	1	1	1	-	1
RAPS- 3&4	-	1	1	4	1	1
RAPS-5&6	-	3	1	2	1	2
MAPS	4	1	1	4	2	1
RAPS-5&6	2	3	1	4	1	1
KGS-1&2	6	6	8	2	1	1
Total	15	15	8	17	6	7

Management Positions: Six persons have been qualified for the management positions at various NPPs.

2.2.4 Significant Events

The events reportable to the regulatory body are divided into two categories, termed as, (a) Events and (b) Significant Events, depending on the importance to operational safety experience feedback and safety significance of the event.

The SERs received from the operating NPPs are also rated on the International Nuclear Event Scale (INES). The INES system of the International Atomic Energy Agency (IAEA) rates events at seven levels (1 to 7) depending on their safety significance. Events rated at level 4 and above are termed as Accidents. Events rated at level 1, 2 and 3 are called Incidents. Events with no safety significance are rated at level 0 or below scale. Security-related events or malicious acts are not in the scope of the scale. The IAEA-INES scale is depicted at the end of the report.

A total of 23 significant events have been reported from NPPs in the year 2009. Out of these, 23 events were rated at level zero. The system wise classification of the SERs at NPPs is given in Figure-2.1. The classification of SERs on INES scale is given in Table 2.6. The numbers of SERs in NPPs during the last five years and their ratings on INES scale are given in Table 2.7.

Table 2.6 Classification of SERs in individual NPPs (2009)

Plant Name	International Nuclear Event scale					
	0	1	2	3	>3	TOTAL
TAPS-1&2	0	0	0	0	0	0
RAPS-1&2	1	0	0	0	0	1
MAPS-1&2	2	0	0	0	0	2
NAPS-1&2	2	0	0	0	0	2
KAPS-1&2	2	0	0	0	0	2
KGS-1&2	1	0	0	0	0	1
RAPS-3&4	4	0	0	0	0	4
TAPS-3&4	9	0	0	0	0	9
KGS-3	5	0	0	0	0	2
Total	23	0	0	0	0	23

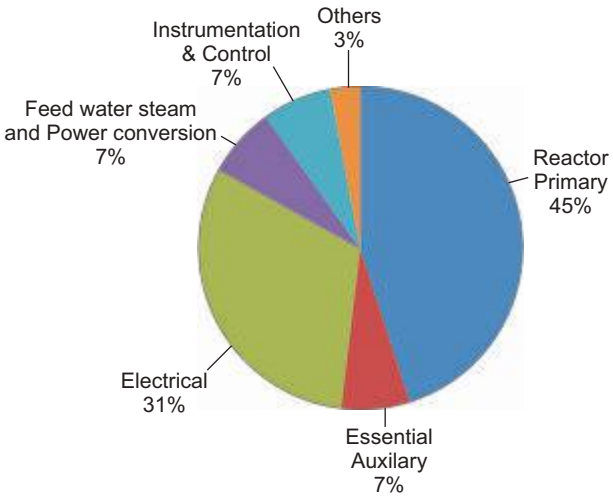


Fig. 2.1
System wise Classification of SERs (2009)

Table 2.7 Classification of SERs in NPP as rated on INES for the last five years

INES levels	2005	2006	2007	2008	2009
0	26	34	38	28	23
1	2	5	8	4	0
2	0	0	0	0	0
3	0	0	0	0	0
>3	0	0	0	0	0
TOTAL	28	39	36	24	23

Important events in NPPs

During the period from January to March 2009, there were three significant events of pin-hole leaks of heavy water from the PHT system tubings in MAPS-1, TAPS-3 & TAPS-4. The considerable period of interference of the tubings with adjacent PHT components such as feeders, MI cable of RTD and the impulse tubings of various instrumentation had resulted in fretting damage of these tubes. Subsequent to these events, all operating/under construction NPPs instituted a comprehensive programme to ensure adequate gap among PHT system components.

2.2.5 Reorganization of Health Physics units at NPPs

Since inception of nuclear power programme in India, the Health Physics Division (HPD) of BARC had been providing support for implementing radiological safety measures in NPPs. The HPD has been discharging its functions through Health Physics Units (HPU) established at the NPPs. The radiological safety support rendered by HPD for these NPPs included operational health physics aspects namely control of personnel radiation exposures, effluent discharges and radiological conditions within the NPP. In addition, the HPD has been responsible for carrying out environmental surveillance around the NPPs, through the Environmental Survey Labs (ESL). HPD has also been providing periodic reports to AERB, on radiological safety status of the operating NPPs, which is an important input to AERB's for regulatory surveillance.

Over the years, HPD, BARC has taken a number of steps in developing adequate human resources having experience and expertise required for satisfactory functioning of these HPUs. The HPD has established a regular programme for training and retraining of personnel for handling the radiological safety support functions. The experience of performing these functions over the years has helped in streamlining the related procedures, administrative controls and infrastructure requirements.

Presently with the growth in the number of NPPs in the country, and the projections for future expansion it is imperative that the radiological safety support for the NPPs would involve commitment of significant manpower and resources. After considering these aspects, the Department of Atomic Energy has decided that as a policy the discharge of operational health physics functions at the NPPs should henceforth be the responsibility of the Nuclear Power Corporation of India Ltd (NPCIL), who is the owner and operator of these NPPs. The regulatory and audit functions will be carried out by AERB.

Pursuant to this, a newly set up Environment Group in the Safety Directorate of NPCIL is responsible for fulfilling the operational health physics functions, through the HPUs at the NPPs. The human resources and infrastructure for this should be the responsibility of NPCIL. In this arrangement, the plant management has the primary responsibility for discharging the radiological safety functions. This organizational arrangement is in line with the practice followed in many countries having NPPs. The Environment Group is also responsible for submission of periodic reports on radiological safety of the plants to AERB.

In order to further strengthen the regulatory controls and audit of aspects related to the operational health physics at the NPPs, AERB intends to enhance the Regulatory Inspections and institute closer surveillance on aspects related to radiological safety aspects in the operating plants. Towards this, AERB is taking steps to augment its man-power having experience in radiological safety assessment.

The Atomic Energy (Radiation Protection) Rules – 2004 and the Atomic Energy (Safe Disposal of Radioactive Wastes) Rules – 1987, specifies the requirements for safety. One of these requirements pertains to designating 'Radiological Safety Officers' (RSO), for the radiation installation. The RSO is a 'legal entity' having responsibilities with respect to discharge of functions and regulatory reporting, as specified in the above rules. Towards strengthening the regulatory controls, AERB has asked all the NPPs to designate RSOs at the NPPs, by following a specified procedure. As per this, the process of designating the RSOs for all the NPPs has been completed.

2.3 FUEL CYCLE FACILITIES AND R & D UNITS

Review and monitoring of safety status of fuel cycle facilities and other nuclear facilities are carried out by Industrial Plants Safety Division (IPSD) of AERB. A three-tier review process is followed for granting consent for major stages for large facilities of nuclear fuel cycle. For other facilities, a two- tier review process is followed with first review being conducted by Design Safety Review Committee (DSRC) or respective Unit Safety Committee (USC) of the operating facility. Safety review of the operating plants is carried out by USC and SARCOP. The nuclear fuel cycle facilities and R&D units are as given below.

- Nuclear Fuel Complex (NFC), Hyderabad and Zirconium Complex, Pazhayakayal, Tamil Nadu.
- Heavy Water Plants (HWP) at Baroda, Talcher, Thal, Hazira, Manuguru, Tuticorin and Kota.
- Uranium Corporation of India Ltd. (UCIL), comprising mines at Jaduguda, Bhatin, Narwapahar, Turamdih,

Banduhurang, Bagjata, Mohuldih, Tummalapalle and Gogi and mills at Jaduguda and Turamdih.

- Indian Rare Earths Limited (IREL) plants at Udyogamandal, Manavalakurichi, Chatrapur and Chavara and Indian Rare Earths Research Centre-Kollam.
- Electronics Corporation of India Ltd., Hyderabad.
- Atomic Minerals Directorate for Exploration and Research (AMD), Hyderabad.
- Beach Sand Minerals Facilities at various locations.

Highlights on safety status and reviews, regulatory inspections and licensing of personnel carried out with respect to the above facilities are given below. The industrial safety aspects of these facilities are discussed in Chapter 4.

2.3.1 Safety Review

(i) Nuclear Fuel Complex (NFC)

All the plants of NFC, Hyderabad operated safely during the year. After ensuring satisfactory compliance to the safety requirements, following proposals were approved.

- The operation of scrap chlorination plant in rehabilitated Zirconium Sponge Plant (ZSP) building.
- Restart of operations in the wet section of uranium oxide plant.
- Construction of New Oxide Chlorination Facility at NFC, Hyderabad.
- Renewal & amendment for authorisation of safe disposal of radioactive waste under GSR-125 for New Uranium Oxide Fuel Plant (NUOFP).
- The commissioning of Oxide Production & Sponge Production Facilities at Zirconium Complex, Pazhayakayal.

The safety related unusual occurrences are now reported as significant events. A brief description of Significant Events that took place at NFC are as below,

- On May 26, 2009 an incident of explosion of nitric acid bottle occurred in the Control Laboratory. The maintenance personnel for the purpose of cleaning used the nitric acid sampling bottle for carrying acetone/ethyl alcohol and the same was kept back on the platform of the lab. As per the practice followed, the left out nitric acid after sampling is poured into a larger bottle by the lab personnel. During the incident the same practice was followed and the lab personnel accidentally poured acetone/ethyl alcohol into the larger nitric acid storage bottle, assuming the content of the bottle as nitric acid, which was not true. A violent reaction occurred between the nitric acid and acetone/ethyl alcohol. After hearing the hissing sound due to reaction, the lab personnel ran away from the area. There was damage on tube light fixtures and other lab chemical bottles due to the incident. However, no person was injured in this incident.
- On May 27,2009 an incident of contamination of water in the overhead tanks of New Uranium Oxide and Fuel Fabrication Plant (NUOFP) took place. A temporary hose connection was provided to the solvent treatment vessel from the service water line of the overhead tanks. During the incident there was no service water supply from the utility section as a result of which, water got siphoned from the solvent treatment vessel to the service water line resulting in the contamination of the overhead water tanks. The overhead tanks cater services to change rooms and drinking water coolers. During construction stage of the plant, service water pipe line connection was wrongly provided to the overhead tanks. NFC has isolated service water supply to overhead tanks and provided dedicated drinking water pipeline to the overhead tanks of NUOFP for change rooms.

These significant events were reviewed in detail by the safety committee and SARCOP and measures to prevent recurrence of such incidents in future, were recommended.

(ii) Heavy Water Plants (HWPs)

The Heavy Water Plants (HWPs) at Thal, Baroda, Hazira, Kota, Manuguru and solvent facilities at Talcher operated normally. HWP-Tuticorin remained under shutdown due to non-availability of synthesis gas from M/s SPIC.

The following important proposals/ safety issues were reviewed in the Heavy Water Plants Safety Committee (HWP-SC), Design Safety Review Committee for Diversified Projects (DSRC-DP) and Uranium Extraction Project (DSRC-UEP), Advisory Committee for Project Safety Review for Fuel Cycle Facilities (ACPSR-FCF) and SARCOP and after ensuring satisfactory compliance to the safety requirements, the following clearances/authorizations/approvals/renewal of Licenses were granted/given.

- The renewal of Licence for operation of HWP-Thal for five years.
- Authorisation for discharge of limited quantity of ash into Ash Pond –1 at HWP, Manuguru.

- Clearance for revamping the instrumentation system with 'Distributed Control System (DCS) and Programmable Logic Controllers (PLC)' of HWP-Kota by replacing the existing pneumatic instrumentation system.

- Consent for commissioning of Heavy Water Clean-Up (HEWAC) Facility at HWP-Kota with non - active feed and without cold box in line.

- Construction clearance for installation of 'Dry Fly Ash Collection, Segregation and Storage Facility (DFACS) at HWP-Manuguru.

- Consent for commissioning of Technology Demonstration Plant (TDP) of Heavy Water Board at RCF, Chembur, Mumbai.

- Approval of 'Site Emergency Preparedness Plan of HWP-Manuguru'.

- Consent for commissioning of Tri-Butyl Phosphate Plant (TBP) at HWP-Baroda.

- Consent for commissioning & operation of Versatile Solvent Production Plant (VSPP) at HWP-Talcher.

- Consent for commissioning & operation of Elemental Boron Plant (EBP), at HWP- Manuguru.

The significant events that took place in the HWPs are discussed below,

- On September 11,2009, an incident of fall of one coal filled bucket from the bi-cable aerial ropeway system on the road protection bridge took place at HWP-Manuguru. The aerial coal transportation is done from Singerini Collieries Company Ltd. (SCCL) to the Captive Power Plant at HWP (Manuguru) through a bi-cable ropeway system. During the operation of the aerial ropeway system, one bucket from full loaded side got derailed in between trestle no. 52 & 53 and fell down on the road protection bridge. The coal from the bucket got spilled on the bridge and small quantity on the road below. No person was injured in this incident.

- On September 22,2009 an incident of fall of a newly installed electric wire rope hoist (10 MT capacity) took place at TBP project site, HWP-Baroda. The incident took place during the conduct of preliminary test by the site contractor. The hoist fell down with the test load during lifting of the trial load up to 1.5 m height. No person was injured in this incident.

These significant events were reviewed in details by the safety committee and measures to prevent recurrence of such incidents in future, were recommended.

(iii) Uranium Corporation of India Limited (UCIL)

Jaduguda, Bhatin, Narwapahar, Turamdih, Banduhurang mines and Jaduguda mill were under normal operations and Turamdih Mill commissioning activities were under progress. Development work at Bagjata, Mohuldih, Tummalapalle and exploratory mining at Gogi were in progress. UCIL Safety Committee (USC), DSRC-UEP and ACPSR-FCF reviewed the following proposals of the UCIL mines/mills for granting clearances.

- The proposals for the production of uranium peroxide as final product (instead of magnesium di-uranate at Jaduguda mill), operation of Bagjata mine, enhancement of production capacity of Jaduguda mill and expansion of Jaduguda ore processing plant are under review.

- The application for construction consent of Uranium Ore Processing Plant at Tummalapalle Site is under review.

- Commissioning activities at Turamdih mill is under progress. The difficulties faced during the commissioning have been reviewed by the safety committee. The compliance to the stipulations of AERB with respect to the incident of outflow of liquid from decant water pond and the check dam at the downstream of Turamdih tailings pond that occurred in June 2008, were reviewed by the safety committee and ACPSR-FCF. Accordingly, the repair work of the decant water pond, strengthening work of the check dam, the construction of garland drain and road at northern side of the tailings pond have been completed and at southern side it is nearing to completion. Based on the review of the commissioning status, authorisation for commissioning of Turamdih Mill of UCIL was extended up to August 31, 2010.

- The mine development status of Tummalapalle mine and mill and Gogi mine were reviewed.

A significant event that took place at Turamdih Mill of UCIL is discussed below:

On November 29, 2009 a significant event leading to amputation of hand of a contractor's helper occurred near the reversible conveyor belt at the top floor of lime plant at Turamdih Mill. The incident took place while carrying out the rectification of slippage in the conveyor belt by making the surface rough by welding. While carrying out the job, the right hand of the helper got trapped in between the pulley and the conveyor. The above significant event was reviewed by the safety committee and measures to prevent recurrence of such incidents in future, were recommended.

(iv) Indian Rare Earths Limited (IREL)

The IRE plants at Chavara, Manavalakurichi, Chatrapur and Udyogamandal operated safely. Beach Sand Minerals Safety Committee and SARCOP reviewed the industrial and fire safety and radiological safety status of the following proposals of the IREL plants for clearance.

- The proposal for setting up a new Slurrying Plant for processing of thorium concentrates from Silo 6 at IREL, Udyogamandal was reviewed. It was agreed for construction of the plant with certain stipulations.
- The proposals for thorium oxalate storage and disposal of other radioactive waste of Monazite Processing Plant (MoPP) in RCC trenches at IREL OSCOM and monazite processing through sulphuric acid route in pilot plant were under review. Status of construction of trenches at IREL OSCOM for storage of thorium oxalate in slurry form were reviewed.
- Based on the review of structural stability aspects of Material Processing Plant (MPP) of IREL, Udyogamandal, IREL was directed to stop the plant operations in the grid 5-9 sections of MPP in view of certain corrosion related problems in the civil structures of the plant and ageing of structures. Subsequently, IREL, Udyogamandal submitted the proposal for restart of the plant operations in grid 1-5 of MPP. This was reviewed by the safety committee and SARCOP. SARCOP agreed for resumption of the plant operations in the area between grid 1-5 of the plant till March 2010.

(v) Beach Sand Minerals Facilities (BSM)

A notification on the requirement of licensing of beach sand minerals facilities by AERB was issued for publication in the Gazette of India. Based on the discussion with representatives of Federation of Indian Placer Minerals Industries, the licensing procedure under the Atomic Energy (Radiation Protection) Rules, 2004 was revised.

Licenses were issued by AERB to ten private beach sand minerals facilities producing ilmenite, rutile, zircon, sillimanite and garnet with validity upto five years.

(vi) Atomic Minerals Directorate for Exploration and Research (AMD)

The exploratory mining activities including establishment of ventilation system at Gogi underground uranium mine in Gulbarga district, Karnataka by AMD were in progress. The status of the exploratory mining activities and the ventilation system were periodically reviewed by AERB.

2.3.2 Regulatory Inspections

Regulatory Inspections on industrial and fire safety aspects under the Atomic Energy (Factories) Rules – 1996, radiological safety aspects under the Atomic Energy (Radiation Protection) Rules, 2004 and waste management aspects under the Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987 were carried out. The major recommendations made were as follows:

(i) Fuel Cycle Facilities (FCF)

- At HWP-Baroda, it was recommended to improve the capacity of Class–I battery bank to meet the designed intent.
- At IREL-Udyogamandal, it was recommended to make the roof extractors at material processing plant functional for effective exhaust of the vapours.
- At IREL, Manavalakurichi, it was recommended that the workers of sillimanite section should be provided with an occupancy area where the radiation level is same as background radiation level.
- At UCIL, it was recommended to issue personal dosimeters to all mine workers and to carry out radium body burden measurement for all UCIL mines workers.
- AT, NFC, Hyderabad Zirconium Oxide Plant, it was recommended to keep the records of all surveillance tests carried out as per technical specifications.

(ii) Beach Sand Minerals Facilities

Regulatory inspections were carried out at Non-DAE Beach Sand Minerals Facilities with respect to radiological safety aspects. The major recommendations arising out of regulatory inspections made were as follows:

- AERB approved radiological safety officer (RSO), shall be available in the facility.
- Radiation monitoring at various locations of the plants should be carried out once in a month.
- The monazite-enriched tailings should be properly packed during transportation to avoid any spillages on road and the collection area should be cordoned off and radiation caution board should be displayed to avoid unnecessary occupancy.
- Use of dust masks while handling monazite-enriched tailings should be strictly ensured.
- The storage location for sub-graded mineral should be identified; barricaded and adequate care should be taken during transportation of the middling.

- Radiological dose estimation of the workers should be carried out and records shall be maintained.

- Monazite content in the raw material, products & monazite-enriched tailings should be measured and records shall be maintained.

2.3.3 Licensing of Operating Personnel

- Licensing Committee for licensing of operating personnel for Heavy Water Plants met at HWP- Thal, Hazira, Baroda, Manuguru and Kota authorised/ re-authorised 96 operating personnel.

- Authorisation of 9 operating personnel of NFC-Hyderabad was done by a local committee of NFC, which included a member from AERB.

- Authorisation of 25 operating personnel of Technology Demonstration Plant (TDP) at RCF, Mumbai was done by a local committee of TDP, Heavy Water Board, which included a member from AERB.

- Authorisation of 25 operating personnel of Indus 2, RRCAT, Indore was done by a local committee of RRCAT, Indore, which included a member from AERB.

2.4 OTHER FACILITIES

2.4.1. Variable Energy Cyclotron Centre (VECC)

The existing cyclotron (K-130) was under shutdown for up-gradation. In Super Conducting Cyclotron (K-500), commissioning of the Radio Frequency (RF) system was under progress. In Radioactive Ion Beam Facility, phase wise testing of stable beam operation was in progress. In Medical Cyclotron Facility, construction work was under progress. The major proposals of these facilities under review by VECC-RRCAT Safety Committee (VRSC) were as follows:

- Proposal for retrofitting measures for seismic up-gradation of the Super Conducting Cyclotron building was reviewed. The original design of the Super Conducting Cyclotron building was carried out following IS1893: 1984. Based on the review of the design basis report of the building by C&SED, AERB, safety committee had asked VECC to carry out analysis for determining the seismic response of the building and ascertain the design adequacy of the structural elements. Based on the recommendations of the safety committee, an analysis was conducted and certain design inadequacy with respect to seismic safety was noted. Hence, it was decided that the building needs seismic up-gradation adopting suitable retrofitting measures. The action plan addressing the issue of seismic qualification of the building was reviewed by VRSC and SARCOP. SARCOP after detailed deliberations on the retrofitting schedule and the proposed commissioning schedule agreed to grant permission for commissioning of the machine till stage –VI (i.e transportation of the beam to Channel #3 of cave-2) with periodical review by VRSC. The permission for the final commissioning stage i.e stage VII would be subject to completion of the seismic retrofits and review by AERB.

- Proposal for a separate building for radioactive ion beam facility at VECC, Kolkata.

During regulatory inspection of VECC, it was recommended to ensure that the cable layout in the High Bay area of Super Conducting Cyclotron are reviewed and approved by the local safety committee, to provide regular supervision at medical cyclotron construction site and to provide fire detection and fire fighting system at Regional Radiation Medical Centre (RRMC), Thakurpukur site (a unit of VECC).

2.4.2 Raja Ramanna Centre for Advanced Technology (RRCAT)

Indus-1 was operating at 450 MeV beam energy and 100 mA current. 10 MeV LINAC (Linear Accelerator) is under shutdown due to non-availability of electrode gun. The industrial and fire safety and radiological safety status of the following proposals of the RRCAT were reviewed for clearance.

- Licence for operation of 750 keV DC accelerator at RRCAT Indore using SF6 gas as insulator was granted in October 2009 with validity for 5 years.

- The proposal for construction clearance of Agricultural Radiation Processing Facility (ARPF) at Choithram Mandi, Indore was reviewed and construction clearance was issued.

- The proposal for trial operation of Free Electron Laser (FEL) Linac for Stage 3, 4, and 5 for two years was reviewed by the safety committee and recommended consent for trial operations with certain stipulations.

- Licence for operation of 10 MeV & 10 kW Electron Linear Accelerator at RRCAT Indore was issued after review by the safety committee with validity for three years.

- Proposal for trial operation of Indus-2, RRCAT at 2.5 GeV with 100 mA stored beam current and status of beam lines of Indus-2 were reviewed by the safety committee and SARCOP and accordingly a consent for commissioning of Indus-2 with 2.5 GeV beam energy and 300 mA in steps of 100 mA beam current was issued by AERB.

In view of an fatal incident that occurred at construction site of substation at RRCAT, Indore (refer Chapter 4, para 4.1.), AERB recommended RRCAT to improve the industrial safety status of the facility and adhere to the safety requirements during construction as per notification issued by AERB in November 2004.

2.4.3. Electronics Corporation of India Limited (ECIL)

A fire incident took place near the Thermal Battery Building of ECIL, Hyderabad in June 2009, which resulted in 10 burn injuries including 5 fatalities and physical damage of the building/equipment. This was reviewed in detail by AERB at various forum and the measures to prevent recurrence of such incidents in future were recommended (refer Chapter 4 para 4.1.).

The proposals for construction of 'Compact Antennae Test Facility (CATF) and 'Extension Building for Manufacturing PCBs with High Density Interconnection (HDI) Technology' are under review.

During the regulatory inspection, ECIL was asked to implement the recommendations of AERB to set up its own fire station and establish a hot line between ECIL and NFC fire station urgently.

CHAPTER 3

RADIATION FACILITIES

3.1 INTRODUCTION

The radiation facilities in India are broadly classified as Medical, Industrial and Research facilities. Medical facilities include diagnostic X-ray machines, Telegamma units, medical Linear Accelerators (LINACs), Brachytherapy units using manual and remote after loading techniques and Nuclear Medicine Centres practicing diagnosis and therapy. Industrial installations include gamma and X-ray radiography equipment, gamma radiation processing plants, ionizing radiation gauging devices (nucleonic gauges) including well-logging devices and facilities manufacturing consumer products that contain radioactivity. Research installations include universities and other research institutes handling a variety of sealed and unsealed radiation sources and also X-ray facilities for research purposes.

Number of various radiation installations and radiation devices, which are regulated by AERB, is given in Table 3.1.

Table 3.1: Radiation Installations Regulated by AERB (Up to December 2009)

Sr. No.	Type of Application	Number of Devices in use	Number of institutions
1	Diagnostic X-ray • Conventional X-ray • Computed Tomography (CT) Units • Interventional Radiology Units	 ~ 50,000 510 217	 ~ 40,000 510 217
2	Radiotherapy • Teletherapy • Brachytherapy	 • Telecobalt units 292 • Telecaesium units 00 • Gamma Knife units 07 • Super Gamma Knife units 01 • LINACs 163 • Tomotherapy 02 • CyberKnife 02 • High Dose Rate 160 • Low Dose Rate 26 • Manual(Intracavitary) 98 • Manual (Interstitial) 34 • Sr-90 Ophthalmic Applicators 20 • Ru-106 Ophthalmic Applicators 02 • I-125 Ophthalmic Applicators 04 • I-125 seeds for Prostrate Implant Applicators 01	266
3	Nuclear Medicine • Diagnostic low dose therapy • Diagnostic low & high dose therapy	Not applicable	177 139 38
4	Research centres using unsealed radioisotopes	Not applicable	238
5	Radio Immuno Assay (RIA)	Not applicable	231
6	Medical cyclotrons	09	09

7	Industrial Radiography • Radiography Camera • X-ray units • Accelerators	 1649 248 12	568
8	Gamma Irradiators	15	15
9	Gamma Chambers	134	109
10	Nucleonic Gauges	8320	1572
11	Consumer Products • Gas Mantle • Lamp starters • Smoke Detectors • Electron Capture Detector (ECD)	Not applicable	 65 18 104 713

3.2 APPROVALS AND CONSENTS

3.2.1 Type Approvals

For the purpose of ensuring that the radiation doses received by workers and members of the public do not exceed the prescribed dose limits and further that such doses are kept As Low As Reasonably Achievable (ALARA), design safety is accorded primary importance and operational control measures are monitored. With this in view, all devices including radiation generating equipment and those incorporating radioactive sources are subjected to a type approval procedure. AERB permits only type-approved radiation devices to be marketed in India. The criteria for type approval are stipulated in the Standards Specifications (SS) documents on a variety of devices, issued by AERB. These SS documents are periodically reviewed and revised, where necessary, in order to meet internationally accepted and current standards. Safety Review Committee for the Application of Radiation (SARCAR) examines the design safety features of each device and recommends issuance of type approval. SARCAR held seven meetings during the year. Based on the recommendations of SARCAR, AERB issued type approval certificates to the manufacturers/suppliers of devices incorporating radioactive materials and radiation generating equipment. Number of the devices type approved during the year is given in Table 3.2a. No Objection Certificates (NOC) issued for procurement of certain equipment and the consents given are reported in the Table 3.2b and 3.2c respectively.

Table 3.2: Approvals Granted (January to December 2009)

Table 3.2a: Number of Type Approvals Issued

Sr. No.	Type of Equipment	Number of Models Type Approved
1	Computed Tomography (CT) Units	29
2	Interventional Radiology Units	24
3	I-125 sealed source for surface mold and interstitial implant brachytherapy Techniques	01
4	Tele Cobalt Units	01
5	Medical Linear Accelerators	07
6	X-ray based Radiotherapy Patient Positioning System	01
7	CyberKnife Robotic Radiosurgery System	01
8	Remote Controlled Afterloading Brachytherapy Units	01
9	Industrial Gamma Radiography Exposure Devices (IGRED)	02
10	Sealed Source Models used for Gamma Chambers and Irradiators	02
11	X-ray Fluorescence Spectrometer Systems for element analysis	02
12	Industrial Radiation Gauging Devices (IRGD)	03
13	X-ray Baggage Inspection System	23

Table 3.2 b: NOCs issued for Import

Sr. No.	Type of Equipment	Number of NOC Issued
1	Computed Tomography (CT) Units	07
2	Interventional Radiology Units	04
3	SPECT-CT Units	01
4	PET-CT Units	01
5	Medical Linear Accelerators	02
6	Remote Controlled Afterloading Brachytherapy Units	01
7	Radiotherapy Simulator	01
8	Gyro Knife Unit	01
9	Gamma Ray Stereotactic Neurosurgery System	01
10	Medical Cyclotron	01
11	Select Seed 'I-125' sources for permanent implant treatment of prostate cancer	01
12	Industrial Gamma Radiography Exposure Device Source Changer Models	01
13	Mobile Industrial radiography X-ray Units	01
14	Industrial radiography X-ray Units	01
15	Neutron based Explosive and Radionuclide Detection System	01

Table 3.2 c : Consents Issued

Sr. No.	Type of Application	Permission Granted
1	Site Approval for installation of Gamma Radiation Processing Facility	3
2	Design and Construction Approval for Gamma Radiation Processing Facility	1
3	Renewal of Licence for routine operation of Gamma Radiation Processing Facility	3
4	Certificate of Approval for radiation processing of food products to Gamma Radiation Processing Facility	3
5	Site Approval for installation of Medical Cyclotron Facility	2
6	Design and Construction Approval for Medical Cyclotron Facility	3
7	Commissioning Approval for Medical Cyclotron Facility	2
8	Site, Design and Construction Approval of 14 MeV D-T Neutron Generator Facility	1
9	Permission for supply the new remote control unit and guide tube applicable to industrial gamma radiography exposure device (IGRED) model GAMMARID- 192/120	1
10	Syllabus Approval of Radiological Safety Officer (RSO) Course in Nuclear Medicine Practices	1

3.2.2 Approval of Radiological Safety Officers

The approval certificates issued to Radiological Safety Officers (RSOs) are given in Table 3.3.

Table 3.3 : Approval Certificates Issued to RSOs (January to December 2009)

Sr. No.	RSO Level	Number Approved
1	RSO Level-III (Medical)	177
2	RSO Level-III (Industrial Radiography)Facility	04
3	RSO Level-III (Gamma Irradiators)	13
4	RSO Level-II (Industrial Radiography)	93
5	RSO Level-II (Nuclear Medicine Diagnosis)	29
6	RSO Level-I (Nucleonic Gauge)	167
7	RSO Level-I (Research Applications)	26
8	RSO Level-I (Well Logging)	5
9	RSO Level-I (Ship Breaking)	1
10	RSO Level-I (Container Scanner)	4
10	RSO Level-I (Beach Sand Minerals)	2

3.2.3 Approval of Packages for Transport of Radioactive Material

As per AERB regulations, Type-A packages, which are permitted to transport radioactive material of activity not exceeding the specified limits, need to be registered with AERB. All Type-B packages are subjected to a stringent approval procedure and are required to fulfill the regulatory standards. Registration certificates, were issued to five Type A packages. Renewal of approvals for two Type B (M) packages was issued. Approval was issued for one package each of Type B(M) and Type B(U).

3.2.4 Shipments Approved

Consignments, which do not meet all the applicable requirements of the transport regulations due to specific reasons, are permitted to be transported under special arrangements, which include provision of compensatory safety measures achieved through operational controls. Five such shipments were approved during the year.

3.2.5 Transport of Radioactive Materials

Forty three permissions for transport of radioactive material were issued, during the year. AERB communicates regularly with other government authorities for the safe transport of radioactive material in and out of the country. The concerned nodal and other agencies are Director General of Civil Aviation (DGCA), New Delhi, Port Trusts, Indian Railways, Airport Authority of India and Customs.

3.3 LICENSING / AUTHORISATION

3.3.1 Licensing / Authorization

Licenses for operation were issued to two medical cyclotrons and one high intensity Gamma Radiation Processing Facilities (GRAPF).

AERB issued 575 regulatory licenses as Certificate of Registration to diagnostic X-ray installations upon confirming that the applicable regulatory requirements are duly satisfied. On the basis of pre-commissioning safety evaluation, authorizations for the commissioning of 44 Teletherapy units (12 Telecobalt units and 32 Medical LINAC) and 33 remote after-loading Brachytherapy units were issued. Permissions were accorded for the decommissioning of 6 Teletherapy units, for re-starting 14 Telecobalt units after source replacement and for 15 new radiotherapy centres. 17 NOCs were issued for the export of radioactive sources. 193 NOCs were issued for transfer of sources abroad for disposal.

Details of Licences/NOCs issued for source procurement during the year 2009, are given in Table 3.4.

Table 3.4: Licences / NOCs Issued (January to December 2009)

A. Procurement of Sources

Sr. No.	Type of application	Regulatory Licences / NOC	
		Local	Import
1	Radiotherapy		
	• Telecobalt	19	05
	• Telecaesium	-	-
	• Accelerators	-	38
	• Gamma Knife	-	-
	• Tomotherapy	-	01
	Brachytherapy	-	
	• HDR	-	163
	• LDR	04	-
	• Manual (Intracavity & Interstitial)	-	-
	• Opthalmic Sr-90	04	-
	• Opthalmic I-125	-	02
	• Ophthalmic Ru-106	-	-
2	Nuclear Medicine		
	• RIA facilities	42	81
	• Diagnostic & Therapeutic	243	212
	• Research	98	211
3	Industrial Gamma Radiography Exposure Devices	1095	58
4	Gamma Irradiators (Category-IV)	03	-
	Gamma Irradiators (Category-I)	05	01
5	Nucleonic Gauges	69	271
6	Diagnostic X-ray (Registration) CT and Cath lab units (License)	575 units 503 units	- -
7	Consumer Products		
	• Gas Mantle	-	-
	• Lamp starters	11	-
	• Electron Capture Devices	05	102
	• Smoke detectors	-	14
	• Explosive detectors	-	63

B. Number of Sources Transferred for Disposal

At BRIT	WMD, BARC	CWMF, Kalpakkam	ECIL, Hyderabad	Original Supplier Abroad
322	137 1225(ICSD) 355.6 kg(DU) [4 packages]	27	17	576

Note: DU stands for Depleted Uranium and ICSD stands for Ionisation Chamber Smoke Detector

3.3.2 Disposal of Radioactive Materials

The users are required to send decayed radioactive sources / materials from medical, industrial and research institutes for safe disposal to the original supplier or to one of the approved radioactive waste disposal facilities in India. The number of authorizations issued for export of 576 numbers of sources to original supplier abroad was 193. The number of authorizations for transfer of 322 numbers of sources to domestic supplier and 1409 numbers of sources to waste management agencies was 259.

Before the authorization for disposal of the material is issued, safety assessments of the disused sources are done by physical inspection, correspondence with the waste generator and the authorized waste management agency. A total of 84 such assessments were done during the year.

An old brachytherapy unit was decommissioned in a hospital. No suitable transport container was available for transport of the decayed sources. The transit source storage container of the unit was converted into a package by providing additional steel frames to support the un-even shaped container. The whole arrangement was inspected by the representatives of AERB and BARC. The disused sources were thus transported to BARC for safe disposal after obtaining prior permission from AERB.

Official of AERB visited a copper mining institute (Khetrinagar, Rajasthan) for verification of the inventory of disused sources lying at the plant. There was a discrepancy between the number of sources as per the record maintained by AERB and the actual number of sources found in the plant at the time of inspection. One official of the plant admitted that two sources were supposed to be buried underground about twenty years back. However, no officials involved at the time of burial were in service at the time of inspection. All officials had retired. The plant official could get some information from one of the retired persons who happened to be settled in Khetrinagar. With his help, the location where sources were buried could be identified. The plant authority used a JCB to dig out and found that there were three containers (instead of two) inside three boxes of lead. The sources were taken inside a secured room and kept there pending for safe disposal. The sources are under process for safe disposal in an authorized waste management agency.

3.4 RADIOLOGICAL SAFETY SURVEILLANCE

3.4.1 High Intensity Gamma Irradiation Facilities

Inspections were carried out at 15 operating gamma irradiation facilities. Quarterly safety status reports were received from all the operating gamma radiation-processing facilities. The occupational exposures in gamma irradiation facilities in the last five years did not exceed 2 mSv/y, which is well below the prescribed dose limit of 20 mSv/y. Three proposals for the loading/ replenishment of Cobalt-60 sources from such facilities were reviewed and clearances were issued. One gamma irradiation facility is under precommissioining. Sites for installation of two more such facilities have been approved by AERB.

One of the gamma irradiation facility operated by M/S Vardaan Agrotech Pvt. Ltd., Sonepat remained non operational as the license for its operation was suspended by DAE and AERB. The ownership issue of the facility is sub-judice due to land dispute. The sources of this facility are in safe and secure custody of BRIT.

3.4.2 Industrial Radiography

During the year, AERB carried out announced as well as unannounced inspections of 57 industrial radiography sites and installations. The monthly safety status reports received from radiography institutions were reviewed by AERB to ensure availability of safety infrastructure and inventory of radiography devices/sources. Type approval applications for new models of radiography devices were reviewed and approved.

3.4.3 Nucleonic Gauging

The application of nucleonic gauges for level monitoring, thickness measurement, density measurement and moisture detection, elemental analysis in many industries such as steel, paper, plastic, textile, cement, power, coal and oil exploration recorded a notable increase. AERB inspected nucleonic devices installed in 7 institutions. Safety status reports from these installations were reviewed by AERB to ensure availability of safety infrastructure and inventory of nucleonic devices/sources. A database of the nucleonic devices housing radioactive sources used by the various industrial and research institutes in India is being maintained by AERB.

3.5 REGULATORY INSPECTIONS

Details related to regulatory inspections during the year are given in Table 3.5. Main thrust in regulatory inspections was to find non-compliances with regulatory requirements. The non-compliances with regulatory provisions during inspection were reviewed in the AERB Safety Committee for Investigation of Unusual Occurrences in Radiation Facilities (SCURF). The enforcement actions recommended by SCURF include issuance of warning letters, suspension of radiation practices, withdrawal of certificates of radiation workers and revocation of license issued to operate radiation installations in radiation facilities.

Table 3.5 : Regulatory Inspections (January to December 2009)

Sr. No.	Facilities	Number of institutions	Number of Inspections
1	Diagnostic X-ray	~ 50,000	46
2	Radiotherapy	266	11
3	Nuclear Medicine	177	41
4	Industrial Radiography	568	57
5	Gamma Irradiators	15	15
6	Nucleonic Gauges	1572	07

In addition to above 429 X-ray units were inspected by DRS, Kerala. Also, 1157 Industrial Radiography devices were inspected prior to source replacement operations.

3.6 UNUSUAL OCCURRENCES

All unusual occurrences at radiation installations were investigated and appropriate enforcement actions were implemented commensurate with the nature of occurrence.

3.6.1 Incident of High Radiation Exposures in Metal Scrap Market in Mayapuri, Delhi *

Incident Reported

An incident involving high radiation exposure unfolded, when a message from Indraprastha Apollo Hospital, Delhi was received by Atomic Energy Regulatory Board (AERB) on 7th April, 2010. The message stated that a patient – a scrap dealer from the Mayapuri Industrial area- who was admitted in the hospital since 4th April developed symptoms suspected to be indicative of high radiation dose.

Immediate Follow Up

After confirming the information, within a few hours on the same day (7th April), two officers from AERB rushed to the Mayapuri area to assess the situation at ground zero. They carried out an extensive radiation survey in and around the scrap shop which belonged to the affected patient and identified the shops and adjoining areas where high radiation levels were prevailing. As an immediate measure, they provided shielding by covering the identified radiation hot spots to reduce radiation levels. The entire affected area was cordoned off.

On 8th, April, in a joint effort, the officers of AERB, Emergency Response Centre of DAE, Narora Atomic Power Station (NAPS), National Disaster Response Force (NDRF) and Radiation Safety Systems Division of BARC, assisted by local police carried out combing operations through extensive radiation surveys. This led to the identification and recovery of most of the radioactive sources. The sources were safely recovered and transported to NAPS for safe and secure storage. By forenoon of April 9th, the area which was cordoned off earlier was cleared off radioactive materials and rendered safe as no unacceptable radiation levels in these areas were observed.

Following these events, a quick survey of the entire market area encompassing several hundred shops was carried out on 13th April to rule out the presence of additional sources. Elevated radiation level was noticed near another scarp shop, around 500 m away from the earlier shop. This led to recovery of two more radioactive sources. The sources were transported to the site of the NAPS for safe and secure storage.

Another occurrence came to light on 15th April after another shop owner of the same scrap market was admitted to a hospital in Delhi. A small Co-60 source was recovered from him.

While radiation surveys indicated absence of any more radiation sources some low level contamination left by dust particles of cobalt was detected in a number of spots.

An awareness programme was also conducted on May 6, 2010 for the Mayapuri scrap dealers on the safety aspects along with legal and regulatory requirements in possessing and handling radioactive sources.

By May 2010 the entire Mayapuri scrap market area were cleaned up - including removal of contaminated soil-and declared open for public access and habitation. By June 14, 2010, the final clean up operations at the affected shop was completed and the shop was handed over to the owner by the police. Thereafter, concretization of the road in front of the affected shops was completed.

Throughout this period, AERB issued periodic press releases to allay the apprehensions of the public and apprise them of the situation in perspective.

Furthermore, a public Notice was also issued by AERB through leading newspapers about the legal/statutory and regulatory requirement of possession, handling and disposal of radioactive sources stating clearly that possession of radioactive sources without proper license/ authorization / registration is an offence.

*** Although this incident pertains to period beyond the reporting period of this annual report, it is being covered here because of its importance.**

A rating of Level 4 in the International Atomic Energy Agency (IAEA) International Nuclear and Radiation Event Scale was accorded to this incident. Information regarding the above incident was also provided to the Illicit Trafficking Data Base (ITDB).

Facts Emerging From Investigations

Investigations carried out at the site of incident, discussions with the affected personnel and the inspections carried out at NAPS by officers of AERB, Board of Radiation and Isotope Technology (BRIT) of DAE and Delhi police, it was established that the radioactive Co-60 sources recovered from the Mayapuri scrap market in Delhi were from an old gamma cell (Model No 220) made by Atomic Energy Canada Ltd which was purchased by the Chemistry Dept of Delhi University in 1969. The gamma cell was being used by a Chemistry professor till his retirement. Since then it remained disused in the same room for more than 15 years till it was auctioned by the Delhi University in Feb 2010 and reached the hands of the scrap dealer who purchased it through this auction.

The whole event got unfolded when the gamma cell was dismantled by local workers at the metal scrap shop, leading to the highly radioactive Co-60 pencil sources coming out of the cage, causing the tragedy of unwarranted high exposure to 7 persons (who were admitted to various hospitals in Delhi with radiation induced symptoms) of whom one succumbed to radiation sickness.

Regulatory Enforcement Actions Taken

- All the radioactive sources originally present in the gamma cell of the Delhi University were recovered and accounted for their number and source strength. These sources will continue to remain in safe and secure custody of the Department of Atomic Energy. Recovery of the entire inventory present in the gamma cell was confirmed by counting of the recovered cobalt slugs in the hot cells in BARC.
- The unauthorized disposal of the gamma cell by the Delhi University as a scrap is in violation of the Atomic Energy (Safe Disposal of Radioactive waste) Rules, 1987 and the Atomic Energy (Radiation Protection) Rules 2004. In view of this, AERB issued a show cause notice to the Delhi University and in the interim, advised the university to suspend forthwith all activities involving the use of radiation sources. The preliminary response submitted by the University is currently under review by AERB.

Reinforcement of Regulatory Mechanism and other corrective actions for Future

Post Mayapuri incident, following actions have been initiated by AERB to reinforce and further strengthening of its regulatory enforcement mechanism.

- Sensitizing all the academic, medical and R&D institutions to undertake inventory of radiation sources under their possession and review their existing safety procedures.
- Issuing guidelines and stipulations regarding the use and disposal of radioactive sources and making the training on radiation emergency management to be part of curriculum in medical education.
- Improving and intensifying the public awareness on legal, regulatory and general safety requirements vis-à-vis radioactive sources by way of issuing notices through print media and knowledge sharing through its website.
- Further strengthening the AERB Data base system of records on source inventory.
- Pursuing with the State Governments for the formation of Directorate of Radiological Safety and enhancing the coverage and effectiveness of inspections of radiation facilities all over the country.
- Instituting the Regional Regulatory Centres (RRC) in the country. RRC in East and South have been formed already. Formation of RRC in North is planned in the immediate future.
- Based on lessons learnt from this experience the system of response to radiation source related emergencies is further strengthened in collaboration with National Disaster Management Authority (NDMA).
- Though not directly related with this incident, following additional actions are being pursued:
  - Ongoing program to install radiation detection equipment at all sea ports is being re-emphasized.
  - Metal recycling industry has again been mobilized to install radiation detection equipment at various processing points in handling of scrap metal.

3.6.2 Breakage of Source Pigtail of a IGRED:

M/s. BRIT intimated AERB regarding breakage of source pigtail near the female coupler of a radiography exposure device model Roli-1, Sr. No. 98348 belonging to M/s. Quality Inspection Technologies, Visakhapatnam. AERB issued show-cause to M/s. Quality Inspection Technologies. Based on the recommendations of SCURF, a Special Committee for Investigation of Industrial Radiography Incidents (CIIRI) was constituted by AERB for investigation of this incident. Appropriate regulatory actions will be decided based on the recommendations of CIIRI and review of the same by SCRUF.

3.6.3 Theft of an IGRED:

On 29-07-2009, a vehicle containing IGRED model Roli-1, Sr. No. 08574 having 0.1 TBq Ir-192 source belonging to M/s. Indian NDT Centre (INDTC), Ghaziabad was snatched by gundas/robbers while traveling from Ghaziabad to Dehradun for carrying out radiography work. The missing IGRED could not be located despite extensive surveys. The surveys were carried out, with the help of local Police Authorities, at different suspected areas around the site of incident. The vehicle was traced by the police after a few days of incident without IGRED. A show cause notice was issued to M/s. INDTC, Ghaziabad. RSD, AERB instructed the Proprietor of the company to carry out search operations and radiation survey in and around the incident site and should continue the efforts for locating the missing exposure device and keep AERB informed periodically. In addition regulatory actions such as the certificate of the Site-in-Charge /RSO was withdrawn for a period of one year, M/s. INDTC has submitted Radiation Protection Programme (RPP) for safe handling and management of radiography devices including transport, for review by AERB and no regulatory consent/clearance would be issued to M/s. INDTC till investigation is completed by police authorities of efforts made by M/s. INDTC for the recovery of the missing IGRED with source were reviewed and approved by AERB.

3.6.4 Falling of an IGRED from a Moving Vehicle:

On 24-08-2009, an incident was reported to AERB, involving falling of a device, model Techops 660 Sr. No. 5864 containing 96 GBq of Ir-192 source, belonging to M/s. Sievert India Pvt. Ltd., (SIPL) Navi Mumbai from a vehicle while moving from Pune to Navi Mumbai on 23-08-2009. Later, this device was recovered with the help of local police of Pimpri, Pune. A show cause notice was issued to the company. The company admitted the negligence of their radiography personnel in the above incident. Following regulatory actions were recommended by RSD, AERB:

- Warning letter was issued to the licensee and radiographer for strict adherence to the Radiation Protection Procedures prepared by M/s. SIPL for safe handling and management of radiography devices including transportation of radiography sources.
- Surprise inspection was carried out at the radiography sites of M/s. SIPL to verify radiography work practices followed by radiography personnel of M/s. SIPL.
- Regulatory approval of M/s. SIPL was suspended for a period of three months from the date of incident.

3.7 FORMATION OF DIRECTORATE OF RADIATION SAFETY

Supreme Court of India issued a Directive to all the states in the year 2001 to establish a Directorate of Radiation Safety (DRS) for regulating the use of medical diagnostic x-rays in the respective states. In line with this directive, AERB had also sent a booklet to all the Principal/Chief Secretaries (Health) of all the States detailing the requirement for formation of DRS. Presently, DRS has been functional in the State of Kerala.

In the light of the above requirement, and to coordinate with AERB in all matters related to radiation safety of medical diagnostic x-ray installations, the State of Mizoram formed a Radiation Safety Committee (RSC) on 10th December, 2008. A meeting of RSC and Chief Secretary, Mizoram was called on 25th March 2010 by Director, Hospital and Medical Education, Mizoram to discuss Memorandum of Understanding (MoU) regarding establishing DRS for Mizoram. Accordingly, the Mizoram Government signed a MoU with AERB on 25th March, 2010 at Aizwal. As per the MoU, the State Government will set up Radiation Safety Agency (RSA) in Aizwal and will function as per regulatory framework of AERB.

3.8 TRAINING AND AWARENESS ACTIVITIES

3.8.1 One day workshop on "Radiation Safety in Interventional Radiology Facility" for cardiologists, interventional radiologists, bio-medical engineers maintaining the cathlab units, suppliers of cathlab units and suppliers of personnel protective devices was held in AERB on April 09, 2009. Twenty six participants attended the workshop.

3.8.2 One day seminar was conducted on regulatory requirements in radiotherapy facilities on 15th April 2009 (Wednesday) at AERB, to address certain regulatory issues in radiotherapy. Fifty seven participants attended the program. Participants included 37 Medical Physicists, 6 Radiation Oncologists and 14 representatives of suppliers of Linear Accelerators, remote afterloading Brachytherapy unit and RFA.

3.8.3 One day awareness programme on radiation safety in safe handling of radioactive material was conducted by AERB on 08-09-2009 at JN Customs House, Nava Sheva for the staff of the Indian Customs for safe handling of the fixed and mobile container scanners.

3.8.4 Two workshops were conducted by the Directorate of Radiation, Kerala for the X-Ray radiographers and radiologists at Thiruvananthapuram on 27th January, 2010 and at Kozhikode on 25th February, 2010. Lectures were delivered by AERB staff on planning of X-Ray installations and on Quality Assurance of X-Ray units during these workshops.

3.8.5 Radiotherapy Group, RSD, AERB conducted a "One day meet on regulatory requirements in layout plan approval for radiotherapy facilities on 4th March, 2010". 24 participants comprising of radiation shielding experts, architects and managers participated from various companies supplying Radiotherapy Units in the country. Most of these participants were involved in either guiding the user institution or designing of radiotherapy plans on behalf of the user institutions. It was noticed that the plans submitted to AERB for approval of the radiotherapy installations had inadequate inputs. This resulted in multiple submissions, delay in the project of the concerned institution. It was observed that more than 70% of the plans are prepared either in consultation or by the suppliers of the Radiotherapy Units. Thereby, it was decided to discuss these issues with the suppliers of the Radiotherapy Units.

3.8.6 A One day meet on Regulatory Requirement for Nuclear Medicine radioisotope suppliers in India was arranged on March 12, 2010 at AERB. Representative of eight suppliers of radiopharmaceuticals to various Nuclear Medicine centres in India attended the meet. The participants were appraised of the regulatory requirements to be adhered to during the supply of the radioisotopes to various nuclear medicine centres in India. There were presentations from the participants and discussions on problems faced by the suppliers. It was also informed to the participants that regulations implemented by AERB were from radiological safety point of view and any other regulations from relevant statutory government agencies should be adhered to by the suppliers.

3.8.7 A Workshop for service engineers of X-Ray units was conducted by AERB in collaboration with BARC and Association of Medical Physicists of India (AMPI) on Quality Assurance and Radiological Safety in Diagnostic Radiology, during 8-12 March 2010 in Mumbai.

3.8.8 One day seminar on Advanced Techniques of Radiotherapy was conducted by AERB, BARC and Association of Medical Physicists of India (AMPI) on March 12, 2010 in AERB, Mumbai.

3.8.9 One day awareness programme on Radiation Safety Aspects of Industrial Radiography and Nucleonic Gauges was conducted by AERB at M/s. HMEL, Bathinda, Punjab on March 20, 2010. About 40 participants attended this special programme. Officers from RSD, AERB made presentations related to regulatory and safety aspects.

3.8.10 A special safety meet on "Radiation Safety, Regulatory and Dosimetry Aspects in the Gamma Radiation Processing Facilities" was organized by AERB on March 29, 2010 at AERB Auditorium. The main objective of the meeting was to provide an opportunity for the Radiation Safety Officers and Operators of the GRAPF's to interact and discuss with the regulatory authority their radiation safety related issues and to appraise them about revised regulatory procedures established by AERB for approval of food dosimetry.

Special meet on "Radiation Safety, Regulatory and Dosimetry aspects in Gamma Radiation Processing Facilities (GRAPF)" *(L to R: Dr. Om Pal Singh, Secretary, AERB, Shri A U Sonawane, RSD, Shri S A Hussain, Head, RSD and Dr. A K Kohli, Chief Executive, BRIT)*

About 30 participants which included facility-in-charges, radiological safety officers, operators, senior representatives of management from various operating gamma radiation processing facilities, and expert(s) from divisions/sections of BARC, BRIT and AERB attended this special meet.

Experts from RSD, AERB, BRIT and RSSD made presentations related to regulatory, safety and dosimetry aspects. The RSO's of all the GRAPF's also made brief presentations on the operational safety status of their gamma radiation processing facilities during the meet. During the panel discussion, feed back session and deliberations, participants requested to curtail the time period for inter-comparison of the dosimeters during dosimetry studies, for issuance of certificate approval and the licence for irradiation facility.

3.8.11 One day awareness programme on Regulatory Requirements for Nuclear Medicine was conducted for Nuclear Medicine Professionals in AERB, Mumbai on 30-03-2010.

3.8.12 RSD, AERB, conducted a one-day awareness programme on radioactive contamination in steel products for the steel manufacturers/suppliers in the western region on March 30, 2010, at Niyamak Bhavan A, Anushaktinagar, Mumbai. There were eight participants representing major steel manufacturers/suppliers for the programme.

The programme started with an introductory lecture on the radioactive contamination in steel products followed by short presentations by the participants about their experiences on how they could tackle the contamination problem, their present strategies to prevent the incidents of contamination and their expectations from AERB for total elimination of this problem.

A number of measures were taken by AERB to prevent recurrence of such incidents. These include holding meetings with the concerned associations of exporters and organizations to improve radiation safety awareness among the manufacturers and exporters.

3.9 OTHER ACTIVITIES

3.9.1 Gold purity check machine:

In the recent years, many jewelers have started installation of X-ray fluorescence based analyzer for checking the purity of gold in the jewelry. Some suppliers of such analyzers have approached AERB to obtain the type approval certificates of such X-ray equipments. Officials of AERB have assessed the radiation safety of such equipments generating low energy and low intensity X-rays; and found to be safe from radiological safety point.

3.9.2 Ship breaking at ALANG:

In connection with a complaint filed by an NGO on Ship Breaking and media report on allowing an alleged toxic ship containing radioactive material anchoring at Alang, Gujarat, for breaking, the Govt. of India, constituted a central team for the inspection of the said ship (Platinum–II) that anchored at Bhavnagar. The terms of reference for the central team were to look into various issues raised by the complainant. The team also had to make qualitative and quantitative assessment of all the hazardous materials/waste contained in the ship including Poly–Chlorinated Biphenyls (PCBs), asbestos and radioactive substances. Two officials from AERB participated in the joint inspection.

3.9.3 Approval of syllabus:

AERB conducted a joint meeting with representatives of the universities conducting M.Sc. (Medical Physics) course on August 13, 2009 to review and strengthen the Medical Physics training programme. During the meeting copy of the approved syllabus was given to the participants.

CHAPTER 4

INDUSTRIAL SAFETY

AERB carries out review and monitoring of industrial safety status in nuclear power plants/ projects, nuclear fuel cycle facilities and other associated facilities of DAE through Industrial Plants Safety Division (IPSD), AERB. Industrial safety with respect to construction and fire safety aspects of new projects are being reviewed by respective project/design safety committees and the corresponding Advisory Committees (ACPSR). The industrial safety aspects of operating units along with significant events and fire incidents are reviewed by the unit safety committees and SARCOP.

Licenses are issued/renewed and regulatory inspections of all DAE units are carried out under the Factories Act, 1948 and the Atomic Energy (Factories) Rules, 1996.

Regulatory inspections for industrial & fire safety aspects were strengthened at projects for effective monitoring and rectification of 'unsafe acts & unsafe conditions' to ensure adequate level of industrial safety at the construction sites.

Competent persons are designated in various DAE units under the Factories Act, 1948 (as amended in 1987) and Rule 31 of the Atomic Energy (Factories) Rules, 1996 for the purpose of carrying out tests, examinations and inspections under the various section (s) of the Factories Act, 1948, namely for civil construction & structural work, operation of dangerous machines, lifts and hoists, lifting machinery and lifting tackles, pressure plant, dangerous fumes, supervision of handling of hazardous substances and ventilation system. Twenty-eight persons were designated as competent persons under various sections of the Factories Act, 1948.

Certifying Surgeon is appointed under Section 10 of the Factories Act, 1948 (as amended in 1987) and under Rule 5 of Atomic Energy (Factories) Rules, 1996 by AERB for carrying out the duties prescribed in Rule 7 of Atomic Energy (Factories) Rules, 1996. Six doctors were appointed by AERB as Certifying Surgeon at various DAE units.

A Fatal Accident Assessment Committee (FAAC) constituted by AERB reviews the fatal accidents at DAE units and gives recommendations. The recommendations made by FAAC are further discussed in respective Advisory Committees/SARCOP and Board of AERB.

4.1 FATAL ACCIDENTS

There were four fatal accidents at construction sites during the year (April 2009-March 2010) one each at Demonstration Fast Reactor Reprocessing Plant (DFRP), Kalpakkam, KK-NPP construction sites, RRCAT, Indore and KAPP-3 & 4 site. One major fire incident that took place at Thermal Battery Building of Electronics Corporation of India Ltd., (ECIL), Hyderabad resulted in five fatalities due to burn injuries. These accidents were investigated to arrive at the root cause and remedial measures were suggested to the sites to prevent recurrence.

A summary of these accidents along with review and recommendations/directives of AERB are described below.

On May 30, 2009 at DFRP, Kalpakkam, one contract worker involved in the shuttering work for roof slab of DG-2 building fell down from 4.3 m El while climbing down a ladder. On the spot assessment of the incident was carried out by an AERB officer and subsequently reviewed in the FAAC. AERB asked the occupier to implement remedial measures such as adherence to relevant Indian Standards for ladders provided to access the higher elevation, enforcement of use of Personal Protective Equipment, continuous job and safety supervision by contractor and by the departmental staff and ensuring first-aid at site. IGCAR was asked to initiate actions against concerned contractor for not using standard ladder as well as for non reporting of the incident to the DFRP/IGCAR management immediately after the incident took place.

On June 19, 2009 at ECIL, Hyderabad, a fire incident took place near the Thermal Battery Building. The fire originated when the accumulated scrap generated out of the process of manufacturing of pyro-heaters (consisting of pyrophoric zirconium powder, barium chromate and asbestos fibres) was being disposed off by burning in a calcium waste salvage pit outside the building instead of using the designated concrete cubicle tank under the direct supervision of the senior personnel from ECIL. The fire got out of control and also reached the scrap storage room through an open window causing burn injuries to ten employees including five fatalities. On the spot assessment of the incident was done by an investigation committee constituted by CMD, ECIL and also by AERB officers. The incident was subsequently reviewed in the FAAC and ECIL Safety Committee and SARCOP and Board of AERB. The committee also directed that production can be resumed only after review of the safety report of 'Thermal Battery Division' by AERB, preparation and implementation of checklist and procedure for scrap burning, compliance of all pending directives made by AERB related to training/retraining of the operating personnel for safe

handling of pyrophoric material and carrying out fire hazard analysis of the 'Thermal Battery Division', etc.

On October 7, 2009 at KK-NPP construction site, one contract worker involved in the installation of brackets for erection of monorail in the UFC building got electrocuted due to accidental contact with the damaged insulation of tube light connection. The victim was using cable tray as working platform. AERB asked the management to carry out thorough assessment of any hazardous activities and to ensure that all safety measures and the safety work permit system clauses are complied by the contractor. AERB also asked to ensure implementation of standard Job Hazard Analysis (JHA), provision of Earth Leakage Circuit Breaker (ELCB) for all industrial power sockets and luminary circuits, capping/covering of open power cable ends, etc.

On December 19,2009 at RRCAT, Indore, one contract worker involved in the construction of a substation building near IT building of RRCAT, Indore, fell down from 6.5 mEL from the top most rung of a ladder. AERB asked the management to implement the measures such as use of ladder and scaffolding made as per relevant Indian Standard and as per the Atomic Energy (Factories) Rules and proper illumination level with suitable arrangement for lighting shall be made available in the construction area during the work. AERB also stipulated to ensure availability of adequate safety staff to look after the construction activities and improve site supervision.

On February 21, 2010 at KAPP-3 & 4, one signalman involved in guiding the dumper movements at the identified dumping site was hit by a dumper and partially buried under the dumped soil. The work at the project site was stopped by AERB from February 21 to March 7,2010 for implementation of remedial measures recommended by AERB. A high level meeting between AERB & NPCIL was held on February 26,2010 to take necessary actions to prevent recurrence of such incidents at all construction sites of NPCIL. The incident was further reviewed by FAAC. AERB directed to sites to provide proper illumination, adequate supervision both from of NPCIL and Contractor Engineers/Supervisors, adequate manpower and restriction on working hours of workers as per statutes. NPCIL was asked to carry out a comprehensive review of JHA and its field checklist and to eliminate the elements responsible for unsafe work conditions. After ensuring the measures taken by the site through regulatory inspection and safety review, AERB allowed resumption of work on March 8,2010.

4.2 LICENSES ISSUED

The following licenses for operation were renewed/issued to various DAE units.

- Operating Licence for HWP-Thal was renewed for a period of five years.
- Licence was issued for operation of 750 keV DC Accelerator and 10 MeV & 10 kW Electron Linear Accelerator at RRCAT Indore.
- Licence was issued under the Atomic Energy (Radiation Protection) Rules, 2004 to thirteen Beach Sand Minerals Facilities with validity upto five years.

4.3 REGULATORY INSPECTIONS

For improving industrial safety status of construction sites, monthly inspections at construction sites of nuclear power projects and quarterly inspections at construction sites of various fuel cycle facilities and other R & D units were carried out to ensure safety requirements (with emphasis on safety in work at height). Monthly industrial safety status reports from all major construction sites are received and reviewed along with compliance of recommendations of previous monthly regulatory inspections.

Regulatory inspections on industrial & fire safety aspects under the Atomic Energy (Factories) Rules, 1996 and Factories Act, 1948 along with radiological safety and waste management aspects were carried out at various DAE units.

During the year, 109 regulatory inspections, including 46 monthly inspections at construction sites of nuclear power projects (including regular regulatory inspection) and 9 quarterly inspections of fuel cycle facilities construction sites were carried out. During these inspections, the inspectors ensured immediate rectification of the unsafe conditions and unsafe acts observed. During the inspection any safety related incident and near miss incidents are also reviewed. The compliance to the findings of these inspections and the AERB directives has improved the overall safety culture of the units. Some of the significant improvements at the operating plants and construction project sites are given below.

- In HWPs, all the safety precautions specified in the AERB notification dated November 29, 2004 are being strictly adhered to during critical shutdown jobs. A job hazard analysis is also carried out for such jobs. Based on the recommendations, the load radius charts of de-rated mobile cranes are being updated to take account of de-rated load capacity.
- In HWP-Tuticorin, a safety review / 'What –If' analysis was carried out to identify hazards and mitigation measures for the various solvent synthesis processes undertaken in lab/bench scale.
- At IREL plants, periodical checks of the conveyor belts are being carried out to ensure the integrity of the belts. Bottom trays are provided below the conveyor belt carrying the dry mill waste to control spillage.

- At NFC, Hyderabad, ISI programme for the identified critical equipment and issue of height pass for workers working at height of more than 3.5 m El after medical examination, has been initiated.
- At UCIL, Tummalapalle mine and mill, formation of safety committees (covering all construction activities), ensuring availability of ambulance room for the purpose of first aid treatment and implementation of permit to work system have been initiated.
- At ECIL, implementation of JHA for activities involving work at height and enforcement of use of antistatic footwear for the persons working in the explosive filling Shop-I & II have been initiated.
- At Regional Radiation Medical Centre (RRMC), Thakurpukur site (a unit of VECC), fire-fighting arrangement has been provided.
- At RRCAT, safety precautions specified as per AERB notification dated November 29, 2004 and implementation of JHA are being complied at construction site.

At the Nuclear Power Projects, there have been improvement in the working conditions achieved through the compliance to the AERB directives and regulatory inspections, enforcement of personal protective equipment to workers, efforts made by the sites in improving the supervision of work and covering of floor openings.

4.4 PROMOTION OF INDUSTRIAL SAFETY

4.4.1 DAE Safety and Occupational Health Professionals Meet

The 26th DAE Safety & Occupational Health Professionals Meet was jointly organized by the Atomic Energy Regulatory Board, Mumbai and the Variable Energy Cyclotron Centre (VECC), Kolkata in the Auditorium of Saha Institute of Nuclear Physics (SINP) Centre, Kolkata during November 16 – 18, 2009. The theme of the Meet was "Cryogenic Safety, Electrical Safety and Ergonomics at Workplace". This year, for the first time, the DAE aided institutes also participated in the Meet. Dr. S.S.Ramaswamy memorial endowment lecture was delivered by Dr. Philippe Lebrun, CERN, Geneva on 'Engineering Science for Cryogenic Safety'. A booklet on the theme of the meet was released during the meet namely, "Cryogenic Safety & Electrical Safety". A compilation by AERB of all major unusual occurrences that have occurred at various DAE units during the period 2005-2009 were also released during the Meet. The Green Site Awards, which consider various factors like effective site area, efforts taken to improve the greenery, etc., were distributed to the winning units. The winners of this year's

DAE Safety and Occupational Health Professionals Meet at Kolkata *(From L to R: Shri Subimal Saha, Head, ATG, VECC , Dr. R. K. Bhandari, Director, VECC, Shri S. K. Chande, Vice Chairman, AERB, Dr. Anil Kakodkar, Chairman, AEC, Dr. Philippe Lebrun, CERN, Geneva, Dr. Bikash Sinha, Former Director, VECC & SINP and Shri R. Bhattacharya, Director, IPSD, AERB)*

Green Site Awards were IREL, Manavalakurichi and Kakrapara Atomic Power Station (KAPS). It was decided to hold the next year's meet at NFC, Hyderabad with 'Chemical safety and Chemical Waste Management' as one of its theme.

4.4.2 Industrial Safety Statistics

The compilation of Industrial Safety Statistics-2009 of DAE units (other than BARC facilities and mines) provides the data on accidents and analysis of number of injuries and man-days loss caused by various factors.

There were 68 reportable injuries including 9 fatalities with a loss of 66,297 man-days in 2009 as compared to 62 reportable injuries including one fatality with a loss of 7866 man-days in 2008. The injury Frequency Rate (FR) [number of lost time injuries per million man- hours worked] in 2009 was almost equal to that in 2008. However, the Severity Rate (SR) [number of man-days lost per million man-hours worked] and consequently the Injury Index (II) [product of frequency rate and severity rate divided by thousand] for 2009 were very high (about 8 times) compared 2008, due to the accidents that caused fatalities. The best performing year in terms of injury statistics for DAE units was 2008 during the period of analysis (2001-2009) with Injury Index at its minimum of 0.03.

Incidence rates of the DAE units were compared between similar industries across the country, which highlights better safety performance of the DAE units. The non-fatal Incidence Rate (IR) in NPP was 0.07 as compared to 4.69 (2005) in other electricity generation companies in India. Non-fatal IR in HWPs was 0.36 as compared to 2.46 (2005) in other chemical manufacturing units in India.

In 2009, 203 Near Miss Accidents (NMA) were reported from different units of DAE. 25 % of the reported near miss accidents were "Fall of Objects" type and 15 % were "Exposure to electricity". Analysis revealed that

almost all "Fall of Objects" type incidents were in construction projects and most of the "Exposure to electricity" type of incidents was in operating units. "Fall of Objects" type NMA reported in 2008 were also at a maximum of 16.8 %.

It was observed that industrial safety performance of DAE units is normally better than that of similar industries in the country. Table 4.1 gives the comparison of incidence rates in some DAE units with other similar industries in the country. Unit wise comparisons of reportable injuries and man-days lost in 2009 are presented in Figs. 4.1 and 4.2 respectively. Unit-wise comparisons of Injury Index and Frequency Rate are given in Figs. 4.3 and 4.4 respectively and year wise comparison of Injury Index in DAE Units is shown in Fig. 4.5. In Figures 4.6 to 4.8, analysis of injuries caused due to unsafe acts, unsafe conditions and injuries with respect to the type of accidents in DAE units are given.

Table 4.1: Comparison of Incidence Rates of DAE Units (2009) with Equivalent Non-DAE Industries (2005)

Comparison of Incidence Rates of DAE Units with Equivalent Non-DAE Industries (obtained from Pocket Book of Labor Statistics 2008)			
Industry Type		Incidence Rate	
		Fatal	Non-Fatal
A	**Chemical**		
	Heavy Water Plants (2009)	0	0.36
	Manufacture of Chemicals & Chemicals products (2005)	0.20	2.46
B	**Manufacturing**		
	Nuclear Fuel Complex (2009)	0	2.94
	Manufacture of Fabricated Metal Products except Machinery and Equipment (2005)	0.11	2.15
C	**Power Plants**		
	Nuclear Power Plants (2009)	0	0.07
	Electricity, Gas, Steam and Hot water supply (2005)	0.28	4.69

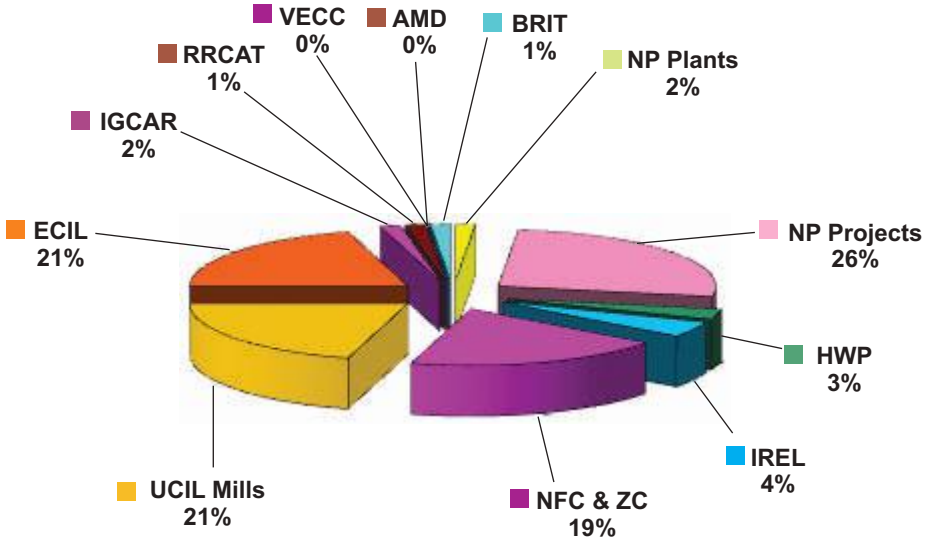


Fig. 4.1: Distribution of Reportable Injuries in DAE Units (2009)

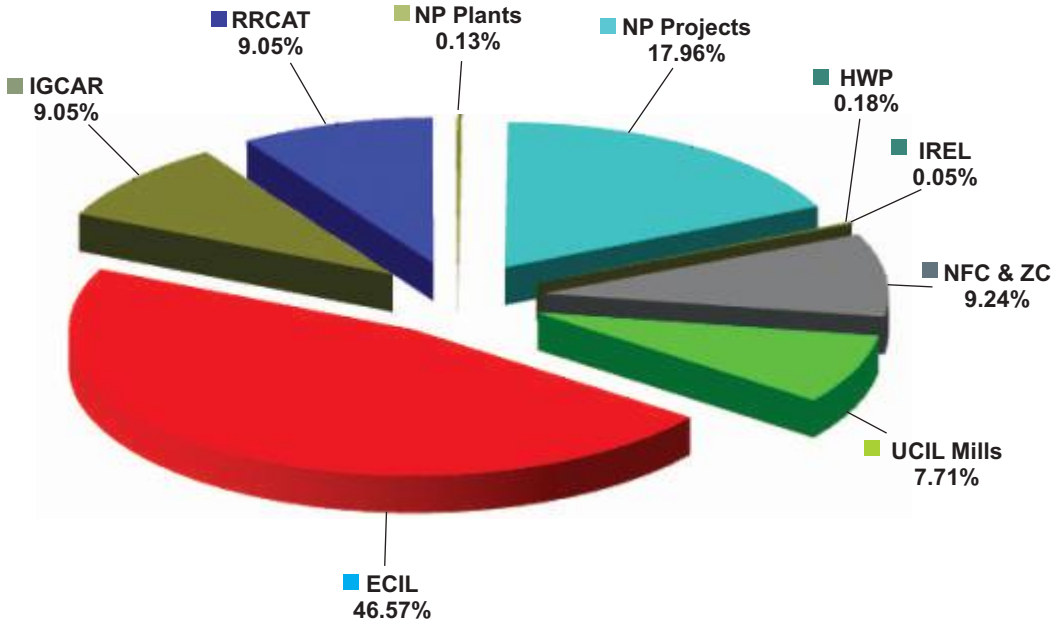


Fig.4.2: Distribution of Man-days Loss in DAE Units (2009)

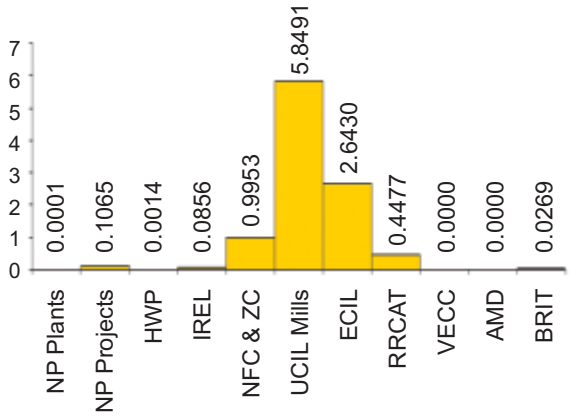


Fig. 4.3: Injury Index of DAE Units (2009)

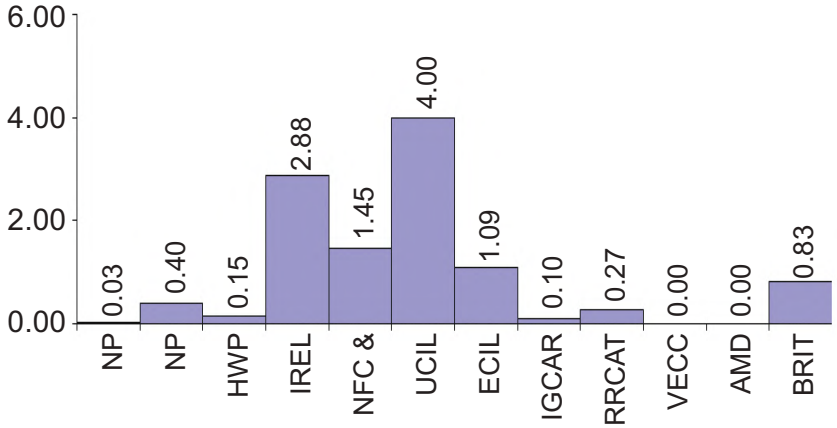


Fig. 4.4 : Frequency Rates in DAE Units (2009)

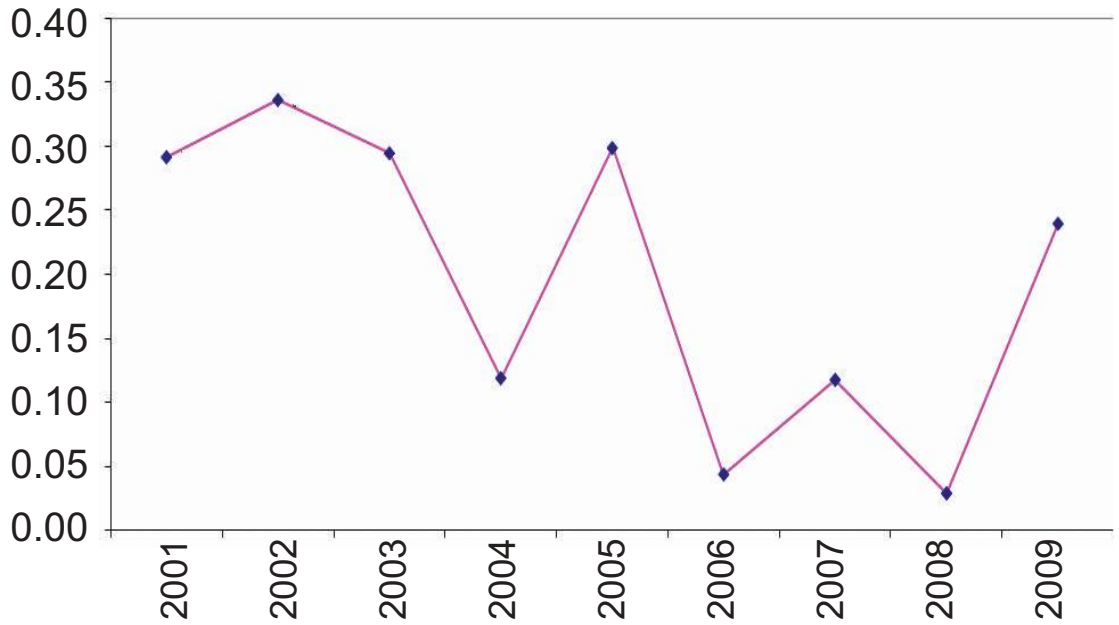


Fig. 4.5: Injury Index in DAE Units over the Years

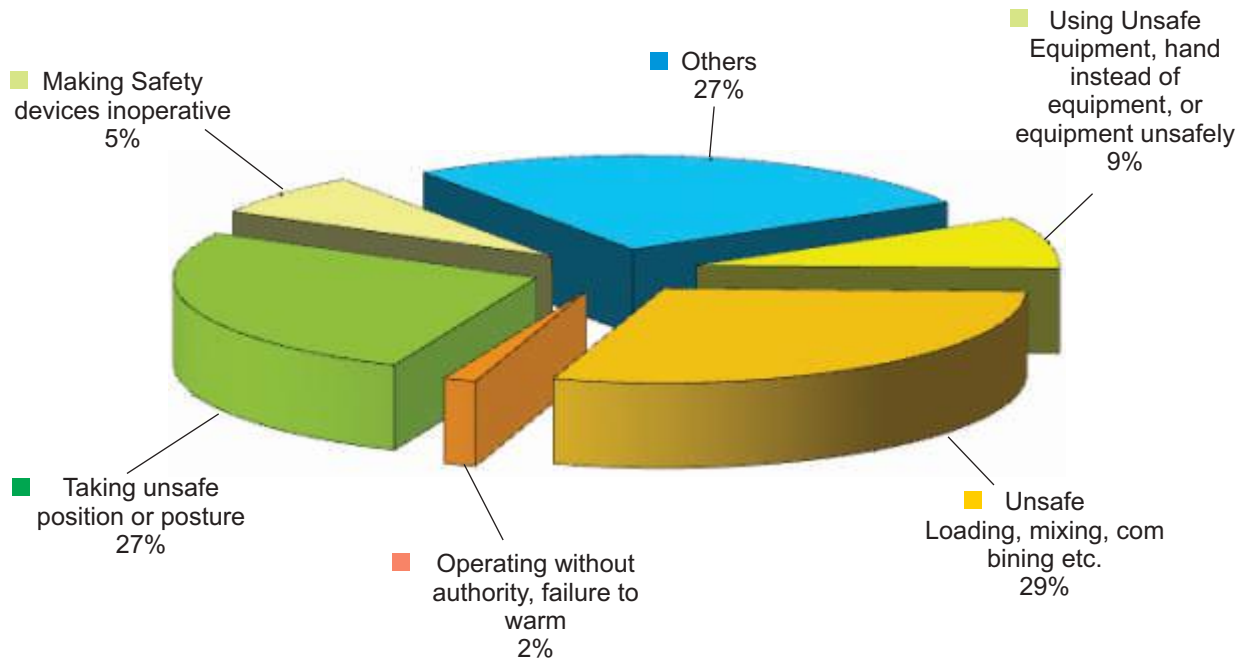


Fig. 4.6 : Distribution of Number of Injuries caused due to various Unsafe Acts in DAE Units-2009

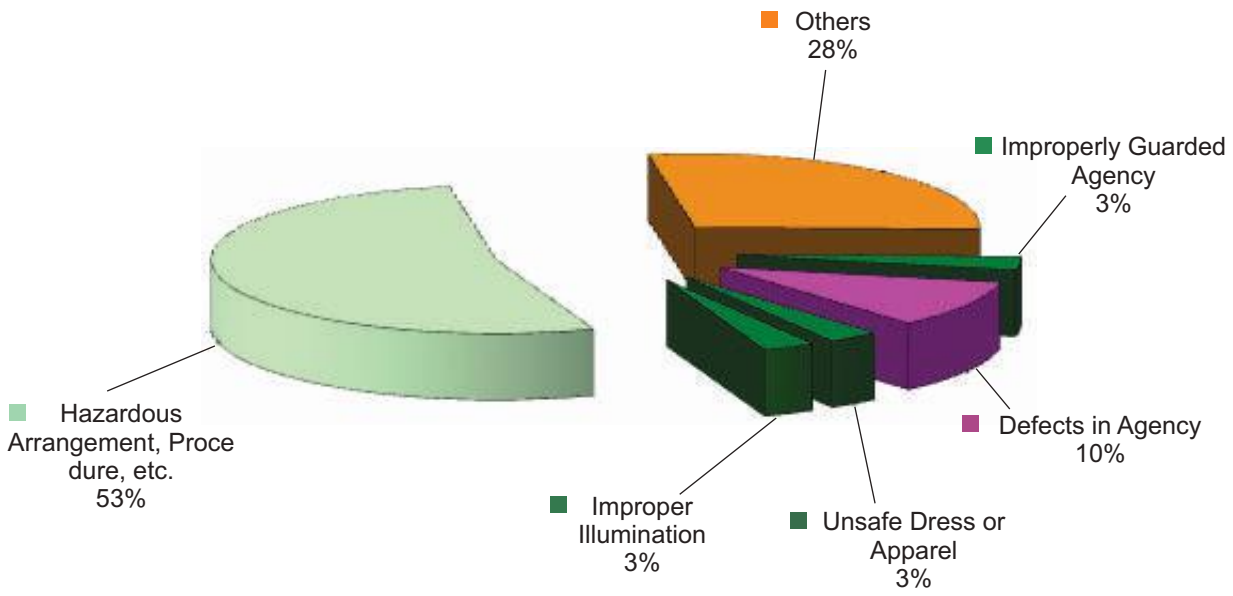


Fig. 4.7: Distribution of Number of Injuries caused by various Unsafe Conditions in the DAE Units- 2009

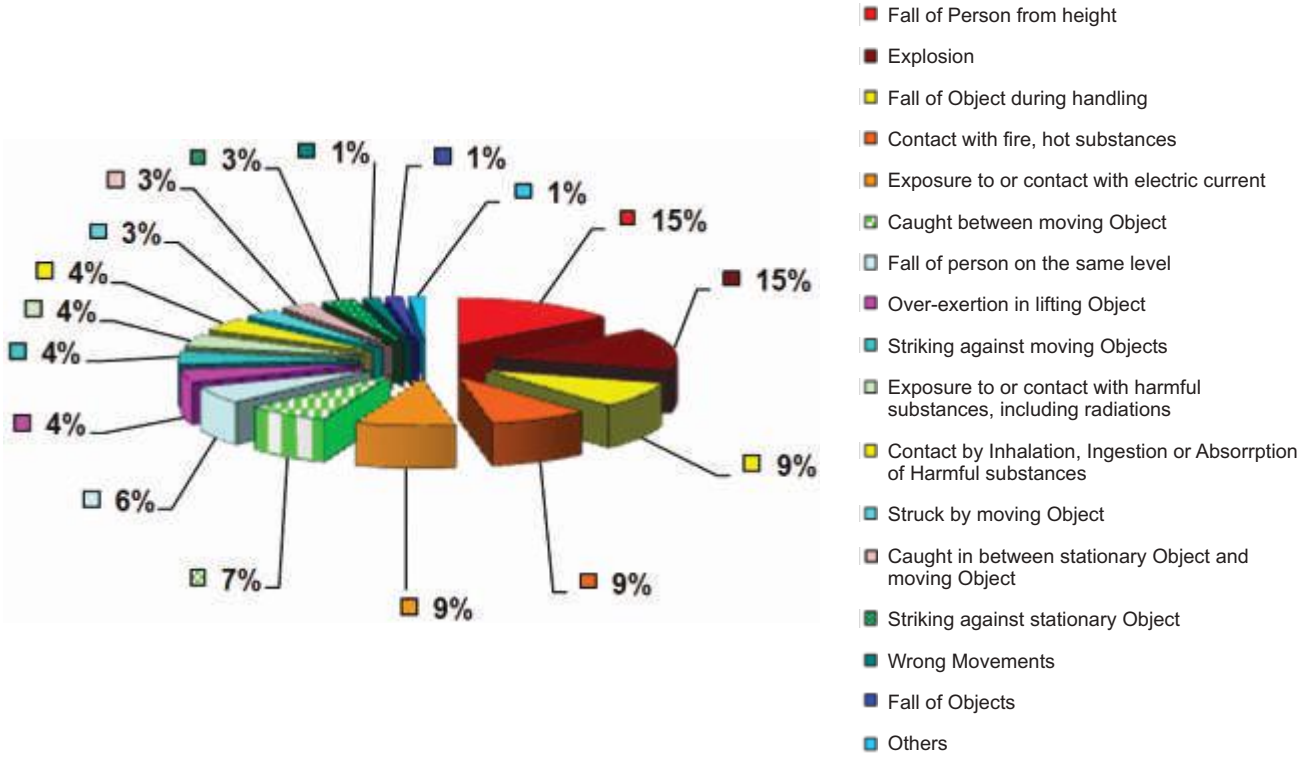


Fig. 4.8 : Distribution of Injuries with respect to the type of Accidents causing Injuries in DAE (2009)

4.4.3 Industrial Safety Awards

Atomic Energy Regulatory Board presents Industrial Safety Awards every year to the DAE units who achieve high levels of performance in Industrial Safety. The Kakarapar Atomic Power Station-1&2 and Rajasthan Atomic Power Station-1&2 in Production Units–I Group and Indian Rare Earths Ltd., OSCOM (Thorium Plant) in the Research /Low Risk Units Group were the winners.

4.4.4 Fire Safety Awards

Fire Safety Awards Function in Progress
(L to R: Shri S. K. Chande, Vice-Chairman, AERB, Shri P. S. Bhargava, Executive Director, BPCL, Mumbai, Shri S. K. Sharma, Chairman, AERB and Shri R. Bhattacharya, Director, IPSD)

The Fire Safety Awards are decided by taking into account the preventive efforts taken by the site, the fire incidents that had occurred during the period and the fire potential at the site. DAE units are categorized based on fire potential as Category-I (all operating NPPs, HWPs and NFC) and Category –II (IREL units, UCIL units, NPPs under construction, BHAVINI, RRCAT, VECC, BRIT, AMD, IGCAR and ECIL) and accordingly awards are given in each category. The annual Fire Safety Awards of AERB for the year 2008 were presented on April 17, 2009. In Category-I joint winners were TAPS-1&2 and NFC, Hyderabad and in Category-II, KGS-3&4 was the winner. Shri P.S.Bhargava, Executive Director, BPCL, Mumbai presented the awards to the winning units.

4.4.5 Green Site Award

The Green Site Award for the year 2008 was given to winning units during the 26th DAE Safety and Occupational Health Professional Meet, which was held at VECC, Kolkata during November 16-18, 2009. The award is based on the highest value of Greenery of the site, which takes into account the existing greenery area, efforts made for making the site greener, terrain conditions of the site and effective site area. The DAE units are divided into two categories based on the total area of the plant including housing colony site, namely, Category-A (<350 hectares) and Category-B (>350 hectares). Based on these criteria, in Category-A, IREL- Manavalakurichi and in Category-B, Kakrapar Atomic Power Station were the winners.

4.5 OCCUPATIONAL HEALTH

4.5.1 Advisory Committee on Occupational Health

The Advisory Committee on Occupational Health (ACOH) of AERB reviews the occupational health records of employees of various DAE Units, recommends measures to ensure their health, informs AERB of any observed case of occupational diseases and suggests ways to improve the occupational health activities. Three meetings of the committee were held during this period. A two days Training programme/Workshop on 'Basic Trauma Life Support' for Para-Medical staff and Certifying Surgeons of DAE units was organised by ACOH with the help of IREL, Udyogamandal during December 28-29, 2009 at Cochin. Sixteen para-medical staffs and fifteen certifying surgeons attended the workshop. Eminent speakers from Ernakulam Medical Centre at Cochin delivered talks on “Immediate Trauma Life Support” and hands-on training of the delegates on human models and torsos.

Inaugural Function of the Workshop on Basic Trauma Life Support in Progress *(Shri R. Bhattacharya, Director, IPSD, AERB, Dr. P.T.V. Nair, Chairman, ACOH, Dr. Mathew Vargees, Course Coordinator, Ernakulam Medical Centre, Cochin, Dr. G. Mohan, Certifying Surgeon, IRE (Udyogamandal))*

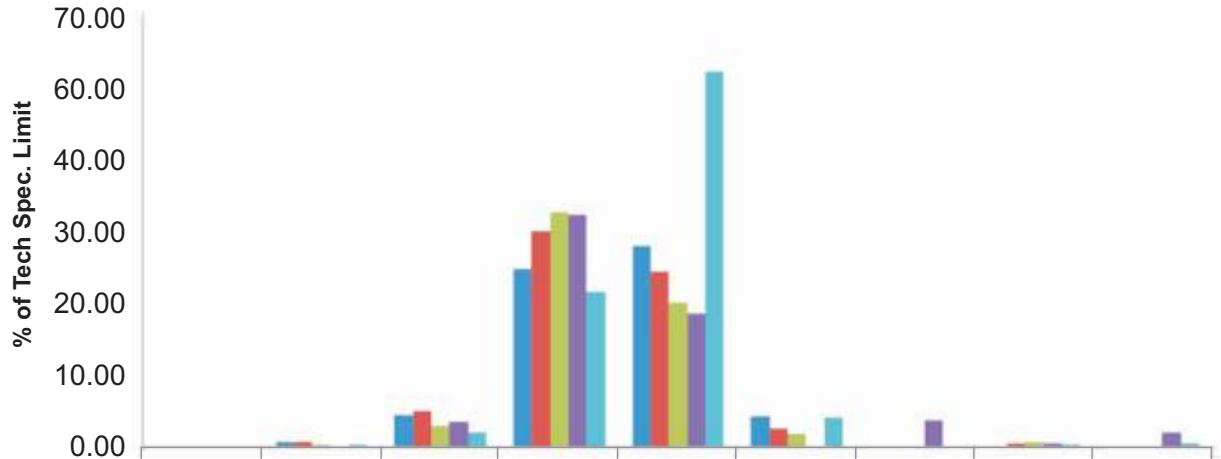
CHAPTER 5

ENVIRONMENTAL SAFETY AND OCCUPATIONAL EXPOSURES

5.1 ENVIRONMENTAL SAFETY

The Environmental Survey Laboratories (ESL) of the Health, Safety and Environment Group, Bhabha Atomic Research Centre (BARC) carry out environmental surveillance at all the operating nuclear power plants at sites. The liquid and gaseous waste discharged to the environment during the year 2009 from the operating nuclear power plants were only a small fraction of the prescribed Technical Specification limits. Figs. 5.1a - 5.1e show the liquid and gaseous discharges from the plants for the years 2005, 2006, 2007, 2008 and 2009 as percentage of permissible limits as per Technical Specifications. Figs. 5.2a and 5.2b show the committed effective dose to the members of the public due to the release of radioactive effluents from the plants. Radiation dose to members of the public near the operating plants is estimated based on measurements of radionuclide concentration in items of diet, i.e., vegetables, cereals, milk, meat, fish, etc and through intake of air and water. It is seen that in all the sites the effective dose to public is far less than the annual limit of 1 mSv (1000 micro-Sievert) prescribed by AERB.

5.1 a : Liquid Waste Discharges from NPPs (Tritium)

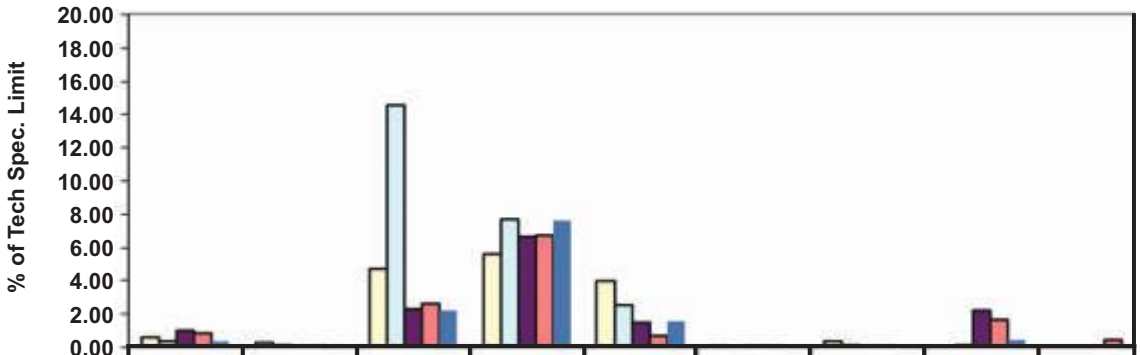


	TAPS 1&2	RAPS 1&2	MAPS	NAPS	KAPS	KGS 1&2	RAPS 3&4	TAPS 3&4	KGS 3&4
2005	0.00	0.77	5.21	28.68	32.45	5.10	0.29		
2006	0.00	0.91	5.81	34.91	28.32	3.07	0.18	0.58	
2007	0.00	0.32	3.50	37.83	23.28	2.12	0.19	0.87	
2008	0.00	0.08	4.05	37.46	21.55	0.13	4.15	0.41	2.32
2009	0.00	0.33	2.40	25.13	60.68	4.89	0.29	0.46	0.66

Notes:

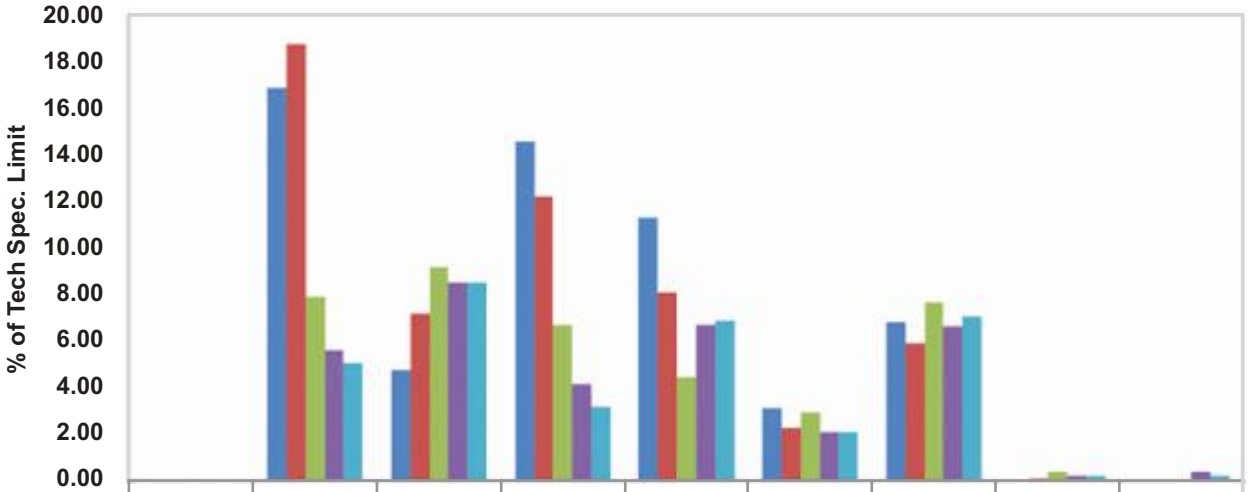
1) TAPS-1&2 are Boiling Water Reactors. Hence, there is no generation / discharge of Tritium.
2) The data of MAPS pertains to transfer of liquid waste to Centralised Waste Management Facility, Kalpakkam for processing & discharge to the environment.
3) In KAPS-1, suppression pool was dewatered during the year 2009 and 71.25 TBq of tritium activity was disposed as liquid effluent after obtaining approval from AERB.

5.1 b : Liquid Waste Discharge from NPPs (Gross Beta)



	TAPS 1&2	RAPS 1&2	MAPS	NAPS	KAPS	KGS 1&2	RAPS 3&4	TAPS 3&4	KGS 3&4
2005	0.62	0.30	4.70	5.61	4.01	0.01	0.34		
2006	0.37	0.07	14.49	7.67	2.56	0.00	0.08	0.12	
2007	0.96	0.01	2.29	6.65	1.44	0.00	0.06	2.16	
2008	0.82	0.00	2.60	6.74	0.65	0.01	0.03	1.65	0.41
2009	0.37	0.07	2.20	7.60	1.56	0.01	0.02	0.45	0.11

5.1 c : Gaseous Waste Discharges from NPPs (Tritium)

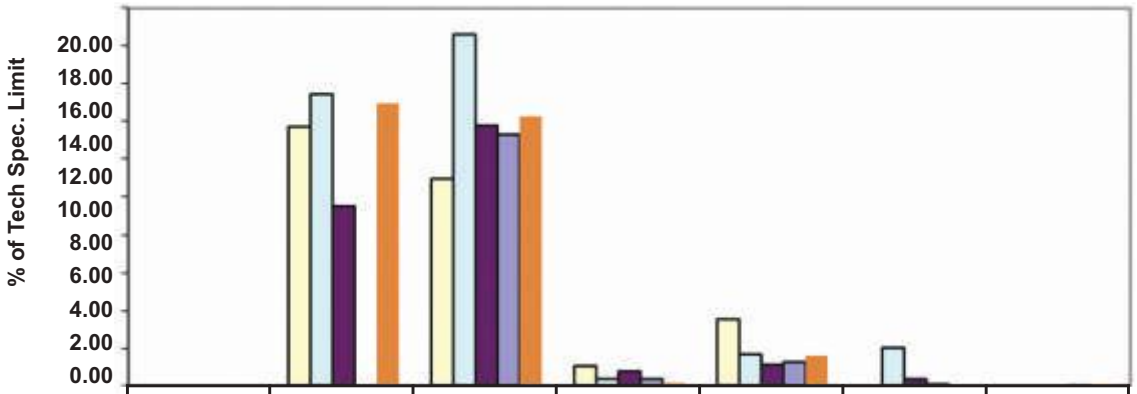


	TAPS 1&2	RAPS 1&2	MAPS	NAPS	KAPS	KGS 1&2	RAPS 3&4	TAPS 3&4	KGS 3&4
2005		16.80	4.78	14.51	11.24	3.15	6.82		
2006		18.65	7.18	12.16	8.07	2.27	5.88	0.14	
2007		7.89	9.17	6.70	4.47	2.98	7.64	0.41	
2008		5.58	8.50	4.16	6.68	2.09	6.63	0.25	0.44
2009		5.04	8.50	3.19	6.84	2.08	7.06	0.25	0.22

Note:

1) TAPS-1&2 are Boiling Water Reactors. Hence, there is no generation / discharge of Tritium.

5.1 d : Gaseous Waste Discharges from NPPs (Argon-41)

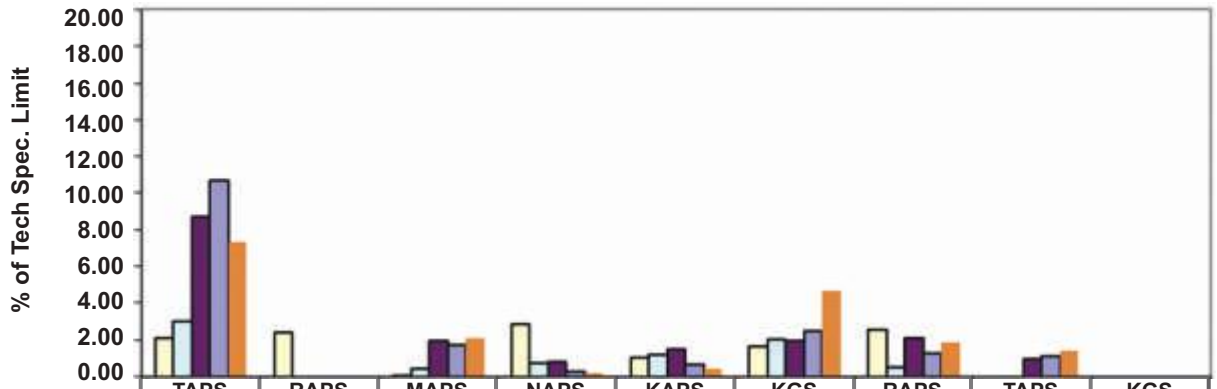


	TAPS 1&2	RAPS 1&2	MAPS	KGS	RAPS 3&4	TAPS 3&4	KGS 3&4
2005	0.00	13.75	10.94	1.02	3.51		
2006	0.00	15.45	18.65	0.34	1.66	1.97	
2007	0.00	9.52	13.77	0.73	1.33	0.32	
2008	0.00	0.00	13.34	0.36	1.29	0.06	0.02
2009	0.00	15.00	14.30	0.15	1.63	0.04	0.08

Note:

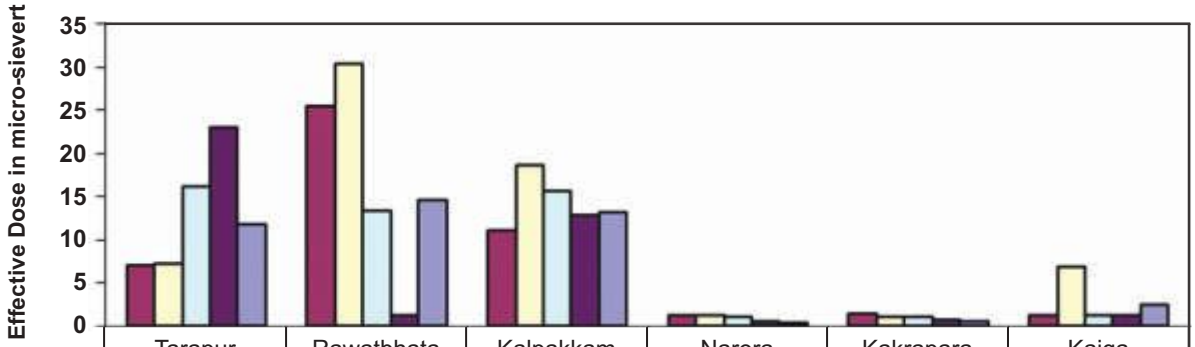
1) Ar-41 releases are less from NAPS reactors onwards because of their operation with filled calandria. Discharge of Ar-41 is controlled under the technical specification limit for FPNG at NAPS & KAPS.
2) Discharge of Ar-41 for NAPS & KAPS is included in the technical specification limit for FPNG and given in Fig. 5.1 e

5.1 e : Gaseous Waste Discharges from NPPs (Fission Product Noble Gases)



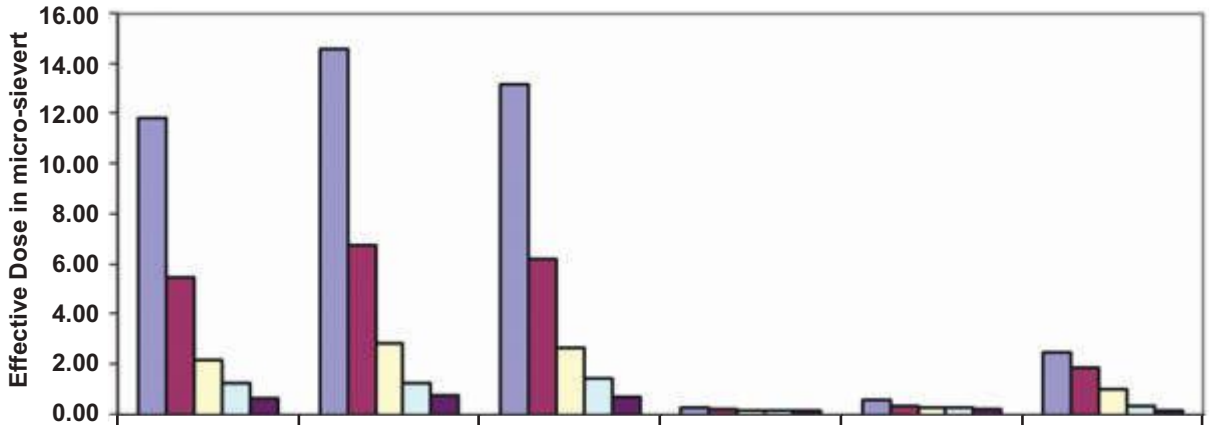
	TAPS 1&2	RAPS 1&2	MAPS	NAPS	KAPS	KGS 1&2	RAPS 3&4	TAPS 3&4	KGS 3&4
2005	2.11	2.37	0.02	2.83	1.04	1.65	2.57		
2006	3.04	0.00	0.40	0.77	1.20	2.00	0.50	0.00	
2007	8.71	0.00	1.95	0.84	1.47	1.92	2.12	1.00	
2008	10.68	0.00	1.70	0.29	1.64	2.46	1.28	1.14	0.00
2009	7.32	0.05	2.10	0.19	0.43	4.70	1.91	1.45	0.00

5.2 a : Public Dose at 1.6 km Distance from NPPs (AERB Prescribed Annual Limit is 1000 micro-Sv)



	Tarapur Site	Rawatbhata Site	Kalpakkam Site	Narora Site	Kakrapara Site	Kaiga Site
2005	7.12	25.43	11.00	1.24	1.36	1.30
2006	7.215	30.40	18.68	1.18	1.12	6.91
2007	16.25	13.30	15.60	1.05	1.00	1.26
2008	23.00	1.26	12.80	0.48	0.79	1.31
2009	11.82	14.60	13.20	0.30	0.60	2.48

5.2 b : Total Effective Dose in Different Zones (AERB Prescribed Annual Limit is 1000 micro-Sv)



	Tarapur Site	Rawatbhata Site	Kalpakkam Site	Narora Site	Kakrapara Site	Kaiga Site
1.6km	11.82	14.60	13.20	0.30	0.60	2.48
1.6-5km	5.48	6.80	6.20	0.24	0.36	1.90
5-10km	2.17	2.90	2.67	0.20	0.29	1.05
10.15km	1.27	1.30	1.44	0.19	0.28	0.38
15-30km	0.70	0.80	0.71	0.18	0.27	0.20

5.2 OCCUPATIONAL EXPOSURES

In each NPP, a Radiological Safety Officer (RSO) and an Assistant RSO are designated by the competent authority to implement the radiation protection programme. The RSOs are entrusted with the responsibility for providing radiological surveillance and safety support functions. These include radiological monitoring of workplace, plant systems, personnel, and effluents, carrying out exposure control, exposure investigations and analysis and trending of radioactivity in plant systems.

All nuclear plants have radiation safety programmes and work procedures intended to control the occupational exposures. AERB Safety Manual on 'Radiation Protection for Nuclear Facilities' (AERB/NF/SM/O-2 Rev.4, 2005) specifies Dose Limits and Investigation Levels (IL) for occupational workers to control the individual doses.

As per AERB guidelines, for an occupational worker annual dose limit is 30mSv, with the condition that it should not exceed 100 mSv in a span of 5 years. For better exposures control the individual cases are investigated and controlled at an early stage, so as to avoid reaching the AERB specified dose limits. Following ILs is applicable to the nuclear facilities.

Monthly dose	-	10 mSv
Quarterly (3 months) dose	-	15 mSv
Annual dose	-	20 mSv

The information on number of workers in NPPs and in medical, industrial and research institutes who received dose between 20 to 30 mSv and above 30 mSv during the year 2009 is given in Tables 5.1 and 5.2 respectively. There were three cases of exposure between 20-mSv and 30-mSv and two cases of exposure exceeding 30 mSv at KGS-1&2 due to drinking of tritium contaminated water from a drinking water cooler. See Table 5.3 on collective dose for operation and maintenance of NPPs (excluding the dose for special campaign like EMCCR, EMFR and up gradation activities) for last five years.

Table 5.1: Radiation Doses Received by Workers in NPPs (2009)

NPP	Number of monitored persons	Average dose for monitored persons (mSv)	Number of persons receiving dose	Average dose among dose receivers (mSv)	Number of workers receiving dose in the range		
					< 20 (mSv)	20-30 (mSv)	>30 (mSv)
TAPS-1&2	2202	2.36	1831	2.84	1831	0	0
RAPS-1&2	1280	1.05	882	1.52	882	0	0
MAPS-1&2	1162	1.51	995	1.76	995	0	0
NAPS-1&2	2135	3.63	1912	4.05	1912	0	0
KAPS-1&2	2337	2.80	2030	3.22	2030	0	0
KGS -1&2	1493	1.74	1074	2.43	1069	3	2
RAPS-3&4	1938	0.87	1205	1.40	1205	0	0
TAPS -3&4	1581	0.27	892	0.47	892	0	0
KGS -3&4	978	0.06	196	0.30	196	0	0

Table 5.2 : Radiation Doses Received by Workers in Medical, Industrial and Research Institutions (2009)

Category of Radiation Worker	No. of Monitored Persons	Average Dose for Monitored Persons (mSv)	No. of Exposed Persons	Average Dose for Exposed Persons (mSv)	Number of Workers Received Annual Individual Dose Excluding Zero Dose, D(mSv)				
					0<D≤ 20	20<D ≤30	30<D ≤40	40<D ≤50	D> 50
Diagnostic X-rays	25176	0.21	9805	0.55	9804	1	0	0	0
Radiation Therapy	5495	0.15	2231	0.38	2231	0	0	0	0
Nuclear Medicine	1387	0.36	836	0.60	836	0	0	0	0
Ind. Radiography & Radiation Processing	5127	0.38	1905	1.01	1904	0	1	0	0
Ind. Radiography & Radiation Processing	5127	0.38	1905	1.01	1904	0	1	0	0
Research	3100	0.05	672	0.24	672	0	0	0	0

Table 5.3 : Collective Dose (Person-Sievert) at NPPs

Year	2005	2006	2007	2008	2009
TAPS	5.45	5.15	4.35	4.92	5.20
RAPS-1&2	2.57	4.64	1.47	0.05	1.34
MAPS	1.46	3.71	1.62	1.95	1.75
NAPS	3.96	4.27	4.57	1.21	1.10
KAPS	3.27	2.53	1.12	0.68	1.36
KGS-1&2	2.05	1.76	1.83	1.66	2.26
RAPS-3&4	1.73	2.45	1.73	1.73	1.68
TAPS- 3&4	-	0.38	0.79	0.53	0.42
KGS-3&4	-	-	-	0.19	0.06

No worker in front end fuel cycle facilities of DAE [IREL (Udyogamandal, Manavalakurichi, Chavara, OSCOM), UCIL (Jaduguda, Bhatin, Narwapahar, Turamdih, Bagjata, Banduhurang), NFC (Hyderabad) received radiation dose greater than 30 mSv during the year 2009. One worker at IREL, Udyogamandal received dose between 20 mSv and 30 mSv i.e., 23.36 mSv during the year 2009. Investigations were carried out based on the AERB's recommendation. This data is given in Table 5.4.

Table 5.4 : Radiation Doses Received by Workers in Front of End Fuel Cycle Facilities (2009)

Type of Facilities	Location	Number of Exposed Persons	Average Dose for Exposed Persons (mSv)	Maximum Dose of Exposed Persons (mSv)	Number of workers received dose in the range		
					< 20 mSv	20 – 30 mSv	>30 mSv
Uranium mines (UCIL)	Jaduguda	852	5.110	10.28	852	0	0
	Bhatin	191	5.320	15.90	191	0	0
	Narwapahar	703	3.650	6.51	703	0	0
	Turamdih	360	6.520	10.10	360	0	0
	Bagjata	168	3.680	5.35	168	0	0
	Banduhurang	49	1.320	1.63	49	0	0
Uranium mill (UCIL)	Jaduguda	515	2.200	3.16	515	0	0
Thorium mines and mineral separation (IREL)	Chavara	88	0.290	1.34	88	0	0
	Chatrapur	146	1.160	8.95	146	0	0
	Manavalakurichi	205	6.460	12.68	205	0	0
Thorium mill (IREL)	Udyogamandal	321	5.610	23.36	320	1	0
Fuel fabrication (NFC)	Hyderabad	760	0.966	17.14	760	0	0

CHAPTER 6

EMERGENCY PREPAREDNESS

Nuclear power plants are provided with adequate safety features to guard against the possibility of any accident. Further, the safety features such as a containment building around each nuclear power unit helps in mitigating the consequences, should an event occur. However in the event of a Beyond Design Basis Accident, it might become necessary to take certain mitigating measures in the public domain. Site-specific emergency preparedness plans are therefore drawn up and maintained at all stations for plant emergencies, site emergencies and off-site emergencies. To test these plans, periodic emergency exercises are carried out involving the station authorities, district administration, and the members of public. Plant Emergency Exercises (PEE) are carried out once in a quarter by each NPP. Site Emergency Exercise (SEE) and Off-site Emergency Exercise (OSEE) are carried out by each site once in a year and once in 2 years respectively.

Table 6.1: Number of Emergency Exercises conducted in 2009

NPP Sites	SEE	OSEE
Tarapur Site	1	1
Rawatbhata Site	1	-
Kalpakkam Site	1	1
NAPS Site	1	1
Kakrapar Site	1	-
Kaiga Site	1	1

The number of site and offsite emergency exercises carried out in NPP sites in 2009 is given in Table 6.1. The response of the plant personnel, district officials and public involved in the exercise was observed by AERB. Based on these, certain improvements suggested in the aspects related to emergency preparedness are in the area of communication facilities and public awareness.

The emergency preparedness exercises are also carried out in fuel cycle facilities. The Periodic Site Emergency Exercises and Off- Site Emergency Exercises were carried out at Hydrogen Sulphide based HWPs at Manuguru and Kota. SEEs are carried out once in 6 months and OSEEs once in a year. SEEs, Periodic Emergency Exercises (PEEs) and Fire drills are carried out at ammonia based HWPs at Baroda, Thal, Hazira and Tuticorin. PEEs are carried out once in a quarter and drills are carried out once in 2 months.

The emergency preparedness plan for HWP-Kota including the Heavy Water Clean-up facility is under review by AERB. AERB officials witnessed the actual SEE & OSEE mock drills at some of the HWPs sites. The responses of the plant personnel, officials and public involved in the exercise and general level of the awareness amongst the public were satisfactory.

CHAPTER 7

SAFETY DOCUMENTS

AERB develops safety documents, which include Safety Codes (SC), Safety Standards (SS), Safety Guides (SG), Safety Manuals (SM) and Technical Documents (TD) for nuclear and radiation facilities and related activities.

The AERB safety documents for regulation of NPPs were mostly oriented towards PHWRs so far. But in view of the setting up of the LWRs in the country, AERB has taken an initiative to develop documents for LWRs as well. As a first step in this direction, the development of the safety guide on commissioning of LWR was initiated on proactive basis. The guide was completed during the year 2009-10 and has been made available before the commissioning of the first pressurized water reactor based nuclear power plant at Kudankulam. This document will be used on a trial basis during commissioning of KK NPP Unit-1 and based on the experience from KKNPP Unit-1, the guide will be revised and finally issued.

AERB has also prepared a regulatory guide to formalise the regulatory requirement for use of computer based systems in various activities of NPPs. Experience gained during the process of review of computer-based systems in the recently constructed NPPs was utilized for the development of this guide.

The progress on various safety documents during the year is given below.

7.1 NEW SAFETY DOCUMENTS PUBLISHED

1. Revised Safety Code on 'Design of Pressurised Heavy Water Reactor Based Nuclear Power Plants' [(AERB/NPP-PHWR/SC/D (Rev. 1)].
2. Revised Safety Standard on 'Fire Protection Systems for Nuclear Facilities' [AERB/NF/SS/FPS (Rev. 1)].
3. Safety Guide on 'Seismic Qualification of Structures, Systems and Components of Pressurised Heavy Water Reactors' (AERB/NPP-PHWR/SG/D-23).
4. Safety Guide on 'Computer Based Systems of Pressurised Heavy Water Reactors' (AERB/NPP-PHWR/SG/D-25).
5. Safety Guide on 'Decommissioning of Nuclear Power Plants and Research Reactors (AERB/NPP&RR/SG/RW-8).
6. Safety Guidelines on 'Uranium Oxide Fuel Fabrication Facilities' (AERB/FE-FCF/SG-3).

7.2 SAFETY DOCUMENTS UNDER REVISION

1. Safety Code on 'Transport of Radioactive Materials' [AERB/NRF/SC/TR-1 (Rev. 1)].
2. Safety Code on 'Nuclear Medicine Facilities' [AERB/RF-MED/SC-1 (Rev.2)].
3. Safety Code on 'Radiation Therapy Sources, Equipment and Installations' [AERB/RF-MED/SC-2 (Rev.1)].

7.3 SAFETY DOCUMENTS TRANSLATED AND PUBLISHED IN HINDI

1. Safety Guide on 'नाभिकीय विद्युत सयंत्रो के स्थल चयन के संबंध में जनसंख्या विभाजन और विश्लेषण (एईआरबी/एसजी/एस-9; 1998)'

   [Population Distribution and Analysis in Relation to Siting of Nuclear Power Plants (AERB/SG/S-9; 1998)].

2. Safety Glossary on 'नाभिकीय एवं विकिरण संरक्षा के लिए शब्दावली' (एईआरबी/एसजी/जीएलओ; 2005)'

   [Glossary of Terms for Nuclear and Radiation Safety (AERB/SG/GLO; 2005)].

7.4 SAFETY DOCUMENTS UNDER DEVELOPMENT

1. Safety Standard on 'Transport of Radioactive Materials' (AERB/NRF/SS/TR-1).
2. Safety Guide on 'Security of Radioactive Sources in Radiation Facilities' (AERB/RF-RS/SG-1).
3. Safety Guide on 'Human Induced Events and Establishment of Design Basis' (AERB/NF/SG/S-7).
4. Safety Guide on 'Commissioning of Pressurised Water Reactors' (AERB/NPP-PWR/SG/O-4C).
5. Safety Guide on 'Classification of Radioactive Waste' (AERB/NRF/SG/RW-1).
6. Safety Guide on 'Predisposal Management of High Level Radioactive Waste' (AERB/SG/RW-3).
7. Safety Guide on 'Decommissioning of Nuclear Fuel Cycle Facilities other than Reactors' (AERB/SG/RW-7).
8. Safety Guide on 'Design of Nuclear Power Plant Concrete Containment Structures' (AERB/NPP/SS/CSE-3).
9. Safety Guide on 'Consenting Process for Radiation Facilities (AERB/RF/SG/G-3).
10. Safety Guide on 'Design of Nuclear Fuel Reprocessing Facilities' (AERB/BE-FCF/SG-1).
11. Safety Guide on 'Renewal of Licence for Operation of Nuclear Fuel Cycle Facilities other than Nuclear Power Plants & Research Reactors' (AERB/FE&BE-FCF/SG-1).

CHAPTER 8

SAFETY STUDIES

8.1 SAFETY ANALYSIS

8.1.1 Reactor Channel Disassembly Methodology Model for PHWR

A methodology model is developed for predicting disassembly of reactor channels of a PHWR under severe accident conditions. High temperature material properties including creep effects are included in the model. Interaction between two adjacent channels is accounted with contact elements. Failure is based on the total strain reaching failure strain at a particular temperature. A 3D failure curve is obtained in terms of time for reactor channel to fail, load on the reactor channel and temperature of the channel. Channel tube temperature transient obtained from thermal hydraulic code was mapped on a sample basis onto the 3D curve to predict the failure of reactor channels.

8.1.2 Accident Sequence Precursor Analysis for IRV Incident at NAPS-1

A case study has been carried out on accident sequence precursor analysis for the Instrumented Relief Valve (IRV) incident in NAPS-1. In the incident, one of the IRVs got opened spuriously and resulted in minor spillage of D2O in fuelling machine vault along with light water injection in primary heat transport system. The event covering the aspects of initial plant conditions, chronology of events, operator actions, etc. was mapped on the existing probabilistic safety assessment (PSA) model. Event progression is modeled considering the 'IRV opening' as the initiating event with success/failure of mitigation systems such as reactor protection system, heat removal systems and systems for maintaining reactor in sub-critical configuration for long duration. The unavailability estimate of these systems are derived. Safety significant components, inter-system dependencies and important human actions are identified. It has been observed that due to adequate mitigation measures available in the reactor design, the IRV opening event is not a 'significant' precursor.

8.1.3 Independent Verification of Reliability Analysis for RPS of NAPS-1&2

In light of the NAPS-2 incident involving leak in one of the ion chambers, AERB asked NPCIL to segregate the primary shutdown system (PSS) and secondary shutdown system (SSS) ion chambers, to avoid common cause failure (CCF). NPCIL proposed the use of ion chamber in reactor regulation system (RRS) for SSS and submitted reliability analyses results for the existing case (i.e. common ion chambers for PSS and SSS) and the proposed case (i.e. separate ion chambers for PSS and SSS). An independent verification of the reliability analysis of both these cases was carried out in AERB. The results obtained by AERB matched with those provided in the NPCIL report except for the case where the ion chambers for PSS and SSS were segregated. The reason for this difference is attributed to different common cause failure (CCF) modeling assumptions used in the two approaches such as coverage of CCF combinations giving realistic reliability assessment and assumptions regarding the partial CCFs.

8.1.4 SBO Analysis of 700 MWe KAPP-3&4 PHWR

A preliminary station blackout (SBO) analysis for 700 MWe KAPP-3&4 has been carried out without taking credit for manual crash cool down. Steady state calculations are compared with designed nominal values and the differences are found to be acceptably small. SBO scenario is modeled, in which transient starts with reactor trip on 'no Reactor Coolant Pumps (RCP) running', stopping the feed water to steam generator, and closing the steam turbine valves at zero second. RCP coast down completes in 120 seconds. Just after tripping the reactor, secondary pressure increases and all four atmospheric steam discharge valves (ASDV) are opened. Primary pressure decreases up to 88 bar and it is maintained till around 8800 seconds as heat is removed during this period through secondary ASDV. When water level in steam generator reaches almost zero, then there is no heat removal from SG. Therefore primary re-pressurization starts and at 9900 seconds, primary pressure reached 110 bar (the opening pressure of IRV) and hence IRV opens. Then decrease in primary inventory starts. Clad temperature starts rising at 13000 seconds and maximum clad temperature reaches 1000 deg C in hot channel at 17000 seconds. Sensitivity analysis was carried out by varying the flow areas of IRV and ASDV. From the analysis, it is observed that the IRV does not allow rising of primary pressure significantly beyond the IRV set point.

8.2 SAFETY ANALYSIS REVIEW

8.2.1 Computational Fluid Dynamic Analysis of Flow through Check Valves in Emergency Core Cooling System of RAPS-2

The check valves of Emergency Core Cooling System (ECCS) of RAPS-2 were not closing fully after

testing. RAPS-2 proposed installing counter weights on operating levers of these check valves. Computational fluid dynamics (CFD) analysis was carried out to assess and analyze flow and pressure variation through check valve of ECCS. The geometry of check valve and internals such as swing disk were modeled. The analysis was carried out for various disk swings of 30, 45, 50 and 54. It was observed that for 54 full swing of disk, maximum pressure drop for V-505 valve (250 mm) was 0.0286 kg/cm2 and for 30 swing of disk, the pressure drop was 0.2274 kg/cm2. It was confirmed that for smaller swing of disk, the pressure drop across the valve is more. The CFD analysis gave better understanding of the flow pattern, velocity pattern and pressure drop across check valve and accordingly further action was decided.

8.2.2 Reliability Analyses Review of KAPS-1&2

The reliability analyses for safety systems and engineered safety features were reviewed in AERB for renewal of authorization (ARA) for KAPS-1&2. The ARA reports are prepared based on the technical guidelines prepared by NPCIL. Some technical issues are identified for improvement of ARA guidelines such as: (i) need for collection and assessment of human failure data, definition of 'component boundary' and repair times, (ii) providing guidelines for estimating the failure rate from the plant-specific data rather than taking 'stand-by failure rate' always as 'zero', (iii) correcting the 'Bayesian update' approach. It is also suggested to include the 'trending analyses' for system reliabilities as it provides valuable insights into system performance, the effect of maintenance and operating practices, etc.

8.2.3 Accident Analysis Review of NAPS-1&2

The safety analysis report on accident analyses was reviewed as a part of periodic safety review. A few areas were identified for improvement in selection of postulated initiating events, safety classification, validation of the computer codes used in the safety analyses, demonstration of acceptance criteria, etc. It was suggested in the review observations that the safety significant operational events that have occurred in the Indian NPPs but are not enveloped by the design basis events should be addressed in the safety report as frequency of occurrence of such events is in the higher range. Some of the examples of such events are: (i) total failure of emergency power supply system, (ii) total failure of reactor regulating system and (iii) moderator water leak from suction flange (much greater than 230 lpm). These would be addressed in future safety analysis reports.

8.3 RESEARCH AND DEVELOPMENT

8.3.1 Development and Validation of 3D Dynamics Code, TRIKIN

Large pressurized water reactors are to be inducted in Indian nuclear power program. These reactors are loosely coupled neutronically and therefore demands space-time kinetics treatment to analyze a wide spectrum of transients for safety studies. Therefore a computer code, 'TRIKIN', has been developed and validated against rod ejection accident benchmark at low power in VVER reactors. As extension of this work, this year, a thermal hydraulics model, based on fuel pin simulation has been developed and coupled with TRIKIN to incorporate fuel and coolant reactivity feedback effects. Thermal hydraulic model is based on simple finite differencing scheme, employed by semi implicit method.

Thermal hydraulic model has been validated against standard benchmark problems in the text. Complete coupled code has been validated against international benchmark problems AERDYN002 and AERDYN003. Benchmark AERDYN002 is to assess the Doppler feedback capability of the coupled code system under rapid transients whereas benchmark AERDYN003 is to assess fuel as well as coolant feedback capability of the code. Both problems are asymmetric control rod ejection transient. The worth of the ejected rod is about two times prompt critical value. The initially critical reactor experiences a power excursion without any reactor SCRAM. The power of the reactor is limited by the continuous accumulation of heat in the fuel and coolant and consequent reactivity feedbacks. TRIKIN results have been found to be in reasonably good agreement with DYN3D. Coupled dynamics TRIKIN code system can be used to analyze a variety of transients in VVER reactor cores, e.g., rod ejection accident, inadvertent actuation of quick boron injection system during power operation, wrong start-up of an inactive reactor coolant loop etc.

8.3.2 A Comparative Study of Xenon Instability in PHWR and PWR

Indian nuclear program includes both light and heavy water based large thermal reactors. These reactors exhibit a neutronic instability (termed as xenon induced oscillations) at full power operation and sometimes under load following operation. A study was taken up to investigate the quantitative comparison and consequent effects of xenon instability and related spatial control effects in two systems. Study aims to highlight the differences in xenon dynamics in two systems due to differences in core physics design. It has been found that harder neutron spectrum, marginally strong reactivity feedbacks and small core dimensions make PWRs relatively more stable compared to PHWRs against xenon instability. Detailed comparative analysis under varying

core conditions and under different initiating events is in progress.

8.3.3 Importance of Flux Tilt Control in PHWRs

Reactivity Regulating System (RRS) is a vital system in the design of PHWRs. Four regulating rods move IN/OUT on AUTO as per the demand from RRS to maintain the global reactor power. These RRs also move differentially to maintain uniform power distribution locally through the signal generated by Flux Tilt Control (FTC). It is always desirable to keep FTC in "ON" mode during all operating conditions to have uniform power in all the quadrants of core. Effect of movement of adjusters in the absence of FTC has been studied to emphasize the need of FTC, in Auto Mode Operation.

The effect of rod movements on the bundle power will be quite significant in regions near to the location of adjuster rods. To observe the effect of bundle power variation locally, central rod has been moved out one at a time in steps of 10%, keeping all other adjuster rods fixed.

In the case of core with flattened power distribution, there was significant increase in the local bundle powers from the neighboring channels on withdrawal of central adjuster rod (UE). Based on the analysis of the results, the average increase in the maximum bundle powers is of the order of 35 %. The magnitude of power increase in bundles would vary depending on the in-core burnup conditions, adjuster rod positions, power level of operation, etc., prevalent at the time of simulation.

When reactor operates in peaked flux mode, the bundle powers are maintained very high in the central region of the core. The bundles with higher power are clustered around the centre of the core and are four lattice pitches away from the location of adjuster rods. Hence, the adjuster rods' movement does not affect the maximum bundle power at the central location. The effect of adjuster rods' movement was overshadowed by peaked flux distribution.

The conclusions of the study are: Substantial increase (~35%) in the bundle power is possible due to inadvertent movement of adjuster rods, which is possible if FTC is not kept on AUTO. There is also a likelihood of the bundle power exceeding the safety limit of the 483 kW in case of unit operating in flat flux mode at 100% FP with FTC not on AUTO mode. The study and the results strongly suggest that FTC should be kept on AUTO in all operating conditions of the reactor so as to avoid unnecessary movement of adjuster rods, leading to higher local powers in the neighboring fuel bundles. All the NPPs generally keep FTC on AUTO during normal power operation and AERB ensures this aspect during the regulatory inspections.

8.3.4 Simulation Study of Tsunami Propagation for Indian Ocean Region

IAEA Extra Budgetary Program (EBP) "Protection of Nuclear Power Plants against tsunamis and Post Earthquake Considerations in the External Zone" (TiPEEZ) consists of two activities, (1) post tsunami/earthquake considerations in the surrounding area of the site (TiPEEZ) and (2) tsunami hazard assessment.

AERB is associated with activity on tsunami hazard assessment and supporting NPCIL for the activity (1) which concerns with the management of disaster. The software for tsunami modeling developed by Japan Nuclear Energy Safety Organization (JNES) was made available by IAEA/JNES. Kalpakkam coast of India was selected as site for carrying out tsunami hazard assessment. Topography/bathymetry information available in public domain (model-1) and proprietary data (model-2) were used for tsunami hazard assessment for this site. Participation of AERB in the exercise resulted in identification of certain issues with respect to tsunami mesher/tsunami analysis program of JNES software that were subsequently resolved.

Successful simulation of the two benchmarking problems using the JNES software and preprocessor, post-processor developed in AERB were conducted. Good matching of the target values and simulated results were observed with respect to the benchmark problems. Kalpakkam coast was analysed for the source parameters of 2004 tsunami event, both for model-1 and model-2. Some of the results of study are depicted in figures 8.1 (a) and 8.1 (b). For tsunami hazard assessment, other tsunamigenic sources around Indian coast were identified. The methodology developed by Japan Society of Civil Engineers (JSCE) for tsunami hazard assessment of NPPs was applied to Kalpakkam coast by conducting tsunami simulations from these sources with parametric variations of tsunamigenic source parameters.

In addition, AERB generated site specific tsunami hazard assessment model and conducted tsunami simulations for Kudankulam site, which is the target site for activity (1). Results of tsunami simulation are one of the inputs to TiPEEZ software used for activity-(1).

BARC Round Robin Exercise: AERB is an active participant in the round robin exercise on estimation of tsunami wave height at location of coastal nuclear facilities, initiated by BARC. As part of this, it has completed the analysis of Kalpakkam site for 2004 tsunami event (see figure 8.1(a) and figure 8.1(b)) and tsunami wave height estimation at Tarapur site from Makran area is in progress.

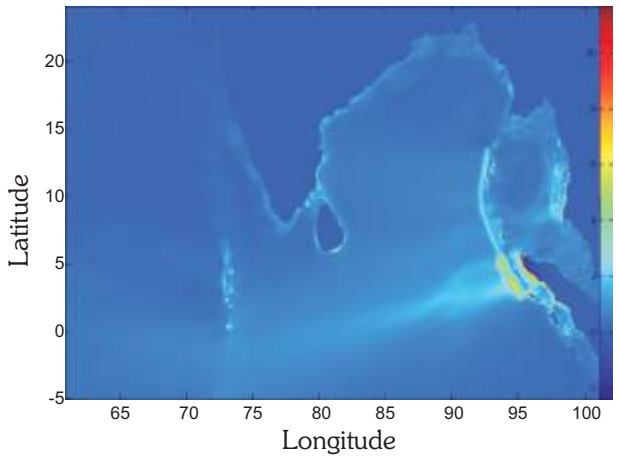


Fig 8.1 (a) : Maximum Predicted Wave Heights based on the Source Model for 2004 Tsunami Event

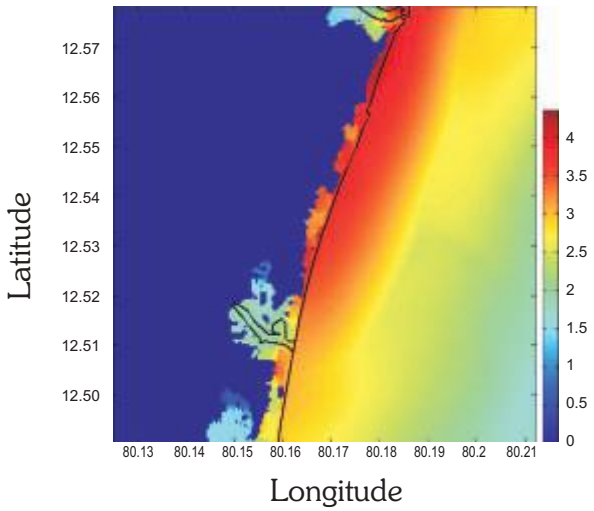


Fig 8.1 (b) : Calculated wave runnup and extent of inundation with respect to coast line near Kalpakkam area

8.3.5 Seismic Re-evaluation of FBTR

Seismic re-evaluation of Fast Breeder test Reactor (FBTR) at Kalpakkam is being carried out jointly by AERB and IGCAR. The final report of seismic re-evaluation covering assessment of seismic margin of plant by deterministic approach and seismic PSA has been submitted for review. Some salient conclusions of the exercise are as follows:

- Three cases were studied. Case-1 considers actual available component High Confidence Low Probability of Failure (HCLPF) capacity, Case-2 considers upgradation of failed components against Review Basis Ground Motion (RBGM) to the least HCLPF capacity of qualified components of the system containing the failed component and Case-3 considers upgradation of failed components against RBGM to a minimum HCLPF capacity of 0.25g. The results are presented in figure 8.2 in terms of seismic fragility curves of the plant for all three cases.
- The seismic capacity of the plant determined in all three cases by seismic probabilistic safety analysis (SPSA) indicates that the minimum acceptable capacity of components does not necessarily guarantee the minimum acceptable seismic capacity of the total plant.
- The plant HCLPF capacity corresponding to initiating events (Loss of offsite power, Primary and Secondary Ward Leonard trip) falls short of Peak Ground Acceleration (PGA) value.
- The study identified number of areas requiring improvement/retrofitting to enhance the seismic margin of FBTR. The review of the findings is under progress.

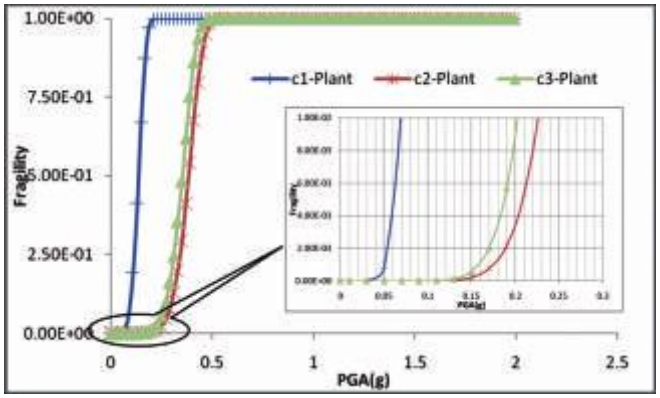


Fig. 8.2 : Mean Plant Seismic Fragility Curves (HCLPF values:- Case-1:0.06g; Case–2:0.225g; Case–3: 0.23g)

8.3.6 Round Robin Exercise on Groundwater Modeling

BRNS had conceived a project proposal for Round Robin Exercise (RRE) on 'Three-Dimensional Groundwater Flow and Contaminant Transport Modeling at the proposed uranium tailings pond in Turamdih, Jharkhand.' AERB is participating in the exercise. A classical sample problem was solved to validate analysis methodology and modeling aspects and results of the participants were discussed in the first meeting. Fig. 8.3(a) shows the velocity vectors alongwith hydraulic heads. The classical solution of the groundwater velocity (v = 2.75 m/day) is matching with the AERB results. Fig. 8.3(b) shows the contaminant plume of steady state concentration from constant source in the X-Y plane after 1748 days for the same classical problem. However, the AERB results for contaminant transport did not match well with the classical solution. Refinement / tuning of the model is being done to validate the model.

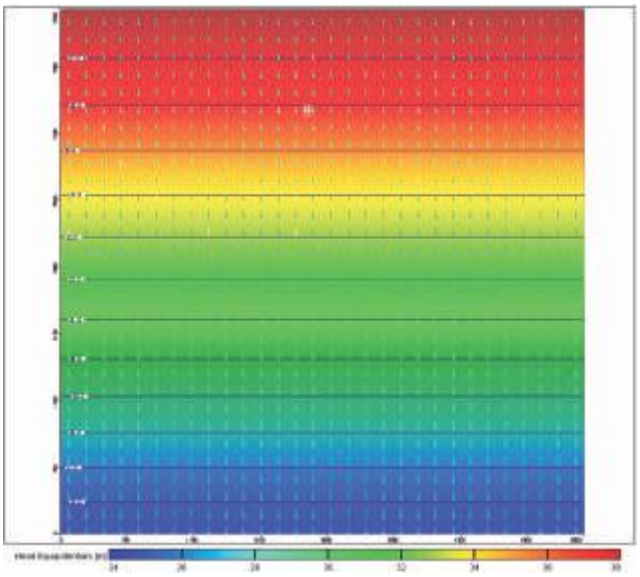


Fig. 8.3 (a) : Distribution of Hydraulic Head with Velocity Vectors

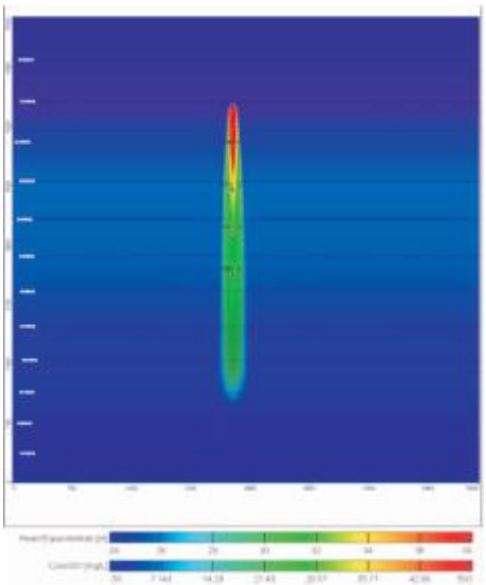


Fig. 8.3 (b) : Contaminant Plume in the X-Y Plane after 1748 Days

CHAPTER 9

SAFETY RESEARCH INSTITUTE

The focus of research activities at the Safety Research Institute (SRI), Kalpakkam has been in the following areas;

- **Nuclear Safety**
  - Reliability and Probabilistic Safety Assessment
  - Reactor Physics and Radiological Safety Studies
  - Fire Modeling and Thermal Hydraulic Studies
- **Environmental Safety**

9.1 NUCLEAR SAFETY

9.1.1 Reactor Physics and Radiological Safety

(a) KKNPP Reactor Core Physics Parameters using SCALE code system

As a part of verification of reactor physics parameters for KKNPP core, independent refueling cycle analysis using SCALE code system was continued. Burn-up dependent criticality calculations for different reactor states with different temperatures of fuel, coolant and soluble boron concentration for different types of fuel subassemblies having averaged fuel enrichment (1.6% to 4.0%) were carried out using ORIGEN-ARP and KENO-VI modules of SCALE code system. Results were found to be in good agreement on comparison with those obtained from EXCEL-TRIHEXFA code systems of RPDD/BARC.

(b) Experimental validation of Radiation Protection factors of Building Materials

The objective is to estimate the gamma radiation protection factors for 150cm thick of soil (1.5g/cc) followed by 21.5cm thick specially prepared concrete (2.7g/cc). Since the measurements are not amenable for such large thickness due to significant contributions from the scattered radiation, experiments are carried out for varying thickness and results are corroborated by Monte Carlo (MC) calculations. After ascertaining the calculated accuracy, the protection factors are deduced by MC calculations.

Measurements were carried out inside a laboratory room of dimensions 457cm x 457cm x 366cm for 33.5, 45.5, and 91cm of soil followed by 21.5cm concrete in 8 different configurations using ^{60}Co as the gamma radiation source with the strength of 20Ci. Further measurements were carried out for 13 and 27cm of soil followed by 21.5cm concrete in 4 different configurations using ^{137}Cs as the gamma radiation source. The gamma camera had a conical half angle opening of 15° towards one side when the experiments were carried out and other regions were heavily shielded. A typical GM survey meter (Rotem – 1μSv/h to 1 Sv/h) was employed to carry out the dose rate measurements. As it is not easily possible to measure the contributions to dose rate due to radiations scattered/reflected from the walls, an equivalent experimental setup was simulated using the Monte Carlo N-Particle (MCNP) radiation transport code. For each experimental configuration, two MCNP simulations (with and without modeling the room walls including floor and ceiling) were carried out to determine the direct as well as reflected radiation dose rates. Simulations could reasonably predict the measurements within a factor of 2 for all the cases measured. It was inferred that the protection factor is 10^7 for ^{137}Cs source and $5x10^5$ for ^{60}Co source.

(c) Radiological Safety Aspects of PET-Cyclotron Facilities

In cyclotron facilities, radiological safety is to be ensured. During the acceleration process, the particle beam may strike various components of accelerators such as collimators, bending magnets, foil strippers, target holders, targets and beam dumps causing nuclear reactions producing prompt radiations as well as inducing artificial radioactivity. The radiations of most common concern for radiological protection are gamma rays and neutrons due to their power of penetration through materials. The intensity of secondary radiations resulting from the first interaction is often referred as source term, which decides the design of cyclotron vault. Besides, the secondary neutrons can also produce, gaseous activity (^{41}Ar) in the cyclotron enclosure and, activation products in the concrete walls (^{60}Co, ^{152}Eu, ^{24}Na etc) of enclosure.

In the present work, empirical relations have been developed to estimate the radiation source term from the particle accelerators, shielding thickness required, activation products and to estimate production of noxious gases inside the enclosures.

(d) Monte Carlo Validation of Dosimetric Measurements for KRUSHAK Food Irradiator Facility

Radiation processing of food involves the controlled application of energy from ionizing radiations such as gamma rays, electrons and X-rays for food preservation. The KRUSHAK Cobalt-60 gamma irradiation facility was commissioned for lower dose applications (up to 1kGy) such as onion and potato sprout control, insect disinfestations of cereals, pulses and their products, and delay in ripening of fruits thereby to increase their shelf life. The effectiveness of processing of food by irradiation depends on proper delivery of absorbed dose and its reliable measurement. Therefore, it is essential to validate dosimetric system of every food irradiator facility for the quarantine of exported products. Towards this objective, Monte Carlo (MC) simulations have been carried out to validate dose rate measurements carried out at KRUSHAK food irradiator facility.

Computations are performed for the experimental systems with and without lead shield. The Monte Carlo N-particle code version 4C (MCNP-4C) is used to perform the desired task. Comparison of MC simulated dose rates with experimental measurements demonstrates that MCNP simulations can be helpful in estimating relative depth dose rate fall inside the product box provided the input information to the code are accurate.

(e) Comparison of Point Kernel Dose rate Calculation Formalism with PLATO Treatment Planning System for Carcinoma of Cervix

A dosimetric comparison of computerised treatment planning (CTP) performed to determine dose at point A, point B, bladder and rectal reference points as suggested by ICRP-38 is made to validate the BrachyTPS, an indigenous point kernel code package integrated with treatment planning computational systems (TPS), against the other commercial TPS software. The present study compares dose calculations generated using BrachyTPS with the results of the recent PLATO (version 14.3.1) TPS system for a few cases treated with high dose rate (HDR) brachytherapy using Fletcher Williamson applicator. Fig.9.1 illustrates the layout of BrachyTPS with the display of an isodose distribution on the patient anatomy image. The study performed throws light on the suitability of the point kernel dose rate calculation formalism for gynaecological treatment planning system.

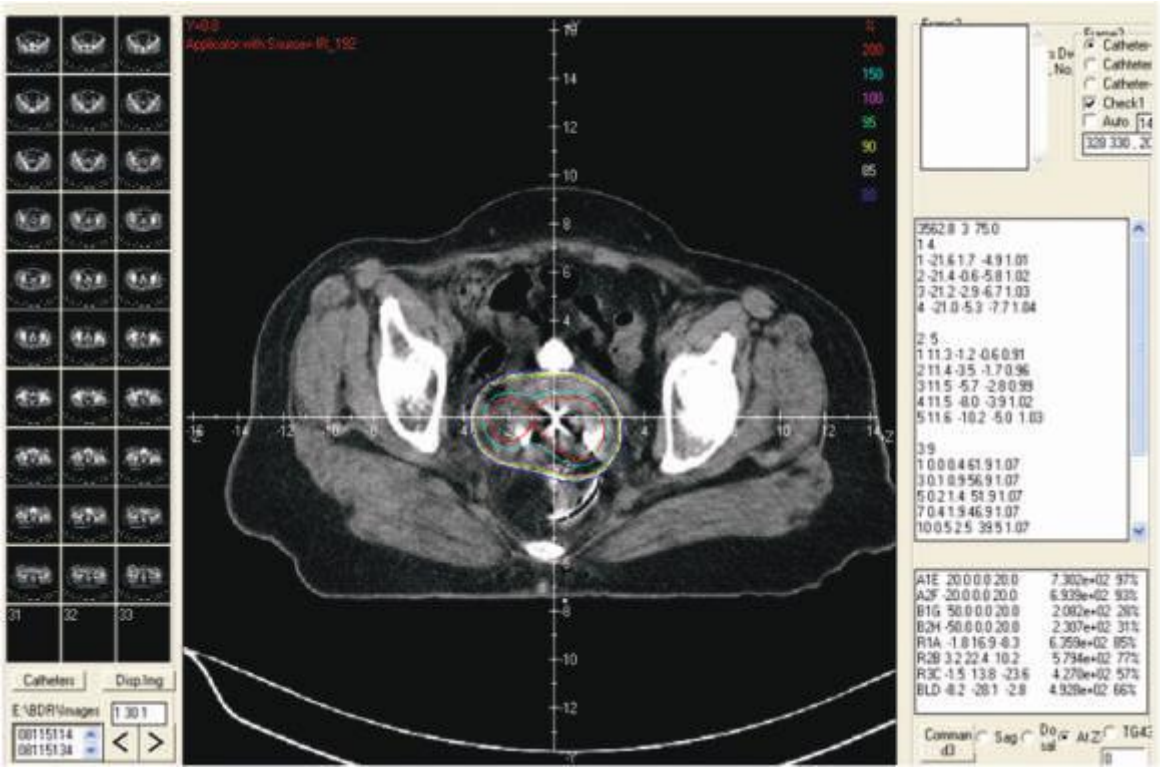


Fig 9.1 Layout of Brachy TPS with the display of isodose distribution

(f) IGSHIELD Code Development

IGSHIELD is an Interactive Gamma-ray Shielding code applicable for complex configuration of sources and shields. Since it is highly versatile, it can be used for computation of dose distribution due to Co-60 units, Brachy therapy templates and also due to injected radioactive sources into organs for diagnostic and therapeutic purposes. The computational methodology is based on the point kernel technique employed in QADCGPIC code (RSICC-CCC-697). In this method, source volume is divided into a finite number of infinitesimally small discrete volumes with strength proportional to their volumes, and then, its transmission probability through shields to the receiver location is estimated. This is multiplied subsequently, with the appropriate buildup factor to account for scattered contribution. The dose rate for entire volume of the source is obtained by summing over all sampled source points.

The program was checked for errors and final modifications were carried out. Workshop on gamma ray shielding was conducted for the benefit of DAE members and the code was distributed.

(g) Brachy TPS Code Development

An interactive point kernel code package "BrachyTPS", incorporating heterogeneities present in the Intra-cavitary Brachytherapy (ICBT) applicators, is developed to perform independent dose rate calculations for treatment planning of gynaecological cancers. The major advantage of this code is that it uses two regions buildup factors proposed by Kalos1 to take into account the effect of heterogeneities present. In addition to performing dose rate calculations, this code package is capable of viewing DICOM images and displaying an isodose distribution curves into the patient anatomical images. The main objective of this study is to validate the developed point kernel package integrated with treatment planning computational systems (TPS) against the other commercial TPS software. The present study compares dose calculations generated using BrachyTPS with the results of the recent PLATO (version 14.3.1) TPS system for a few cases treated with high dose rate (HDR) brachytherapy using Fletcher Williamson applicator.

9.1.2 Reliability and Probabilistic Safety Assessment

(a) Functional Reliability Analysis SGDHR of PFBR

Functional reliability analysis of passive Safety Grade Decay Heat Removal System (SGDHR) of PFBR was carried out by augmentation of approximate solutions generated from deterministic codes. The procedure involves usage of an advanced simulation technique known as 'Response Conditioning Method' with subset simulation based on Markov chain Monte-Carlo technique. This involves creation of first order linear response surfaces for all important parameters of SGDHR system by regression analysis. Subsequently, functional failure probability of SGDHRS is evaluated by incorporating the insight gained from these approximate response surfaces to subset simulation. Typical results obtained are validated with direct Monte Carlo Simulation. The functional failure probability of SGDHRS is evaluated for various initiating events and hardware configurations and to cumulative damage of critical structures. The sensitivity of the important parameters to functional failure is quantified using Bayes' theorem. The relevance of inter-wrapper flow and primary forced circulation on decay heat removal of PFBR is clearly brought out.

(b) Development of a Procedure for Seismic Capacity Assessment of Expansion Joints

Criteria for checking the stability and fatigue failure of the expansion joints using equivalent axial duty are given in ASME and EJMA for normal operating conditions. But these criteria can't be used for their qualification against seismic load, whenever analysis is carried out with Response Spectrum Approach (RSA) or Time History Approach (THA) with mode superposition. Even the detailed finite element analysis of the expansion joints using the displacements obtained from these analyses has its limitations. Therefore, based on THA utilizing the features of simplified linear elastic model as well as detailed finite element analysis of components is developed.

In this procedure, a full transient time-history analysis of the simplified model of pipeline along with expansion joints is performed and criteria given in the EJMA is used for the evaluation of equivalent axial duty on the expansion joints on each time-step. Maximum relative displacements on the expansion joint are estimated using suitable spatial combinations, which in turn is used for the detailed FE analysis with high-order shell element. A case study is carried out for typical expansion joints, where FEA is performed and equivalent axial duty is calculated using MATLAB. Analysis is also performed with RSA using Integrated Model where expansion joint is modeled with higher order shell element and pipeline is modeled with 2-node line elements. The results from both the methods are in good agreement.

9.1.3 Thermal Hydraulics and Fire Safety

(a) Studies on Hydrogen Distribution in Enclosures

The accurate modeling of hydrogen transport and distribution in the presence of steam is still considered a challenging area and presently there is no comprehensive commercial code available to address the

steam condensation phenomena. In the light of the above, an in-house Finite Volume based code named Hydrogen Distribution Simulator (HDS) addressing heat and mass transfer aspects has been developed. HDS solves the mass, momentum, energy and species conservation equations in the Cartesian co-ordinate system along with appropriate turbulence models. Further to validation with laminar flow conditions, the capability of the code was enhanced and turbulence models were rigorously validated against experimental data available in literature. Fig. 9.2 shows contour plots of temperature and velocity for a case with Rayleigh number of 1.58×10^9.

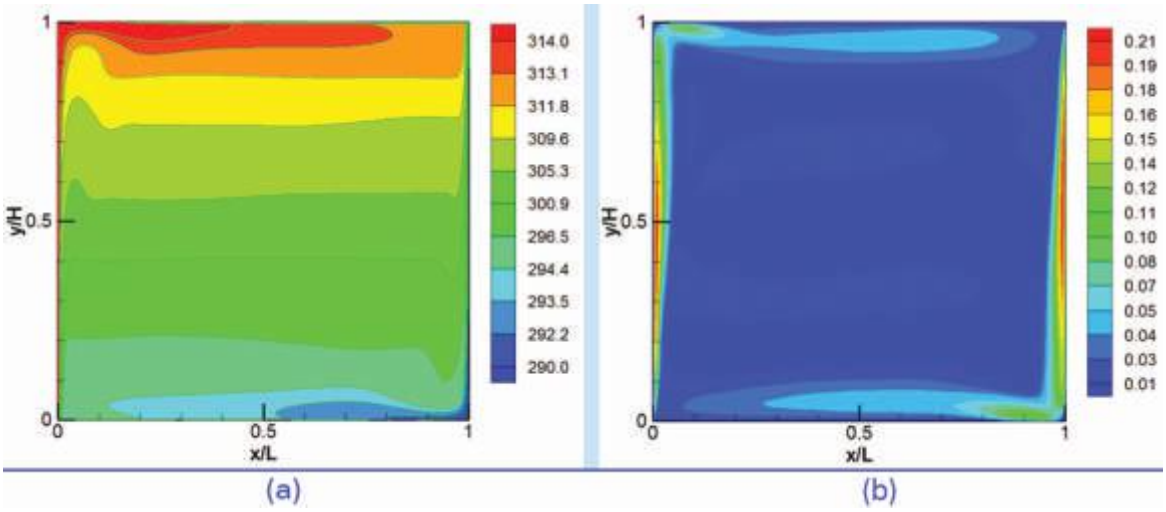


Fig. 9.2: Contours of (a) Temperature (K) and (b) Magnitude of Velocity (m/s) for Turbulent Natural Convection in a Square Enclosure

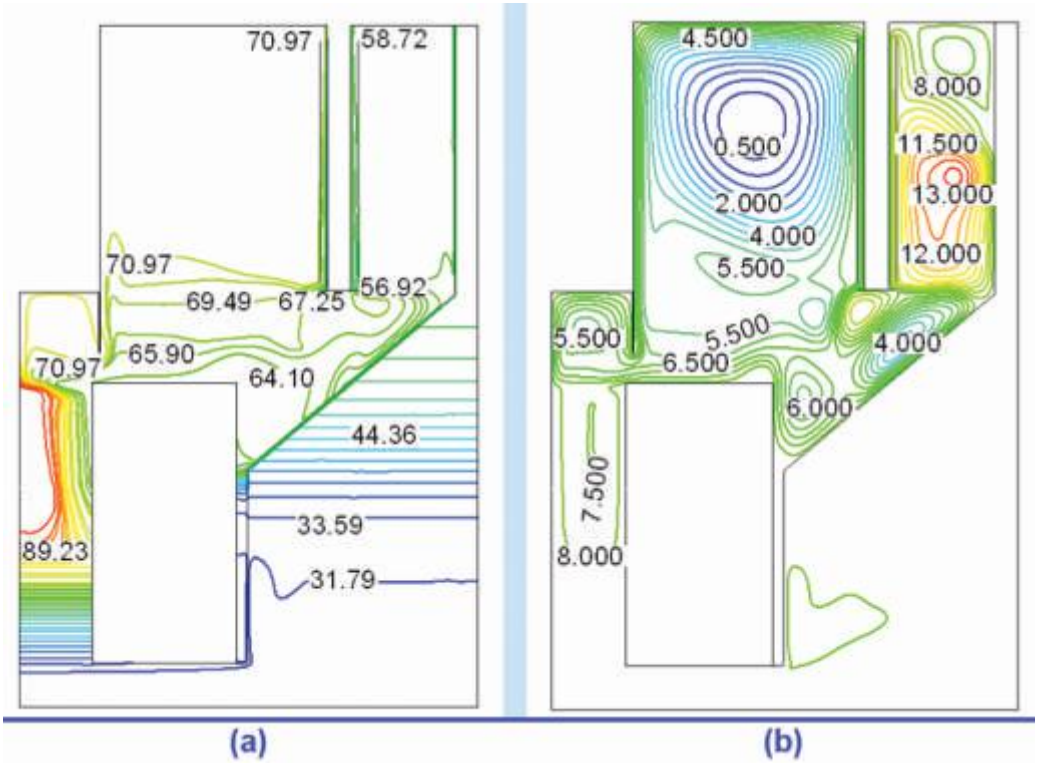


Fig. 9.3: Contours of (a) Temperature (°C) and (b) Stream Function (kg/s) for Porous Media model of 'SAMRAT' facility

(b) Numerical Analysis of Decay Heat Removal System of PFBR

The PFBR has been provided with a safety grade decay heat removal system (SGDHRS) to ensure the removal of decay heat after reactor shutdown under station blackout condition. The system works solely under natural circulation principle. Experiments have been conducted in the 'SAMRAT' facility of IGCAR using water as a simulant, to establish the adequacy of the design of SGDHRS.

In a joint exercise between SRI and IGCAR, numerical modeling of natural circulation phenomena on the primary side of the 'SAMRAT' facility has been undertaken. At present, two numerical models are considered; in the first one, the entire core is assumed as a porous media and in the second, the fuel subassemblies are modeled separately. Both these cases are 2-D half sector representation of the test facility, wherein the DHX is modeled as an equivalent wall with heat flux boundary condition. A typical case in which IHX, blanket and storage subassemblies are all blocked, was simulated using the above two models. Shear Stress Transport (SST) k-ω turbulence model was used in these simulations. Simulations show that the porous media approach is able to reproduce the hot pool temperature distribution better than the model with individual subassemblies. Fig. 9.3 shows the temperature and stream function contour plots for the former case.

(c) Fire Safety Studies

The focus in the area of combustion / fire modeling is on experimental and numerical modeling of enclosure fires, with particular emphasis on developing numerical models for fire spread process. A CFD code based on Finite Volume method is currently being developed to address the flame/fire spread issue from fundamental principles. At present, the numerical model can simulate laminar steady flames, under forced as well as natural convective conditions. These capabilities have been thoroughly validated against experimental results available in literature. Fig. 9.4 shows the flame shapes (indicated by temperature contours) obtained for three different fuel surface orientations, demonstrating the ability of this code to model fire on inclined surfaces under natural convective conditions. The above numerical code provides a convenient starting point for extending the model to fires spread over liquid pool surfaces.

A lab scale experimental facility for investigating burning behavior of various fuels/solvents was set up at IIT Madras. A number of experiments were conducted under forced as well as natural convective environment to generate data for validation of the numerical model being developed. Furthermore, a separate lab scale setup is also being built to investigate transient flame/fire spread process on liquid fuel pools.

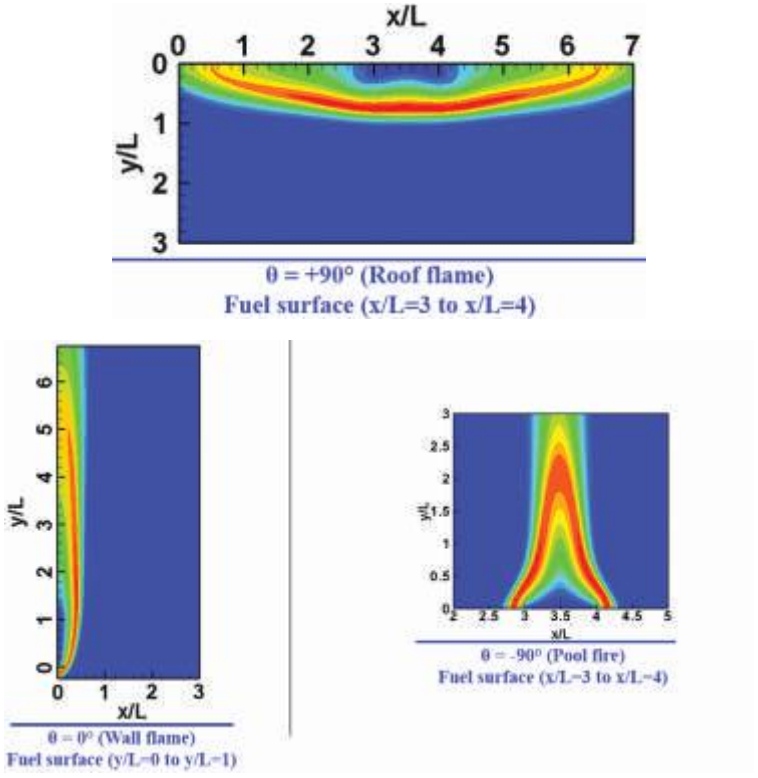


Fig. 9.4 Flame Configuration on Inclined Surfaces

9.2 ENVIRONMENTAL SAFETY

9.2.1 RS-GIS Studies

(a) GIS Database Generation for Uranium Mine, Mill and Tailing Pond Area of Turamdih

A Remote Sensing and GIS based digital database has been generated for Turamdih mine and mill area as three-dimensional groundwater flow and contaminant transport modeling at the proposed Uranium Tailings Pond in Turamdih. This is part of a Round Robin Exercise (RRE) of DAE. In this study, digital database on geomorphology, land use/land cover, lithology, soil features, DEM, surface water bodies, drainage and roads were generated for Turamdih area. A typical thematic map (Fig. 9.5) of the land use/land cover is shown below. The above thematic maps will be utilized in contaminant transport modeling studies.

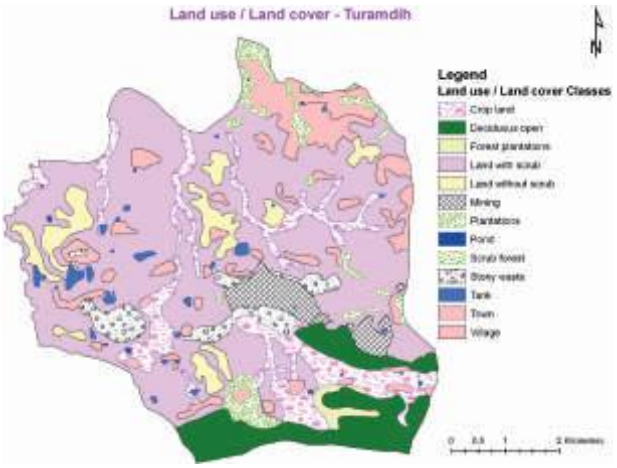


Fig.9.5: Land use / Land cover map of Turamdih area

(b) A Study on Impact Assessment of Tsunami Protection Wall along Kalpakkam Coast

A study was undertaken to assess the impact of construction of Tsunami Protection Wall (TPW) around the Kalpakkam Township surroundings based on periodic measurements of changes in High Water Line (HWL) and sedimentation pattern. Monthly beach profiling was carried out to monitor the sedimentation patterns at selected locations with the help of L3 Precision Level survey instrument for 2 year period i.e., 2008 and 2009. The detailed investigations and analysis revealed no apparent impact on the shoreline and sedimentation patterns due to the construction of TPW, within the township as well at two fishing hamlets adjoining Kalpakkam Township. The variations of HWL along the coast were within 10 m and sedimentation changes were in the range of 0.5 m. These variations were found to be similar with those measured prior to the construction of TPW. Typical pattern of sedimentation for the location P-4 is shown in Fig. 9.6

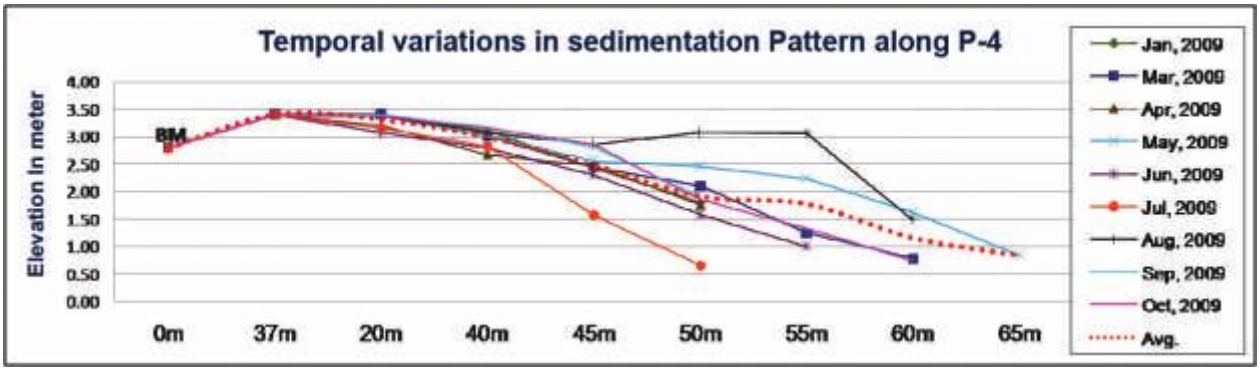


Fig. 9.6: Profile on Sedimentation Pattern at Location

(c) Database Generation for DAE-RRE on Atmospheric Modeling for Kalpakkam

As a part of DAE-Round Robin Exercise (RRE) on Atmospheric Modeling, GIS database requirements of Digital Elevation Model (DEM), soil features were generated for 120 km, 10 km and 2 km zones around MAPS, Kalpakkam. The above thematic map data is shared with IGCAR. In the soil map, 42 soil types were classified and in the land use / land cover 25 types were characterized in the study area. The DEM data will be used as basic input to run the atmospheric codes and the map on soil and land use/ land cover will be used for fall out calculations. Further, compilation of data is in progress. The soil map (120 km radius) generated with 42 classes is shown below. (Fig. 9.7)

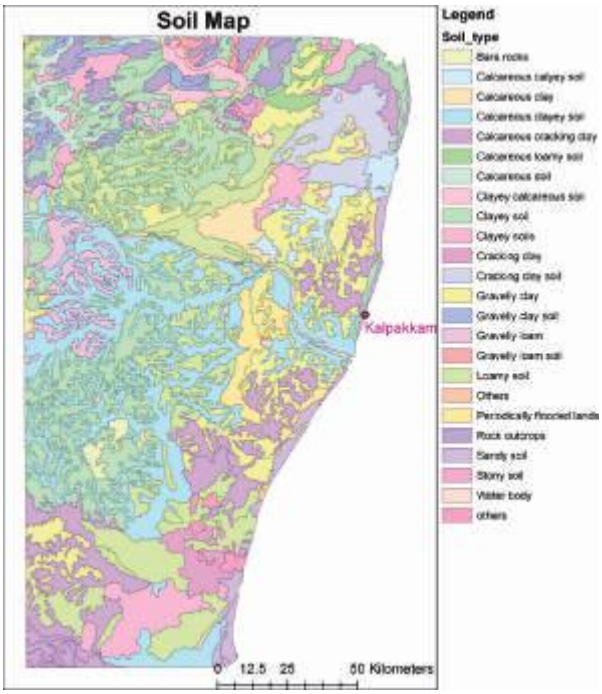


Fig. 9.7: Soil Map (120 km radius

(d) Development of Spatial Decision Support System for Flood Hazard

The Spatial Decision Support System (SDSS) was developed in the GIS platform at SRI to simulate flood hazard. SDSS helps visualizing various scenarios caused by sea level rise by way of overlay analysis. The SDSS also provides a tabular summary to estimate the impact of flood inundation on land use/land cover and population. Also, the user can measure the maximum inundation reach at a particular location using a distance measurement tool. The user-friendly system has map navigation functions such as zooming-in, zooming-out, panning and chosen sea level rise etc., to explore the map window. The SDSS allows the user to get the tabular summary of the flood impact over the land use categories and socio-economic data of the affected villages. The tabular summary for 4 m sea level rise and its impact on land use categories is provided in Table 9.1.

Table 9.1: Flood Inundation Impact on Land Use Categories for Typical 4 m Sea Level Rise

Land use Categories	Total Area (m^2)	4m Sea level rise	
		Area (m^2)	%
Barren Rocky/Stony waste	3416372	6981	0.20
Built-Up (Urban)	3225903	467623	14.50
Built-Up (Rural)	1121552	189990	16.94
Coastal Natural	515962	334039	64.74
Fallow	491916	96768	19.67
Forest Plantation	5016522	1383577	27.58
Habitation with plantation	3482865	951806	27.33
Marshy/Swampy	252761	29105	11.51
Sandy area	9943343	4471638	44.97
Tanks	105761	80281	75.91

9.2.2 Hydrogeological Investigations at Kalpakkam site

(a) Groundwater Modeling

VISUAL MODFLOW Pro computational software tool was employed for the steady state analysis for two-layer groundwater model for Kalpakkam site. The monthly groundwater head was recorded periodically from field measurements. Inputs to the model such as hydraulic conductivity, specific yield and specific storage were obtained by carrying out pumping tests in the study area. The model runs have provided groundwater flow and velocity maps.

(b) Groundwater characterization

Thorough understanding of groundwater hydrology and geochemistry are vital towards siting, construction and operation of vital installations at Kalpakkam site. In order to have a thorough understanding of the different chemical species present in the groundwater, monthly samples collected from different bore wells for one hydrological cycle have been characterized at SRI laboratory using wet chemical analyses as well as instrumental analysis. A dual channel ion chromatography system (IC 850; Metrohm, Switzerland) has been procured and installed at SRI (Fig.9.8). The instrument can simultaneously measure the cations and anions using conductivity detector.

Fig. 9.8: Ion Chromatography System (IC850)

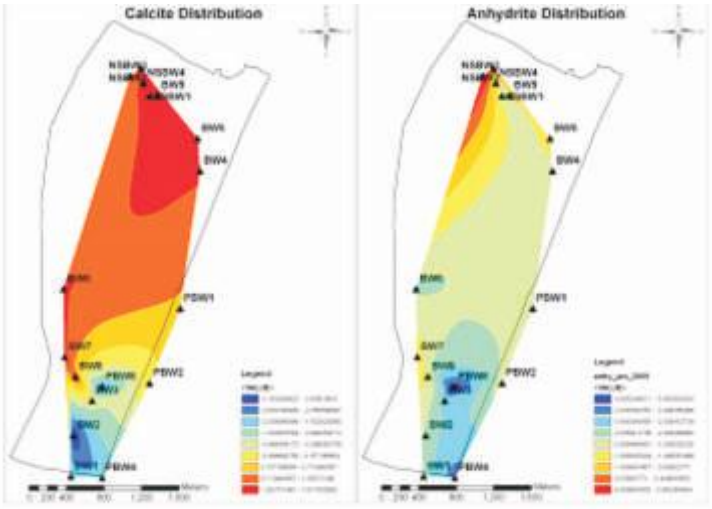


Fig. 9.9: Distribution Pattern of Calcite and Anhydrite at Kalpakkam Site

(c) Geochemical Modeling

For studying presence of various minerals and their compositions based on the chemical analysis of groundwater, geochemical software, PHREEQC has been employed. Solubility equilibrium hypothesis were tested by computing ion activity product (IAP) from activities of uncomplexed ions based on stoichiometries of minerals and other solids. The model generates output as molarities and activities of various possible minerals based on equilibrium calculations. The distribution patterns of various possible minerals at Kalpakkam site have been generated by using Arc-GIS software. While carbonate concentration is significantly small in majority of the bore wells, the samples collected from bore wells that are closer to the saline water bodies have significant quantifies of bicarbonate. For Kalpakkam site, saturation index for the carbonate minerals Calcite and Anhydrite were determined and they seem to follow the order Calcite < Anhydrite (Fig.9.9). Further investigations are in progress.

(d) Colloidal Transport of Radionuclides in Groundwater

The effect of several parameters such as pH, time, temperature, ionic strength and strontium ion concentration on adsorption on kaolinite clay was investigated. The Kaolinite is the clay found predominantly in the subsurface at Kalpakkam. The percentage sorption of strontium on kaolinite increased with increase in pH. The experimental data were fitted to the Langmuir and Freundlich adsorption isotherms (Fig 9.10). The adsorption isotherm of strontium on kaolinite clay was in good agreement with Langmuir isotherm model.

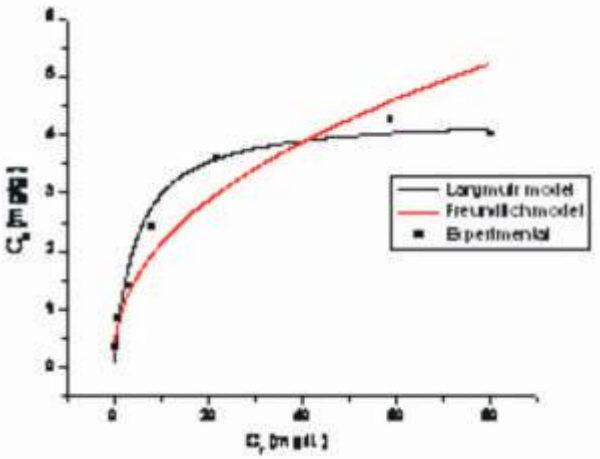


Fig. 9.10: Langmuir and Freundlich Adsorption Isotherms

The sorption of strontium as a function of pH was studied in the pH range 2-9 and it was observed that the sorption of strontium increased with increase in pH of the solution. The variation of Kd with pH is shown in Figure 9.11. The distribution coefficient appeared to increase with increase in pH in the range of 2-7. Subsequently, the Kd values decreased with increase in pH in the range of 7-9. Further, studies are in progress to understand the mechanism of adsorption.

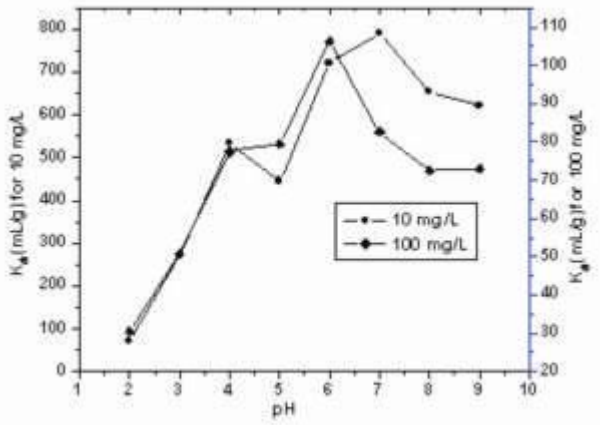


Fig. 9.11: Variation with pH

9.2.3 Safety Assessment of Near Surface Disposal Facilities of Kalpakkam site

(a) Sensitivity Analysis of Hydrogeological Parameters

As a part of safety assessment of the near surface disposal facilities at Kalpakkam, a sensitivity analysis was carried out using RESRAD-OFFSITE software. The important parameters studied included hydraulic conductivity, porosity, precipitation rate, saturated and unsaturated zone thickness for radionuclides ^{90}Sr, ^{129}I, ^{99}Tc, and ^{135}Cs.

From the sensitivity analysis, it was found out that hydraulic conductivity is the most sensitive among the parameters considered. The graph showing the variation of normalized peak dose for radionuclides, ^{90}Sr, ^{129}I, ^{99}Tc, and ^{135}Cs are shown in Fig 9.12.

Short lived radionuclide ^{90}Sr showed an increase in peak dose, as the hydraulic conductivity changes from 1.8m to 2m. While all other long lived radionuclides did not show any marked change in peak dose within this region. Further studies are in progress.

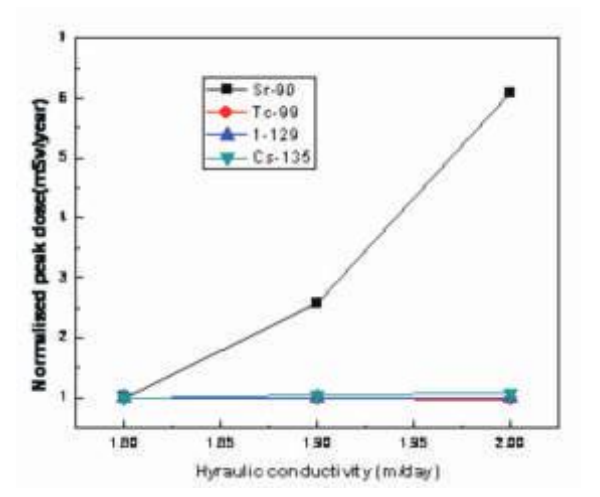


Fig. 9.12 : Normalised Peak Dose Values vs Hydraulic Conductivity

CHAPTER 10

PUBLIC INFORMATION

10.1 PRESS RELEASES

AERB periodically issues press releases in English and Hindi to keep the public informed about important regulatory and other related activities. The following press releases were issued during the year.

April 20, 2009
AERB Fire Safety Awards

Atomic Energy Regulatory Board (AERB) presents Fire Safety Awards every year to the units of Department of Atomic Energy (DAE) which excel in fire prevention and protection measures. This year, the Fire Safety Awards presentation function was held on April 17, 2009 at AERB Auditorium, Mumbai. Shri P. S. Bhargava, Executive Director – Mumbai Refinery, Bharat Petroleum Corporation Limited (BPCL), Mumbai as Chief Guest of the function presented the Awards to the winner units of the DAE. For the purpose of award all DAE Units are divided into two categories depending upon their fire risk. Based on assessment for achieving high levels of performance in Fire Safety, Tarapur Atomic Power Station - 1&2 and Nuclear Fuel Complex at Hyderabad received the award jointly in the High Risk Units category. Also, Kaiga Generating Station 3&4 received the award in the Low Risk Units category. On this occasion, Shri S. K. Sharma, Chairman, AERB addressed the gathering. Shri S. K. Chande, Vice Chairman, AERB delivered the welcome address and Shri R. Bhattacharya, Head, Industrial Plants Safety Division, AERB proposed the vote of thanks.

August 26, 2009
Recovery of Industrial Radiography Device

On August 23, 2009 at about 9 PM, an industrial radiography device of a private radiography company fell from a moving vehicle during transportation from Pune to Mumbai by road, near Ambedkar Chowk, Pimpri. Atomic Energy Regulatory Board deputed a team of officials to the site of incident and with the help of police, the device was recovered at about 6 PM on 24 August. The device was picked up by a group of youngsters and taken to a nearby village. The radioactive source in the device was found intact and inside its shielding and as such did not pose any radiation hazard. Such devices are used for testing of structures and welds. These devices contain radioactive source which is securely locked inside the shield. The source can be brought out only by trained personnel using special tools. These devices do not contain any explosive.

November 29, 2009
Incident of Tritium uptake at Kaiga Generating Station

An incident of tritium uptake of some workers at the Kaiga Generating Station (KGS) occurred on November 24, 2009. This was noticed during the routine urine sample analysis of workers that is carried out regularly at all nuclear power plants that use heavy water. AERB deputed two of its officers to KGS who, along with the plant authorities, investigated the incident. There was no heavy water leak in the plant and all plant systems were found to be functioning normal. A drinking water cooler was found to be the source of this tritium contamination and this water cooler was isolated immediately. The tritium contamination was limited to only this water cooler and all other sources of drinking water were checked and found to be free of any such contamination. The water tank of this cooler, like all other water coolers, was kept locked. However, it appears that some mischief maker added a small quantity of tritiated heavy water to the cooler, possibly from a heavy water sampling vial, through its overflow tube. Further investigations are in progress in this regard. All persons working in the plant were checked and personnel found to have received any tritium uptake were referred to the hospital for administration of diuretics (administration of diuretics accelerates the process of removal of tritium from the human body by urination). With this, now only two persons are having tritium in their body that can cause their extrapolated annual radiation exposure to marginally exceed the AERB specified limit of 30 milli-sievert (mSv). All other persons are back to their normal duties. However, even in the case of these two persons further medical management will bring down their potential radiation exposure to less than the AERB specified limit in a short time (The limit prescribed by the International Commission on Radiation Protection is 50 mSv per year, whereas AERB has prescribed a lower limit of 30 mSv per year as a matter of abundant caution). AERB would like to assure everyone that the incident is well under control and there is no cause whatsoever for any radiation safety concern.

January 14, 2010
Shri S. S. Bajaj appointed as Chairman, AERB

Shri S. S. Bajaj has been appointed as Chairman of the Atomic Energy Regulatory Board (AERB) in place of Shri S. K. Sharma who relinquished charge on January 14, 2010 on expiry of his tenure as Chairman, AERB. Prior to this, Shri Bajaj has been serving under Raja Ramanna Fellowship Scheme of Department of Atomic Energy

(DAE) and advising various units of DAE on safety issues. He retired as Senior Executive Director (Safety) from Nuclear Power Corporation of India Limited (NPCIL) in July 2007. Shri S. S. Bajaj, a Mechanical Engineer, began his career with the Department of Atomic Energy in 1969 after completing the 12th Batch of BARC Training School. His specific areas of work have included reactor safety analysis, system thermal hydraulics, plant transient studies, probabilistic safety assessment, system safety studies and reviews, containment engineering, reactor physics and fuel safety. He played a pioneering role in successfully establishing a sound infrastructure in NPCIL for safety analysis of Indian Pressurized Heavy Water Reactors (PHWRs), both deterministic and probabilistic. He has been closely involved in the development and validation of several computer codes for safety analysis. He performed several pioneering and definitive safety studies for PHWRs covering plant-wide response to postulated/actual events and to identify preventive/ mitigative actions. Shri Bajaj has been associated with several AERB Committees for design and operational safety review of nuclear power plants. He has also actively contributed to preparation of several regulatory safety codes and guides. Shri Bajaj is a recipient of the Indian Nuclear Society Award for outstanding achievement in Nuclear Technology including Nuclear Safety and is a Fellow of the Indian National Academy of Engineering.

10.2 AERB NEWSLETTER

AERB Newsletter covers AERB press releases, important national and international news, safety reviews of plants / projects and authorizations issued to nuclear and radiation facilities, activities related to training, workshops, colloquia, seminars, symposiums, etc., The Newsletter also carries expert views regarding safety of nuclear and radiation facilities. AERB Newsletters Vol. 22 No.1 and 2 covering the period from January to June, 2009 and July to December, 2009 were published in English and Hindi during the year 2009.

10.3 ANNUAL REPORT

Annual Report of AERB brings out the details of work carried out in various divisions of AERB during every financial year. The report is widely circulated to all the Units and Public Sector Undertakings under the DAE, Nuclear Regulatory Agencies of other countries, IAEA, premier educational and research institutes in India, Radiological Safety Officers of various hospitals and nuclear installations, news agencies in India, ex-members and Chairmen of AERB, Ex-Directors and Ex-Heads of the divisions of AERB. The report is published in English as well as in Hindi.

10.4 WEBSITE MANAGEMENT

AERB as part of its policy of public information has been posting information relevant to public and licensees on its website. The information related to use of radiation in medicine, industry and research for societal benefits and beach sand mineral industries has also been put on the website. The information includes the applicable acts, codes and rules, regulatory and safety documents and regulatory application forms related to issuance of licenses, authorizations and registration etc. A new layout of AERB website was developed and put in use. Various additional features like Visitors Count, Drop down menu access etc. were incorporated. About 6 lakh hits to the website were reported during the period.

10.5 INTERACTION WITH MEDIA

Queries raised by media are replied by phone, T.V. interviews and e-mails as well as during press meets by the senior officers of AERB.

10.6 RIGHT TO INFORMATION ACT-2005

Required measures were taken on the implementation of 'Right to Information Act (RTI)-2005' in AERB and the required information has been put on AERB website. Thirty queries received from various applicants under RTI Act were replied during the year.

In a meeting organized by Administrative Training Institute (ATI), DAE on 'Experience Sharing Workshop on RTI', a presentation was made by PIO of AERB. In the above interaction meeting, the members shared their experiences to improve the implementation of RTI Act-2005.

CHAPTER 11

INTERNATIONAL COOPERATION

AERB continues its active participation with the international agencies, namely, IAEA, USNRC, French and Russian Regulatory authorities, CANDU Senior Regulators Group, etc., in the areas of nuclear and radiation safety. The salient interactions and the objectives of the international cooperation during the year are brought out below. Several safety studies have also been carried out as part of international cooperation of AERB with regulatory bodies of other countries and IAEA. These are also reported here.

11.1 AERB AND ROSTECHNADZOR (RTN) WORKSHOP ON SAFETY SUPERVISION AND CONTROL OF VVER - 1000 TYPE OF REACTORS

Senior Officials of AERB and Rostechnadzor (RTN) during Joint Workshop at SEC-NRS in Moscow
(Shri S. K. Chande, Leader of Indian Delegation and Shri Boris Gordon, Director, SEC NRS are seen along with Other Members/ Invitees)

The AERB-Rostechnadzor (RTN) Joint Workshop was held at Scientific and Engineering Center for Nuclear Radiation Safety (SEC NRS), Moscow, Russia, during March 22-24, 2010. This was the third workshop under the AERB-RTN Co-operation Agreement in the field of Safety Regulation signed in 2003. Two earlier workshops were held in Mumbai during February 2005 and March 2008. Issues discussed during the workshop include:

(i) Experiences during Commissioning of VVERs in the recent past,

(ii) Commissioning of First of A Kind System,

(iii) Safety Aspects of Management of the Reactor Core,

(iv) PSI/ISI and Surveillance Aspects of Reactor Pressure Vessel,

(v) Safety Review and V&V of digital instrumentation and control,

(vi) Role of regulators in QA during manufacture of safety related components,

(vii) Review of design changes in-corporated during project implementatioin stage,

(viii) Safety review experience of KK NPP,

(ix) Regulatory Inspection of NPPs,

(x) Verification and Certification of Codes used for NPP Safety sub-stantiation, etc.

Both the sides expressed satisfaction about technical discussions in the Workshop and agreed for more focused interactions on selected topics in future.

11.2 ANNUAL MEETING OF THE FORUM OF THE STATE NUCLEAR SAFETY AUTHORITIES OF THE COUNTRIES OPERATING VVER TYPE REACTORS

The 16th Annual Meeting of the Forum of the State Nuclear Safety Authorities of the Countries Operating VVER Type Reactors (VVER Forum) was held from July 7 - 9, 2009 in Ledenika Complex, Bulgaria. The mai objective of the meeting was to exchange experience and information on VVER specific issues and practices. The meeting was attended by the heads of the regulatory authorities or their representatives of all countries operating or constructing VVER type reactors, namely Armenia, Bulgaria, China, Czech Republic, Finland, Hungary, India, Iran, Russian Federation, Slovak Republic and Ukraine. Observers from IAEA and GRS also attended the meeting. The meeting was inaugurated by Dr. Sergey Tzotchev, Chairman of the Bulgarian Nuclear Regulatory Agency (BNRA). All VVER Forum members presented reports on the recent most important national issues and developments in the field of nuclear regulation and safety, followed by discussions among peers.

Mr. S. K. Chande, Vice-Chairman of AERB and Mr. R.I. Gujrathi, Director, NPSD, AERB participated in the meeting and presented information on the NPPs in India, the plans for AERB expansion, safety review activities of operating NPPs and of on-going projects. Some design modifications especially in 'First Of a Kind Systems' and related safety issues; plan for safety review during commissioning phase and salient aspects of training and licensing of O & M staff were presented in brief.

Conveners of Working Groups on 'Operating Experience Feedback for Improving Safety of NPPs', 'Regulatory Aspects of Organizational, Management and Safety Culture Related issues of NPPs' and 'Regulatory Use of PSA' made brief presentations on the respective topics.

11.3 AERB- USNRC MEETING

A meeting between AERB Senior Officials and two Officials from USNRC was held on February 1, 2010. The status of various programmes under the on-going AERB-USNRC technical Co-operation was discussed. More specifically the meeting reviewed the status of the on-going Standard Problem Exercise on Containment Ultimate Load Strength and Leak Behaviour (based on experiments carried out in Sandia National Lab.)

USNRC-AERB Meeting in Progress between Senior Officials of AERB and USNRC *(Shri S. S. Bajaj, Chairman, AERB, Shri S. K. Chande, Vice-Chairman, AERB and Directors of Divisions of AERB are seen in the pictures along with USNRC officials)*

It was also proposed to host the next technical discussion meeting in Mumbai or in Washington on the following topics:

a. Feedback for new reactor certification review.
b. Passive safety systems reliability.

The firm programme will be arrived at with mutual concurrence achieved through email and other correspondences.

11.4 AERB - IRSN COLLABORATION

Under the collaboration between AERB and French Institute for Radiological Protection and Nuclear Safety (IRSN), France supplied to AERB an Accident Source Term Evaluation Code (ASTEC) and AERB carried out in kind contribution in form of analyses for a reactor similar to VVER-1000 MWe for different cases using the software. These results were compared with the SCDAP/RELAP results carried out earlier. Following are the three cases analysed.

(i) Simultaneous rupture of all four steamlines (MSLB ALL)
(ii) Simultaneous occurrence of Loss of Coolant Accident (LOCA) with Station Blackout (SBO)
(iii) Station blackout with and without passive decay heat removal system

The accidents sequence progression in cases (i) and (iii) is slow whereas the progression in case (ii) is rapid. In general, the trend and magnitude of the predicted parameters by the two codes are in good agreement with each other. However, differences were observed in a few parameters such as total amount of hydrogen generated.

11.5 PARTICIPATION IN CANDU SENIOR REGULATOR'S GROUP

Candu Senior Regulator's (CSR) meeting was held at Buenos Aires, Argentina from 26 to 30 October 2009. The countries operating PHWR type of reactors, viz. Canada, China, Argentina, Romania, Pakistan, Korea, India and representatives of Candu Owners Group (COG) and IAEA participated in the meeting. The participants discussed the annual reports and operating experience related to PHWR type of nuclear power reactors. India presented its annual report on activities related to PHWR reactors like restart of Rajasthan-2 after en-masse replacement of feeders and en-masse replacement of Narora-2 and Kakrapar-1. The presentation also included event of spurious opening of instrument relief valve of primary heat transport (PHT) system leading to actuation of safety systems at Narora-1 and PHT tubing failures due to fretting in Kalpakkam-1 and Tarapur-3&4 reactors. India also presented the event reporting system followed in India, lessons learnt from Periodic Safety Review (PSR) and refurbishments in Indian reactors, regulatory requirements for life management of coolant channels, criteria used for reducing frequency of mandatory outages and regulatory review of long term outages. Some of the other issues discussed were licensing criteria, PSR for refurbishments, risk informed decision making, large loss of coolant accident and void reactivity co-efficient related issues. The participants were also invited to Embalse nuclear power station in Argentina. The proceedings of the meeting were widely circulated to different organizations connected with nuclear power in India and the follow-up actions of the issues applicable to Indian NPPs were also initiated.

11.6 INTERNATIONAL COLLABORATIVE STANDARD PROBLEM (ICSP) EXERCISE ON COMPARISON OF CODE PREDICTIONS OF HWR THERMAL HYDRAULICS WITH EXPERIMENTAL DATA OF SMALL BREAK LOSS OF COOLANT ACCIDENT (SBLOCA)

The objective of the ICSP is to improve understanding of important phenomena expected to occur in SBLOCA in PHWR, evaluate code capabilities by simulating an integrated experiment and suggest either code improvements or new experiments to reduce uncertainties.

Thermal hydraulic analysis of small break loss of coolant accident experiment on RD14M facility (Canada) was carried out as part of the 'International Collaborative Standard Problem Exercise on HWR Code Predictions' organized by IAEA. The steady state qualification was carried out. Initial conditions for the analysis are in good agreement with the experimental data. Calculations were carried out for the two identified tests, viz., B9006 (7 mm break) and B9802 (3 mm break) as part of this exercise. Sensitivity analysis was carried out for the tests by varying break area and heat transfer. The predicted trend and magnitude of the various thermal hydraulic parameters for both the tests are as expected. The results would be compared with the experimental data which have been made available.

11.7 IAEA CRP ON 'UNCERTAINTY EVALUATION IN BEST ESTIMATE ACCIDENT ANALYSIS'

AERB has been participating in IAEA Coordinated Research Programme (CRP) on 'Uncertainty Evaluation in Best Estimate Accident Analysis of Light Water Reactors' since June 2006. Seventeen organizations from 12 countries are participating in the CRP. The uncertainty evaluations were carried out for SBO in PSB VVER integral thermal hydraulic test facility at EREC, Russia and hot leg break LOCA (SB-HL-02) in LSTF/ROSA IV, Japan by modifying the reference input decks provided by IAEA.

Steady state level qualification was carried by comparing the input deck values of geometrical, thermal hydraulic and boundary conditions with the experimental values. Transient level qualification was carried by identification/ verification of CSNI phenomena validation matrix, phenomenological windows, key phenomena and relevant thermal-hydraulic aspects and comparison between experimental and code calculated time trends of relevant parameters. Assessment of input decks for both the tests for steady state and transient level qualifications met the acceptance criteria.

Monte Carlo (i.e., sampling based) approaches were used to uncertainty and sensitivity analysis. The methodology adopted consists of screening/importance analysis of input parameter, assigning probabilistic density functions to input parameters, calculation matrix generation using Latin Hypercube Sampling, performing best estimate thermal hydraulic code runs, representation of uncertainty analysis results (between 5th and 95th percentile, histogram and scatter plots), and importance/sensitivity analysis using linear regression (standardized rank regression coefficients and partial correlation coefficients).

Output parameters were very sensitive to primary and secondary heat loss, primary pump cooling rate etc. for SBO in PSB VVER and the parameters are sensitive to break location discharge coefficient, accumulator isolation set level, accumulator injection set pressure, SG relief set pressure for SB LOCA in LSTF. Uncertainty band is found to be in the order of 20 % of the nominal value. It is observed that as the accident progresses, the uncertainty bands increase.

11.8 IAEA-EBP KASHIWAZAKI-KARIWA RESEARCH INITIATIVE FOR SEISMIC MARGIN ASSESSMENT (KARISMA) BENCHMARK STUDY

Subsequent to the Niigataken-chuetsu-oki (NCO) earthquake of August 2007 that affected Japanese nuclear power plant located at Kashiwazaki-Kariwa, IAEA floated an extra budgetary program (EBP) on seismic safety of existing NPPs. This EBP focuses on quantifying available margins, understanding the behaviour of structures, soil and equipment during earthquake and identification of main parameters influencing the response. AERB is associated with two working areas of KARISMA; (1) WA2: Re-evaluation of safety of existing NPPs, and (2) WA3: Post earthquake plant operational response and seismic instrumentation. WA2 is further divided into two tasks, Structural benchmark and Equipment benchmark. Structural benchmark consists of studies related to Reactor building analysis, soil column analysis and seismic margin assessment. Analysis of piping, sloshing in fuel pool and behaviour of atmospheric tank forms part of Equipment benchmark. These activities are under various stages of completion.

A 3D finite element model of reactor building has been developed (see figure 11.1(a)). Seismic analysis of rector building for fixed base condition is in progress. For capturing global behaviour a 3D stick / wire frame model of the rector building is developed (see figure 11.1(b)). A soil model for the area near rector building has also been developed. Simulation of soil layer strata considering observed earthquake signals and dynamic properties of soil layers is in progress. A preliminary investigation for piping system has also been completed. Preliminary results have been reported to IAEA (see figure 11.1(c)). Further studies such as soil column analysis, analysis of piping, sloshing in fuel pool, atmospheric tank behaviour etc., are in progress.

11.9 OTHER INTERNATIONAL CO-OPERATIVE ACTIVITIES

AERB also participates in several activities of the International Atomic Energy Agency (IAEA). These include the Incident Reporting System (IRS), International Nuclear & Radiation Event Scale (INES) based reporting of events, Commission on Safety Standards and the work related to development of Safety Standards, Conduct of Training Workshops and Technical Meetings, etc. Experts from AERB also participate in several committees of IAEA.

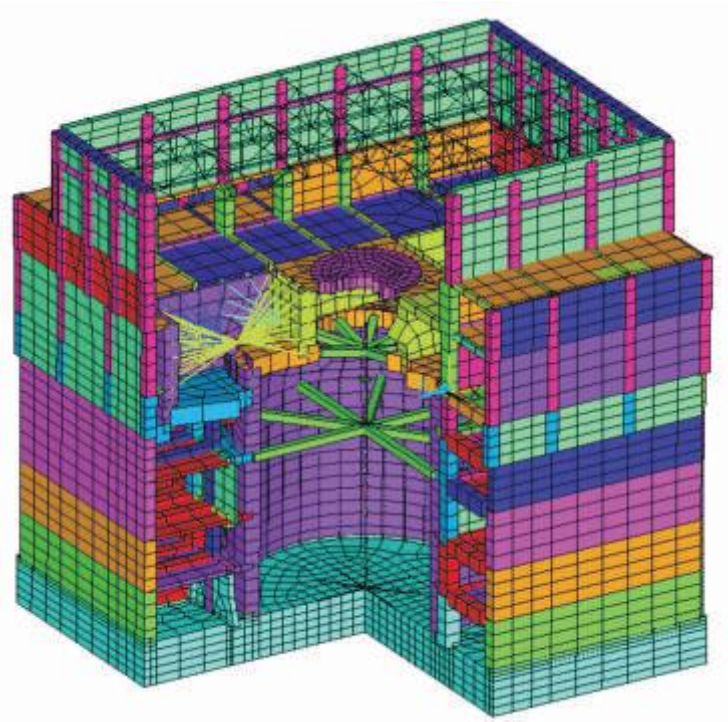


Fig. 11.1 (a) : Reactor building showing various elements like outer wall, inner circular wall, fuel pool and stick model of reactor vessel with supports

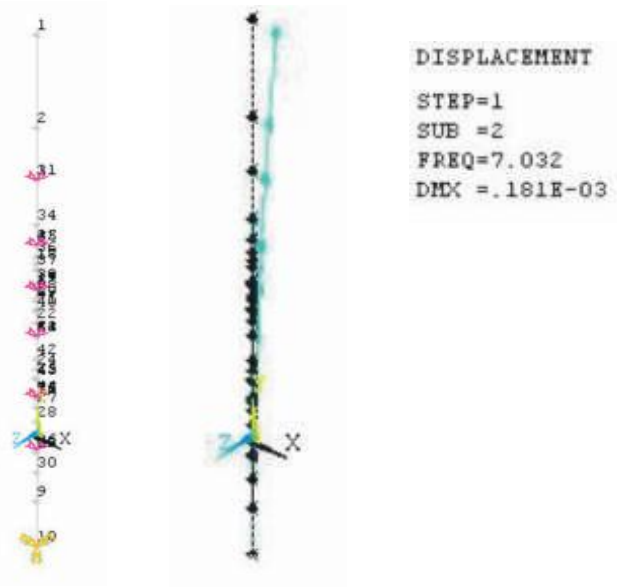


Fig. 11.1 (b) : Wire frame model and displacement

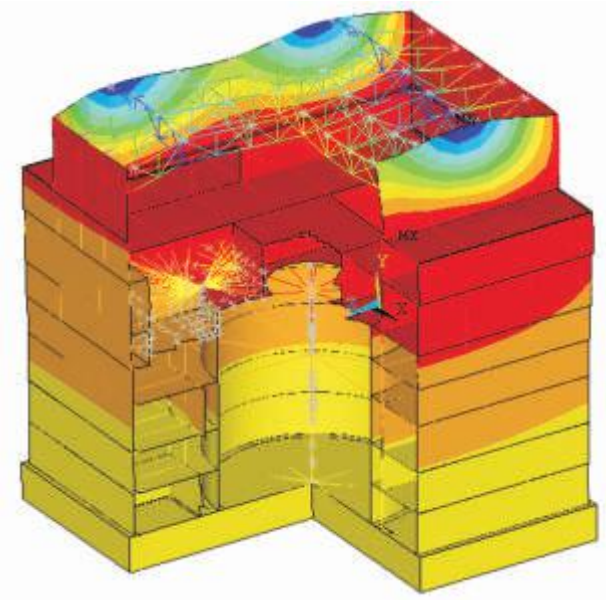


Fig. 11.1 (c) : Mode shape of Reactor building

CHAPTER 12

HUMAN RESOURCE DEVELOPMENT

12.1 MANPOWER AUGMENTATION

AERB manpower is being augmented at various levels and through various channels by taking into consideration the expanding nuclear power programme and increasing number of radiation facilities in the country. Government of India has sanctioned posts considering the above needs. Steps were taken to fill up these posts form Indian industry by advertisements in the newspapers, transfer of experienced personnel from operating plants and R&D institutes like BARC, Mumbai and IGCAR, Kalpakkam and induction of postgraduates through AERB Graduate Fellowship scheme (AGFS) in IIT Bombay and IIT Madras. During the year, the following manpower was inducted in AERB.

- A total of 22 candidates were selected from the Indian industry through open advertisement in the newspapers.
- Two students sponsored in AGFS for M. Tech in 2007 joined AERB in August 2009.
- Four officers, two from training school of BARC, one from training school of IGCAR and one from training school of NFC, joined AERB in September 2009.
- Two officers joined AERB through inter-unit transfer; one from BARC and one from IGCAR.
- Five students, 3 in IIT Madras and 2 in IIT Bombay were sponsored for M.Tech in August 2009.
- Two officers joined AERB through direct recruitment.

As on 31-03-2010, the total staff strength in AERB is 211 comprising 173 scientific and technical and 38 supportive staff. In the 11th five year plan, a total of 78 scientific officers, 25 scientific assistants and 28 supportive posts have been sanctioned by the Government of India. Efforts are on to fill up these posts.

12.2 IMPLEMENTATION OF PERSONS WITH DISABILITIES (EQUAL OPPORTUNITIES, PROTECTION OF RIGHTS & FULL PARTICIPATION) ACT, 1995 AND IMPLEMENTATION/WELFARE OF RESERVATION POLICY FOR SCHEDULED CASTES/TRIBES/OBC

During the year 2009-10 efforts were made to make appointments in reserved posts for SC/ST/OBC and 'Orthopedically Handicapped (OH)' categories. The backlog vacancies have been worked out and the same has been intimated to DAE. In order to clear the backlog, a special recruitment drive was conducted to fill up vacancies reserved for physical handicapped category in the grade of Scientific Officer 'C' (Group 'A') and one physical handicapped candidate was empanelled. Offer of appointment has been issued to the candidate.

During the year 2009-10, efforts were made to ensure that reservation policy for SC/ST/OBC is implemented properly. Rosters are maintained as per the orders on the subject. Prescribed periodical returns on the subject are sent to DAE from time to time. A special recruitment drive was conducted during February 9-10, 2010 exclusively to recruit candidates belonging to SC/ST/OBC to the post of Scientific Officer (C) and 6 OBC candidates and one SC candidate were empanelled. Offers of appointment were issued to 3 OBC and 1 SC candidates from the select panels.

12.3 TRAINING

12.3.1 Orientation Course for DAE Graduate Fellowship Scheme (DGFS) Fellows

Two engineers, selected under AGFS, underwent training in Orientation Course for DGFS Fellows (OCDF) of Human Resource Development Division, BARC, Mumbai.

12.3.2 Nuclear Training Centers (NTC) of NPCIL

1. Two engineers are undergoing training specific to VVER type reactors at Kudankulam site.
2. Four engineers/scientists are under training on Fast Breeder Reactor Technology, IGCAR, Kalpakkam.
3. One scientist is undergoing training at BARC, Mumbai in PHWR Reactor Physics.

12.4 REFRESHER COURSES

A Refresher Course on Probabilistic Safety Analysis was organized in AERB on December 24, 2009. The topics namely, PSA Overview, Quantitative Risk Assessment in Chemical Industries, Seismic PSA and PSA Activities in AERB were covered. Experts on PSA in AERB delivered all the talks. The course was essentially for AERB scientists and engineers.

12.5 AERB TECHNICAL TALKS

The following Technical Talks were organized during the year.

a) 'Commissioning Aspects for Pressurized Water Reactors' by Shri D. Bhattacharya, NPSD, AERB.

b) 'How the "Internet" Works?' by Shri V.P. Gholap, ITSD, AERB.

c) 'TRIVENI - A Computer Code for Core Simulations of PHWR' by Smt. Reeta Malhotra, ITSD, AERB.

d) 'Transport of Radioactive Material' by Shri S. P. Agarwal and Shri A. U. Sonawane from RSD, AERB.

e) 'Experimentation and Modelling of Passive Decay Heat Removal System in Nuclear Reactors', M. Tech Project, IIT-Bombay, by Prasad S. Wani, NPSD, AERB.

f) 'Thermodynamic Data Base for Phase Stability Calculations for Plant Stability pertaining to P91 Steels and its Derivatives', IIT-Madras, M. Tech Project by J. Christopher, SRI, AERB.

g) 'Fuel Management Aspects of Pressurized Water Reactors (PWR)' by Shri A. Ramakrishna, ITSD, AERB.

h) Technical Talk in Hindi 'Use of Unicode fonts' by Shri Vaibhav P. Gholap, ITSD, AERB.

12.6 KNOWLEDGE MANAGEMENT

A 'Knowledge Portal' is in operation at the internal website of AERB, as part of knowledge preservation and easy retrieval. Training/teaching material, proceedings of Conferences and Seminars, Papers presented/published by AERB personnel etc., were posted on the portal at regular intervals. National and international codes/guides/manuals are also being posted on the portal. Knowledge portal was reorganised for further improvement in easy retrieval of information.

A well-equipped library is maintained in AERB. A total of 53 new publications have been added during the period and with this, the total collection of publications has gone up to 9956. In addition, 25 Journals were subscribed during the period. List of New Additions, World Nuclear News, NucNet News, NEI Newsletter, Bulletin of the Atomic Scientist Newsletter etc. are circulated regularly, in digital form, to AERB Staff.

12.7 MANAGEMENT INFORMATION SYSTEM

The Corporate Human Asset and Resource Management System (CHARMS) has been installed in AERB with the help of NPCIL. The personnel data like designation, date of birth, date of joining in AERB, promotion records, expertise, etc. were compiled and uploaded to the System. The demonstration on usage of system was given in AERB Auditorium as well as divisional meetings of some of the Divisions. Various changes were incorporated in the CHARMS for suitability to AERB environment. The system now uses the LDAP environment for authentication.

CHAPTER 13

SAFETY PROMOTIONAL ACTIVITIES

13.1 SAFETY RESEARCH PROGAMME

One of the objectives of AERB is to promote safety research and related activities relevant to safety and regulatory work. For this, a Committee for Safety Research Programmes (CSRP) has been constituted to frame rules, regulations and guidelines and to evaluate, and recommend grants for the research projects and to monitor their progress periodically. The Committee also recommends financial assistance to universities, research organizations and professional associations for holding symposia and conferences of interest to AERB. The CSRP met two times during the year and deliberated on 14 new project proposals and recommended Grant-in-Aid for 7 new projects as given in Table 13.1. It also approved the renewal of 4 ongoing projects as given in Table 13.2. In addition, financial support was provided to 32 seminars, symposia and conferences.

Table 13.1: New Research Projects Approved

Sr. No.	Project Title	Principal Investigator	Institution
1	Investigations on Startup Transients in Natural Circulation Boiling Water Reactor	Dr. Man Mohan Pandey	IIT-Guwahati, Guwahati
2	Retrospective Assessment of Indoor Radon Exposure in Garhwal Homes by Measurements of 210Po implanted on Glass Surface	Dr. R.C. Ramola	H.N.B. Garhwal University, Tehri Garhwal
3	Reliability Assessment of Large Complex Computer Codes	Dr. R.B. Misra	IIT-Kharagpur, Kharagpur
4	Evaluation of Burst Criterion of Zircaloy Clad	Dr. Mohd Kaleem Khan	IIT-Patna, Patna
5	Development and Testing of Indigenous Affordable 3D RFA	Dr. K.M. Ganesh	Kidwai Memorial Institute of Oncology, Bangalore
6	Establishment of Diagnostic Reference Levels (DRLs) in Select Procedures in CT Imaging	Dr. Govinda Rajan K.N,	PSG College of Technology, Coimbatore
7	Studies on the Transport of Hydrogen-Air-Steam Mixture within a Confinement	Dr. S.K. Das	IIT-Madras, Chennai

Table 13.2: Research Projects Renewed

Sr. No.	Project Title	Principal Investigator	Institution
1	Hydrogeochemical Modeling of Coastal Aquifers in and around Kalpakkam-An Integrated Approach	Dr. S. Chidambaram	Annamalai University, Chidambaram
2	Impact of Power Plant Entrainment on Zooplankton: Assessment of Thermal & Chemical Stress Effects on Copepods	Dr. K. Altaff	The New College, Chennai
3	Microbial Biofilm Formation and Corrosion of Firewater Pipelines in NPPs	Prof. S. Jayachandran	Pondicherry University
4	Development of TLD base on Borate Glass: Implication to Clinical Dosimetry	Dr. A. Nabachandra Singh	Thoubal College, Thoubal

Principal Investigators (PIs) of some of the research projects being carried out in South-India were invited to make presentations during November 2009 in the meeting held at Safety Research Institute, Kalpakkam before the Committee on their projects to highlight the progress made, details of the methodologies/experimental procedures used and results obtained. The corresponding collaborators/coordinators were also invited. Member-Secretary and one of the members of CSRP and two of the Principal Coordinators of the two projects visited Pondicherry University, Puducherry, Annamalai University, Chidambaram and New College, Chennai and VIT, Vellore, where there are on-going research projects of AERB and interacted with the Principal Investigators, research scholars including JRF/SRF of AERB projects and visited laboratory facilities available in the institutes. At one of the institute, i.e., Vellore Institute of Technology, Vellore, one of the member made a presentation on 'AERB Safety Research Programme' before the faculty members and research scholars of the institute.

CSRP Members & Project Investigators witnessing the indigenously developed "Optical CT Scanner" at Vellore Institute of Technology, Vellore, Tamilnadu
(L to R) : Shri Senthilkumar (Research Scholar, VIT), Dr.Velmurugan (Project coordinator, Anna University), Dr.R.M.Nehru (Project coordinator AERB), Dr.Om Pal Singh (Member, CSRP, Secretary, AERB & Director, ITSD, AERB) and Dr. Jabaseelan (Principal Investigator, VIT)

13.2 WORKSHOPS/SEMINARS

13.2.1 Workshop on 'Awareness on Safety and Regulatory Requirements of Beach Sand Minerals Facilities'

In order to familiarize the Beach Sand Minerals (BSM) facilities about the necessity of radiological protection, safe disposal of monazite enriched tailings and regular radiation monitoring and also considering the request from Federation of Indian Placer Mineral Industries (FIPMI), Tamilnadu, a one-day workshop on 'Awareness on Safety & Regulatory Requirements of Beach Sand Minerals Facilities' was organized by AERB on December 4, 2009 at Niyamak Bhavan, AERB, Mumbai. There were about sixty participants from various DAE and non DAE BSM facilities.

Workshop on 'Awareness on Safety and Regulatory Requirements of Beach Sand Minerals Facilities'
(L to R: Dr. P. M. B. Pillai, Former, OIC, HPU, IREL, Udyogamandal, Shri R. Bhattacharya, Director, IPSD, AERB, Shri V. K. Kansal, Chairman, BSMSC and Shri V. D. Puranik, Head, EAD, BARC)

The workshop covered the topics on 'Natural Radioactivity and Fundamentals of Radiation Protection',

AERB organised a one day seminar on regulatory requirements in radiotherapy facilities on 15th April 2009 at AERB to address some of the regulatory issues, pertaining to radiotherapy as also the diagnostic and nuclear medicine facilities

- Requirement of Radiation Field Analyser (RFA).
- Feasibility of HDR unit as a mobile unit to treat patient.
- Requirement of adequate number of Medical Physicist(s).
- Recognition of additional Medical Physics Courses.
- Requirement of Medical Physicists in Diagnostic and Nuclear Medicine facilities.

One Day Meet on Regulatory Requirements in Approval of Layout Plans for Radiotherapy Facilities
(L to R: Shri S. A. Hussain, Head, RSD, Dr. Y. S. Mayya, Head, RPAD, BARC, Dr. Om Pal Singh, Secretary, AERB and Shri P. K. Dash Sharma, RSD)

Oncologists and 14 representatives of suppliers of Medical Linear Accelerators, Remote after-loading Brachytherapy units and RFA.

The above issues were discussed at length and the debate on the above issues was very constructive. Since a consensus could not be generated among the participants, it was felt that feedback from the Medical Physicists and Radiation Oncologists of all the Radiotherapy Centres in the country need to be taken. Accordingly, AERB has sent feedback forms to all Medical Physicist(s) and Radiation Oncologist(s) of all the centres. This would help AERB to collect wider opinion on the subject to help review the guidelines of AERB for regulatory control on Radiotherapy Facilities.

13.2.4 Workshop on 'Radiation Safety in Interventional Radiology including Catheterisation Labs'

AERB organized a workshop on 'Radiation Safety in Interventional Radiology including Catheterisation Labs' on April 09, 2009 at AERB. The objective of the workshop was to apprise all the stake holders, including cardiologists, interventional radiologists, suppliers of Cath Labs equipment, technologists, biomedical engineers and supplier of personal protective devices for interventional radiology. A total of 26 professional representing the above facilities attended the workshop.

Dr. K.S. Parthasarathy, Former Secretary, AERB made opening remarks and Dr. V. Karira, Head, Medical Division, BARC inaugurated the workshop. In his inaugural address, Dr. V. Karira explained that side effects associated with interventional radiology procedures should be briefed to patient and his family members. Shri S.P. Agarwal, Head, RSD, AERB, mentioned that it is recognized that there is a potential of high radiation doses to patients, cardiologists and other staff in Cath Labs procedures including fluoroscopy and cine angiography. Therefore it is essential that doses are optimized while getting the desired results. Dr. K.S. Parthasarathy shared his experience on reports of radiation injuries to patients and staff reported in some of the Cath Labs procedures which is attributed to poor quality of Cath Labs equipment and lack of knowledge on radiation safety. Dr. Haresh Mehta a noted cardiologist from Dr. Balabhai Nanavati Hospital, Mumbai made a presentation on the current scenario of handling Cath Labs units by cardiologists.

A very active feedback session was held after the presentations. It was noted that there is need to enhance radiation safety awareness among radiation cardiologists and technical staff of Cath Labs. It was also suggested that all consultants performing Cath Labs procedures must use TLD badges for personal monitoring. Periodic quality assurance of Cath Labs and fluoroscopic units needs to be done. Suppliers of Cath Labs equipment should also be made responsible to ensure that the hospital requesting for installation of interventional radiology X-ray unit meets with all the safety requirements and should provide radiation protection accessories as an integral part of the Cath Labs unit to diagnostic centers. It was suggested that Medical Council of India should be advised to include radiation safety chapter in the syllabus of cardiologists course.

13.3 REVIEW OF IAEA DRAFT DOCUMENTS

AERB is the nodal agency to coordinate the review of draft IAEA documents by Indian experts. During the year, following documents of IAEA were received for review. The comments on the following documents were obtained from various experts and integrated and communicated to IAEA.

Sr. No.	Document No.	Document Title
1	DS 405	Volcanic Hazards in Site Evaluation for Nuclear Installations
2	DS 417	Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations
3	DS 426	Periodic Safety Review of Nuclear Power Plants
4	DS 356	Near Surface Disposal of Radioactive Waste
5	DS 351	The Use of a Graded Approach in the Application of the Safety Requirements for Research Reactors
6	DS 414	Safety in Nuclear Power Plant : Design
7	DS 411	Orphan Sources and Other Radioactive Material in the Metal Recycling and Production Industries
8	DS 410	National Strategy for Regaining Control over Orphan Sources and Improving Control over Vulnerable Sources
9	DS 396	Safety Assessment for Research Reactors and Preparation of the Safety Analysis Report
10	DS 424	Establishing a Safety Infrastructure for National Nuclear Power Programme
11	TS-R-1	Regulations for Safe Transport of Radioactive Material

13.4 OTHER ACTIVITIES

13.4.1 Task Force for preparation of the Document 'Harmonized Risk Assessment Standard' on behalf of the Ministry of Environment & Forest (MOEF)

Ministry of Environment & Forests (MoEF) entrusted AERB to prepare a national document on "Risk Assessment Guidance Manual and Risk Acceptance Criteria". Chairman, AERB constituted a Task Force to complete the assigned job. The Task Force studied the different approaches available and used nationally and internationally for hazard identification, international risk acceptance criteria, the statistical data on road accident & natural accident like lightning in India and worked on estimation of consequences, estimation of frequencies, risk computation and characterization. The committee reviewed the comments received from the MoEF. The revised document has been accepted by MoEF.

CHAPTER 14

OFFICIAL LANGUAGE IMPLEMENTATION

AERB continued its efforts to ensure effective implementation of Official Language Policy and increase the use of Hindi in official work. Consequently, more than 5000 letters were issued in Hindi/Hindi-English as compared to 3428 during last year.

Efforts were continued to prepare scientific and technical literature in Hindi. Two AERB safety documents were published in Hindi during the year. These are: Safety Guide on 'Population Distribution and Analysis in Relation to Siting of Nuclear Power Plants' [Safety Guide on 'नाभिकीय विद्युत संयंत्रो के स्थल चयन के संबंध में जनसंख्या विभाजन और विश्लेषण (एईआरबी/एसजी/एस-9; 1998')] and Safety Glossary 'Glossary of Terms for Nuclear and Radiation Safety' [Safety Glossary on 'नाभिकीय एवं विकिरण संरक्षा के लिए शब्दावली' (एईआरबी / एसजी / जीएलओ; 2005)'].

Annual Report and Newsletters of AERB are published in Hindi and English and distributed to DAE Units, educational institutes, press media, hospitals and industrial units. Press releases are also issued in Hindi and in English.

Facility of sending e-mails in Hindi was not available till 2009. Hindi documents were sent as attachment along with English e-mails. A talk on 'Use of UNICODE' for office work was organized in Hindi. Total 44 officials including Official Language Implementation Committee (OLIC) members were imparted practical training. As a result e-mails are also sent in Hindi.

A technical paper in Hindi on 'Significance of Regulation in Nuclear Energy Safety' was delivered by Dr. Om Pal Singh, Secretary, AERB & Director, ITSD at the National Scientific Seminar on Development of Atomic Energy in India, IGCAR, Kalpakkam during September 3-4, 2009.

Twenty six Hindi books were purchased on various subjects including Science, Indian Culture, Literature, Official Language, History, etc., during the year, which is in addition to various Hindi Magazines available in the Library.

Various Hindi Competitions were held during the year. These competitions include: Hindi Typing, Noting, Drafting, Essay Writing, Scientific and Technical Translation, Hindi Quiz etc. to encourage AERB officials to express themselves in Hindi. Two AERB Officers won First prize in their respective groups in Hindi Essay competition held by DAE.

In addition to efforts taken at unit level, joint efforts were also taken by AERB along with three more DAE units (i.e., Heavy Water Board, Directorate of Construction, Services & Estate Management and Directorate of Purchase & Stores) situated in Anushaktinagar. Hindi Day was celebrated jointly. On this occasion, a Scientific Talk on 'Prevention of Cancer' was delivered in Hindi by Dr. S. Sastry, Head, Preventive Oncology, Tata Memorial Centre. 'World Hindi Day' was also celebrated jointly by four units. Renowned writer Dr. Suryabala was present on this occasion and gave a talk on Hindi Language bringing out the importance of use of Hindi in official communication. A grand cultural programme was also organized on this occasion. Quarterly Hindi Workshops were also held jointly during the year.

All necessary steps are being taken continuously to implement Official Language Policy successfully in AERB.

Official Language Prize Distribution Function in Progress
(L to R: Shri M.M. Gaikwad, DCA, AERB, Shri S.K. Chande, Vice-Chairman, AERB, Shri S.K. Sharma, Chairman, AERB, Shri A. Ramakrishna, Chairman, OLIC and Shri V.M. Thomas, AO-III, AERB)

CHAPTER 15

MISCELLANEOUS

15.1 QUALITY MANAGEMENT SYSTEM (QMS) OF AERB

Revision of QMS Documents and Renewal of ISO Certification

Quality Management System (QMS) of AERB was awarded IS/ISO 9001: 2000 certification on November 15, 2006 by Bureau of Indian Standards (BIS). AERB had identified Consenting Process, Regulatory Inspection and Development of Regulatory Documents under the scope of its Quality Management System (QMS). The certificate has to be renewed every three years. IS/ISO 9001: 2000 standard has been revised as IS/ISO 9001:2008. Therefore, as per requirement of new QMS, the QMS documents such as Quality Manual and all the Level-II procedures were revised and issued.

Monitoring of QMS and Re-Certification Audit

Internal audits of different Divisions of AERB were carried out on March 24-26, 2009 and September 30, 2009- October 6, 2009. Two management review meetings, one on August 5, 2009 and other on October 23, 2009 were also held during the period to review and discuss the necessary actions taken for compliance of the non-conformances and observations brought out during internal audits. Decisions on proforma for issue of minutes of meeting, time frame, follow-up procedures for preparation of minutes of Safety Committee's Meetings were taken in the meeting.

Re-certification audit for Quality Management System of AERB in line with IS/ISO 9001:2008 was carried out by Bureau of Indian Standards (BIS) on November 3-4, 2009. Auditors were satisfied with the performance of QMS in AERB and the renewal of ISO Certification has been issued by BIS on January 13, 2010.

Workshop on Promotion of Awareness of Client's Requirements

A workshop on "Promotion of Awareness of Client's Requirements" was held on August 25, 2009 for better understanding of AERB's client requirements related to the three identified processes. Around 50 participants attended the workshop including Directors/Heads of Divisions, the internal auditors, Divisional Coordinators and a few other nominated staffs. Dr. P. C. Basu, Director, C&SED and MR to QMS in his welcome address talked about the purpose of the workshop. Chairman, AERB in his opening remarks said that ISO standard should also consider requirement of regulatory processes. He also mentioned that the workshop will benefit both regulator and licensee to improve the effectiveness of their processes. Vice-Chairman, AERB made his kind presence in the workshop and provided some valuable inputs during discussion. Dr. Devendra Mohan, Bureau of Indian Standards talked about the salient points of revised IS/ISO 9001:2008 standard. Shri M. K. Pathak, IPSD, AERB presented the salient points of revised QMS documents whereas Shri K. Ramprasad, IPSD talked on the Client's requirements and feedback system. Client's expectations and requirements were presented by Shri N. P. Srivastava, Chief Engineer & MR of QA Directorate, NPCIL, Shri S.Sundaresan, Associate Director (O), Heavy Water Board and Shri Rajiv Adukia, Director, M/s A. V. Processors Pvt. Ltd.

15.2 FAREWELL TO SHRI S.K. SHARMA

A fond farewell was given to Shri S.K. Sharma on January 13, 2010 on his superannuation from AERB as Chairman, AERB. Shri R. Bhattacharya, Director, IPSD, AERB informed the large audience about the profile of Shri Sharma right from his entry into DAE family. Dr. S. Banerjee, Chairman, AEC also was present to bid a fond farewell to Shri Sharma. Shri S.K. Mehta, Consultant, AERB who has been a long associate of Shri Sharma spoke on the occasion. Various dignitaries from NPCIL, BARC like Dr. S. K. Jain, CMD, NPCIL, Shri A.L.N. Rao, Chief Executive, Heavy Water Board and others also brought out the professional and personal traits of Shri Sharma. Shri S.K. Chande, Vice-chairman, AERB who has been working with him since long in various capacities like Member-Secretary, SARCOP and Vice-chairman, AERB

Shri S. K. Sharma, Outgoing Chairman, AERB receiving a Silver Plaque on the Occasion of Farewell organized by AERB Staff

said that his guidance in every matter was valuable to all in AERB for bringing about a creative and efficient working environment in AERB. It was in his period that AERB has made a significant progress and has earned a place of pride in international arena as an effective regulatory body. It was in his period that AERB became an ISO: 9001:2008 certified body, a one of its kind in India. He also welcomed Shri S.S. Bajaj on this occasion. Shri Bajaj, Chairman, AERB wished Shri Sharma a fruitful retired life ahead. Dr. S. Banerjee, Chairman, AEC said that AERB will be facing challenging tasks ahead and appreciated Shri Sharma's efforts in grooming an organization that is now capable of facing any challenges ahead. Shri Sharma in his usual humorous and thought provoking thanks-giving speech said that it was the efforts put in by every AERBite that has earned AERB such a reputation. He thanked one and all.

15.3 INTERNATIONAL WOMEN'S DAY CELEBRATION

'Women's Day Celebration' by AERB Ladies and Invited Guests

A cultural programme was organized by ladies of AERB on International Women's Day on March 8, 2010. The Chief Guest of the programme was Smt. Surekha Chande and other invitees were Smt. Rita Basu, Smt. Swati Gujrathi, Smt. Pushpa Devi Singh, Smt. Rama Lakshmi Rao and Smt. Suman Gaikwad. All the ladies actively participated in various competitions and games and enjoyed the events. Prizes were distributed to the winners. The success of the programme was in the team spirit shown by all the ladies who worked collectively to make it a memorable event.

15.4 AWARDS

Dr. R. D. Lele, Former Member AERB Board and Shri S.K. Mehta, Former Director, Reactor Group, BARC and Consultant to AERB were honored with Indian Nuclear Society (INS) Homi Bhabha Lifetime Achievement Award.

Shri A.R. Sundararajan, Former Director, Radiological Safety Division, AERB received INS Award for Nuclear Fuel Cycle Technologies, including Radiation Safety and Environmental Protection.

Shri Utkarsh Chikkannagoudar of Nuclear Projects Safety Division, AERB was presented with INS Medal.

The awards were conferred by INS during their Annual Conference (INSAC-2009) on January 4, 2010 at Chennai.

15.5 OBITUARY

Three former stalwarts of AERB, Shri M.S.R. Sarma, the first Chairman of SARCOP, Shri P. N. Krishnamoorthy, the first Member-Secretary of AERB and Shri J.C. Shah, a former Member of the AERB Board and the former Chairman, Atomic Power Authority passed away during second half of 2009. They made immense contribution to AERB during its formative years.

APPENDIX

PUBLICATIONS

A. JOURNALS

- T. Sajith Mathews, A. John Arul, U. Parthasarathy, C. Senthil Kumar, M. Ramakrishnan, K.V. Subbaiah, "Integration of Functional Reliability Analysis with Hardware Reliability: An Application to Safety Grade Decay Heat Removal System of Indian 500 MWe PFBR", Annals of Nuclear Energy, Vol.36, Issue 2, 2009.
- A.U. Sonawane, V.K. Shirva and A.S. Pradhan, "Estimation of Skin Entrance Dose (SED) for Common Medical X-ray Diagnostic Examinations in India and Proposed Diagnostic Reference Levels (DRLs)", Journal of Radiation Protection Dosimetry, Nuclear Technology Publications, 138, 129-136 (2009).
- S.K. Saxena, A.K. Pandey and Pankaj Tandon "A Novel Approach to Prepare 90Y-EDTMP Patches for Superficial Brachytherapy", Applied Radiation and Isotopes Vol. 67(7-8), pp 1416-20, 2009.
- Tapas Das, Sudipta Chakraborty, H.D. Sharma and Pankaj Tandon "170Tm-EDTMP: A Potential Cost Effective Alternative to 89SrCl2 for Bone Pain Palliation", Nuclear Medicine and Biology Vo. 36(5):561-8, 2009.
- A. Achal, A. Mukherjee, P. C. Basu, M. S. Reddy, "Strain Improvement of Sporosarcina pasteurii for enhanced urease and calcite production", J. Ind. Microbiol Biotechnol, DOI 10.1007/s10295-009-0578-z, published online: 02 May 2009.
- Obaidurrahman K. and Om Pal Singh, "'A Comparative Study of Kinetics of Nuclear Reactors", Nuclear Technology and Radiation Protection, 24(3), 167-176, 2009.
- Munish Kumar, G. Sahani, G. Chourasiya; "Magnetic Removal of Electron Contamination for ^{60}Co Panoramic Gamma Ray Exposure Investigations with CaSO4:Dy and LiF based Dosimeters", Application of Radiation and Isotopes, Vol. 68 (2010).
- A. Ramakrishna, R.P. Jain and V. Jagannathan, "Validation of Lattice Code 'EXCEL' with TIC Experiments on Uniform and Regularly Perturbed Lattices", Annals of Nuclear Energy, March 2010; Under Communication.

B. INTERNATIONAL CONFERENCES

- Arun Aravind, R. Deepthi Rani, R. Kaviyarasan, H. Seshadri and P. Sasidhar, "Influence of Saline Water Bodies on the Geochemistry of Coastal Aquifers at Kalpakkam", National Seminar on Recent Trends in Water Research (RETWAR-2009); Annamalai University, Chidambaram; 2-3 March 2009.
- F. Lall, "Design and Operational Provisions for Security of Nuclear Installations in India", Symposium on Nuclear Security; Vienna; Mar. 30 – Apr. 3, 2009.
- A. Suresh, S. Mallick, P. Sasidhar, T.G. Srinivasan, P.R. Vasudeva Rao, "Studies on Third Phase Formation in the Extraction of Nitric Acid by Octyl (phenyl)-N, N-diisobutyl Carbamoyl Methyl Phosphine Oxide (OΦCMPO) Modified with TBP" Proceedings of Nuclear and Radiochemistry Symposium (NUCAR 2009), B-80 (2009).
- A. Suresh, S. Mallick, P. Sasidhar ,T.G. Srinivasan, P.R. Vasudeva Rao, "Metal loading capacity of Octyl (phenyl)-N, N-diisobutyl Carbamoylmethyl Phosphine Oxide (OCMPO) based solvents", Proceedings of Nuclear and Radiochemistry Symposium (NUCAR 2009), B-81 (2009).
- K. Obaidurrahman and J.B. Doshi, "Computational Modeling Procedures for Core Dynamics Analysis of large Nuclear Reactors", International Nuclear Conference 2009 (INC '09) & Exhibition, Putra World Trade Centre (PWTC); Kuala Lumpur; 29 Jun.1 Jul., 2009.
- S.K. Chande and R.I. Gujrathi, "Report of AERB", 16th Annual Meeting of WWER Forum; Ledenika, Bulgaria; 7-9, Jul. 2009.
- Ajai S. Pisharady and P.C. Basu, "Seismic Fragility of a Civil Engineering Structure", Proc (CD ROM) of 20th International Conference on Structural Mechanics in Reactor Technology (SMiRT 20); Espoo-Helsinki, Finland; 9-14 Aug. 2009.
- A. D. Roshan and P.C. Basu, "Sensitivity of PSHA in the Region of Peninsular India", Proc (CD ROM) of 20th International Conference on Structural Mechanics in Reactor Technology (SMiRT 20); Espoo-Helsinki, Finland; 9-14 Aug. 2009.
- Obaidurrahman K. and Om Pal Singh, "Nuclear Power: An Eco Friendly Energy Source for Sustainable Development", International Conference on Peaceful uses of Atomic Energy; New Delhi, Sep. 29 – Oct. 1, 2009.
- C.S. Varghese, "Experience in Regulatory Oversight during Construction of Nuclear Power Projects in India", Technical Meeting on Regulatory Oversight of Licensee's Activities during Major NPP Projects, Vienna, Sept. 28 – Oct. 2, 2009.

- S.K. Dubey, S. Sengupta and S.K. Gupta, "Qualified Post Test Transient Analysis for Station Blackout in PSB VVER Integral Test Facility", 20th National and 9th International ISHMT-ASME Heat and Mass Transfer Conference; Mumbai, India, 4-6 Jan. 2010.
- S. Sengupta, S.K. Dubey S.K. Gupta, K. Sasidhran and V.K. Raina, "Post-test Analysis of 10% hot leg Break LOCA of LSTF using RELAP/MOD3.2", 20th National and 9th International ISHMT ASME Heat and Mass Transfer Conference; Mumbai, India, 4-6 Jan. 2010.
- N. Agrawal , Seik Mansoor Ali, K. Velusamy , S.K. Das, and S.E. Kannan, "Natural Convection in Hydrogen Air Mixture", Proceedings of the 20th National and 9th International ISHMT-ASME Heat and Mass Transfer, pp 450-455; Mumbai; 4-6 Jan. 2010.
- C. Anandan, P. Sasidhar, P. Rajasekar, B. Venkatraman, and S.E. Kannan, "Tsunami Protection Wall at Kalpakkam - An Assessment"; IAEA Workshop on "External Flooding Hazards at Nuclear Power Sites; Kalpakkam; 11-15 Jan. 2010.
- P. Sasidhar, M. Sankar Ram, S. Joseph Winston, R. Rajaraman and S.E. Kannan, "A Vector based GIS approach to predict tsunami inundation and impact assessment at Kalpakkam", IAEA Workshop on "External Flooding Hazards at Nuclear Power Sites; Kalpakkam; 11-15 Jan. 2010.
- P. Shylamoni, L. R. Bishnoi and P. C. Basu, "Indian Regulatory Requirements for Safety of NPPs against External Flooding Hazard", 'International Workshop on External Flooding Hazards at NPP Sites in commemoration of Five years of Indian Ocean Tsunami Event'; Kalpakkam, 11-15 Jan. 2010.
- M. Sankar Ram, R.Deepthi Rani and P. Sasidhar "Applications of GIS in Transportation and Spatial Requirements during Nuclear Emergency Evacuation Management", International Conference on Advances in Materials Mechanics and Management, pp.300-306; Trivandrum; Jan. 14-16, 2010.
- R. Deepthi Rani and P. Sasidhar "Role of Clays in Radioactive Waste Disposal". International Conference on Advances in Materials Mechanics and Management, pp. 584-589; Trivandrum; Jan. 14-16, 2010.
- P. Shylamoni and P. C. Basu, "Concrete Structures of Nuclear Power Plants", Proc of fib-days 2009 International Conference on Concrete – 21st Century Superhero Building a Sustainable Future, Volume-1, IMC-fib & Institution of Engineers (India); Kolkata; 29-30 Jan. 2010.
- Swayam Mallick, A. Suresh, T.G. Srinivasan, and P.R. Vasudeva Rao "Influence of the alkyl chain length of extractant on phase splitting in the extraction of Thorium Nitrate by Tri-n-alkyl-phosphates, BRNS-DAE Biennial Workshop on Emerging Trends in Separation Science and Technology (SESTEC-2010); Kalpakkam; 1-4 March 2010.
- Swayam Mallick, A. Suresh, T.G. Srinivasan, and P.R. Vasudeva Rao, " Influence of diluent chain length on phase splitting in the extraction of Thorium Nitrate by Tri-n-butyl-phosphates, Proc. of BRNS-DAE Biennial Workshop on Emerging Trends in Separation Science and Technology (SESTEC-2010); Kalpakkam; 1-4 March 2010.
- H. Seshadri, M. Cheralathan, P. Sasidhar and P.K. Sinha, "Photocatalytic degradation of 1,4 Dioxane in aqueous solution using nanocrystalline Anatase Titania", Proc. of BRNS-DAE Biennial Workshop on Emerging Trends in Separation Science and Technology (SESTEC-2010); Kalpakkam; 1-4 March 2010.
- R. I. Gujrathi, "Review of Design Changes Incorporated during Project Implementation of Kudankulam NPP", Third AERB-ROSTEKHNADZOR Workshop on "Information Exchange on Nuclear Safety"; SEC-NRS, Moscow, Russia; 22-24 Mar. 2010.
- R. I. Gujrathi, "Regulatory Inspection of KK-NPP", Third AERB-ROSTEKHNADZOR Workshop on "Information Exchange on Nuclear Safety"; SEC-NRS, Moscow, Russia; 22-24 Mar. 2010.
- S. C. Utkarsh, "QA during Manufacture of Safety Related Components-Role of Regulator", Third AERB-ROSTEKHNADZOR Workshop on "Information Exchange on Nuclear Safety"; SEC-NRS, Moscow, Russia; 22-24 Mar. 2010.
- A. Ramakrishna, "Safety Aspects of Management of the Reactor Core", Third AERB-ROSTEKHNADZOR Workshop on "Information Exchange on Nuclear Safety"; SEC-NRS, Moscow, Russia; 22-24 Mar. 2010.

C. NATIONAL CONFERENCES

- Seik Mansoor Ali, S.E. Kannan and V. Raghavan, "Numerical Simulation of Pool Fire in a Forced Ventilated Enclosure", 7th Asia-Pacific Conference on Combustion, National Taiwan University; Taipei, Taiwan; 24-27 May 2009.
- G. Sahani, D.N. Sharma, P.K. Dash Sharma and S.P. Agarwal, "Exploring the Techniques for Radiation Leakage Measurements of a Telegama Machine", Proceedings of 11th World Congress on Medical Physics and Biomedical Engineering; Munich, Germany, 7-12 Sept. 2009.
- H.K. Kulkarni and R. Bhattacharya, "Disaster Management in Chemical Industries- A Case Study", Second India Disaster Management Congress; New-Delhi; 4-6 Nov. 2009.

- H.K. Kulkarni, V.V. Pande and P. Gupta, "Cryogenic Safety & Hazard Management in Air Separation Unit", Proceedings of 26th DAE Safety & Occupational Health Professional Meet; Kolkata; 16-18 Nov. 2009.
- K. Ramprasad and R. Bhattacharya, "Study on Accident Prone Behavior- An Accident Prevention Technique", Proceedings of 26th DAE Safety & Occupational Health Professional Meet; Kolkata; 16-18 Nov. 2009.
- S. Kodolkar, V.V. Pande and R. Bhattacharya, 'Status of Injury Statistics & Requirements under Atomic Energy (Factories) Rules, 1996", Proceedings of 26th DAE Safety & Occupational Health Professional Meet; Kolkata; 16-18 Nov. 2009.
- M. K. Pathak, "Safety Requirements and Feedback of Commonly Used Material Handling Equipment", Proceedings of 26th DAE Safety & Occupational Health Professional Meet; Kolkata; 16-18 Nov. 2009.
- S.K. Gupta and K. Srivasista, "Defence in Depth for Electric Power Supplies in Indian Nuclear Power Plants", '26th DAE Safety and Occupational Health Professionals' Meet; Kolkatta, 16-18 Nov. 2009.
- K.V. Subbaiah, Deepak Gopalani, C.S. Gautam, A.S. Jodha and L R Meghwal,"Gamma Radiation Protection Factor of Building Materials – Validation of Wall Reflections from Measurements", National Conference on Accelerator and Low Level Radiation Safety (NCALLRS); IUAC, Delhi; 18-20 Nov. 2009.
- K.V. Subbaiah," Radiological Safety Aspects of High Energy Particle Accelerators", National Conference on Accelerator and Low Level Radiation Safety (NCALLRS); IUAC, Delhi; 18-20 Nov. 2009.
- K.C. Upadhyay; "Dose Estimation of Gas Mantle Industries in Mumbai using Breath Measurement technique": National Conference on Accelerator and Low Level Radiation Safety; Inter University Accelerator Centre; New Delhi, 18-20 Nov. 2009.
- K. Obaidurrahman, J. B. Doshi, R. P. Jain and V. Jagannathan, "Development of the Space-time Kinetics Model for VVER Reactors using Improved Quasistatic Method", National Symposium on Radiation Physics; Udaipur; 19-21 Nov., 2009.
- Susheel Kumar, K. Obaidurrahman and Om Pal Singh, "Reactor Stability Analysis using Sinusoidal Reactivity Input", National Symposium on Radiation Physics; Udaipur; 19-21 Nov. 2009.
- V. Anuradha, "Studies on Impact of Design Basis Accidents of a Typical Nuclear Power Plant" 18th National Symposium on Radiation Physics, NSRP-18; Udaipur; 19-21 Nov. 2009.
- K.V. Subbaiah, L. Thilagam, and K. Thayalan, "Comparison of Point Kernel Dose Rate Calculation Formalism with PLATO Treatment Planning System for Carcinoma of Cervix", Annual Conference of Association of Medical physicists of India, AMPICON-2009; Hyderabad; 22-25 Nov.2009.
- P.K. Dixit, P.K. Dash Sharma, R.K. Yadav, G. Sahani ,B. Mishra and S.A. Hussain, "Neutron Dose Management in Medical Electron Accelerator Facility: A Few Case Studies": XXX Annual Conference of Association of Medical Physicists of India on Advances in Medical Physics & Technology for Conformal Dose Delivery in Cancer; Hyderabad; 22-25 Nov. 2009.
- Bibekananda Mishra, P.K. Dash Sharma, G. Sahani, R.K. Yadav and P.K. Dixit, "Decommissioning and Disposal Status of Radiation Sources used in India": XXX Annual Conference of Association of Medical Physicists of India on Advances in Medical Physics & Technology for Conformal Dose Delivery in Cancer; Hyderabad; 22-25 Nov. 2009.
- R.K. Yadav, P.K. Dash Sharma, P.K. Dixit, B.K. Mishra and G. Sahani, "Evaluations of Layout Plans for Radiotherapy Facilities & Problems Encountered": XXX Annual Conference of Association of Medical Physicists of India on Advances in Medical Physics & Technology for Conformal Dose Delivery in Cancer; Hyderabad; 22-25 Nov. 2009.
- P. Tandon "Hybrid Imaging: An overview", published in the Souvenir and Book of Abstracts for 30th Annual Conference of Association of Medical Physicists of India, Vol. 32, Supp. Pp 36-37, November 22-25, 2009.
- J. V. K. Sunil Kumar, A. U. Sonawane, Meghraj Singh, B. K. Singh, Amit Sen, Alok Pandey and D. M. Rane, "Analytical and Computational Evaluation of Biological Shield of Enclosure Housing 3.7 TBq ^{60}Co Source": National Seminar & Exhibition on Non-Destructive Evaluation (NDE) organised by the Indian Society for Non-Destructive Testing (ISNT); BHEL & NIT, Tiruchirapally; 10-12 Dec. 2009.
- Sajith Mathews T, A. John Arul, and K V Subbaiah,"Functional Reliability Analysis using Subset Simulation: A Case Study", Proceedings of International Conference on Quality, Reliability and Infocom Technology & Mathematical Modeling and Related Optimization Techniques; Delhi; 15-18 Dec. 2009.
- Sajith Mathews T, A. John Arul, U Parthasarathy, and K V Subbaiah, "Functional Reliability Analysis of Safety Grade Decay Heat Removal System Using Method of Moments", Proceedings of Conference on Quality, Reliability and Infocom Technology & Mathematical Modeling and Related Optimization Techniques; Delhi; 15-18 Dec. 2009.

ANNEXURE

LIST OF ABBREVIATIONS

ACI&FS	:	Advisory Committee on Industrial & Fire Safety
ACRS	:	Advisory Committee on Radiological Safety
ACNS	:	Advisory Committee on Nuclear Safety
ACOH	:	Advisory Committee on Occupational Health
ACPSR	:	Advisory Committee for Project Safety Review
ACPSR-FCF	:	Advisory Committee for Project Safety Review for Fuel Cycle Facilities
AEC	:	Atomic Energy Commission
AERB	:	Atomic Energy Regulatory Board
AFFF	:	Advanced Fuel Fabrication Facility
AFR	:	Away From Reactor
AGFS	:	AERB Graduate Fellowship Scheme
ALARA	:	As Low As Reasonably Achievable
ALPAS	:	Automatic Liquid Poison Addition System
AMD	:	Atomic Minerals Directorate for Exploration and Research
AMPI	:	Association of Medical Physicists of India
ARA	:	Application for Renewal of Authorization
ASDV	:	Automatic Steam Dump Valve
BARC	:	Bhabha Atomic Research Centre
BDBA	:	Beyond Design Basis Accident
BEXD	:	Boron Enrichment Exchange Distillation
BHAVINI	:	Bhartiya Nabhkiya Vidyut Nigam
BIS	:	Bureau of Indian Standards
BRIT	:	Board of Radiation and Isotope Technology
BRNS	:	Board of Research on Nuclear Sciences
BWR	:	Boiling Water Reactor
CC	:	Core Catcher
CCC	:	Construction Completion Certificate
CCF	:	Common Cause Failure
CDA	:	Core Disruptive Accident
CEO	:	Chief Executive Officer
CESC	:	Civil Engineering Safety Committee
CESCOP	:	Civil Engineering Safety Committee for Operating Plants
CFD	:	Computational Fluid Dynamics
CHF	:	Critical Heat Flux
CIIRI	:	Committee for Investigation of Industrial Radiography Incidents
CJR	:	Condensation Jet Reactor
CLRI	:	Central Leather Research Institute
CMD	:	Chairman & Managing Director
CMG	:	Crisis Management Group
CNS	:	Convention on Nuclear Safety
COIS	:	Computer Operator Information System
CORAL	:	Compact Reprocessing of Advanced Fuels in Lead Cells
CPRI	:	Central Power Research Institute
CRCS	:	Control Room Computer System
CSED	:	Civil and Structural Engineering Division
CSRP	:	Committee for Safety Research Programmes
CT	:	Computed Tomography
DAE	:	Department of Atomic Energy
DCS	:	Distributed Control System
DDU	:	Deeply Depleted Uranium
DEM	:	Digital Elevation Model
DFACS	:	Dry Fly Ash Collection, Segregation and Storage Facility
DFRP	:	Demonstration Fast Reactor Fuel Reprocessing Plant
DG	:	Diesel Generator
DGCA	:	Director General of Civil Aviation
DGFS	:	DAE Graduate Fellowship Scheme
DHX	:	Decay Heat Exchanger
DNBR	:	Departure of Nucleate Boiling Ratio
DP	:	Diversified Projects
DRS	:	Directorate of Radiation Safety
DSRC	:	Design Safety Review Committee
DU	:	Depleted Uranium / Delhi University
EBP	:	Extra Budgetary Project
EBP	:	Elemental Boron Plant
ECCS	:	Emergency Core Cooling System
ECIL	:	Electronics Corporation of India Ltd

EJ : Expansion Joint
EFD : Experimental Fluid Dynamics
EMCCR : En-Masse Coolant Channel Replacement
EMFR : En-Masse Feeder Replacement
EMTR : Emergency Transfer
EPR : Evolutionary Pressurised Water Reactor
ESL : Environmental Survey Laboratory
EVS : Eigenvalue Separation
FAAC : Fatal Accident Assessment Committee
FAC : Flow Assisted Corrosion
FBR : Fast Breeder Reactor
FBTR : Fast Breeder Test Reactor
FCF : Fuel Cycle Facility
FDS : Fire Dynamics Simulator
FEP : Features, Events and Processes
FFR : Fatal Frequency Rate
FHA : Fire Hazard Analysis
FHI : Fire Hazard Index
FHS : Fuel Handling System
FM : Fuel Machine
FOAK : First Of A Kind
FP : Full Power
FRF : Fuel Reprocessing Facility
F.R. : Frequency Rate
FT : Fuel Transfer
FTC : Flux Tilt Control
FRFCF : Fast Reactor Fuel Cycle Facility
FW : Feedwater
FWPH : Fire Water Pump House
GIS : Geographic Information System
GRAPF : Gamma Radiation Processing Facility
HA : Hydro Accumulator
HCLPF : High Confidence of Low Probability of Failure
HCR : Human Cognitive Reliability
HDS : Hydrogen Distribution Simulator
HDPE : High Density Poly Ethylene
HRA : Human Reliability Analysis
HEF : Head End Facility
HEWAC : Heavy Water Clean-up Facility
HTC : Heat Transfer Coefficient
HWB : Heavy Water Board
HWL : High Water Line
HWP : Heavy Water Plant
HX : Heat Exchanger
IAEA : International Atomic Energy Agency
ICMS : In Core Monitoring System
ICSP : International Collaborative Standard Problem
IDCT : Induced Draft Cooling Tower
IFSB : Interim Fuel sub-assembly Storage Building
IGCAR : Indira Gandhi Centre for Atomic Research
IGRED : Industrial Radiography Exposure Device
IGRPP : Industrial Gamma Radiation Processing Plant
IICT : Indian Institute of Chemical Technology
INES : International Nuclear and Radiological Event Scale
IPCL : Indian Petrol Chemical Ltd.,
IQS : Improved Quasi Static
IR : Incident Rate
IREL : Indian Rare Earths Limited
IRS : Incident Reporting System
IRV : Instrumented Relief Valve
ISI : In-Service Inspection
ISO : International Organisation for Standardization
IPSD : Industrial Plants Safety Division
ITSD : Information & Technical Services Division
JHA : Job Hazard Analysis
JLR : Jet Loop Reactor
JNES : Japan Nuclear Energy Safety Organization
JNPP : Jaitapur Nuclear Power Plant
KAMINI : Kalpakkam Mini Reactor
KAPP : Kakrapar Atomic Power Project
KAPS : Kakrapar Atomic Power Station
KGS : Kaiga Generating Station
KK-CG : KK-Coordination Group
KK-NPP : Kudankulam Nuclear Power Project
LEU : Low Enriched Uranium
LHGR : Linear Heat Generation Rate
LHS : Linear Heat Sensing
LINAC : Linear Accelerator

LMC	:	Lead Mini Cell
LOCA	:	Loss of Coolant Accident
LOR	:	Loss of Regulation
LPIS	:	Liquid Poison Injection System
LTTM	:	Low Trajectory Turbine Missile
LWR	:	Light Water Reactor
MAPS	:	Madras Atomic Power Station
MC	:	Monte Carlo
MDNBR	:	Minimum Departure from Nulceate Boiling Ratio
MIAS	:	Multiple Input Alarm System
MOX	:	Mixed Oxide
MV	:	Main Vessel
MWTP	:	Mineral Water Treatment Plant
NAPS	:	Narora Atomic Power Station
NDMA	:	National Disaster Management Authority
NDFA	:	National Disaster Response Force
NDT	:	Non-Destructive Test
NEA	:	Nuclear Energy Agency
NFC	:	Nuclear Fuel Complex
NOC	:	No Objection Certificate
NPCIL	:	Nuclear Power Corporation of India Limited
NPP	:	Nuclear Power Plant
NPSD	:	Nuclear Projects Safety Division
NRSC	:	National Remote Sensing Agency
NSDF	:	Near Surface Disposal Facility
NTC	:	Nuclear Training Centre
NU	:	Natural Uranium
NUOFP	:	New Uranium Oxide and Fabrication Plant
OBE	:	Operating Basis Earthquake
OCDF	:	Orientation Course for DGFS Fellows
OCRP	:	Orientation Course for Regulatory Processes
OECD	:	Organisation for Economic Cooperation & Development
OJT	:	On Job Training
OLIC	:	Official Language Implementation Committee
OPF	:	Oxide Production Facility
OPSD	:	Operating Plants Safety Division
OSCOM	:	Orissa Sand Complex
OSEE	:	Off-site Emergency Exercises
PCCS	:	Passive Containment Cooling System
PDSC	:	Project Design Safety Committee
PEE	:	Plant Emergency Exercises
PET	:	Positron Emission Tomography
PFBR	:	Prototype Fast Breeder Reactor
PGA	:	Peak Ground Acceleration
PHRS	:	Passive Heat Removal System
PHT	:	Primary Heat Transport
PHTS	:	Primary Heat Transport System
PHWR	:	Pressurised Heavy Water Reactor
PIV	:	Particle Image Velocimeter
PLC	:	Programmable Logic Controller
PPF	:	Process Plant Facility
PPP	:	Primary Pressurising Plant
PRA	:	Probabilistic Reliability Analysis
PSA	:	Probabilistic Safety Assessment
PSAR	:	Preliminary Safety Analysis Report
PSR	:	Periodic Safety Review
PSR	:	Project Safety Review
PSS	:	Primary Shutdown System
QA	:	Quality Assurance
QMS	:	Quality Management System
RADAS	:	Radiation Data Acquisition System
RAPP	:	Rajasthan Atomic Power Project
RAPPCOF	:	RAPP Cobalt Facility
RAPS	:	Rajasthan Atomic Power Station
RB	:	Reactor Building
RBGM	:	Review Basis Ground Motion
RCC	:	Reinforced Cement Concrete
RCP	:	Reactor Coolant Pump
R&D	:	Research and Development
RI	:	Regulatory Inspection
RPV	:	Reactor Pressure Vessel
RRCAT	:	Raja Ramanna Centre for Advanced Technology
RRE	:	Round Robin Exercise
RRS	:	Reactor Regulating System
RS	:	Remote Sensing
RSA	:	Response Spectrum Analysis
RSD	:	Radiological Safety Division
RSO	:	Radiological Safety Officer
RTD	:	Resistance Temperature Detector

RTI : Right to Information
SADD : Safety Analysis & Documentation Division
SAR : Safety Analysis Report
SARCAR : Safety Review Committee for Applications of Radiation
SARCOP : Safety Review Committee for Operating Plants
SBLOCA : Small Break Loss of Coolant Accident
SC : Safety Code
SC : Safety Committee
SCR : Supplementary Control Room
SCRAM : Safety Control Rod Accelerated Movement
SCURF : Safety Committee for Investigation of Unusual Occurrences in Radiation Facilities
SCWR : Super Critical Water Cooled Reactor
S/D : Shutdown
SDSS : Special Decision Support System
SEC : Site Evaluation Committee
SEC NRS : Scientific and Engineering Center for Nuclear Radiation Safety
SEE : Site Emergency Exercise
SER : Site Evaluation Report
SER : Significant Event Report
SG : Safety Guide
SG : Steam Generator
SG : Specialists Group
SGDHRS : Safety Grade Decay Heat Removal System
SIMPLE : Semi Implicit Method for Pressure Linked Equations
SINP : Saha Institute of Nuclear Physics
SLHS : Small Leak Handling System
SM : Safety Manual
SPE : Standard Problem Exercise
SPF : Sponge Production Facility
SPND : Self Powered Neutron Detector
SPSA : Seismic Probabilistic Safety Analysis
SRI : Safety Research Institute
SR : Severity Rate
SREH : Safety Related Electrical House
SRPH : Safety Related Pump House
SS : Stainless Steel
SSA : Site Safety Assessment
SSSC : Seismic Structures Systems and Components
TAPS : Tarapur Atomic Power Station
TBP : Tri-Butyl Phosphate
TDP : Technology Demonstration Plant
TF : Task Force
TIPEEZ : Tsunamis and Post Earthquake Considerations in the External Zone
THA : Time-Histories Analysis
TG : Turbine Generator
TPW : Tsunami Protection Wall
Type B (U) : Type B (Unilateral)
UEP : Uranium Extraction Plant
UGC : University Grants Commission
UHS : Uniform Hazards Spectra
USC : Unit Safety Committee
UCIL : Uranium Corporation of India Limited
USNRC : United States Nuclear Regulatory Commission
VECC : Variable Energy Cyclotron Centre
VRSC : VECC and RRCAT Safety Committee
VSPP : Versatile Solvent Production Plant
VVER : Voda Voda Energy Reactor
WANO : World Association of Nuclear Operators
WG : Working Group
WIP : Waste Immobilization Plant
WWER : Water Water Energy Reactor
XRD : X-ray Radiography
ZMT : Zone Mean Temperatures
ZMTD : Zone Mean Temperature Deviation
ZSP : Zirconium Sponge Plant

INTERNATIONAL NUCLEAR AND RADIOLOGICAL EVENT SCALE (INES) (REVISED)

Level/Descriptor	Nature of the Events	Examples
7 MAJOR	• Major release: Widespread health and environmental effects requiring implementation of planned and extended counter	Chernobyl NPP, USSR(now in Ukraine),
6 SERIOUS ACCIDENT	• Significant release: Likely to require full implementation of planned counter measures.	Kyshtym Reprocessing Plant, Russia,1957
5 ACCIDENT WITH WIDER CONSEQUENCES	• Limited release: Likely to require partial implementation of some planned counter measures • Severe damage to reactor core/Several Deaths from radiation. • Release of large qualities of radioactive material within an installation with a high probability of significant public exposure. This could arise from a major criticality accident or fire	Windscale Pile, UK, 1957 Three Mile Island, NPP, USA, 1979 Goiania, Brazil, 1987
4 ACCIDENT WITH LOCAL CONSEQUENCES	• Minor release of radioactive material unlikely to result in implementation of planned countermeasures other than local food controls. • Fuel melt or damage to fuel resulting in more than 0.1% release of core inventory. • At least one death from radiation/Release of significant quantities of radioactive material within an installation with a high probability of significant public exposure.	Tokaimuro,Japan,1999 Saint-Laurent des Eaux NPP, France, 1980 Fleurus, Belgium, 2006
3 SERIOUS INCIDENT	• Near accident of an NPP with no safety provisions remaining. • Highly radioactive sealed source lost or stolen/misdelivered without adequate radiation procedures in place to handle it. • Exposure rates of more than 1 Sv/hr in an operating area • Severe contamination in an area not expected by design, with a low probability of significant public exposure • Exposure in excess of ten times the statutory annual limit for workers/ Non-lethal deterministic health effect(e.g. burns)from radiation	Vandellos NPP, Spain, 1989 Ikitelli, Turkey, 1999. Sellafield,UK,2005 Yanango,Peru,1999
2 INCIDENT	• Significant failures in safety provisions but with no actual consequences • Exposure of member of public in excess of 10mSv/Exposure of a worker in excess of the statutory annual limits/Radiation level in an operating area of more than 50mSv/hr • Significant contamination within the facility into an area not expected by design • Found highly radioactive sealed orphan source, device or transport package with safety provisions intact./Inadequate packaging of highly radioactive material sealed source	Forsmark.Sweden,2006 Atucha,Argentina,2005
1 ANOMALY	• Minor problems in safety components with significant defence in depth remaining/ Low activity lost or stolen radioactive source, device or transport package • Overexposure of member of public in excess of statutory limits.	Breach of operating limits at a nuclear facility/Theft of a moisture density gauge
0 DEVIATIONS BELOW SCALE	No safety significance	

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