# ANNUAL REPORT

## 2012-13


सत्यमेव जयते

**Government of India**

**Department of Atomic Energy**

# ANNUAL REPORT

## 2012-13


**Government of India**

**Department of Atomic Energy**

# CONTENTS

# EXECUTIVE SUMMARY

The Department of Atomic Energy's vision is to empower India through technology, creation of more wealth and providing better quality of life to its citizens. DAE is engaged in the design, construction and operation of nuclear power/research reactors and the supporting nuclear fuel cycle technologies to achieve these objectives.

Advanced technologies such as accelerators, lasers, supercomputers, advanced materials and instrumentation are developed to encourage transfer of technology to Industry which contributes to the national prosperity.

The Department is also engaged in the development of radiation technologies and their applications for better crop varieties, techniques for crops protection, radiation based post-harvest technologies, techniques for radio-diagnosis and radiotherapy of diseases particularly cancer, technologies for safe drinking water, better environment and industrial growth.

DAE also contributes to the enrichment of knowledge domain by way of support to basic research in nuclear energy and related frontier areas of science; Interaction with universities and academic institutions; Support to research and development projects having a bearing in DAE's programmes, and international cooperation in related advanced areas of research.

During the year 2012-13, the programmes of the Department achieved impressive growth in all the segments and domains. These are described below.

## NUCLEAR POWER PROGRAMME: STAGE 1
### PRESSURISED HEAVY WATER REACTORS

Nuclear Power Corporation of India Ltd. (NPCIL), a public sector undertaking of DAE and a dividend paying company with AAA credit rating by CRISIL and CARE, is responsible for design, construction, commissioning and operation of nuclear power reactors. At present, it operates 20 nuclear power reactors with an installed capacity of 4780 MWe (megawatt electrical) and 4800 MWe capacity under construction that comprises two light water reactors of 1000 MWe each in advance stage of commissioning at Kudankulam in Tamilnadu and four Pressurised Heavy Water Reactor (PHWR) of 700 MWe each, two at Kakrapar in Gujarat and two at Rawatbhata in Rajasthan.

### Power Generation

NPCIL completed 25 years of operation and celebrated its silver jubilee in September 2012. During the year, NPCIL registered highest ever nuclear power generation of about 33170 MUs, (Million Units) that was higher by 2% compared to the previous year.

The overall weighted average availability factor for operating reactors was 91% and the overall capacity factor was 80% up to December 2012 in the financial year 2012-13. PHWRs on indigenous fuel continued to operate at power level matching fuel supply and the Capacity Factor for these reactors was about 76% up to December 2012.

## Projects under construction

Units-1&2 of Kudankulam Nuclear Power Plant (2x1000 MWe LWRs) of NPCIL are in advance stage of commissioning. The Initial Fuel Loading (IFL) was successfully completed in Unit-1. This unit is expected to go critical by February 2013 after obtaining stage wise clearance from AERB. The Unit-2 was closely following Unit-1.

Kudankulam Nuclear Power Project-1&2

The construction work continued and made progress for the first pair of indigenously designed 700 MW PHWRs, at Kakarapar Atomic Power Project Units-3&4 (2x700 MWe PHWRs) and for the second pair of indigenously designed 700 MWe at Rajasthan Atomic Power Project Units-7&8 (2x700 MWe PHWRs). The above projects of NPCIL are expected to be completed by the year 2016-17.

## New Projects

Preparatory works for launching of two approved units of Light Water Reactors at Kudankulam in Tamilnadu and Jaitapur in Maharashtra were started. For the Kudankulam Nuclear Power Project Units-3&4 (2x1000 MWe LWRs) environmental and CRZ clearances were obtained. Works relating to site infrastructure, made progress. For Jaitapur Nuclear Power Project (JNPP-1&2, 2x1650 MWe LWRs) environmental clearance from MoEF and Coastal Regulation Zone (CRZ) clearance was obtained and land was acquired. Techno Commercial discussions of project reached advanced stage.

## New Sites

The Government of India in- principle approved, setting up of 1000 MWe or larger capacity Light Water Reactors based on foreign technical cooperation in the inland sites at Gorkhpur in Haryana, Chutaka and Bhimpur in MP, MahlbBanswara in Rajasthan, expansion of existing site at Kaiga in Karnataka to set up 700 MWe PHWRs, and coastal sites at Kovvada in AP, Chhaya-Mithi virdi in Gujarat & Haripur in west Bengal. Pre-project activities including land acquisition process, Environmental Impact and other studies for Environmental clearance by Ministry of Environment and Forest (MoEF) and AERB were at various stages of progress.

# FRONT END FUEL CYCLE

Front-End Fuel Cycle comprises operations such as mining, milling and processing of ore, and fabrication of fuel. In addition, production of heavy water, used as moderator and coolant in pressurized heavy water reactors, also constitute a major programme segment of the Nuclear Power Programme.

DAE has wide-ranging capabilities in uranium mining and mineral processing, and is self-sufficient in the production of heavy water, zirconium alloy components and other materials and supplies, for pressurised heavy water reactors. The Nuclear Fuel Complex at Hyderabad manufactures fuel assemblies for pressurised heavy water reactors, boiling water reactors and fast breeder reactor.

## Heavy Water Production

The Heavy Water Board (HWB) is responsible for production of heavy water for the Indian PHWRs. It is also engaged in the development and demonstration of technological

feasibility of various processes for the products required for the Front and Back End operations of the Nuclear Fuel Cycle.

Heavy Water Board continued to support the first stage of Nuclear Power Programme of DAE by supplying Heavy Water to all the operating Pressurized Heavy Water Reactors. HWB has emerged as the largest global producer of Heavy Water and has developed production capabilities in various other areas, like organo-phosphorous solvents and $^{10}B$ enriched Boron.

During the year, the performance of the Board was excellent with respect to heavy water production, specific energy consumption, on stream factor, safety performance, environment management etc. The total percentage production target achieved during the period was about 109%.

HWB continued to adopt means to reduce the specific energy consumption through process intensification and optimization. HWP (Manuguru) supplied the surplus electrical energy generated at the captive power plant to the power grid and made revenue generation. Schemes were also drawn up for life extension of the first generation of Heavy Water Plants (HWPs).

HWP (Kota) completed more than 25 years of operation, handling $H_2S$. A thorough check for healthiness of plant equipment was carried out.

Three export orders were executed during the year with FE realization of over 7.5 million US Dollars. DAE established its presence in the French market for the first time as a supplier of high quality heavy water for non-nuclear applications. HWB bagged three export orders worth 5.4 Million US Dollars for supplying heavy water to M/s. Linde Electronics and specialty Gases, USA, M/s. Cambridge Isotope Laboratories, USA and M/s. Euriso Top, France.

For societal benefit, small quantities of heavy water were supplied to Indian research institutions for application in life sciences as well as other technological developments. All the Heavy Water Plants were certified for ISO Quality Management system, Environmental Management System and OSHA System. The overall safety standards of the Plants were far better than similar chemical industries in the country.

## Diversification Activities

HWB has made major progress on the extended mandate entrusted by DAE on development, demonstration and deployment of technologies for in-core and out core material inputs for Indian Nuclear Power Programme, required at the Front-end as well as Back-end of nuclear fuel cycle.

### Solvent Technology

The newly installed industrial facilities at HWP (Baroda) and HWP (Talcher) performed very well. Production technologies were industrially deployed for organo-phosphorous solvents like Di-2-ethyl hexyl phosphoric acid (D2EHPA) and Tri-n-butyl phosphate (TBP) and various other solvents at HWP (Talcher) and HWP (Baroda).

Heavy Water Board made a noteworthy achievement in the area of Uranium recovery from phosphoric acid and successfully commissioned a Technology Demonstration Plant at RCF, Chembur with production of tonnage quantity of yellow cake. Advance actions were taken by the Heavy Water Board for pre-project activities for production of rare material on industrial scale plants as a result of encouragement of successful synergistic operation of TDP.

**Boron Enrichment**

HWB successfully delivered the entire quantity of $^{10}B$ enriched Boron for the first core of PFBR. Boron Enrichment plants at HWP (Manuguru) and HWP (Talcher) were operating very well and achieved $^{10}B$ enrichment beyond 95% at HWP (Talcher).

**Sodium Metal**

Collaborative Work on development of safe and efficient closed cell for production of nuclear grade sodium metal was carried at M/s National Metallurgical Laboratory, Jamshedpur. Fabrication and test operation of 500 A cell was completed. Design for 2000 Amp cell has been approved which will be set up at HWP (Baroda).

**Depleted Uranium**

Design, engineering and setting up of Uranium Oxide Facility of 250 Te/annum capacity to convert Uranyl nitrate solution from reprocessing plants into uranium oxide powder as final product was taken up. The design & engineering was completed, civil work was started at site and equipment fabrication was in advanced stage.

## Mineral Exploration and Mining

Atomic Minerals Directorate for Exploration and Research (AMD) continued the accelerated pace of exploration activities during the field season 2011-12. This resulted in the establishment of over 14,260 tonnes of additional uranium oxide reserves in the areas of Andhra Pradesh, Rajasthan, Meghalaya and Jharkhand. The country's uranium resources currently stands updated to over 1, 86,650 tonnes of Uranium Oxide.

Promising uranium anomalies were located in parts of Tamil Nadu, Rajasthan, Andhra Pradesh, Chhattisgarh and Madhya Pradesh. About 1,88,200 m of drilling was carried out to establish additional uranium resources.

Exploratory mining at Gogi, Yadgir district, Karnataka was carried out by UCIL on behalf of AMD and a progress of 225.00 m in shaft sinking was achieved,

AMD also carried out geochemical surveys (2639 sq km), ground geophysical investigations (192 sq km). Airborne survey and Remote Sensing by Time Domain Electromagnetic (TDEM), Magnetic and Radiometric techniques were carried out over 38520 line km.

Rare Metal and Rare Earth investigations resulted in location of new occurrences of columbite-tantalite and beryl bearing pegmatites in Karnataka, Rajasthan, Odisha and Chhattisgarh.

AMD continued its surveys and exploration activities along the coastal tracts of Gujarat, Andhra Pradesh, West Bengal, Odisha, Tamilnadu and Karnataka and encouraging heavy mineral concentrations were recorded in Odisha, West Bengal; Karnataka and Andhra Pradesh. Heavy mineral (THM) resources were updated to 1064.79 million tonnes.

The mining and processing of uranium ore in India is done by the Uranium Corporation of India Ltd. (UCIL). This corporation operates in Jharkhand state with six mines at Jaduguda, Bhatin, Narwapahar, Turamdih, Bagjata and Banduhurang, and two processing plants at Jaduguda and Turamdih.

The new mine and processing plant at Tummalapalle in Andhra Pradesh was commissioned and started production of 2000 tpd ore and adequate stockpile was created. The

plant is based on indigenously developed alkali leaching technology and it made substantial progress. The product packaging was also started.

Mohuldih underground mine in Jharkhand recorded uranium ore production. The mine is expected to be commissioned in March 2013 and shall feed the plant at Turamdih which is under expansion. UCIL presented the case for expansion of mine and plant at Turamdih before MoEF and final environmental clearance is expected soon. Terms of Reference (TOR) for extension of Narwapahar Mine Project & Tummalapalle Expansion Project were also presented. Judicious utilization of recycled water through meticulous monitoring of chloride pick-up resulted in 50% reduction in process water consumption per ton of ore processed in Turamdih.

At Indian Rare Earths Limited (IREL), the draft EIA & EMP report for environmental clearance of existing operations of Manavalakurichi plant was prepared and public hearing is expected to be carried out in March 2013. Expert appraisal committee meeting for grant of environmental clearance for capacity expansion of mining and mineral separation unit (CEMMU), OSCOM was successfully concluded and detailed engineering activities were under progress. Construction of plant building, structural works, installation of equipments, etc were on the verge of completion for Monazite Processing Plant. Plant facilities for production of separated high pure rare earths from mixed rare earth chloride produced at MoPP, OSCOM made progress. Alternative secondary sources to augment uranium production were being pursued.

## Fuel Fabrication

Nuclear Fuel Complex (NFC) fabricated and supplied fuel bundles for Pressurised Heavy Water Reactors (PHWRs) and Boiling Water Reactors (BWRs) of NPCIL. Highest ever production of PHWR fuel bundles, BWR fuel assemblies, PHWR fuel tubes, Niobium metal and SS tubes were achieved during the year.

Manufacturing and supply of critical components and various sub-assemblies to meet the commissioning schedule of 500MWe PFBR was in the advanced stage of completion. Manufacturing process was established for pressure tubes of 700 MWe PHWRs through new route of double radial forging of billets.

Production of 2 charges of UNS 6800 U-bend Steam Generator tubes for 700 MWe PHWRs was completed. Manufacturing process was established for Inconel 617 and Super 304HCu tubes for Advanced Ultra Super Critical thermal power plant.

Mechanised $UO_2$ powder and pellet handling system was introduced in pellet production.

NFC launched 19 new projects to meet the fuel and zircaloy requirements of forthcoming 700 MWe PHWRs and 300 MWe AHWR, in addition to augment and modernise the present production facilities to 900 tpy, in line with the

Automatic Boat Charging System for pellets for final compaction press

demand from NPCIL. Financial sanction is obtained for 8 projects.

The project "Capacity expansion of Zirconium Alloy Fuel Tubes Plant at NFC" was completed and the capacity was enhanced to 13, 00,000 no. of tubes per annum. Activities were in progress for establishing Niobium Thermit Production Facility (NTPF) to meet the Niobium requirement of VSSC (Dept. of Space) indigenously.

## BACK END FUEL CYCLE

### Fuel Reprocessing and Waste Management

Power Reactor Fuel Reprocessing Plant (PREFRE) at Tarapur continued to function satisfactorily. PREFRE-II continued to operate successfully and achieved all time record in capacity utilization. The plant completed full year of operation with outstanding performance both in terms of production and process parameters.

Additional Waste Tank Farm (AWTF) was in regular use for safe storage of High Level Liquid Waste (HLLW), Intermediate Liquid Waste (ILW) & Organic Liquid Waste (OLW) generated from regular operations of PREFRE.

Cold commissioning trial of Project WIP-3A, Kalpakkam was initiated. Kalpakkam Reprocessing Plant (KARP) & Spent Fuel Storage Facility (SFSF) was in operation and it achieved an all time record in capacity utilization.

Waste Management plant in Tarapur (TWMF) continued to provide service in management and safe disposal of radioactive waste in solid and liquid form obtained from BARC and NPCIL unit at Tarapur. Advanced vitrification facility at Tarapur was commissioned and it is under regular operation.

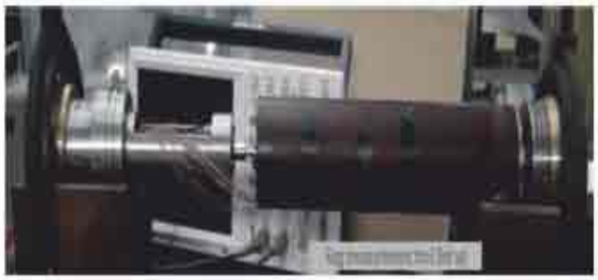
## R&D SUPPORT TO POWER SECTOR

The Research and development support to the Nuclear Power Programme is provided by the research centres of DAE.

As a part of the R&D support for ageing management of existing PHWRs, fuelling machine operated remote inner diameter measurement tool, wet scrapping tool-III, replica tools for 540 MWe and 220 MWe PHWRs and sag measurement tools were developed by BARC. The Hydrogen Recombiner Test Facility (HRTF) was commissioned at Tarapur for containment safety studies of PHWRs.

Hydrogen Recombiner Test Facility, Tarapur

An automated visual inspection system was developed for quality assessment of $UO_2$ fuel pellets during fabrication for detecting visible flaws like pits, chip offs, cracks etc.



A Sag Measurement Tool for PHWRs developed at BARC

Based on Indigenously designed Trombay Programmable Logic Controller-32 (TPLC-32), a Distributed Control System for Integrated Project of Nuclear Recycle Board was developed.

## HEALTH SAFETY & ENVIRONMENT

At NPCIL, review of safety of operating stations was carried out on regular basis. One such review, carried out by IAEA Operational Safety Review Team (OSART), concluded that the safety and safety culture of the Indian nuclear power station are excellent and several good practices are worth emulating by other nuclear power plants across the world. NPCIL achieved 370 reactors years experience of safe operation up to December 2012. Highest standards of safety within the Nuclear Power Plants (NPPs) are were maintained by keeping the Individual and collective occupational exposures of radiation workers within the limits approved by Atomic Energy Regulatory Board by following the principle of ALARA (As Low as Reasonably Achievable).

For quick estimation of excretion rates and help in taking appropriate protection measures, rapid and reliable radiochemical methods for the separation of Pu, Am and U from urine matrix using solid extraction chromatographic resins were developed at BARC. Radiation Detector System (RDS) for police vehicles was developed and installed over 60 Mumbai police patrolling vehicles. About 350

Thyroid monitoring system at BARC

Environmental Radiation Monitors (ERMs) were manufactured, calibrated & field tested and 180 ERMs were installed under the countrywide "Indian Environmental Radiation Monitoring Network (IERMON)".

To have a real-time radiation monitoring system along with meteorological parameters, the Environmental Radiation Monitor (ERM) system of BARC was integrated with the Automatic Weather System (AWS) of ISRO. An integrated software called TLD Badge Management (TLDBM) system was developed for harmonization of personnel monitoring services.

# NUCLEAR POWER PROGRAMME: STAGE 2

## FAST BREEDER REACTORS

For the second stage of the Nuclear Power Generation Programme, the Indira Gandhi Centre for Atomic Research (IGCAR) is pursuing development of sodium cooled fast breeder reactors and associated fuel cycle technologies. Breeder reactors produce more fuel than they consume.

The Fast Reactor Programme of IGCAR is supported by its research and development endeavour in a range of disciplines such as

reactor engineering, metallurgy, materials science, instrumentation, safety, and others. The Fast Breeder Test Reactor (FBTR), operating at Kalpakkam for over 25 years, also caters to technology development related to fast reactors.

Based on the fast breeder reactor technology developed by IGCAR, a 500MWe Prototype Fast Breeder Reactor (PFBR) is coming up at Kalpakkam. The project is being executed by the Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI), a public sector undertaking of DAE.

BARC contributes to the research and development, and manufecture of fuels for fast reactors, technology for reprocessing of fuels, waste management and health and safety of the work force.

## Prototype Fast Breeder Reactor

PFBR is a pool type reactor using mixed oxide of uranium and plutonium as fuel and sodium as coolant The project is implemented by BHAVINI (Bharatiya Nabhikiya Vidyut Nigam Limited), located 500m south of the existing Madras Atomic Power Station.

During the year the civil structural work for nuclear Island connected building was completed and the roof of reactor containment building was concreted and closed.

Erection of most of the equipments of nuclear steam supply system (NSSS) was completed. The core subassemblies and dummy fuel sub-assemblies were loaded in the grid plate. Installation of large and small rotating plugs over the roof slab was also completed. Erection of fuel handling equipment at various locations of fuel building was nearing completion.

In all, eight steam generators and four decay heat exchangers were erected. The plant hoisting mechanisms were commissioned.

Inside view of reactor vessel with Sub-assemblies loaded, BHAVINI

Pre-commissioning works for the conventional auxiliary systems were in the advance stage of completion. Commissioning of 4 diesel generators, 230 KV gas insulated switchyard and 6.6KV switchgear boards was also achieved.

The project has achieved an overall physical progress of over 91% at the end of November-2012.

To meet stringent requirements for fuel handling at high temperature and sodium environment, Inclined Fuel Transfer Machine (IFTM) was designed. Metallic fuels and blanket material of compositions U-15 wt. % Pu and U-6wt.% Zr respectively were also prepared at BARC.

IFTM Control System Development Setup at BARC

### Fast Breeder Test Reactor

During the year 3 irradiation campaigns were successfully completed in FBTR at its target power of 20.3 MWt. Turbo Generator was connected to the grid, generating 3.4 MWe. Important experiments such as irradiation of ferro boron shielding material, testing of high temperature neutron detectors, drop time measurement system of DSRDM, start of irradiation of sodium bonded natural uranium metallic fuel, irradiation of yttria for production of strontium isotope for medical applications etc; were completed. The PFBR MOX test fuel subassembly was irradiated successfully giving confidence in achieving the PFBR target burn-up of 112 GWd/t.

### FBR Fuels

Plutonium bearing fuels for the Fast Reactor Programme are supplied by BARC. Fabrication of MOX fuel pin by vibro-compaction route was done.

### Fast Reactor Fuel Reprocessing

Several reprocessing campaigns of FBTR spent fuel were successfully completed in COmpact Reprocessing facility for Advanced fuels of Lead cells (CORAL). All the major equipments and systems required for the Demonstration Fast Reactor Reprocess Plant were received at site for installation and commissioning.

Towards construction of the Fast Reactor Fuel Cycle Facility (FRFCF), environmental clearance and the recommendations of the Project Design Safety Committee to AERB for issue of consent for construction were received.

### FBR Related Technologies

As a part of electronics and instrumentation programme, development of virtual reality system, 3D modeling & visualization of the fuel handling operation of PFBR and FRFCF, modeling of all sub-systems and benchmark transients for operating training simulator, installation & commissioning of high performance computing cluster systems, R&D on intelligent human-machine interface for plant monitoring & control were actively pursued.

In the domain of Chemistry, R&D on development of advanced separation schemes for actinide recovery, engineering scale studies on unit operations in pyroprocessing, thermo chemical studies and thermo physical property measurements of several systems involving fuel & control rod materials etc were some of the major important activities completed. Sodium bonded test metallic fuel pin fabrication facility was commissioned and trial pins of U-Zr were made.

In the materials front, development of 9Cr ODS clad tubes, improved D9 cladding material, procedure for joining SS pipes by A-TIG welding, GMR array sensor based magnetic flux leakage technique for non-destructive detection of defects, fabrication of irradiation capsules, development of partially stabilized zirconia coatings on metallic and graphite substrates, fabrication of dissimilar joint by innovative explosive cladding technique etc were completed.

### Future FBRs

Towards design and manufacturing technology of future MOX reactors, a few major components were innovatively designed and manufactured indigenously. R&D on the design of future FBRs on the reactor safety, large scale

sodium fire, simulation of post-accident scenarios were completed by designing novel experiments.

Towards the design of Metal Fuel Reactor, studies were completed for the basic design of core, plant main parameters and candidate sites at Kalpakkam.

# NUCLEAR POWER PROGRAMME: STAGE 3

## THORIUM BASED REACTORS

The Stage-3 of the Indian Nuclear Power Programme aims at using thorium as fuel for power generation on commercial scale. In the Thorium Fuel Cycle, Thorium-232 is transmuted into the fissile isotope Uranium-233 which is a nuclear fuel.

As a part of this programme, BARC has been developing a 300MWe Advanced Heavy Water Reactor (AHWR). Fuelled by thorium and using light water as coolant and heavy water as moderator, this reactor will have several advanced passive safety features.

### Advanced Heavy Water Reactor

Advanced Heavy Water Reactor Thermal-hydraulic Test Facility (ATTF) vessels and heat exchangers were installed. A novel buckling pin type passive valve was developed and demonstrated for Emergency Core Cooling System (ECCS) of AHWR. A prototype Fuelling Machine (FM) was designed and fabricated. Several equilibrium core clusters were studied for the on-power refuelling of AHWR-LEU core. For evaluating hydrodynamic effects, experiments were carried out to study the liquid behaviour in Gravity Driven Water Pool (GDWP) of AHWR.

Buckling Pin Valve-80 NB

Critical Facility for AHWR and 540 MWe PHWR was operated on several occasions for various experiments. Fuel fabrication process flow sheet for AHWR 300 LEU was established using natural $UO_2$ in laboratory (kg) scale.

### Other Reactor Systems

For the Compact High Temperature Reactor (CHTR) critical facility, alternative design of the SDS-2 system, based on liquid poison injection was worked out. Reactor physics analysis and layout related studies were carried out by BARC.

Computational Fluid Dynamics (CFD) based thermal hydraulic analysis of the reactor and detailed thermal analysis of the core of the reactor under normal and postulated accident conditions were carried out.

Detailed project report for construction of a 30 MW High Flux Research Reactor (HFRR) and a new thermal research reactor of 125 MW at new BARC campus Vizag were prepared.

### KAlpakkam MINI (KAMINI) Reactor

At Kalpakkam, KAMINI reactor was in regular operation upto a maximum power of 30kW and was utilized towards neutron radiography of fuel, ferro boron capsules and testing of newly developed neutron detectors.

### Research Reactors

Detailed engineering of the 2 MW upgraded APSARA reactor was in progress. Shielding design of reactor was completed. Safety review of various reactor systems was in progress. The design stage Level 1 Probabilistic Safety Analysis (PSA) for the upgradation of APSARA Reactor to a 2 MW reactor, involving safety system and process system reliability analysis and quantification of the model by generic data was completed.

Research reactor Dhruva continued to operate with a high level of safety and an availability factor close to 80%. Dhruva continued to be the only facility for radioisotope production and served as a national facility for neutron beam research. Over 1100 samples were irradiated during the year.

Vacuum Circuit Breakers

## ADVANCED TECHNOLOGIES

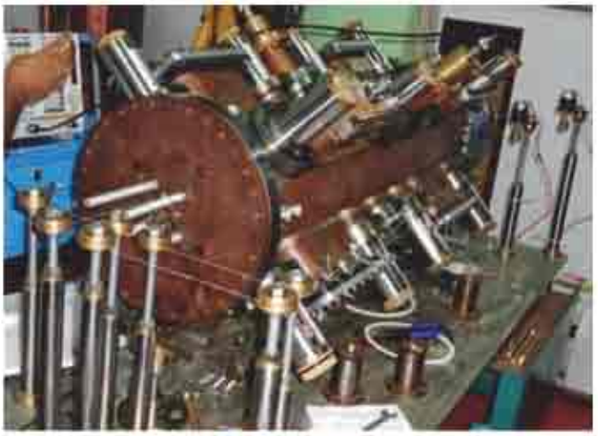
The research centres of DAE are engaged in developing advanced technologies such as accelerators, lasers, advanced materials, robotics, supercomputers, instrumentation and others. BARC, RRCAT, VECC and BRIT are also engaged in the development of radiation technologies & their applications for better crop varieties, techniques for crops protection, radiation based post-harvest technologies, techniques for radio-diagnosis & radiotherapy of diseases particularly cancer, technologies for safe drinking water, better environment & industrial growth.

### Accelerators

During the year, experimental nuclear physics programs were carried out extensively using the light ion beams from K-130 cyclotron at VECC. Several developmental activities were taken up for the facility development of K-130 cyclotron and superconducting cyclotron and significant progress was achieved.

Collaborative studies between BARC and VECC on radiation damage using ion beam from Variable Energy Cyclotron and ECR ion sources at VECC were carried out on different nuclear structural materials.

The phase control loop for the 3-phase RF System of K500 Superconducting cyclotron was upgraded. R&D on development of multi-cell medium- Superconducting RF linac cavity was taken up at VECC and for this a state-of-the-art



ECR Ion source

Inductive Output tube (IOT) based high power RF amplifier was developed and tested.

The power conditioning system for the prototype Superconducting Magnetic Energy Storage (SMES) System was developed and tested at VECC.

At BARC, a state-of-the-art superconducting Electron Cyclotron Resonance (ECR) Ion Source was commissioned at Van-de-Graff lab. For Accelerated Driven System (ADS), a 400 keV, 1 mA, 4 vane Radio Frequency Quadrupole (RFQ) for $D^+$ beam was fabricated and its cold testing was completed at BARC.

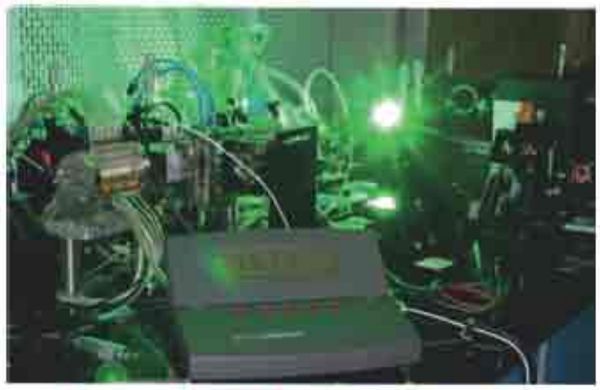
## Laser Technology Development and Applications

A high beam quality, frequency doubled Nd:YAG green laser system with an output average power of 100 W was developed at RRCAT. A Master Oscillator Power Amplifier chain of 3 CuBr laser units delivering 100 W average laser powers was also developed.

As a first step in the development of all fiber laser, a 160 W continuous wave single transverse mode fiber laser was developed using bulk mirror components. An all-normal-dispersion mode-locked Yb-doped fiber laser of an average output power of 150 mW was also developed. Long period grating (LPG) based wave length encoded fiber sensors with a very high limit of integrated radiation dose measurement were developed.

The technology developed at RRCAT for various applications included a high quality quasi-mono energetic electron beam, with divergence charge and energy; development of set-up for simultaneous depth resolved imaging of the tissue morphology and blood flow velocity; study of the effect of photodynamic treatment on healing of murine excisional wounds; development of a prototype light emitting diode (LED) based system for cancer diagnosis.

The work on the high average-power liquid dye laser systems based on water



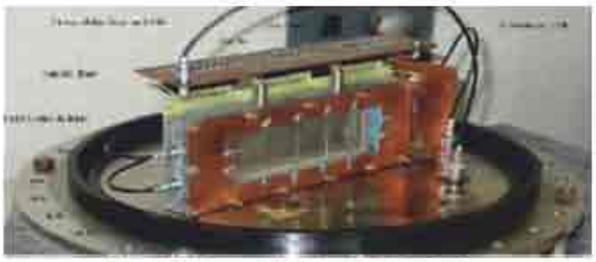
High beam quality Nd:YAG green laser with 100W output power developed at RRCAT

Yb-doped femtosecond fiber laser and compressor developed at RRCAT

continued at BARC. A non scanning atomic magnetometer with simultaneous frequency standard based on coherent population trapping has been developed. A laser heating facility was setup using IR laser.

## Electronics & Instrumentation

On the nuclear instrumentation front BARC developed a large area 2D position sensitive cathode strip gas detectors for detecting the fission fragments. Very sensitive Differential MicroBarometer was developed to measure very minute and very slow variations of atmospheric pressure around the mean.



A multi-wire cathode strip detector

Three application-specific integrated circuits (ASICs) – Anusanskar, Anuspandan, Anusparsh-II were designed, fabricated and tested in BARC.

Electronics Corporation of India Limited (ECIL) is engaged in the design, development, manufacture, supply, installation and commissioning of a wide variety of electronic equipment for the Atomic Energy, Defence, Aerospace, Security, Information Technology and e-Governance sectors. ECIL is also a key partner in the implementation of National Population Register (NPR) and socio-economic & caste census (SECC) projects of Govt. of India.

During the year, ECIL took major initiatives to introduce new products such as indigenously designed carrier switch routers, secure network access system (SNAS) and integrated threat management appliance (ITMA) to mitigate the information security concerns especially in strategic areas. New Products introduced during the year were BF3 based Drum Monitor, EC Router, Voter Verifiable Paper Audit Trail (VVPAT), MPROGICON PLC System and Software Defined Radio (SDRs). Work on projects such as Carrier Switch Routers; Development of Software for Intelligent Traffic Management System and Building Automation; Design, development and production of Secure Router and Transporters; Integration of ECSCADA software with ECIL's MPROGICON 5000 PLC was under progress.

Other significant achievements during the year 2012-13 included supply of Control & Instrumentation (C&I) equipment to PFBR project, Field Engineering Services to Kudankulam Nuclear Power Project; supply of MSRS-II equipment, sensor packages, and Ground Control Systems for Akash and BrahMos Missiles for Defence sector; Communication equipment including antennas for establishing a Ground Station at Antarctica for space sector; Automation of Maharashtra Sales Tax Department's operations and Supervisory Control and Data Acquisition Equipment to Oil and Steel industries. The data digitization work of NPR project was completed.

## Robotics

Mobile tracked robot was designed and developed by BARC to work on rough terrain and climb staircases. Portable wireless controlled,

Tracked Robot Climbing Staircases

rugged mobile robot with on-board articulated arm was also developed.

A Mobile robot based online radiation mapping system was developed by VECC and successfully used in different experiments to measure the dose rate at various regions of K-130 cyclotron facility.

## Cryogenics

A prototype of a Variable Temperature Insert (VTI) was developed in-house at VECC and it was put in a glass cryostat. This was used as a cryogenic thermometer calibration facility commissioned in fulfilment of the stringent requirements on the temperature control of the cryogenic systems for calibrating industrial cryogenic thermometers that include a temperature sensor and the wires heat-intercept.

The 2 K cryostat was tested, accepted and installed in a subterranean pit at the cryogenics building. Installation of hardware, electronic controls and helium transfer lines etc. was in progress at RRCAT.

Pipeline Inspection Gauges (PIGs) for pipelines of several sizes under a MoU with IOCL was developed. An experimental helium liquefier

2 K Cryostat installed in an underground pit in the Cryogenics building at RRCAT

was built at BARC. Process design of a new 250 W at 4.5 K helium refrigerator to be developed during the 12th plan was completed.

# RADIOISOTOPES & RADIATION TECHNOLOGY AND THEIR APPLICATIONS

DAE has been playing a significant role in the development and applications of various radioisotopes in healthcare, industry, agriculture and research. India is one of the leading countries in the isotope technology today as a result of the consistent efforts of DAE.

Radioisotopes are produced in the research reactors at Trombay, accelerator at Kolkata and the various nuclear power plants of NPCIL. During the report period, a wide variety of radioisotopes for medical, industrial and research applications were produced and supplied by BARC. The Board of Radiation and Isotope Technology (BRIT) produced and supplied a wide range of radioisotope products, and radiation technology equipment for medical and industrial uses. BRIT's plants for radiation sterilization of medical products and radiation processing of spices and allied products continued to offer services to medical and agro-industry. Radiation technology based tools and techniques benefitted variety of industries and social sector.

## Agriculture

A large seed Trombay groundnut variety, TG 47 (Bheema) was released and notified as RARS T1 for commercial cultivation for early kharif and rabi under irrigated conditions in all agro-climatic zones of Andhra Pradesh. About 372 quintals breeder seed of Trombay groundnut varieties were multiplied and distributed to different seed agencies and farmers for further foundation seed production.

In mungbean, two recessive genes governing resistance to yellow mosaic virus (MYMV) were identified. In uradbean, breeding programme on development of yellow mosaic virus and powdery mildew disease resistant black gram variety was undertaken. A selection of rice involving mutant as a parent was tested and found to be high yielding. In wheat, early mutants of Cv. C306 were tested at IARI, Indore. A protocol for extraction and HPLC separation of various sugars in blackgram was standardised.

Investigations on the indigenous medicinal plant Ophiorrhiza species were pursued for the production of the Camptotheca alkaloids used in cancer therapy. Plant tissue and organ cultures of Ophiorrhiza were established and mass cultivated for the extraction and isolation of bioactive constituents.

A novel plasma membrane aquaporin (MusaPIP-2) was identified from banana Expressed Sequence Tag(EST) database and used to transform embryogenic suspension cultures of banana. Stably transformed banana plants showed improved tolerance to salt, drought and cold stress.

Two important fungal proteins namely Velvet protein and a Fungal Transcription Factor (ftf1) in Fusarium Oxysporum Cubense (FOC) involved in spore germination and mycelial growth in filamentous fungi of fusarium disease, were identified.

A large seed Trombay groundnut variety, TG 47 released for Andhra Pradesh

Fruit fly infestation on fruit and vegetables crops was analyzed with the help of National Research Institutes and Agricultural Universities using different designs of pheromones based on methyal eugenol and Cue-lure traps.

The DC accelerator at RRCAT was utilized for exploiting the potential of electron beam irradiation as phyto-sanitary treatment against pulse beetles in seeds of various grain legumes.

## Food Technology

A process for preventing browning and extending shelf life of litchi fruits for 45-60 days by a sequential dip treatment using GRAS chemicals and the technology transfer was developed by BARC. Dosimetry protocols were standardized at KRUSHAK facility for application of radiation processing as a quarantine requirement for export of pomegranate to USA.

A combination of nisin (1000 U) and low dose radiation treatment (1kGy) to improve microbiological quality of minced meat using packed inoculum studies was investigated. Protocols were standardized for determining the optimum dose for extension of shelf life of Ready-To-Cook (RTC) pumpkin.

A process was developed for preparation of Ready-To-Cook (RTC) kidney bean (Rajma) by precooking and drying. Methods were standardized for identification of marker volatiles in food packaging for early detection of food spoilage.

At RRCAT, collaborative research and development work on electron beam irradiation of pulses for food preservation and quarantine was done with National Bureau of Plant Genetic Resources, New Delhi.

## Nuclear Medicine and Healthcare

At BARC, regular operation of Medical Cyclotron and production of $^{18}F$ and synthesis of $^{18}F$-FDG, $^{18}F$-NaF, $^{18}F$-FLT and $^{18}F$-FMISO was carried out to meet the in-house as well as the nearby hospital requirements. Large numbers of thyroid cancer patients were given $^{131}I$ therapy and palliative care was extended to bone-metastatic patients. $^{99m}Tc$-tetrafosmin, a radiopharmaceutical for myocardial perfusion studies was developed and clinical studies of $^{99m}Tc$-TRODAT for diagnosis of Parkinson's disease and $^{99m}Tc$-Hynic-TOC for neuro - endocrine diseases was undertaken. The technology for Indigenous Digital Radiotherapy Simulator for localization of tumor, radiotherapy planning and treatment plan verification was also developed.

VECC in collaboration with BRIT, Kolkata developed and tested an automated $^{99m}Tc$ generator, AUTOSOLEX. The entire development starting from the hardware design, the firmware code and the software application were done in-house.

BRIT supplied consignment of 20,000 ready to use radiopharmaceuticals of which $^{131}I$ radiopharmaceuticals amounted to about 530 Ci in over 17,000. Production and supply of injectable products was considerably increased.

A new facility was set up at BRIT for production of high activity I-131 capsules which will enhance the volume of I-131 capsule production and enable manufacturing of capsules containing higher I-131 radioactivity for the treatment of thyroid cancer.

BRIT continued to produce and supply radioimmunoassay (RIA) and immunoradiometric assay (IRMA) kits. RIA Laboratory received UKAS (United Kingdom Accreditation Services) accreditation and

Iodine-131 capsule production Hot Cell

Radiopharmaceutical Production Facility

International Quality Standards certification. Two new products $^{99}Mo$-$^{99m}Tc$ alumina column generator and ready to use radiopharmaceutical Colloidal Samarium Phosphate $^{32}P$ were launched. Commissioning of the column generator production facility at BRIT and availability of generator "COLTECH" made a great market impact.

Regional Centres of BRIT in Delhi and Bangaluru regularly supplied ready-to-use $^{99m}Tc$ Radiopharmaceuticals and cold kits in their regions; Regional Centre, Kolkata was engaged in $^{99m}Tc$ production through $^{100}Mo$ reaction in the cyclotron. The purification work of $^{99m}Tc$ suitable for preparation of $^{99m}Tc$-radiopharmaceuticals was

carried under the IAEA CRP. Regional Centre, Dibrugarh rendered the RIA and IRMA diagnostic services for the benefit of patients of the entire north-eastern region. Regional Centre, Hyderabad in collaboration with RMC, BARC, Mumbai developed a gel based PCR diagnostic kit for detection of M tuberculosis. Work relating to the setting up of new Radioanalytical Laboratory at Regional Centre, Bangaluru and also at BRIT Project House, Deonar, Mumbai is in progress.

At Regional Center, RAPPCOF, KOTA, a total Cobalt-60 activity of 861 kCi in 17 sub assemblies was processed. Fifteen numbers of W-91 sources were fabricated at RAPPCOF. Two teams of RAPPCOF successfully carried out source loadings at OGFL and JCPL, Bhiwadi.

## Alternative Applications of Heavy Water

Alternate applications of Heavy Water are opening up new business opportunities in the field of medicine. Heavy Water Board made following significant progress in keeping pace with these developments:

HWB took up process development for separation of $^{18}O$ from natural water on realization of potential requirements of $^{18}O$ having application in nuclear medicine and bio-chemical research. Doubly Labeled Water (DLW) having certain concentration of $D_2{}^{18}O$ was used for measuring energy expenditure, total body water content, etc. $^{18}O$ finds use in Positron Emission Tomography (PET) used for detection and staging malignancies.

Actions were initiated for collaborative research work on alternate uses of Heavy Water. Developmental activities, as per the MOU signed between Heavy Water Board and BRIT on deuterium labeled compounds and allied value added products are in progress. HWB also signed agreements with three Indian companies for development of D-labeled reagents, D-labeled APIs and NMR solvents and allied value added products.

## Cancer Diagnostics & Treatment services

The Tata Memorial Centre (TMC) comprising Tata Memorial Hospital (TMH) and the Advanced Centre for Treatment, Research and Education in Cancer (ACTREC) engaged in research, education and comprehensive care of cancer patients is a grant-in-aid institution under the administrative control of DAE. The TMC continued its activities in diagnosis, treatment and research in cancer as well as in training and education to provide the highest standard of patient care.

During the report period, at the Tata Memorial Hospital, about 56,000 cases of conventional radiography and over 9300 cases of mammography were handled. Around 20,200 cancer surgeries were done at TMH & ACTREC.

TMC continued its outreach programmes such as 'TMC-Rural Outreach Programme' in the districts of Ratnagiri, Maharashtra and 'TMC-Urban Outreach Programme' in the slums of eastern suburbs of Mumbai viz. Mankhurd, Paylipada.

As part of its Information Education and Communication activities about 50 cancer awareness programmes for general population were conducted. Cancer Education pamphlets in regional languages, posters, flip charts, audio-visual cancer education clips and Cancer Exhibition aids were distributed. Around 11,000 people got benefitted through these programs.

Under its Training and Capacity Building programs Capacity Building workshops in

Cancer Prevention Control and Early Detection activities for Medical and Para medical health professionals were conducted.

Collaborations with Maharashtra State Public Health Department and Navi Mumbai Municipal Corporation (NMMC) to establish Cancer Control, Prevention and Early Detection Programs for Cervical, Oral and Breast cancers to be Integrated with the National Non Communicable Diseases (NCD) and National Rural Health Mission (NRHM) were in progress.

## Industrial Applications of Radioisotopes & Radiation

Irradiator sources of 1300 kCi activity were supplied to NIPRO, Satara, JPCL, Bhiwadi, UML Vadodara, and AVPP Ltd., Ambernath. ISOMED, Trombay was loaded with additional 78 kCi and RPP, Vashi received 200 kCi of cobalt-60 activity.

Source Loading at Radiation Processing Plant

Radiometry of HDR Flask NIPRO, Satara

Radiography Sources of 900 Ir-192; 7 Co-60 and 1 Tm-170 with a total activity of 40 kCi; 400 Ci and 10 Ci respectively, were fabricated and supplied to various NDT users in the country. Radiation Sources of Co-60, Cs-137 and Tm-170 for Nucleonic Gauges and other various applications were made. GC-4000 unit supplied to Urugway brought from USA in two numbers of Type A lead pots were sent back to them after removal of sources.

For the first time, 3 Ci Ir-192 HDR source was fabricated for the Indigenous HDR unit. Newly installed 3 port laser system was used for the radiometry of the HDR transport flasks.

## Radiation Processing

At ISOMED, Trombay, the average plant utilization factor was around 96% and load availability of healthcare product was 100%. The source strength was augmented to 400 kCis.

About 2733 MT of spices were processed at Radiation Procession Plant, Vashi. E-payment facility was provided to customers for payment of processing charges. Two Radiation Processing Plants namely, M/s Hindustan Agro Co-Operative Ltd., Rahuri, Maharashtra and M/s Nipro India Corporation Pvt. Ltd, Pune with source loading of 65 kCi and 275 kCi respectively were commissioned.

BRIT signed three MoU's with M/s Isorad Tech Pvt Ltd, Chennai, M/s Divyakiran Agro Processing Pvt. Ltd, Anand, Gujarat and M/s Radura Irradiators, Nashik, Maharashtra for setting up of Radiation Processing plant.

## Radiation Technology based Equipment & Services

A cross linked polymer for moldable electrical insulation components were developed

at BRIT using 2 MeV electron beam ILU-6 EB accelerator. Gamma Chamber GC 1200 was supplied and installed at National Botanical Research Institute, Lucknow. A GC 5000 unit was kept ready for export to Bangladesh Institute of Nuclear Agriculture.

A new source extraction tool was developed for removing and transferring the decayed source from Gamma Chambers to type B (U) packages. Three Blood Irradiator 2000 units were supplied and installed at Rajeev Gandhi Cancer Institute, Delhi; Surat Raktadan Kendra, Surat and Apollo Hospital, Hyderabad.

A new radiography camera model ROLI-2 was introduced in November 2012. BRIT supplied 56 radiography exposure devices, serviced 371 ROLI cameras, removed 789 decayed sources and inspected 581 imported cameras. ROLI 1 cameras were tested at the REPF workshop and the Radiological lab of BARC.

Radiotracer technique was used for leak detection in series of heat exchangers at Chennai Petroleum Corporation Limited (CPCL), Chennai and Bharat Petroleum Corporation Limited (BPCL), Mumbai.

Gamma scanning of process columns was carried out by using sealed source $^{60}Co$ in various refineries and chemical industries for troubleshooting. Eight fabrication work orders were executed to supply BC188 type source transportation cages to domestic and international irradiators. Work on Fission Molybdenum Project for setting up of a State-of-the Art GMP compliant facility capable of producing 300 Ci per week $^{99}Mo$ was in progress.

The 6 MeV Linac was developed at Electron Beam Centre BARC to provide Z-material discrimination in container cargo scanning.

## Isotope Hydrology & Water Desalination

An Isotope Hydrological investigation was carried out by BARC to understand groundwater recharge to shallow groundwaters at Dhamanvne village, Chiplun and at Medhal village in Guhagar Taluk, Maharashtra.

Multi-Stage Flash (MSF) section of NDDP Kalpakkam

A solar energy driven membrane based desalination/ water purification system was developed by BARC. Nuclear Desalination Demonstration Plant (NDDP) at Kalpakkam, consisting of Multi-Stage Flash (MSF) and Reverse Osmosis (RO) sections was operated round the clock producing quality product water. A 240 m3/day capacity Multi-Effect Distillation Thermal Vapor Compression (MED-TVC) plant was designed and developed by BARC.

## BASIC & APPLIED RESEARCH

Basic and applied researches relevant to DAE's programme are carried out in the research centres of the department. The autonomous research institutes are supported by the grant-in-aid. Following were the notable developments in the fields of basic and applied research carried out during the report period, by these research institutes.

## Mathematics & Computation

At TIFR, representation equivalent lattices in products of real and p-adic Lie groups were investigated. The power of sequential decoding for channels with classical input and quantum output was studied, and a strategy for achieving existing capacity bounds was developed.

At SINP, the eigenvalue problem of the DN type of Calogero model was solved by mapping it to a set of decoupled quantum harmonic oscillators through a singular similarity transformation. The level density distributions for a class of 1-dimensional classical vertex models related to Haldane-Shastry like spin chains were studied. Phases of matter at the Planck scale, where quantum effect of gravity are important were studied. The twisted statistics of quantum fields in the vicinity of a noncommutative black hole at the Planck scale were investigated. In quantum field, the on-going work included the study of correlators of the topological charge density, wilson loop, pion and nucleon propagator, and topological charge and susceptibility, with the Domain-Decomposed Hybrid Monte Carlo algorithm.

At HRI, the research work spanned the domains of number theory, algebraic number theory and analysis and geometry.

Institute of Mathematical Sciences continued its ongoing projects of Mathematics Education on Mathematical Sciences without Walls; Developing tools for dynamical modelling of C elegans neuronal network activity; Interplay of non-linearity with quantum effects and curve geometry; INO Project and Potential Theory on Infinite Networks and Trees.

The School of Mathematical Sciences at NISER continued its teaching and research activities and conducted seminars regularly. National Institute of Science Education & Reseach (NISER) has academic expertise in harmonic analysis, operator theory, representations of geometries, number theory, cryptography, algebraic graph theory and probability theory.

## Physics

At BARC the Gamma-ray spectroscopy of neutron rich nuclei, populated in thermal neutron induced fission of $^{235}U$ at Dhruva reactor facilities was taken up. BARC continued to participate in the Pb+Pb and p+p data analysis in the Compact Muon Solenoid (CMS) heavy Ion experiment at CERN, Large Hadron Collider (LHC).

A systematic Raman spectroscopic study of thorium based nuclear fuels was carried out at BARC to demonstrate non-destructive composition analyses of proposed nuclear fuels like ThO2-UO2 mixture and simulated high-burnup nuclear fuel (SIMFUEL).

A new process was developed to prepare optically transparent ceramics (OTC) of the $CaF_2$:Mn and $CaF_2$:Mn+Ce.

The TACTIC gamma ray telescope at Mt. Abu was deployed for observation of a number of Active Galactic Nuclei to monitor their flaring activity in the TeV energy range.

Assembly of MACE telescope at Hyderabad

Manufacturing activities related to the various sub-systems of the 21m diameter Major Atmospheric Cerenkov Experiment (MACE) gamma-ray telescope progressed well. A prototype of the 16-channel detector module was assembled and its detailed testing was under progress.

At RRCAT, generation of quasi-mono energetic electron beam in plasma plume produced from the ablation of nylon target was demonstrated. The Bose-Einstein Condensation has been observed in a $^{87}$Rb atom-cloud by an absorption probe technique using an upgraded in-house developed double magneto-optical trap (MOT) setup.

A new laboratory for fabrication of neutron detector was developed at VECC. Several neutron time of flight (TOF) detectors of dimension 7"x 5" were developed and a detector with new design was fabricated on the basis of R&D carried out on various design aspects of neutron detector made of liquid scintillators.

New Neutron detector fabrication laboratory

The studies conducted at TIFR included a nano-electromechanical system fashioned out of an incommensurate charge density wave (CDW) and a theoretical model of proportionate growth of baby animals.

In Astronomy and Astrophysics, detectors for hard X-ray astronomy and an Infrared Spectroscopic Imaging Survey (IRSIS) payload for an Indian Small Satellite were developed. Near infrared imaging camera developed in-house was successfully used for science observations. The major upgrades of various sub-systems of Giant Metrewave Radio Telescope (GMRT) progressed further. Evidence for the Standard Model Higgs boson at a mass of ~125 GeV was presented.

At SINP, the correlations between electric dipole polarizability and the neutron-skin in 208Pb nucleus were studied using several non-relativistic and relativistic mean-field models. Thermodynamic properties and other phenomenological aspects of very hot and dense matter created in heavy-ion collisions were pursued. The strangeness −2 sector was investigated by studies of the (K−,K+) reactions on proton and heavier nuclei.

HRI, carried out research activities in five major areas of Physics and they were Astrophysics, Condensed Matter Physics, High Energy Physics, Quantum Information and Computing and String Theory. The astrophysics group carried out measurement of the power spectrum and the bi-spectrum for various inflationary models were carried out and in general relativity, various aspects of quantum fields in curved space time were studied.

The Condensed Matter Physics group works in many areas such as Statistical Mechanics and Chaos, Strongly correlated Systems and Cold Atoms, Mesoscopic Systems and Spintronics, and Electronic Structure and Clusters. During the year the quantum information and computation group at HRI produced 15 research papers. The members of the string group undertook a study of the decay of massive fields in de Sitter space.

The High Energy Physics group continued to focus on systematic studies of physics signals at the Large Hadron Collider (LHC), the biggest ever international experiment in the history of fundamental science. Work on supersymmetric extensions of the Standard

Model and the Implications of a non-standard Higgs sector and extra space-time dimensions were also carried out.

The Institute of Physics is involved in pursuing research in String theory, Cosmology and Particle physics. Some of the topics of recent interest are gauge / gravity duality, black hole Physics, anisotropic power law inflation, different aspects of relativistic heavy ion collisions, and dual superconductor model of Hadronization. Study of cross section processes of one loop which are important for analysis of LHC data in high energy phenomenology was carried out. Research was also focused on nuclear structure and nuclear reactions.

Major activities on experimental side at IOP included studies of accelerator based material science, surface and interface physics and nano systems. Analysis of valence band electronic structure and band mapping of transition metal-oxide compounds using photoelectron spectroscopy was undertaken. New facilities like SQUID-VSM and spectral response system for studies of magnetic and optical properties of materials were also added.

At NISER, The School of Physical Sciences continued to provide research activities and the areas covered included High-energy physics, Condensed-matter physics, Bose-Einstein condensation, nonlinear optics, Laser Physics and Nano-photonics.

## Synchrotrons and their Applications

For carrying out advanced basic research, the Raja Ramanna Centre for Advanced Technology (RRCAT) had earlier set up Synchrotron Radiation Sources Indus-1&2.

The synchrotron radiation sources Indus-1 and Indus-2 at RRCAT operated in the round-the-clock mode. The beam lifetime of Indus-2 at 2.5 GeV, 100 mA got improved from 5 hours to 16 hours. A feedback control system was installed to actively maintain the electron orbit of Indus-2 both in horizontal and vertical planes. Eight beamlines on Indus-2 are now operational.

A section of the Indus-2 experimental hall showing the beamlines fanning out at RRCAT

Beamline developed by SINP

The X-ray photo-electron spectroscopy, protein crystallography and visible diagnostic beamlines on Indus-2 were commissioned during the year. The scanning extended X-ray absorption fine structure and grazing incidence X-ray scattering beamlines were in advanced stages of commissioning. Existing beamlines were upgraded with facilities for carrying out experiments at low & high-temperature and high-pressure. The commissioned beamlines were used for a variety of research investigations.

The dispersive extended X-ray absorption fine structure (EXAFS) beamline on Indus-1 was upgraded with a low temperature facility.

SINP developed an Indian Beamline at Photon Factory Synchrotron, KEK, Japan. Fifteen research institutes of India used this beamline. This beamline is expected to be opened for international use on March 2013. SINP is also the nodal institute for Indian access to PETRA-III synchrotron at DESY, Germany.

## Fusion and Other Plasma Technologies

At the Institute of Plasma Research the experiments on Aditya tokamak continued to remain focused on breakdown and startup for generating necessary inputs for first plasma operation inSuperconducting Steadystate Tokamak (SST-1). In the refurbished SST-1 machine, engineering validations of various subsystems commenced. The assembled SST-1 Toroidal Field Magnet system was successfully charged to 1.1T after the system became superconducting. The diagnostics needed for the first plasma were integrated and tested for plasma operation. Ion Cyclotron RF (ICRF) systems based gas breakdown was achieved with low toroidal magnetic fields. The initiation of tokamak like plasma production was in progress.

The 42GHz Electron Cyclotron Resonance Heating system (ECRH) was commissioned to carry out ECRH assisted breakdown experiments in both SST-1 and Aditya tokamaks. Tungsten coating technology was developed for first wall components of tokamak with the collaboration of ARCI, Hyderabad.

High Power (200kW) Electron Beam System required for high heat flux facility was commissioned at the institute. A pump driven Lead-Lithium loop with indigenously developed components for corrosion experiment was successfully commissioned and set for operation in IPR.

Development of large cryogenic systems was undertaken. Remote handling (RH) and robotics technologies related activities were also initiated.

An accelerator based 14Mev neutron generator was developed for neutronics diagnostics and to study tritium breeding. Characterization of polycrystalline chemical vapor deposited (CVD) diamond detector was done. Experiments on tritium extraction studies on irradiated Lithium Titanate ($Li_2TiO_3$) powder were in progress. MCNP code analysis necessary for shielding design of the proposed laboratory was completed.

At Facilitation Center for Industrial Plasma Technology (FCIPT), IPR while completing and executing the committed projects, various new projects were also accepted.

## Chemistry

A procedure was developed at BARC to prepare stable composite beads containing $TiO_2$ by preparing cross linked chitosan-$TiO_2$ composite beads. These composite beads were prepared using locally available titanium oxide and natural polymer chitosan (derived from shrimp shells), making it highly cost effective.

A two dimensional infrared (2D-IR) spectrometer was developed around a 1 kHz amplified femto-second (fs) laser system. The infrared laser pulse used for the excitation of the sample was generated in two optical parametric amplifiers (OPA).

Several enantio-selective chemical and enzymatic asymmetric protocols were formulated and used for the syntheses of a diverse array of anti-cancer and immuno-modulatory compounds.

New protocols for D-labeling were developed and used for the synthesis of D-labeled tributyl phosphates and deuteriated-drugs. To explore new biocides for bio-fouling and microbial control, a wound dressing that works on the principle of release of nitrogen oxides from acidified sodium nitrite was developed.

A facility for femtosecond transient spectroscopy was setup at TIFR and studies of reaction mechanism in utrafast photoinduced ET was initiated along with work in carotenoid metabolism and molecular photocatalyst development. Studies on the mechanical properties of a ubiquitin-like protein SUMO2 were also completed.

The School of Chemical Sciences, NISER embarked on teaching and research activity in the traditional organic, inorganic, physical and theoretical chemistry areas as well as in the interface areas of Biology, Material Sciences and Medicine. It also imparted high quality undergraduate and postgraduate level of knowledge to students.

## Biology

At BARC, the activities were focused on basic and applied research aimed at understanding mechanisms underlying cellular responses to radiation, oxidative and other stresses in Deinococcus radiodurans, Anabaena, E. coli and rice at molecular and structural level using recombinant DNA techniques and TEM facilities.

Surface Plasmon Resonance and Atomic Force Microscope procured under XIth plan were installed and made functional.

Matrix-assisted Laser Desorption/Ionization-Time of Flight Mass Spectroscopy facility was used to identify about 400 proteins from cyanobacteria native to Indian soils to generate proteomic maps and understand their response to oxidative stress.

Gglycolytic enzyme Enolase, a novel drug target and vaccine candidate for Plasmodium species that cause malaria in humans and are increasingly becoming resistant to existing drugs was identified by TIFR. An Ecosystem ecology laboratory and Greenhouse facility was set up and genetic sequencing and genotype services were initiated with the addition of more NGS instruments.

SINP scientists took active initiative in structural genomics and proteomics research in hematological and neurodegenerative diseases. Gene therapy of chronic myeloid leukemia and structural elucidation of two important hemoglobin variants, implicated in thalassemia were done.

Understanding the biomolecular recognition process and the structure-function correlation in nucleic acids through bioinformatics based theoretical approach were the major activities in biophysics at SINP. Study of biophysical properties of lamins to understand their roles as intermediary filaments was also carried out. In chemical sciences, a new method for label free and rapid impedimetric sensing of Escherichia coli using antibody antigen bound on conducting polyaniline film was reported.

Interdisciplinary learning through extensive subjects covering all fields of modern biology and inter-phasing with other scientific disciplines and undertaking high quality research activities in defined areas of biosciences was the focus of the school of Biological Sciences at NISER.

## Materials Science

Molten Salt Natural Circulation test facility was setup in BARC. Effect of various orientations of heater and cooler can be studied in this experimental facility. As a part of indigeneous development of Scanning Electron Microscopy (SEM), fabrication of the filament support assembly was accomplished in BARC. A test facility to study the in situ corrosion in the molten salt environment was setup.

Test facility to study corrosion in molten Salt

Various types of glass based devices like ionization vacuum gauge (BA Type), glass-to-metal and ceramic-to-metal seals were produced. Several Fe and Co based amorphous and nanocrystalline metallic glasses were synthesized using rapid solidification technique.

An investigation on formation of aluminide coatings on Ni-based superalloy 690 substrate by low Al-containing pack aluminization process followed by its characterization have been undertaken.

A 400 kV accelerator which would transact helium and other gaseous ions to the UHV irradiation system of the 1.7 MV tandetron accelerator together forming a dual beam facility, was developed indigenously at IGCAR.

Studies conducted at TIFR included inducing metal-insulator transition in VO2 using an electrolyte gate, wide bandwidth actuation and detection of nanowire NEMS and incidence angle and polarization independent plasmon excitation and second harmonic generation in Plasmonic quasi-crystals. Highly oriented films of $TiO_2$ aligned nanorods were successfully grown directly on FTO. $ZnTiO_3$, a novel titanate was synthesised with phase purity and shown to be photocatalytic under visible light.

## Cancer Research

ACTREC provided public interface to cancer research through its focus on nationally relevant research on common cancers, outstanding clinical outcome in a large volume Bone Marrow Transplantation programme and by developing and disseminating indigenous technology such as Bhabhatron in collaboration with BARC.

The Clinical Research Centre programs continued to show an upward trend during 2012, particularly in terms of the patient services provided. Over 4400 new patients were referred to the Centre for investigation or treatment as a part of various IRB approved translational or clinical research projects. A Dental Clinic and Pediatric OPD were set up and made fully functional to meet patient requirements. A new Digital Subtraction Angiography (DSA) facility was donated to the Centre by a philanthropic organization.

The new investigations at the Cancer Research Institute included study of the structure, function and specificity of proapoptotic proteins and their role in cancer; examination of infra red absorption, Raman and fluorescence spectroscopy methods; development of imaging protocols for human cancer; early detection of molecular changes in ovarian cancer cells; use of

biophysical techniques, macromolecular crystallography, structural biology and bioinformatics tools to visualize cancer susceptibility genes and proteins; study of molecular and cellular mechanisms governing stem cell regulation and their perturbation during oncogenesis.

Assessment of the anti-metastatic activity of drugs and other complexes and a detailed study of the aberrant expression in cancer of the intermediate filament proteins keratin and vimentin made progress.

Quality initiatives undertaken during the year in order to improve patient care were: analysis of incident reporting with root cause analysis; patient feedback redressal with response from the respective areas with regard to patient suggestions and complaints; registering patients at ACTREC and implementation of referral card facility.

# INTERNATIONAL RESEARCH COLLABORATIONS

India is setting up the Global Centre for Nuclear Energy Partnership which will provide a forum for joint work with its international partners in development of proliferation resistant reactor technologies, nuclear security technologies, radiological safety and radiation technology application.

BARC is a major collaborator in the Compact Muon Solenoid (CMS) heavy ion experiment at Large Hadron Collider (LHC) at CERN.

Under DAE-JHR bilateral collaboration, conceptual design of sample carrier for high temperature irradiation in Jules Horowitz Reactor (JHR) was carried out at BARC. Advanced research was carried out on application of Physics-of-Failure methods to prognostics and health management of electronic components and R&D collaborative programme was under taken with Center for Advanced Life Cycle Engineering, University of Maryland, USA.

International Atomic Energy Agency awarded a project to BARC on 'Development of an IAEA Safety Series on Application of Probabilistic Assessment for Research Reactor'.

Under CEA–IGCAR cooperation on LMFBR safety, eleven collaborative projects were in progress. Based on design experience and feedback derived from construction experience of PFBR, IGCAR recommended revisions / new rules for the design and construction code RCC-MR (2010). AFCEN is discussing them with IGCAR on the recommendations.

Under Indian Institution Fermilab Collaboration (IIFC), RRCAT fabricated a 1.3 GHz 5-cell SCRF cavity and the pre-processing qualification tests for the cavity were carried out. A Prototype power extraction and transfer structure components (PETS bars) were fabricated in India and supplied to CERN.

1.3 GHz five-cell superconducting RF cavity

The participation of VECC scientists at LHC-CERN for the quest of Quark Gluon Plasma (QGP) had borne fruits in terms of analyzing huge amount of data collected from p+p and Pb+Pb collisions. The Photon Multiplicity Detector (PMD) built by VECC was a strong partner in data taking. Dedicated efforts on data analyses made progress.

VECC made significant contributions both in hardware and analysis in STAR experiment at BNL-USA. The first Multigap Resistive Plate Chamber (MRPC) module built at VECC was installed in the STAR experiment after detailed testing and a prototype MRPC-based TOF system was installed to demonstrate the proof-of-principle of using MRPC.

At TIFR, work on the upgrade of the silicon vertex detector (SVD) for the next phase of experiment called Belle II progressed.

SINP remained involved in experiments at the LHC at CERN. It is also involved in the ALICE experiment. During the year, the Large Hadron Collider provided large amount of data. The ALICE group in the institute constructed a part of the forward muon spectrometer which has been working satisfactorily during the entire period.

Joint projects of IMSc with other international institutes included Indo-Austrian (DST-BMWF) Joint Research Project on Parameterized Complexity of Local Search; CEFIPRA: Arithmetic circuits computing polynomials with University of Paris VI; Indo-German research grant of the Humboldt Foundation for research on the graph isomorphism problem; British Royal Society project on above guarantee kernelization with University of London.; LIA-Informel Project on Concurrency and Automata theory with University of Bordeaux and ENS-Cachan; INRIA - Indo-French-Singapore project on Logic, Games and Control theory.

### ITER-Project

The Institute for Plasma Research (IPR) is a major participant in the International Thermonuclear Experimental Reactor (ITER) Project coming up at Cadarache, France.

For ITER project, five more procurement arrangements (PAs) were signed. A total credit worth 4600 IUA was received from IO for the in-kind contribution and 266.835 IUA for the credited Task Agreements. The building for ITER-India laboratory at IPR was completed and being used for various R&D activities.

At Center for Plasma Physics (CPP), Guwahati, the divertor simulator experiment progressed well. Design of the magnets for the experiment along with the chamber was completed.

Towards development and fabrication of Nb3Sn based superconducting wire, a composite extrusion billet containing 1324 Niobium elements was assembled at BARC. Metallurgical characterisation of the product was carried out. An innovative space saving online fabrication facility was set up.

Reduced activation Ferritic-Martensitic steel for Test Blanket Module for ITER was developed at IGCAR by optimizing the content of tungsten and tantalum for achieving superior combination of ductile-to-brittle transition temperature and tensile and creep properties. Low cycle fatigue life of this steel was found to increase with increase in both tungsten and tantalum contents.

## OTHER ACTIVITIES

### Research Education Linkages

DAE supports synergetic interaction amongst the national laboratories and the university systems mainly through grants-in-aid to institutes of national eminence, funding of extra-mural research, DAE-UGC Consortium for Scientific Research and others. During the report period, the major activities relating to Research Education Linkages included the following.

As a part of collaborative project with Jadavpur University, Kolkata, fracture tests were conducted by BARC towards investigation on Master Curve an important input for integrity assessment of RPV under PTS.

1 Cryo-chamber 2 Controller 3 Operator panel
4 Support computer 5 Liquid nitrogen cylinder
6 Temperature indicator.

**Experimental Setup for Generating Master Curve**

Dhruva continued to be the only facility for radioisotope production and served as a national facility for neutron beam research. A number of research scholars from various academic institutions in the country utilized the reactor under the aegis of the UGC-DAE Consortium for Scientific Research.

Collaborative research and development work was done by RRCAT with National Bureau of Plant Genetic Resources, New Delhi, to issue Import Permits and Phyto-sanitary Certificates for radiation processed food in our country.

The India-based Neutrino Observatory (INO) prototype laboratory worked continuously over last one year at VECC. Students from all over the country take part in data taking and data analysis.

# HUMAN RESOURCE DEVELOPMENT AND KNOWLEDGE MANAGEMENT

## Homi Bhabha National Institute

Homi Bhabha National Institute (HBNI) continued to grow smoothly and steadily. HBNI strengthened its linkages with premier research and academic institutes in the country and abroad. Two MoUs – one with Indian Institute of Science, Bangalore and the other with University of North Texas, Denton US were signed during the year in this direction. MoUs with Indian Institute of Technology, Bombay and the Institute of Chemical Technology, Mumbai were renewed. A general agreement for academic co-operation and exchange with Institute of fusion studies and Department of Physics at the University of Texas at Austin was also signed during the year.

## Training

BARC continued the academic programme of Orientation Course for Engineering Graduates & Science Post-Graduates (OCESS-2011) and conducted written tests.

Advanced courses from electrical sciences group were offered to the eligible employees under 'QUEST-Continuing Education Programme' scheme and six advanced courses were held under QUEST-3 and QUEST-4.

The Radiation Medicine Centre (RMC) of BARC regularly conducted two year diploma course namely DRM for medical graduates under Homi Bhabha National Institute. These training courses were very useful in the propagation of Nuclear Medicine throughout the country. The

course included lectures, practicals, apprentice programmes, demonstrations, scan review and reading sessions and dissertations on short projects. RMC also conducts one-year diploma course under HBNI for science graduates.

BARC Training School AMD Campus, Hyderabad continued its activity in second year for Geology (12) and Geophysics (9) Trainee Scientific Officers (TSO). AMD studentship programme was continued and 125 M.Sc./M.Tech. students of different Universities completed their project. BRNS projects (43 nos.) were continued in collaboration with various University/ Academic Institutions as R & D efforts of AMD.

In NPCIL the human resource initiatives were directed towards fulfilling the NPCIL's mission and vision by attracting, motivating and retaining right talent. These measures included developing strategic and incremental packages from time to time for effective Human Resource Management and also to meet the aspirations of the employees. During the year, 5056 man-days of training were imparted. Training and Development activities covered competency development for fresh as well as experienced manpower across hierarchy. Well developed internal training programs, customized management development programs with the involvement of professional training institutes and experts were also organized for higher levels.

The Institute of Physics contributed in a significant way towards quality human resource development in the form of a one year pre-doctoral course followed by a Ph.D. program. The Institute actively promoted interactions with colleges, universities, academic institutions and laboratories by means of visitor programs, workshops, symposia and other academic events.

Tata Memorial Hospital (TMH) registered students for various postgraduate medical courses. A two years short term Advance diploma in Radio Imaging Technology is started. Training programmes were conducted for Doctors, Nurses and Technicians on continuing basis. Short term observership and summer training was provided to more than 500 Doctors, Nurses, Technicians and graduate and postgraduate science students.

NISER continued with its education and research programmes in the fields of mathematics, physical, chemical and biological sciences.

Students selected by IMSc undergo two years of rigorous course-work, and after successful completion they join doctoral thesis work. Several students visited the institute for a semester working on short-time research projects. IMSc is involved in joint projects with many national and international institutes. It conducted several national and international conferences, workshops and instructional schools on regular basis. During the year, more than 15 such events were organised.

Administrative Training Institute continued professional development of officials for various programmes catering to wide spectrum. During the year, 96 programmes were organised. About 380 programmes covering over 11000 employees have been organized till now by ATI and a growth of about 175% was achieved.

In order to align with the National Training Policy, strategies such as “Training for All” and “Training at Doorstep” were used and training programmes were arranged in many languages at different localities like Shillong, Manuguru, Kalpakkam, Hyderabad, Baroda, etc.

As part of employee welfare a two day workshop on "Emotional Intelligence” and a one

day workshop on "Security Awareness" were organised for the family members of employees.

# SPONSORED RESEARCH

## Promotion of Extra-mural Research in Nuclear Science

The Board of Research in Nuclear Sciences (BRNS) an advisory body of the Department of Atomic Energy provides financial assistance to universities, academic institutions and national laboratories for encouraging and promoting scientific research in areas of relevance to the mandate of DAE. . It also plays a proactive role in tapping some of the highly talented young scientists and technologists by offering K.S. Krishnan Research Associateship (KSKRA). DAE Graduate Fellowship Scheme (DGFS) of BRNS identifies and encourages graduate level students doing M.Tech. at IITs and NITs to initiate them in a career to pursue scientific research. Selected young scientists are awarded fellowship under DGFS to work on research projects in any one of the DAE units, simultaneously pursuing Ph.D. degree through HBNI. Raja Ramanna Fellowship and Homi Bhabha Chair is also funded through BRNS. In addition BRNS provides partial support to DAE - Mumbai University Centre for Excellence in Basic Sciences and Homi-Bhabha Centre Science Education.

During the financial year till January 2012, about 300 new research projects were sanctioned. In addition, three new CRPs (Co-ordinated Research Projects) were sanctioned for coherent collaborative research work with various academic institutes. During the year, fourteen new DAE-SRC fellowships and five ongoing prospective research fellowships (PRF) were granted. Twenty KSKRA fellows were selected, 9 M.Tech. and 36 Ph.D students were offered fellowships under DAE Graduate Fellowship Scheme (DGFS). Thirty-eight fellowships were awarded under the Raja Ramanna Fellowship Scheme (Senior Scientists Scheme) and Homi Bhabha Chair. Financial support of about 4 Crores was extended for funding 148 seminars.

## Promotion of Mathematics

The National Board for Higher Mathematics (NBHM) has been established for promoting excellence in higher mathematics education and research in the country.

The year long period from December 22, 2011 - December 22 2012 was celebrated as National Mathematics Year to mark the 125th birth anniversary year of Ramnujan. Eminent Mathematians across the globe delivered "Panorama Lectures" in various institutes of the country.

NBHM with the help of HBCSE conducted Mathematics Olympiad activity for talented young students at higher secondary (the plus two) level. The Indian team consisting of six-member, secured 2 Gold medals, 3 Silver medals and a Honorable mention at the 53rd International Mathematical Olympiad held at Sao Paulo, Argentina. Suitable infrastructure, in the form of human resources was under process for conducting Madhava Mathematical Competition for the undergraduate students.

During the year, NBHM supported 24 mathematicians to attend International Congress of Mathematics Education held at Seoul, South Korea to acquire latest Information in the field of Mathematics Education.

NBHM provided grants to various mathematical centers for promoting higher mathematics; promoting activities in pure and applied mathematics, under several schemes,

including support to research projects, travel grants for participation in workshops, conferences, and undertaking collaborative research, funds for organizing conferences etc. and grants to mathematics libraries around the country. It also distributed selected books to various postgraduate institutions under its book distribution scheme.

Financial support to 65 national and international conferences; 17 Instructional Schools and 31 research projects were provided during the year. Travel grants to 59 mathematicians to participate in conferences were also provided. Post Doctor Fellowships were awarded to 36 (including the ongoing ones) researchers.

# GRANTS-IN-AID

## Grants to Aided Institutions

The aided institutions of the Department of Atomic Energy are an integral part of the Department. There is frequent interaction between the academicians of the aided Institutions and the Scientists of the R&D Units. Several joint projects were undertaken between the Units and Aided Institutions. These institutions are growing at a faster pace in terms of the projects undertaken by them.

The Department has nine aided institutions fully funded in terms of their recurring and non-recurring expenditure. The funds (Plan & Non-Plan) allocated to these Aided Institutions by the Department of Atomic Energy during the financial year 2012-13 were: Tata Institute of Fundamental Research (TIFR), Mumbai (403.68 crores); Tata Memorial Centre (TMC), Mumbai (248.14 cr.); Saha Institute of Nuclear Physics (SINP), Kolkata (153.50 cr.); Institute of Physics (IOP), Bhubaneswar (21.70 cr.); Institute of Mathematical Sciences (IMS), Chennai (31.41 cr.); Harish-Chandra Research Institute (HCRI), Allahabad (37.21 cr.); Institute for Plasma Research (IPR), Gandhinagar (661.22 cr.); Atomic Energy Education Society (AEES), Mumbai (83.92 cr.); National Institute of Science Education and Research (NISER), Bhubaneswar (220 cr.)

### Grants to Cancer Hospitals

The Department of Atomic Energy (DAE) is releasing grant to Dr. B. Barooah Cancer Institute (BBCI), Guwahati through Third Tripartite Agreement [which was signed between DAE and the North-Eastern Council (NEC) and the Government of Assam]. This hospital is a Regional Cancer Centre (RCC) for cancer treatment and control in the North-Eastern Region (NER). The Department's total share as per the Tripartite agreement upto the year 2012-13 is approximately Rs.2449.35 lakh for revitalization of the BBCI which includes the cost of construction for expansion of the hospital as well as the procurement of major radiation related equipment during its Revitalization Project-III which has been started during the year 2004 – 05. Department is also proposed to set up a Cancer Hospital at Punjab.

The Department also extended financial assistance to Cancer hospitals located in other parts of the country. The budget provision for the year 2012-13 for such partial financial assistance is to the tune of Rs.165.70 crore.

An increasing need was felt to use the expertise available in the DAE funded Tata Memorial Hospital for creating a better network between cancer institutions all over the country. An Apex Committee was formed under the Chairpersonship of Director, TMC, for this purpose. The Apex Committee met on several times and deliberated on indigenous development and manufacturing of the

equipment related to radiation oncology such as Cobalt 60 Teletherapy, Low Energy Linear Accelerator, High Energy Linear Accelerator, simulator development, Brachytherapy.

The initiatives taken to achieve the above stated objectives will lead to further gains in the DAE's outreach in the cancer care programme.

### Olympiad Programme

DAE provides financial support for organizing Olympiad programmes and for participation in International Olympiads in Physics, Chemistry, Biology, Mathematics, Astronomy & Astrophysics, and Junior Science Olympiad.

The Indian Science Olympiad Programme supported by DAE, Department of Science and Technology and Ministry of Human Resources Development continued to bag laurels for the country.

In the International Olympiads, 32 medals were won including 12 gold, 18 silver, and 2 bronze medals besides one honorary mention. Over 20 new experiments in the Olympiads project were developed. Several resource generation camps and exposure camps were held for school and college teachers. Academic preparations are being made for the International Junior Science Olympiads in 2013 to be hosted by India.

## TECHNOLOGY TRANSFER

During the year BARC transferred about fifteen technologies to 28 private entrepreneurs this included Nisarguna, Online domestic water purifier, Membrane assisted defluoridation process for safe drinking water, Preparation of composite polyamide reverse osmosis membrane for BWRO desalination technology, UF membrane assisted device for removal of iron from contaminated water for drinking purposes, Kvp meter, Dip N Drink, Glass to metal seals technology, Lascan Dia Gauge, Production of Dy Doped $CaSO_4$ TLD Phosphor Powder, Process for retaining pericarp colour and extending shelf life of litchi, Fresh Water Generator, Micro-propagation of Banana, Production of $CaSO_4$ : Dy Embedded Teflon Discs and TLD Cards and arsenic removal from drinking water-ultrafiltration membrane assisted process.

BARC recently completed the technology transfer for Ni-Ti-Fe shape memory alloy heat shrinkable sleeves for LCA -TEJAS to the Foundry and Forge Division of Hindustan Aeronautics Limited, Bangaluru. Thirteen technology licenses were renewed. Two patents were granted and one patent application was filed. BARC Technology Incubation Cells were ready for operation and handed over to respective divisions. Expression of interests was invited from industries for incubation of various technologies.

Facilitation Centre for Industrial Plasma Technology (FCIPT) at Institute for Plasma Research executed several projects and also signed new projects with various organisations, autonomous bodies and private sector companies.

## COLLABORATIVE PROGRAMMES

At BARC, four pieces of prototype fuel tube made of high-density carbon-carbon composite was prepared in collaboration with National Physical Laboratory (NPL), New Delhi. Under a MoU with IOCL, BARC developed Pipeline Inspection Gauges (PIGs) for pipelines of several sizes ranging from 12" to 24". The BARC developed Environmental Radiation

Monitor (ERM) system was integrated with the Automatic Weather System (AWS) developed by ISRO, under a BARC-ISRO, MoU. Under a tripartite MoU between BARC, HESCO and BRNS, an isotope hydrology laboratory was been set-up at HESCO, Dehradun to train the local people as in-house facility for spring recharge related studies carried out at BARC.

BRIT signed a MoU with M/s Isorad Tech Pvt Ltd, Chennai, M/s Divyakiran Agro Processing Pvt. Ltd, Anand, Gujarat and M/s Radura Irradiators, Nashik, Maharashtra for setting up of Radiation Processing plant.

At IMSc, the collaborative research programmes included, CERPRA: Arithmetic circuits computing polynomials with University of Paris and an Indo-German research grant of the Humboldt Foundation for research on the graph isomorphism problem.

## SOCIETAL INITIATIVES

DAE has launched `DAE Societal Initiative' for utilization of non-power applications (NPAs) and spin-off technologies (Spin-offs) in the areas of water, land, agriculture, food processing and urban-rural waste management. Within this frame work, a structured programme called 'AKRUTI-KRUTIK-FORCE' was formulated and is being implemented by BARC for techno-economic growth of the rural sector, as one of the many schemes for large scale deployment of NPAs and Spin-offs. During the report period under DAE social initiative programme, AKRUTI Tech pack was transferred to 8 parties by BARC.

## INTELLECTUAL PROPERTY RIGHTS

DAE-IPR Cell works as a nodal agency for all Intellectual Property Rights (IPR) related matters including filing of patents within India and abroad for all the units including public sector undertakings and autonomous institutions under DAE. During the calendar year 2012, four regular DAE-IPR cell meetings were held during which 13 new inventions and 2 of the previously filed applications under Patents Cooperation Treaty (PCT) applications were reviewed for the patentability and national phase entry respectively. DAE filed 21 new patent applications of which 9 were in India, 4 in USA, 3 in European Union, 2 in Japan, one each in China and Canada and one under PCT. Eight of the previously filed patents were granted to the Department of which seven were in foreign countries.

During the year, 60 patent applications were referred to the Department by the Controller General of Patent, Intellectual Property (IP) India, to screen for the applicability of section 20 (1) of Atomic Energy Act, 1962, i.e., whether the application is related to or useful for atomic energy, and give its opinion. Directions of the Department were communicated to the Controller of Patents in India.

A Technology Information, Forecasting and Assessment Council (TIFAC)-BARC training program on IPR and WTO issues was conducted through DAE's Administrative Training Institute (ATI). Lecture on IPR and its relevance to DAE was also delivered at the Administrative colloquium of BARC.

## PUBLIC SECTOR UNDERTAKINGS

### (Financial Performance)

Financial performance of DAE's public sector undertakings namely, the Nuclear Power Corporation of India Ltd., Uranium Corporation of India Ltd., Indian Rare Earth Ltd. and Electronics

Corporation of India Ltd. are given below. (BHAVINI is yet to commence commercial operations)

### Nuclear Power Corporation of India Ltd.

The provisional net profit after tax (PAT) for the year 2012-13 was Rs. 1525 crore (up to December 31, 2012) The net profit after tax for previous FY 2011-12 was Rs. 1906 crore.. The NPCIL bonds continued to be rated at AAA (Highest Safety) by CRISIL and CARE.

### Uranium Corporation of India Ltd.

The overall performance of the Company in terms of MoU signed with DAE was rated as "Very Good" for the year 2011-12. The total income of the Company during the year 2011-12 was Rs.707.29 crore as against Rs.760.26 crore in the previous year. The profit before tax during the year 2011-12 was Rs.86.27 crore.

### Indian Rare Earths Ltd.

For the financial year 2011-12, the Sales Turnover (net off excise duty) was Rs. 622.40 crore and Profit Before Tax was Rs.249.84 crore. As against this, for the financial year 2010-11 the Sales Turnover and PBT were Rs. 368.50 crore and Rs. 52.44 crore respectively. During the year 2011-12 IREL had earned foreign exchange of Rs. 200.78 crore which is 115% more than the previous year. The Company paid Rs.34.50 crore as dividend for the financial year 2011-12 which amounts to 20% of profit after tax of the current year. IREL is expecting a total turnover of Rs. 638.00 crores for the year 2012-13.

### Electronics Corporation of India Ltd.

During the financial year 2012-13, against an MoU target of Rs.1600 crore each of production and net sales, ECIL achieved a production of Rs 984 crore and a net sales of Rs.927 crore upto November 2012 as compared to Rs.691 crore and Rs.562 crore respectively for the corresponding period during 2011-12. The company has sufficient orders on hand and is confident of meeting the targets set for the year.

## INTERNATIONAL RELATIONS

India continued to contribute to policy management and programmes of the International Atomic Energy Agency (IAEA).

The Atomic Energy Regulatory Board signed a MoU with the National Commission for Nuclear Activities Control of Romania for the exchange of information and cooperation in the field of regulation of nuclear activities for peaceful purposes. AERB also signed an agreement with the State Nuclear Regulatory Inspectorate of Ukraine for exchange of technical information and cooperation on nuclear safety and radiation protection.

India offered its expert services in a number of fields under the IAEA Technical Cooperation Scheme and hosted several IAEA workshops, technical meetings etc. India made extra budgetary contributions of USD 1 million to the IAEA Nuclear Security Fund and USD 50,000 to the Innovative Nuclear Reactors and Fuel Cycles (INPRO) of IAEA.

Units 3&4 of Rajasthan Atomic Power Stations were reviewed by the Operational Safety Review Team of IAEA during their first-ever mission to India. The Atomic Energy (Radiation Processing of Food and Allied Products) Rules, 2012 were notified on 30th June 2012.

India continued to participate in collaborative work in the European Organisation for Nuclear Research (CERN) and the International Thermo-nuclear Experimental Reactor (ITER) project. In April 2012, AERB joined the Multinational Design Evaluation Programme as a full member.

## CRISIS MANAGEMENT

The Crisis Management Group (CMG) coordinates the Department's response to any radiation emergency in the public domain.

With multiple safety systems and due to inherent design features, the possibility of any accident in a nuclear facility or during transport which might lead to a radiation emergency in the public domain is highly remote. However, to handle any unforeseen situation, formal emergency response systems were in place and were tested regularly to ensure that there would be no radiation hazard to the public. All these activities are overseen by an independent regulatory authority, which ensures that all radiological safety issues are adequately addressed. Further, in case such an unlikely event does occur and leads to a radiation emergency in the public domain, a response system is in place to tackle such situations by mobilizing the expertise in the Department of Atomic Energy.

The CMG also provides its expertise in various forums in the field of disaster management at both national and international levels.

The Crisis Management Group during its meetings, reviews the crisis management plans at different facilities, discusses on issues related to radiological incidence, if any, in the country and provides necessary guidance on matters related to radiological safety in the public domain to avoid the recurrence of such incidence.

At DAE, two emergency communications rooms having multiple modes of communication are manned on a round-the-clock basis throughout the year and it is in constant contact with various nuclear facilities in the country as well as with the International Atomic Energy Agency (IAEA).

The Emergency Response System of DAE is also available to respond to any request from public official in the event of the reported presence or suspected presence of radioactive material.

To ensure that the emergency plans are in high state of readiness, major nuclear facilities like nuclear power stations and hydrogen sulphide based heavy water plants periodically carry out a variety of emergency exercises. The numbers of exercises carried out during the year 2012 were: Communication Exercises-395; Fire Emergency Exercises-60; Plant Emergency Exercises-47; On-Site Emergency Exercises-9 and Off-Site Emergency Exercises-3 nos.

The Off-Site Emergency Exercises were carried out in the public domain in the vicinity of Heavy Water Plant, Kota, Kudankulam Nuclear Power Plant at Kudankulam and at Heavy Water Plant, Manuguru. In addition to these exercises, the National Disaster Management Authority (NDMA) had arranged special training workshops on 'Disaster Risk Reduction' at several Nuclear Power Plant sites.

The Emergency Response System of DAE effectively communicated the message of international tsunami alert received on 11 April, 2012 at 1400 IST, with the 8.7 magnitude earthquake hitting the west coast of northern Sumatra to all our Nuclear Power Plants which enabled them to promptly take the necessary measures.

## BARC-SAFETY COUNCIL

BARC-Safety Council continued its regulatory function to ensure the safety of all the plants and facilities under its purview.

To comply with the requirement of licensing/authorization for operation of the variety of radiation installations in BARC, the BARC-Safety Council Secretariat had earlier prepared Regulatory Guidelines, which specify the requirements to be fulfilled for reauthorization of existing old facilities of BARC. It addresses the requirements for new radiation installations in BARC.

## SCIENCE RESEARCH COUNCIL

DAE-Science Research Council that comprises eminent scientists, continued with the peer reviews of basic research to ensure that highest possible level of excellence is maintained.

## NATIONAL SECURITY

BARC continued implementation of the necessary research and development as well as manufacturing activities required for national security.

## VIGILANCE

The overall responsibility of vigilance activities rests with the Chief Vigilance Officer (CVO) of the Department of Atomic Energy. To facilitate proper functioning of the vigilance machinery and to establish effective co-ordination amongst the organizations, a senior officer in each Unit was designated as Vigilance Officer for vigilance functions. In the Public Sector Undertakings of DAE, full time CVOs were available to co-ordinate the vigilance activities.

Vigilance functions of the Department included timely transmission of various vigilance returns to the Central Bureau of Investigation (CBI), Department of Personnel and Training (DoPT), Central Vigilance Commission (CVC), issuance of prosecution sanctions, processing of vigilance & disciplinary cases, monitoring of the progress of inquiry proceedings, investigation of complaints and others. DAE prepared a compendium of CVC guidelines on tendering process and circulated it to all its units.

As per directives of CVC, Vigilance Awareness Week was observed in the DAE and its constituent units, from 29th October to 3rd November 2012.

## SCIENTIFIC INFORMATION RESOURCE MANAGEMENT

The Scientific Information Resource Division at BARC continued to provide seamless access to information to all the DAE scientists and engineers. During the year, BARC Newsletter, Scientific Information Resource Bulletin, Pulse and several internal and external reports were brought out. A comprehensive brochure covering all R&D activities of BARC was also brought out.

At IGCAR, a state-of-the-art live streaming facility of the events from the auditorium was implemented and made available across the user's desktops. Based on the research needs of the centre, the e-collections were augmented. The library was equipped with CCTV base surveillance systems

# PUBLIC AWARENESS

The Department of Atomic Energy (DAE) continued to promote the awareness about peaceful uses of atomic energy in the correct perspective with prime focus on benefits to the society in the areas of power production, applications of radiation technologies, healthcare, food & agriculture, industry, water, environment, advanced technologies etc.

Dr. R K Sinha, Chairman, Atomic Energy Commission, at the DAE pavilion during the 100th Indian Science Congress at Kolkata

To alleviate unwarranted fears, misconceptions and address apprehensions harboured against nuclear energy, DAE on a mission mode organised and participated in various exhibitions, seminars, events, workshops, conducted essay and quiz contests in different regions of the country by means of a neoteric state-of-the-art multimedia display system, video films, presentations which were well received by the students, faculties, scientists, government officials, policy makers, ex-servicemen, farmers, emerging entrepreneurs, leaders from Industry, NGOs, media professionals, general public and other visitors. Several public awareness lectures on atomic energy were also delivered.

Dr. Anil Kakodkar, Former Chairman Atomic Energy Commission at the DAE pavilion during the 6th Science Expo at Nehru Science Centre, Mumbai

The 24th All India Essay Contest on Nuclear Science & Technology was organised by DAE in October 2012 as a part of Founder's Day Celebrations.

Participants of the 24th DAE All India Essay Contest with the Officials of the Public Awareness Division, DAE

During the year, NPCIL carried out a gamut of public outreach activities conveying the facts on nuclear power in a simple transparent and credible manner. Following the Fukushima accident, the outreach activities were scaled manifold in a structured manner adopting a multi-pronged approach to allay the apprehensions about nuclear power and its safety. An action plan was implemented with clear set of objectives and timelines including a review and monitoring mechanism.

The public outreach programme of NPCIL comprised of regular visits by the senior officials to surrounding areas and enhanced interaction with locals, visits of villagers, students, media persons and other members of public to nuclear power plants and organizing awareness campaigns on nuclear power for various target groups.

Use of TV commercials, advertisements, digital cinema, radio jingles, single-sheet print publications, innovative comic books and animated films, etc. in vernacular languages, enhanced interaction with press and media, e-public awareness campaigns, rallies in support of nuclear power are a few, among many, modules that were adopted to supplement the scaled up outreach activities.

BARC provided media coverage to various events that were organized in the research centre. During the year, more than 30 public awareness programmes were conducted. As a part of this programme, students from various colleges in and around Mumbai and from other states visited BARC and interacted with the scientists. "Nuclear Waste Management" exhibition was organized during the National Technology Day to provide a platform for better interaction amongst scientists and engineers. A week long programme on the theme 'Clean Energy Options and Nuclear' along with the National Science Day celebrations was organised. BARC Logo and an enhanced BARC website were launched.

School children attending a Media Awareness Programme at BARC

The Atomic Minerals Directorate continued Public awareness programme in a big way in various cities as well as in remote field areas.

## SOCIAL WELFARE

### Corporate Social Responsibility

NPCIL continued its Corporate Social Responsibility and implemented 32 projects in education, 17 projects in healthcare and 67 projects in infrastructure development during the year 2011-12. For the year 2012-13 about 250 CSR projects were planned by NPCIL and Rs. 55 crores was allocated for CSR programme. An additional Rs. 125 crore was also allocated as additional CSR fund in the Silver Jubilee year of the Corporation to be used in next two years.

## AWARDS & PRIZES

Shri K. Balaramamoorthy, former Chief Executive, Nuclear Fuel Complex, Hyderabad; Prof. R. Balasubramanian, Director, Institute of Mathematical Sciences, Chennai; Dr. Ravi Bhushan Grover, Principal Adviser, Department of Atomic Energy, Mumbai and Dr. Satinder Kumar Sikka, Homi Bhabha Chair Professor, BARC, Mumbai were conferred with the DAE's Lifetime Achievement Award for the year 2011 by Dr. Manmohan Singh, The Prime Minister of India.

BARC bagged the "Best Establishment Award for the 89th Regional Skill Competition for Apprentices held in September 2012 for western region.

AMD officers were awarded DAEs medals and Hindi Sevi Samman during 2011-12.

NPCIL units received several awards during the year for performance in safety, environment protection and other areas. TAPS-1&2, TAPS-3&4, RAPS 1&2, RAPS-3&4, MAPS, APS 1&2 and KGS-1&2 bagged National Safety Council of India's various Safety Awards for the year 2011. AERB's Safety awards for the year 2011 for industrial safety, environment protection and fire safety were bagged by RAPP 7&8, KAPP 3&4 and KGS 3&4 respectively. NPCIL achieved excellent MoU rating for the year 2011-12.

The awards received by the Professors of Institute of Mathematical Sciences during the year were as follows: Prof. Ronojoy Adhikari received Google Research Award by Google Incorporation, USA on January 2011, Dr. Sanoli Gun won ICTP Associate Award for the year 2011 and Dr. Saket Saurabh was awarded with the Award of European Research Council.

Prof. Ashoke Sen of HRI was conferred with the prestigious "The Fundamental Physics Prize - 2012" by Milrer foundation Established by Yuri Milrer for his contribution to string theory which helped to show that multiple string theories are all different versions of a single underlying theory.

Heavy Water Plant, Manuguru won "Golden Peacock Environment Management Award-2012" in recognition of sustainable and effective Environment Management system. HWP, Hazira was selected for National Safety Award for the year 2010 from Directorate General Factory Advice Services and Labour Institutes, Faridabad, Ministry of Labour & Employment. Plant also received "Certificate of Appreciation-2010" awarded by Gujarat Safety Council, Vadodara and Directorate of Industrial Safety & Health.

"Miniratna Category–I" status was granted to IREL on 11th October, 2011. OSCOM Unit received the 1st prize in the safety & training during the Odisha metalleferious mines safety week 2011-12. During the Mine Safety week organized by the Kerala Mine Safety Association, Chavara unit received three 1st prizes and five 2nd prizes.

Two quality circle teams from GSO viz. EDISON and SAKTHI participated in the Regional Level meet at Hosur during the year and were awarded the gold and silver cup respectively. Two teams – PLEISTOCENE and SUSHRUTHA were nominated for the National meet.

The Prime Minister, Dr. Manmohan Singh & Dr. R.K. Sinha, Chairman, Atomic Energy Commission with the recipients of DAE's Lifetime Achievement Award 2011 along with their family members in New Delhi on January 15, 2013.

# CHAPTER -1

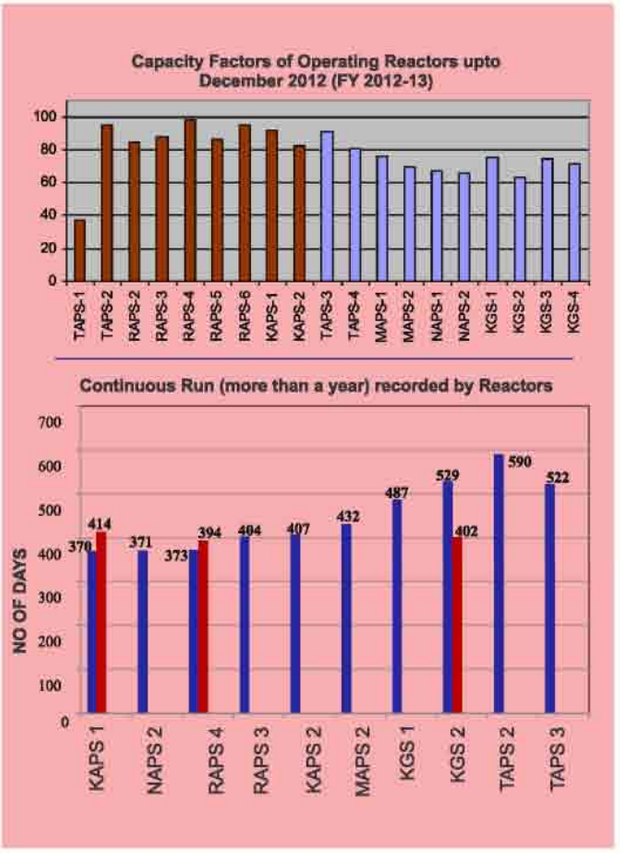
# NUCLEAR POWER PROGRAMME STAGE-I

Kudankulam Nuclear Power Project-1&2

View of Main Plant construction area of Atomic Power Project-3&4

# PRESSURISED HEAVY WATER REACTORS (PHWRs) & LIGHT WATER REACTORS (LWRs)

Nuclear Power Corporation of India Ltd. (NPCIL), a public sector undertaking of DAE and a dividend paying company with AAA credit rating by CRISIL and CARE, is responsible for design, construction, commissioning and operation of nuclear power reactors. At present, it operates 20 nuclear power reactors with an installed capacity of 4780 MWe (megawatt electrical) and additional 4800 MWe capacity under construction that comprises two light water reactors of 1000 MWe each in advance stage of commissioning at Kudankulam in Tamil Nadu and four Pressurised Heavy Water Reactor of 700 MWe each, two at Kakrapar in Gujarat and two at Rawatbhata in Rajasthan.




## Operating Reactors

The electricity generation in the calendar year 2012 was the highest ever at 33174 MUs, registering about 2% increase over the last calendar year 2011 generation (32405 MUs). In the current financial year 2012-13, the generation clocked, till December 31, 2012 was 24664 MUs.

The nuclear power reactors, under IAEA safeguards and using imported fuel, recorded a Capacity Factor (C.F.) of about 86% till December 2012. In view of improved domestic uranium supplies, the reactors fuelled with domestic fuel registered a C.F. of about 76%, higher than previous year at 67%. The overall C.F. up to December 2012 was about 80% which is 2% higher compared the previous year's C.F. of 78%.

The overall availability factor recorded in the current financial year 2012-13 up to December 2012 was 91%. TAPS-3 achieved continuous operation of 522 days during the year 2012. Ten reactors registered continuous operation of more than a year of which three reactors registered this twice.

## Ongoing and New Projects

At present, NPCIL has three ongoing projects, KKNPP (2x1000MW LWRs), KAPP-3&4 (2X700 MW PHWRs), RAPP-3&4 (2X700 MW PHWRs) comprising of six reactors at various stages of construction and two new projects to be

launched. Also there are additional seven new sites and one extension site at an existing station.

## Projects under Construction

**Kudankulam Nuclear Power Project-1&2 (KKNPP-1&2, 2x1000 MW LWRs)**

Located in Tirunelveli District of Tamil Nadu, the Kudankulam project, is being implemented with technical co-operation of Russian Federation. The power generated from the project (2x1000 MW) shall be fed to Tamil Nadu and other beneficiary states in the southern grid.

The work at Kudankulam Site was affected during Oct 2011 to March, 2012 due to local protest / agitation.

Unit-1 was in advance stage of commissioning. The Initial Fuel Loading (IFL) was completed. All the pre-operational tests which includes the functional test of individual equipment / system, Integrated Leak Rate Test (ILRT) of reactor building containment, circular flushing & hydro test of primary circuit, hot run of the Nuclear Steam Supply System (NSSS) and

Multi Stud Tensioner (MST) for RPV sealing at Kudankulam Nuclear Power Project-1

inspection of main equipments, were successfully completed. The unit is expected to achieve criticality by the end of the financial year.

Unit-2 works followed Unit-1 with a gap of 7-8 months. Construction and equipment erection works were completed. Mechanical piping erection works were nearing completion. Electrical and Instrumentation cabling works are in advanced stage of completion. Commissioning works of systems and equipments are in progress.

**Atomic Power Project-3&4 (2x700 MW PHWRs)**

Construction of first pair of indigenously designed 700 MW PHWRs, Atomic Power Project Unit-3&4 (KAPP-3&4, 2x700 MW PHWRs), commenced with First Pour of Concrete (FPC) on November 2010. The main plant civil works were in full swing and around 3.5 lakhs Cu.M. (i.e. 71% of total estimated quantity) concrete were poured till end of December 2012. Construction of fuelling machine service area, slabs at El 100 M and El 104.5 M of Reactor Building were completed in the current financial year after completion of raft of nuclear building-3, construction of calandria vault and fuelling machine vault was nearing completion.

The inner containment wall which acts as one of the barrier against release of radioactivity was constructed with embedded steel liner for the first time in Indian PHWR. Inner containment wall construction in reactor building-3 was completed up to El 106.5 M and similar works for reactor building-4 progressed. Construction of other buildings also made progress. Turbine building-3 raft and turbine generator mat for both the unit was completed and the construction work above raft progressed well. Civil works for 220 kV switchyard were completed and subsequent activities of tower structure work and equipment erection were planned. All Major EPC packages

contractor's site mobilization was completed. Nuclear piping, common services piping and electrical works commenced.

Major equipments delivered to site include calandria tubes, CS pipes and fittings for common services and plant water pump house package, D2O tanks, MAL, AAL frames, etc. Manufacturing of critical equipment like end-shields, calandria, steam generators, etc. were in progress. Both the units are expected to be completed by the year 2016-17.

**Rajasthan Atomic Power Project-7&8 (2x700 MW PHWRs)**

To complete raft of Nuclear Building-7 & 8, the civil works at Rajasthan Atomic Power Project Unit-7&8 were accelerated. Purchase orders for all major packages/equipment were placed. Delivery of equipment to site includes calandria tubes, end fittings, CS pipes and fittings for common services, etc. Manufacturing of critical equipment like end-shields, calandria, steam generators, etc. were in progress. Both the units are expected to be completed by the year 2016-17.

View of the Rajasthan Atomic Power Project-7&8

## New Projects

**Kudankulam nuclear Power Project-3&4 (2x1000 MW LWRs)**

Located in Tirunelveli district,Tamil Nadu, the Kudankulam Unit-3&4 are an expansion of Units-1&2, that are planned to be implemented in technical cooperation with Russian Federation in accordance to Inter Governmental Agreement (IGA).

The project has already been accorded environment clearance, Coastal Regulation Zone (CRZ) by MOEF and siting clearance by AERB. Clearance from Tamil Nadu Pollution Control Board was under process. Application for excavation consent was under review of AERB. First priority design activities achieved 73% progress.

Site grading and levelling, Phase-1 infrastructure works for plant site and township property fencing, security fencing, development of master plan for township and plant site were completed. Re-tendering for main plant pit excavation, consolidation grouting and confirmatory soil investigation was in progress. Engineering service contract for design of Balance of Plant (BOP) was completed during the year 2012. Tendering of Phase-II Plant site infrastructure like roads, main guard house, construction power supply, access control system, etc, were under progress. Township expansion also made progress.

Revised Techno Commercial Offer (TCO) was under process of acceptance. The proposal for financial and administrative sanction for the project was initiated. All preparations were targeted to launch the project by the end of year 2013.

**Jaitapur Nuclear Power Project-1&2 (2x1650 MW LWRs)**

In October, 2009, the Government of India accorded in-principle approval of Jaitapur site, Maharashtra, to locate 6 x 1650 MW and utilize full potential of the site. The reactors proposed to be set up are Evolutionary Pressurised Water Reactors (EPRs) in technical cooperation with France in phases of 2X1650 MW EPRs.

The land was acquired at Jaitapur site. Environment and Coastal Regulation Zone (CRZ) clearances by MoEF were obtained. Technology independent site infrastructure development works were in progress along with other pre-project activities like Geo- technical investigation etc. The construction of boundary wall towards land side was completed. The liaison office cum information centre were constructed and made operational at Ratnagiri. Various pre-project activities like geo-technical investigation, permanent meteorological tower, chain link fencing, construction power supply etc., were in progress at JNPP site. Revised Techno-commercial offer (TCO) submitted by AREVA was under advanced stage of negotiation.

Several public awareness activities were undertaken to dispel apprehensions among people from surrounding villages of the project, local press and media and various groups ideologically opposed to nuclear power / Jaitapur project. The information centres were set up at Ratnagiri and JNPP plant site to disseminate information regarding nuclear power including JNPP.

As a part of neighborhood development, several welfare programmes / schemes were initiated in the surrounding villages of Jaitapur. These included, training the persons in various skills to prepare them for employment, self employment, apart from providing regular jobs to some of the people, electrification of nearby villages by providing solar lamps, electrification of nearby schools, distribution of fishing nets to fishermen of nearby villages, Distribution of three wheeler scooters to physically challenged persons, water supply through bore holes and hand pumps were completed.

## New Sites

After completion of Environment Impact study, review by Expert Appraisal Committee (EAC), a Public hearing at Haryana site was completed in July 2012 at the Haryana project site. Over 95% compensation money was disbursed to land owner and land acquisition process was in final stages. Consequent to this, Geo-technical investigation work was started at the site. First order Detailed Project Report, cost estimates etc. were prepared.

Section 4 notifications were issued by respective State Govt. authorities for Chutka site in Madhya Pradesh and Mahi Banswara site in Rajathan.

Pre-project activities at other new sites comprising of land acquisition process, EIA studies for hastening of the environmental clearances, geo-technical investigations and other studies for Site Evaluation Report (SER) for clearance by AERB reached in various stages in respect of Chutka in Madhya Pradesh, Kovvada in Andhra Pradesh, Chhaya Mithi Virdi in Gujarat, Haripur in West Bengal, Mahi Banswara in Rajasthan, Bhimpur in MP and Kaiga-5&6 in Karnataka.

Environmental monitoring and studies for the three seasons were completed for NPPs at Chutka, M. P., Mithivirdi, Gujarat and Kovvada, A. P. The draft EIA report which includes thermal dispersion study, marine impact assessment study and CRZ demarcation study, for NPP at Mithivirid Gujarat, was submitted to regulating

agency for organisation of Public Hearing and No Objection Certificate under Costal Zone Regulation. Three seasons monitoring for terrestrial and intertidal area for Biodiversity Studies in the region around Jaitapur NPP were completed and for marine area the studies were initiated to develop Biodiversity Conservation Plan.

# FRONT-END

### Heavy Water Production

Heavy Water Board (HWB) supplies heavy water to all the operating pressurized heavy water reactors and supports the first stage of nuclear power programme of DAE. HWB is working on the extended mandate entrusted by DAE on development, demonstration and deployment of technologies for in-core and out of core material inputs for Indian nuclear power programme, required at the front-end as well as back-end of nuclear fuel cycle.

HWB has emerged as the largest global producer of heavy water and has developed similar capabilities in various other areas, like organo-phosphorous solvents and $^{10}B$ enriched Boron.

During the year, the performance of the Board was excellent with respect to heavy water production, specific energy consumption, on stream factor, safety performance, environment management etc. The total percentage production target achieved during the period was about 109%.

HWB continued to adopt means to reduce the specific energy consumption through process intensification and optimization. HWP (Manuguru) exported the surplus electrical energy generated at the captive power plant to the power grid and made revenue generation.

Following are the highlights of performance of the Heavy Water Board:

### Heavy Water Plant, Manuguru

During the period, the performance of Heavy Water Plant, Manuguru was excellent and achieved 106.9% of target production and on stream factor was very close to 1. Throughout the period, system gas purity was consistently maintained at around 99.3 % and average system gas pressure at 19.2-19.3 kg/cm$^2$g.

As a result of the smooth operation of Auxiliary Steam Turbo Generator (TG-4) and installation & commissioning of VFDs in Captive Power Plant and in main plant, lowest ever specific energy consumption of 29.6 GJ/kg was achieved and surplus power was generated and exported. For environment management, the

Electrowinning Cell at HWP (Manuguru)

Electrowinning cell for Elemental Boron Plant At HWP (Manuguru)

plant installed and commissioned Dry Fly Ash Collection/Segregation and Storage for supply of fly ash to cement Industries.

Boron Enrichment Plant for production of Enriched Boric Acid (EBP) and Elemental Boron Plant were operated on sustained basis. A plant for converting the enriched KBF4 into elemental boron based on molten salt electrolysis process was also set up.

The plant completed 3 million man hours of continuous working without any reportable disabling injury, consecutively for the 5th time. The plant also won "Golden Peacock Environment Management Award-2012" in recognition of sustainable and effective Environment Management system.

**Heavy Water Plant, Kota**

The Plant at Kota (Rajasthan) achieved 114.6% a highest ever annual production of with on-stream factor of 0.97.

Heavy Water Plant (Kota) completed more than 25 years of operation with $H_2S$. All $H_2S$ storage tanks were thoroughly inspected, hydro tested and kept ready for storage of H2S during the shut-down.The effluent from exchange unit was cooled through mist cooling system. The cooled effluent was utilized as make up for cooling tower which resulted in water conservation and led to significant reduction in the water charges.

Auxiliary Turbo-generator was installed at HWP (Kota) to generate 2 MW power by recovering energy from throttling of steam.

A Technology Demonstration Plant for Heavy Water Clean-up (HEWAC) was set up at HWP, to reduce the internal dose to occupational workers as well as to enable recycle of heavy water from decommissioned PHWR to other PHWR. Commissioning of all the utilities and testing of the cryogenic circuit of HEWAC and commissioning of the cryogenic loop was in progress. Both $N_2$ & $H_2$ compressors were in operation. Lowest temperature of 42.8 K was achieved with sustained vacuum in the cold box system and further cooling down of $H_2$ & $D_2$ circuit with $H^2$ gas up to 20 K was planned.

Towards forward integration of HEWAC, installation of Hydrogen Oxidation Unit was completed and pre-commissioning activities were in progress.

**Heavy Water Plant, Hazira**

The performance of Hazira plant was satisfactory. It achieved 105.8% of the targeted production in spite of operating most of the time with only one ammonia plant resulting in low feed gas supply as well as lower deuterium concentration. Plant operated with on-stream factor was very close to 1.

**Heavy Water Plant,Thal**

Heavy Water Plant, Thal performed very well and plant achieved 108.7% of targeted production due to sustained operation. The on-stream factor was very close to 1. Feed gas flow and its deuterium concentration remained low in August due to gas supply which remained connected with only one ammonia plant.

Revamping of 3 cells of cooling tower taken up under capital scheme was safely completed. VFD was installed for ammonia reflux pump and 11 kWe power saving was achieved. Energy meters and CTs/PTs of requisite class specified by MSEB were procured and their installation was nearing completion for implementation.

**Heavy Water Plant, Baroda**

As directed by Atomic Energy Commission, actions were taken for stoppage of heavy water production at HWP Baroda. The Tri Butyle Phosphate Plant and the Potassium Metal Plant remained in operation.

Towards development activity on alternate uses of heavy water, deuterated NMR solvents were being synthesized at laboratory scale using conventional as well as innovative process.

Tri Butyle Phosphate Plant, Baroda

The plant produced 2 kg of acetonitrile-$d_3$ and deuterated sulphuric acid ($D_2SO_4$). Deuterium synthesis methods for benzene-$d_6$ and dichloro methane-$d_2$ ($CD_2Cl_2$) were also developed.

Performance evaluation of the wet proof catalyst, developed and produced in collaboration with RRCAT, Indore for $H_2$-$H_2O$ exchange process was carried out in chemical Laboratory of HWP (Baroda).

**Heavy Water Plant, Tuticorin**

Synthesis routes of tri-iso-amyl phosphate (TiAP), ethyl hexyl ester of ethyl hexyl phosphonic acid (D2EHPA-II) and di-hexyl octanamide (DHOA) solvents were developed at laboratory scale by BARC and IGCAR and the synthesis processes at bench scale were successfully established by HWB.

A Versatile Solvent Synthesis Pilot Plant (VSSP) was commissioned in March 2012 at HWP, Tuticorin. Ten campaigns of TiAP synthesis and six campaigns of D2EHPA-II were completed. Fine tuning of synthesis process parameters were in progress. Samples of DHOA & TiAP were sent to BARC and NFC, Hyderabad for solvent extraction studies and D2EHPA-II were sent to IRE, Cochin for product evaluation.

Indigenously designed and fabricated 360 NB centrifugal extractor was installed and commissioned at HWP, Tuticorin. Its hydraulic performance evaluation was successfully completed with various grades of phosphoric acid and organic solvent mixture of D2EHPA+ TBP in HNP.

Solvent extraction test facility operation was continued for collecting data on RM recovery from wet phosphoric acid received from M/s Green Star Fertilizers. Cycle-1 operation has been completed and cycle – II operation is in progress.

"$^{17}O$ Enrichment Pilot Plant", designed and fabricated indigenously, was successfully installed and commissioned at HWP, Tuticorin. It was operated with off-grade heavy water using DX packing for collection of engineering data for designing the full-fledged commercial plant, coming up at HWP, Manuguru.

**Heavy Water Plant, Talcher**

At HWP, Talcher, the production facility for D2EHPA and TBP were operated continuously to meet the target production. In TBP facility, reduction of effluent generation was achieved by a new step of reusing reject water from Butanol Distillation Unit for preparation of alkali solution.

Boron enrichment facility was operated continuously and achieved $^{10}B$ enrichment beyond 95% and $^{11}B$ enrichment beyond 99.5%. More than 110% of design recovery and feed processing rate of more than 65% $^{10}B$ was established and targeted production was surpassed. Chemical conversion of enriched $BF_3$-Ether complex to $KBF_4$ was carried out in the $KBF_4$ conversion unit and the product was sent to HWP, Manuguru for producing elemental Boron

**Technology Demonstration Plant**

Technology Demonstration Plant (TDP), Mumbai for recovery of Rare Material (RM) from phosphoric acid has successfully achieved the intended deliverables. The plant was under normal operation in integration with phosphoric acid plant of RCF. Two consignments of the final product generated in TDP were dispatched to IREL for further processing/purification.

Mixer settler for solvent extraction purpose was used as a contacting device in Solvent Extraction Plant. Alternative contacting device for solvent extraction were set up in TDP for performance analysis and one such device, an Asymmetrical Rotating Disc Contactor (ARDC) was commissioned and was under performance evaluation. A centrifugal extractor, another type of contacting device was also set up in the facility.

A sample Electrolytic Reduction Cell Assembly (ERCA) was installed for performance evaluation in the premises for reduction of RM in phosphoric acid for better extraction. Cold commissioning of the equipment was under progres.

**Heavy Water Upgrading & Hydrogen Isotope Separation**

Operation of heavy water upgrading plant and processing of downgraded heavy water received from DHRUVA to nuclear grade was continued. Low IP heavy water, accumulated over more than 2 decades was processed to recover valuable nuclear grade product along with disposable IP reject less than 2%.

Parametric study was carried out to optimize the operating temperature and gas flow rates for absorption and stripping columns of hydrogen isotope exchange from liquid lead-lithium loop by purge gas at high temperature following design of packed extractor column.

Hydrodynamic study of the single fluid flow through corrugated structured packing was done to simulate the flow behavior inside the packed columns. To achieve compact design, thermal hydraulic study of sphere packed pipe heater was conducted for gaseous heating with different heating conditions. Design, modeling and parametric optimization of ambient adsorber for moisture separation, cryogenic adsorber and permeator for hydrogen isotope recovery from helium purge gas was successfully carried out.

## MINERAL EXPLORATION

During the annual programme of work 2011-12 (November 2011 to October 2012), The Atomic Minerals Directorate for Exploration and Research (AMD) established a total of 14,263t of uranium oxide. During the XIth Plan the Uranium Oxide reserves established were 67,742 t. AMD continued uranium investigations in the thrust areas for uranium mineralisation.

Substantial inputs of airborne and ground geophysical surveys and drilling helped in identification of the new areas / blocks and delineation of ore bodies. Exploratory mining was also continued for detailed assessment of the ore body at Gogi, Gulbarga district, Karnataka.

In addition, pegmatite belts of Chhattisgarh and Odisha for the rare metals and sand bodies of coastal stretches and lake sediments of Tamil Nadu were targeted for augmentation of rare metals and heavy mineral resources of the country.

Significant highlights of the achievements of the mineral exploration programme are summarized below:

## Uranium Investigations

Reconnaissance (4708 sq km) and detailed (182 sq km) surveys helped in locating new uranium anomalies/extension of known occurrences in the following geological environs:

**Dharampuri Shear Zone, Tamil Nadu:** Uranium mineralisation associated with quartz barite veins and altered epidote hornblende gneisses were located near Kalarapatti/Ponmalai/Almarakottai, Vellore district.

**Ajabgarh Group, Rajasthan:** Uranium mineralisations associated with brecciated calc silicate near Sirsori Ki Dhani, albitized quartz biotite schist at Kalakota, pink albitite near Kalakhera, Sikar district were located.

**Surguja Crystalline, Chhattisgarh:** Granite samples of Chattanpani were analysed, $U_3O_8$ and $ThO_2$ located in Surguja district and discrete grains of uraninite have been identified in this granite.

Unconformity contact between basement granite and Srisailam Formation at Chitrial, Nalgonda district, A.P.

Drilling at Rasimalai Hill, Vellore District, Tamil Nadu

**Mahboobnagar Granite, Andhra Pradesh:** Uraniferous anomalies were located in granite and overlying sandstone/grit at Akkawaram, Mahboobnagar district.

**Talchir Gondwana, Madhya Pradesh:** Uranium mineralisation hosted in sheared brecciated

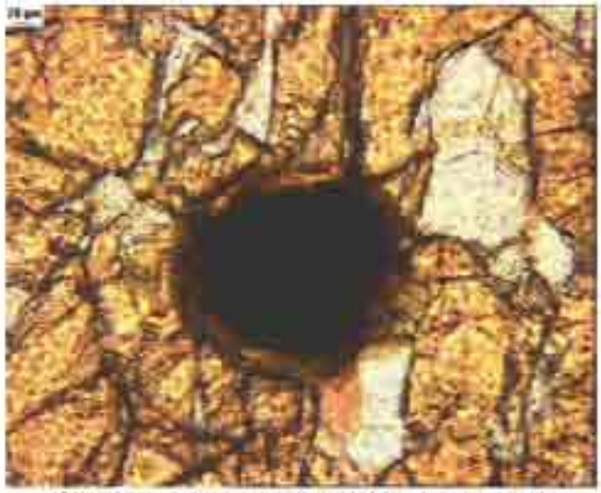
ferruginised arenite of Taichir Formation, close to basement granite was located west of Kota village, Betul district.

**Nimar Sandstone, Madhya Pradesh:** Uranium mineralisation associated with calcareous ferruginised sandstone was located at Bhimpura-Mogra, Dhar district and Salkhera, Alirajpur district.

**Sambalpur Granitoids, Odisha:** Uranium mineralisation was located in quartzo- feldspathic cataclasite to the east of Malaikharuan, Bargarh district.

Beryl Crystal within Quartz Core, Pandikimal Area, Odisha.

Photomicrographs of Uraninite from Duthorna Chatanpani, Chhattisgarh



Uraninite with alteration halo occurring as inclusion in garnet, Salem, Tamil Nadu.

Heavy Mineral Layering in Udupi Coast, Karnataka.

**Geochemical Surveys**

Geochemical surveys were carried out over 2,640 sq km in different parts of the country. Uranium values of 25-227ppb in Lalji Ka Dongri and 12-615ppb in Arwa Rann, Jalore district, Rajasthan were recorded in water samples. Uranium values 1-140 ppb was recorded in water samples Jharsuguda district, Odisha and Raigarh district, Chhattisgarh.

**Ground Geophysical surveys**

Ground geophysical- regional and detailed surveys have been carried out in different geological domains. High chargeability and low

resistivity zone corroborating the heliborne geophysical anomalies have been established in Himpur and Indora, Chatterpur district, Madhya Pradesh. High chargeability and low to moderate resistivity clusters over a strike-length of 3.2km are recorded in Chandur-Kairhatti area in Belgaum district, Karnataka. A NE-SW magnetic high zone is delineated parallel to present coast in extension area of Brahmagiri deposit, Puri district, Odisha.

### Airborne survey and Remote Sensing

Heliborne geophysical survey comprising of electromagnetic, magnetic and radiometric systems were carried out in Cuddapah basin, Andhra Pradesh and Aravalli Fold Belt, Rajasthan, through NGRI in South Purulia Shear Zone & Singhbhum Shear Zone in Jharkhand and West Bengal respectively and Singhora sub-basin in Chhattisgarh. A total of 38,520 line km was covered.

Detailed litho-structural mapping using high-resolution satellite data was carried out in three geological domains viz. contact zone of Mahakoshal and Vindhyan, Sindreth-Purnagarh basin of South Delhi Fold Belt and parts of Cuddapah basin to prepare base-geological map and supplement the integrated evaluation of heliborne geophysical and ground-exploration data-sets.

The interpretation of magnetic, electromagnetic and radiometric data generated by heliborne geophysical surveys over Kaladgi basin during 2009-10 and 2010-11 was completed and the integrated thematic maps were finalised. Fifty four anomalies of heliborne radiometric data were ground checked and Islampur Gudda anomaly of Kaladgi basin in quartz arenite were analysed upto 0.039% $U_3O_8$.

Heliborne Survey operations at Chirwa, Udaipur District, Rajasthan.

### Drilling

A total of 1,88,140 m was carried out during 2011-12 field season to establish additional uranium resources in the known occurrences and sub- surface continuity of mineralisation in the new promising areas.

**Exploration in the extension / new areas**

**Significant mineralised intercepts / bands explored during the field season:**

- **Extensions of correlatable uranium mineralization, associated with Vempalle dolostone was intercepted both in hangwall and footwall at Tummalapalle Block-I, Tummalapalle Block-II, Kanampalle, Rachakuntapalle, Motunutalapalle, Velamvaripalle-Gidarikpalle and Madyalabodu blocks in Kadapa district, Andhra Pradesh**

- **Uranium mineralisation was intercepted close to the unconformity between Srisailam quartzite and basement granite in Nalgonda district, Andhra Pradesh**

- **Correlatable uranium mineralisation was intercepted close to the unconformity between Bangenapalle quartzite and basement granite and within the Bangenapalle quartzite in Guntur district, Andhra Pradesh**

- **Correlatable uranium mineralisation related to albitite zone were intercepted in Rohil Central block & North block, Ghateswar-Khandela, Hurra Ki dhani, Narsingpuri and Raghunathgarh in Sikar district, Rajasthan**

- **Correlatable uranium mineralization was intercepted in Lower Mahadek sandstone at Wahkut and Umthongkut deposits in West Khasi Hills district, Meghalaya**

- **Correlatable uranium mineralization associated to limestone, exactly similar to Gogi uranium deposit, intercepted in boreholes of Kanchankayi in Yadgir district, Karnataka**

- **Correlatable uranium mineralisation associated with brecciated granite, grey granitic and granite- gneisses were intercepted in number of boreholes at Devri, which is located between Dumhath and Jajawal uranium deposits in Surguja district, Chhattisgarh**

- **Correlatable uranium mineralisation intercepted in boreholes associated with Bortalao sandstone of Khairagarh Group and also in**


Newly procured Thermal Ionization Mass Spectrometer (TIMS) added in Geochronology Lab, AMD, Hyderabad


Moisture proof CRM and Shielded Probe developed by Instrumentation Group AMD, Hyderabad

Pitepani metabasics (Dongargarh Group) near the unconformity in Durg district, Chhattisgarh

- Correlatable uranium mineralisation intercepted in two of boreholes of Narwapahar deeper series associated with quartz-chlorite-sericite schist at Narwapahar in East Singhbhum district, Jharkhand

- Correlatable uranium mineralisation associated quartz-chlorite-sericite schist intercepted in number of boreholes at Banadungri-Singridungri in East Singhbhum district, Jharkhand

- Correlatable uranium mineralisation associated with zones of secondary silicification and magnetite-apatite vein lets intercepted in number of boreholes in Seraikella-Kharswan district, Jharkhand

## Exploratory Mining

**Exploratory mining at Gogi, Gulbarga district, Karnataka**

During current field season, 13.00m shaft sinking was developed and cumulative progress of 225.00m in shaft sinking has been achieved.

**Total Uranium Resources**

The country's uranium resources were updated to 1, 86,653t of $U_3O_8$ as on 31.10.2012.

## Rare metal and rare earths investigations

Reconnaissance (1105 sq km) and detailed (11.5 sq km) surveys resulted in location of new occurrences of columbite-tantalite and beryl bearing pegmatites at Karnataka, Odisha, Chhattisgarh and Rajasthan.

Additional reserves of 6787 kg of columbite-tantalite are estimated in pegmatites of Allapatna-Marlagalla, Mandya district, Karnataka; Arehalli, Hasan district, Karnataka; Bodenar, Bastar district, Chhattisgarh; Dummapara, Bastar district, Chhattisgarh; Latmetta, Dantewara district, Chhattisgarh; Kirmira, Jharsuguda district, Odisha; Jangapara, Jharsuguda district, Odisha and Richmaliya, Ajmer district, Rajasthan.

A total of 2630 kg of columbite-tantalite and recovery of 3305 kg of beryl as by-product was produced from the field units of Pandikimal and Jangapara, Jharsuguda district, Odisha; Bodenar in Bastar district, Chhattisgarh and Richmaliya, Ajmer district, Rajasthan.

## Beach Sand and Offshore Investigations

For identifying the additional beach sand heavy mineral resources, surveys (Reconnaissance- 200 sq km & detailed-12.2 sq km) and exploration (drilling, sampling and evaluation) were continued along the coastal tracts of Andhra Pradesh, West Bengal, Odisha, Karnataka and Tamil Nadu.

**Exploration**

1387 boreholes with a cumulative depth of 10587m were drilled in a grid pattern and 7116 individual and 67 bulk samples were generated. Composite samples were processed for separation of monazite and zircon.

A total of 2786 individual samples and 39 composite samples were analyzed for slime, shell and total heavy mineral contents. Grain counting was carried out on 23 composite samples

The following potential heavy mineral zones have been delineated:

- Manamelkudi and Thondi area (10-15% THM), Ramnathpuram district, Tamil Nadu;
- NW extension of Brahmagiri mineral sand deposit (upto 10% THM), Puri district, Odisha;
- Depal-Kanthi tract (0.12-13% THM), Midnapore district, West Bengal;
- Kaup-Udupi-Koni-Kondapura tract (3-8% THM), Udupi district, Karnataka;
- Along berm zone at Kesavadasupalem coast (10-30% THM), Godavari district and Rayadoruvu-Swarnamukhi river mouth (5-15% THM), Nellore district, Andhra Pradesh.

**Detailed Reports**

Fourteen technical reports on beach sand heavy mineral deposits were finalized and 151 technical reports were archived in 'SANDBASE'-a database developed by AMD.

## Mining & Mineral Processing

In India, mining and processing of uranium ore is done by the Uranium Corporation of India Ltd. (UCIL). This corporation operates in Jharkhand state with six mines at Jaduguda, Bhatin, Narwapahar, Turamdih, Bagjata and Banduhurang, and two processing plants at Jaduguda and Turamdih. At Mohuldih, also in Jharkhand, a new mine is under construction. A new mine and a processing plant are also under construction at Tummalapalle (Andhra Pradesh).

The overall performance of the company during the year 2011-12 was recognized as Very Good. The construction of Tummalapalle mine and plant in Andhra Pradesh achieved significant

Yellow cake from Tummalapalle Processing Plant

Mohuldih underground mine in Jharkhand

success. The mine started production of 2000 tpd ore and adequate stockpile was created. The plant which is based on indigenously developed alkali leaching (under pressure) technology made substantial progress. The product packaging was started on Jan 2013. Successful commissioning of this plant is expected to pave way for utilization of vast uranium resources already identified around Tummalapalle.

Mohuldih underground mine in Jharkhand recorded uranium ore production. The mine is expected to be commissioned in March 2013 and shall feed the plant at Turamdih which is under expansion.

UCIL successfully presented the case for expansion of mine and plant at Turamdih before MoEF (Ministry of Environment & Forest) and final environmental clearance is expected to be

obtained soon. Significant progress was also been made towards the completion of the above expansion projects. UCIL also presented the case for Terms of Reference (TOR) extension of Narwapahar Mine Project & Tummalapalle Expansion Project.

UCIL achieved treatment and recycling of all mine after modifications in layout through in-house research. Judicious utilization of recycled water through meticulous monitoring of chloride pick-up resulted in 50% fall in process water consumption per ton of ore processed in Turamdih. Energy consumption in Turamdih Process Plant reduced from 45.37 kwH to 37.38kwH per ton of ore processed.

## Nuclear Fuel Fabrication

Nuclear Fuel Complex is engaged in the production of natural uranium oxide fuel bundles for PHWRs, enriched uranium fuel assemblies for BWRs, reactor core structurals, reactivity control mechanisms and special materials like tantalum, niobium etc.

In addition, NFC produces all the core sub-assemblies and other critical components like fuel cladding tubes, Hexagonal wrapper tubes etc., made out of special stainless steels/ D9 materials for fast breeder reactors. NFC also caters to the demand of high quality stainless steel tubes/ pipes and titanium half alloy products for critical and strategic application

### PHWR Fuel

The requirement of fuel bundles for all the PHWRs under operation was timely met. All the indigenous raw material in the form of MDU/HTUP supplied by UCIL were converted into 19 element and 37 element fuel bundles to meet the requirement of the reactors that are out of IAEA safeguards.

Automatic Boat Charging System for pellets for final compaction press

Safeguarded fuel plants continued processing of safeguarded uranium raw material and maintained sufficient stock of fuel bundles at safeguarded PHWR sites. As a part of modernisation effort, SCADA system with central control was fully operational in Uranium Oxide Plant.

### Modifications in Fuels Plants

- Automatic boat charging from press was conceived, developed and commissioned. This eliminates manual boat charging operation.

- Modification was carried out in granules container and granules blending for mechanised feeding into final compaction press.

- Modification was carried out in pick and place system of final compaction press for reducing pellet chipping and breakdown of presses thus improving productivity and recovery.

- Development was carried out in die sets for reducing grinding allowance in pellet production to enhance recovery.

- Development was carried out in processing parameters for safe handling of HTUP.

Re-engineering of INVAP grinder was carried out to suit to the PHWR fuel pellet requirement. The unit is in continuous operation.

An automated visual inspection system was developed at BARC for quality assessment of UO2 fuel pellets during fabrication for detecting visible flaws like pits, chip offs, cracks, etc. Severity of defects was evaluated by quantifying geometrical parameters.

U-metal and alloys of various grades in bulk ingot and powder form was produced for Indian research reactors. Development of laboratory scale facility for preparing Th-U and Th-Zr alloys from in house starting materials, development of facility for production of LEU ingot for making U-Zr alloy for use in FBR and supply of LEU metal powder of desired grade for new APSARA core were some of the important achievements.

Energy Efficient Paddle Drier Unit

Carousel type resin-in-pulp set up for separation & purification of uranium bearing leach slurry

Optimum process parameters for production of U-metal ingot from $UF_4$ were established following a dry route. In order to enhance uranium production, a novel energy efficient paddle drier was commissioned for drying ammonium di-uranate powder in tonnage scale.

The hot deformation behaviour of natural uranium was studied to identify the optimum hot working conditions.

Laboratory-scale studies were carried out to recover dissolved uranium values from an alkaline leach slurry of a medium-grade uranium ore from Gogi (Karnataka) using the resin-in-pulp (RIP) process. A systematic effort was directed to explore the possibility of recovering uranium values from uraniferous black shales of Mussorie Syncline of Uttarakhand.

**Zirconium activities**

As a energy conservation measure, double drum type steam heated dryer for continuous drying of zirconium hydroxide wet cake and low temperature rotary calcination furnace were commissioned which will be operated in place of old high temperature drying ovens on batch mode.

Commissioning of new chlorination facility with PLC based process monitoring & control system was completed and primary ventilation with 2 stage scrubbing for production of 1500 MT per annum of zirconium tetra chloride was improved.

Installation & commissioning of a new rotary incineration furnace of 30MT per month incineration capacity of pyrophoric waste was also completed.

Process modification was done through optimisation of melting time and temperature in vacuum distillation operation which resulted into 15% saving in energy consumption.

**Zircaloy fabrication**

3780 T Extrusion Press at NFC was used for meeting the entire requirements of Indian PHWRs & BWRs and other strategic materials were also processed for several applications.

Extrusion of inconel-718 and inconel-690 super alloy tubes for high temperature applications and Al-6Mg alloy for indigenization of components of BrahMos was carried out.

Al- profile tube extrusion for production of aluminium fin tubes in symmetric profile and asymmetric profiles were carried out for DHRUVA clad tubes in 630 ton vertical extrusion press using a direct die instead of conventional method of porthole die.

The calandria tubes required for RAPP 7&8 were manufactured and supplied during the year.

Modified process route for fabrication of Zr-2.5Nb pressure tubes based on double radial forging, extrusion and single pass pilgering route was demonstrated. The tubes were characterized and they met the desired metallurgical and mechanical properties. Based on the result, manufacturing of pressure tubes for KAPP 3 was taken up.

High temperature test loop for thermal hydraulics experiments operating above 1100oC was successfully fabricated and supplied to BARC for CHTR project. The loop design consists of mainly tubular and sheet components of Nb-1Zr-0.1C alloy. The high strength alloy was melted and extruded and cold pilgered to suitable sizes of tubes for test loop fabrication. Extrusions were

520 mm Ø Arc Melted and Machined Ingots

Radial Forged Ingots

As Extruded (119mm OD X 6mm Wt) blanks

also carried out to produce other critical components. Further fabrication was carried out through electron beam welding and other precision welding techniques and necessary QC checks were done.

The clad for AHWR-LEU fuel is zircaloy-2. To increase the burn up, it was decided to introduce double clad tube with low tin zircaloy as inner tube and zircaloy-2 as the out clad tube. The tubes were produced by shrink fitting the mother blank tubes in each other, degassing the shrink fitted blank tube and welding the two liners at the faces by EB, co-extrusion and multiple co-pilgering.

**Commercial activities**

**I) UNS 8800 grade Steam Generator tubes for 700 MW PHWRs**

First charge of 2489 nos. QA cleared tubes for SG-I were produced and dispatched to L&T. These are U-Bend and glass bead shot peened tubes in 72 radii from 91mm CLR to 1014mm CLR, meeting stringent specification requirements of UT, ET, visual and dimensions meeting special packing requirements identical with steam generator configuration. Second set of tubes were also produced and were being despatched.

**ii) Process development for Production of Inconel-617 and UNS 30432 grade tube**

Process route for the production of inconel-617 and SS 304 HCu grade tubes for advanced ultra super critical thermal power plant application was established and tubes were produced meeting all critical quality requirements.

**Projects**

**NFC-Kota:**

- M/s EIL was appointed as consultants for carrying out detailed engineering and construction supervision.
- Public hearing was conducted and final EIA report submitted to MoEF for environmental clearance.
- Site evaluation report was submitted to AERB for obtaining siting consent
- Preparation of DBRs for submission to AERB was in progress.

**NFC-5:** For supply of 1250 tpy of fuel for initial and reload requirement of 10 x 700 Mwe PHWRs being planned by NPCIL at Haryana, Madhya Pradesh and other places, yet to be notified.

- Site selection committee was formed for evaluation of the proposed sites.
- Letters were written to AP, MP and Rajasthan governments for providing suitable land.
- Preliminary visit was made to the proposed sites in AP.
- Rajasthan and MP Governments were being followed up for response.

**Zirconium Complex**

Zirconium Complex (ZC), Pazhayakayal, Tuticorin, Tamil Nadu was set up to produce 250 tonne per annum of nuclear reactor grade zirconium sponge. Plant was commissioned in November 2009 and production activities for both

zirconium oxide and zirconium sponge were started on regular basis and meeting the production target for past 2 years.

- Construction of quarters planned to accommodate staff of Zirconium Complex and CISF personnel and other amenities like medical centre, shopping complex etc. were in advanced stage of completion.

- Desalination Plant with two streams each of capacity 30 $m^3$/h of product water was set up at Zirconium Complex. Civil construction works for plant buildings and RCC water storage tanks were in progress. Purchase orders were released for major equipment by vendor and part supply of equipment / materials was received. Work was in progress for sea water intake system to supply feed water (sea water) to the Desalination Plant.

**Niobium Thermit Production Facility**

Various activities were in progress for establishing Niobium Thermit Production Facility (NTPF) for indigenous production of special grade niobium which will be used in manufacture of different components in INSAT programmes of VSSC (Dept. of Space). Works contracts awarded for civil, electrical & other works and procurement of related equipment were in progress.

## BACK END

**Fuel Reprocessing & Waste Management**

Plutonium Plant, Trombay was operational for recovery and purification of plutonium and uranium from spent fuels from research reactor. The nuclear material recovered in the plant was used for various programmes of the Department.

At BARC, several ligands were evaluated for actinide partitioning studies. Uranium extraction studies were also carried out for the evaluation of dihexyl octanamide (DHOA). Plutonium was recovered from analytical laboratory waste using hollow fibre supported liquid membrane (HFSLM) technique.

Thermal denitration of magnesium nitrate was taken up as a stimulant to uranyl nitrate. Jet grinding system as a particle size control tool for agglomerating nitrates was installed and tested. Smooth and steady operation was established with 10 LPH and 15 LPH feed of magnesium nitrate solution.

Centrifugal contactors

Hollow fibre membrane facility in glove box

Conversion of 95 % of magnesium nitrate was achieved by optimizing parameters like fluidisation velocity, bed height, air-liquid ratio in the spray nozzle, jet grinding air pressure and flow rate. The efficacy of operation under vacuum was also established. Other salient feature was satisfactory performance of indigenous spray nozzle fabricated, pneumatic transfer system for the lifting of silica seed particles and vacuum system for vacuum operation of the reactor and off-gas system.

Preliminary safety review of foundation / raft of pre-concentration section & process bay equipments of Uranyl Nitrate Conversion Facility (UNCF) at Kalpakkam were carried out.

Synthesis of di tertiary butyl DCH18 Crown 6 (DTBDCH18C6), a precursor to DTBDCH18C6 was carried out in lab scale and a process flow sheet was generated. The crude compound was formed with 80 % yield and 95 % purity. Process development for purification of this crude and its conversion to the final product by catalytic hydrogenation was in progress. Lab scale synthesis of grafted di-Benzo18 crown6 on Zeocarb resin was carried out and a process flow sheet was developed.

Ru nano catalyst was synthesized using techniques like micro emulsion (ME), solvo-thermal (ST) and micro wave (MW) and characterized.

Various studies carried out included process of drop formation at a single hole in sieve and nozzle plates for quiescent continuous phase using numerical simulations; Effects of various geometric and physical properties on the drop formation process; Effects of flow direction, physical properties and pore size on the phenomena of simultaneous extraction and stripping and numerical simulations were carried out to study mass transfer in a single pore for supported liquid membrane.

Single-phase CFD simulations of pulsed sieve plate columns were carried out for pressure drop and pulse amplitude for different hole sizes and plate spacing and validation.

Based on hollow fiber dispersion liquid membrane (HFDLM) process in recirculation

HFDLM experimental set up with Hollow Fibre module

Drop formation at a single hole, a snapshot from numerical simulation

mode, number and size scale up of hollow fiber contactor unit for recovery of U from U raffinate in single pass mode was taken up.

Power Reactor Fuel Reprocessing Plant (PREFRE-I) at Tarapur continued to carry out aged Pu purification work.

Power Reactor Fuel Reprocessing Plant (PREFRE-I), Tarapur

PREFRE-II was continuously operating successfully and it achieved all time record in capacity utilization. The plant completed the full year of operation with outstanding performance both in terms of production and process parameters. Spent Fuel Storage Facility (SFSF), Tarapur continued to be utilized for storage of spent fuel from Indian PHWR and special permission for enhancement of capacity was received.

PREFRE-II

Kalpakkam Reprocessing Plant (KARP) & Spent Fuel Storage Facility (SFSF) was in operation and it achieved all time record in capacity utilization. The plant operated successfully with outstanding performance both in terms of production and process parameters. Introduction of modified process had reduced the recycle volume and increase in through put. SFSF operated with safe storage of spent fuel from MAPS with high capacity utilization.

Spent Fuel Storage Facility

The project P3A is designed to increase the capacity at PHWR fuel reprocessing at Kalpakkam. Incell and outcell piping work progressed well along with inter connectivity checking. Air conditioning, ventilation and

Power Reactor Fuel Reprocessing Plant – 3 (P3A), Kalpakkam

exhaust (ACVE) and steam generation system were near completion stage. Pre-project activities for setting Integrated Nuclear Recycle.

Plant (INRP) was in progress. The siting and dose apportionment clearance was obtained from regulatory authority. Environment clearance was also been obtained from Ministry of Environment & Forest (MoEF). Construction of Additional Spent Fuel Storage Facility (ASFSF) works had made progress.

Distributed Control System for Integrated Project of Nuclear Recycle Board was developed based on in-house developed Trombay Programmable Logic Controller-32 (TPLC-32).

Control system for the Integrated plant was configured in a distributed architecture with control algorithms for each process block implemented in dual redundant TPLC-32 based programmable controllers. Prior to building the actual system, a prototype was setup at Reactor Control Division to establish the capability of the control system

Prototype pellet inspection system

Prototype setup of Distributed Control System

**Waste Management**

Waste Management plant in Tarapur (TWMF) continued to provide service in management and safe disposal of radioactive waste material in solid and liquid form obtained from BARC and Nuclear Power Corporation India Limited (NPCIL) unit at Tarapur. The discharge of activity to the environment was kept well below the prescribed limits set by the regulatory bodies.

During the year about 54000 $m^3$ of liquid waste and 840 $m^3$ of solid waste was collected and disposed safely within stipulated discharge limits after adequate treatment at Centralised Waste Management Facility.

Additional Waste Tank Farm (AWTF) was in regular use for safe storage of High Level Liquid Waste (HLLW), Intermediate Liquid Waste (ILW) & Organic Liquid Waste (OLW) generated from regular operations of PREFRE. Liquid radioactive waste streams were treated by various chemical processing settler and dilution methods before discharging in to sea.

Solid radioactive waste materials were conditioned and properly disposed in different engineering barriers. The discharges / disposal were well within authorisation limits.

Gaseous discharge of active particles was properly treated by filtering with High Efficiency PArticulate air filter (HEPA) to reduce the discharge to bare minimum.

New technique for disposal of self power neutron detectors (cobalt) after its useful life in reactor was developed.

Facility for processing of thorium lean raffinate waste a) Shielded Pre-filter

b) Shielded Ion Exchange Column

Advanced vitrification facility at Tarapur was hot commissioned and started operating vitrifying HLW into glass matrix, on a routine basis. The plant continued to receive fresh HLW of specific activity of 95-100 Ci/l and thorium lean raffinate (TLR) waste generated during processing of thorex process raffinate from Plutonium plant, Trombay.About 18.2 $m^3$ of thorium-lean raffinate waste, having average beta gamma radioactivity of 25 mCi/l were sent to Waste Immobilization Plant, Trombay for further processing/management. About 5 $m^3$ of sulphate bearing HLW was vitrifies safely during the report period.

Studies for the development of a chemical precipitation method for separation of $^{90}Sr$ from HLW was completed. Studies on the destruction of cellulosic waste using electrochemical method at laboratory scale were carried out.

Ion Exchange System was set up at Pump House, WIP Trombay to serve as a dedicated treatment facility for treatment of historical ILW. This system was designed for separation of cesium and strontium from ILW stored in Waste Tank Farm (WTF), of PP. ILW is generated during decladding and reprocessing of spent fuel at PP. This ILW was characterized by the presence of $^{137}Cs$ as the major radionuclide, amounting to 98-99 % of the total radionuclides.

A facility based on neutralization of acidic TLR waste followed by ion-exchange was commissioned for treatment of this thorium lean raffinate waste. The facility was hot commissioned and put into operation after safety clearances.

Spent radiation sources received from all over the country from various users are being conditioned and disposed off safely at Trombay and Kalpakkam.


Facility for treatment of ILW
a) Self-shielded ion exchange columns.

b) Ion exchange feed pump with associated valving

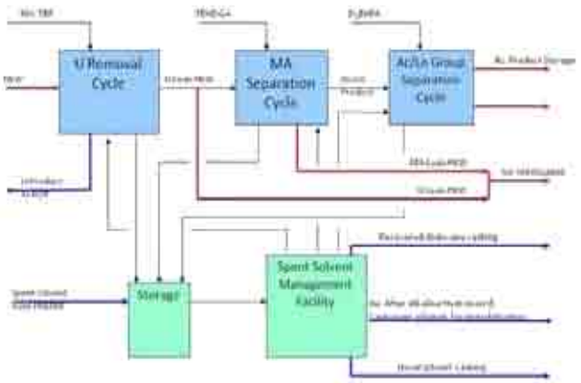
Advanced vitrification system (AVS-1)

High Efficiency PArticulate air filter (HEPA)

Dismantling and removal of highly active Joule Melter – AVS-1 and associated system was carried out. Vitrified glass was stored in canisters and overpacks and under surveillance in solid storage surveillance facility (SSSF).

The industrial scale test facility for partitioning of high level waste has been set up at BARC, Tarapur and commissioned. Cold commissioning trials resulted in near total separation of trivalent lanthanides, used as inactive surrogates for the process. Group separation of actinides from the co-extracted lanthanides was successfully simulated using in-on TALSPEAK process with neodymium as marker.

The spent solvent management facility integrated to the partitioning facility has also been cold commissioned with respect to the alkaline hydrolysis process for treating spent PUREX solvent.




Block diagram of integrated spent solvent management facility.

A poly vinyl alcohol based viscous gel formulation has been developed in house for decontamination of loose as well as weakly fixed contamination from metallic surfaces. An engineering test facility is under fabrication to demonstrate this technology.

An advanced oxidation technique employing ozone has been developed for removal of $^{106}Ru$ from alkaline waste as volatile $RuO_4$ species. An inorganic sorbent has been identified for effective trapping of volatile Ru species from ozone environment. The process has been tested with actual intermediate level, high salt loaded, alkaline waste at lab. scale.

An $Ag^{2+}$ mediated electrochemical process has been developed for oxidative destruction of alpha contaminated tissue papers in nitric acid medium at laboratory scale successfully tested with actual waste arising in RMD facilities. A pilot scale experiments for recovery of fissile material from cellulosic waste and its management are on the way.

New semi automatic melt densification system for melt densification of plastic wastes was procured, installed and commissioned. Geo-technical investigations for Alpha Waste Storage Facility, New Above-ground Tanks in Dyke and Ventilation Buildings were completed. Civil work was in progress for the new Dilution Water System at PFBR premises.

Project WIP-3A, Kalpakkam is designed to treat various type of waste at high, intermediate, low levels and organic waste generated by KARP, P3A & Demonstration Fast Reactor Fuel Reprocessing Plant (DFRP). Various systems of the project were in the advanced stages of commissioning and cold commissioning trials were initiated.

The Heavy Water Board is executing a project for NRB for conversion of uranium nitrate to uranium oxide and for carrying out denitration. The civil construction of project was under progress.

USB based Multi-Channel Scaler for Non-Destructive Assay of waste drums was developed by BARC as part of nuclear instrumentation for non-destructive assay of drums containing nuclear waste. The drums were mounted on PLC controlled drum manipulator assembly. The Na-I detectors mounted on a nearby stand detected the gamma radiation from the radioactive waste from within the drum.

Centralised Waste Management Facility

Project WIP-3A, Kalpakkam

USB based Multichannel scalar developed by BARC

## SAFETY PERFORMANCE OF REACTORS

To bolster the safety in Indian nuclear power plants, IAEA Operational Safety Review Team (OSART) carried out a first ever safety review of RAPS-3&4 (2X220 MW, PHWRs) at Rawatbhata, Rajasthan. The purpose of IAEA OSART review was to assist member states in enhancing the operational safety of individual nuclear power plants and to promote the continuous development of operational safety within all member states by the dissemination of information on good practices.

IAEA

**Impressions**

"Open communication, enthusiasm, motivation and sense of ownership were observed at all levels during the OSART Mission. These attributes have cultivated an environment of strong safety culture at RAPS-3&4."

*Mark Kearney*
*Deputy Team Leader*

*Miroslav Liper*
*Team Leader*

*OSART Mission-2012 RAPS-3&4*

IAEA OSART review findings, shared by the team leader in an interview to BBC, brought out that RAPS 3&4 were one of the best and safest in the world. Reactor Pressure Vessel (RPV) inspection at TAPS-1 was carried out for its healthiness confirmation and it met international standard.

## HEALTH, SAFETY AND ENVIRONMENT

NPCIL recorded about 370 reactor years of safe operation of reactors by the month of December 2012. The Review of safety of operating stations was carried out on a regular basis. The individual and collective occupational exposures of radiation workers at various NPPs were maintained within the budget approved by Atomic Energy Regulatory Board by following the principle of ALARA (As Low as Reasonably Achievable) and maintaining the highest standards of safety within the Nuclear Power Plants (NPPs). The radioactive effluents from NPPs to the environment were maintained very low in comparison to the limits specified by AERB. The Environmental Management System (EMS) and Occupational Health and Safety Management System (OHSMS) were maintained at all the stations.

All the Heavy Water Plants were certified for ISO Quality Management system, Environmental Management System and OSHA System. The overall safety standards of Heavy Water Plants were far better than similar chemical industries in the country.

At BARC, Radiation Detector System (RDS) for police vehicles was developed to install

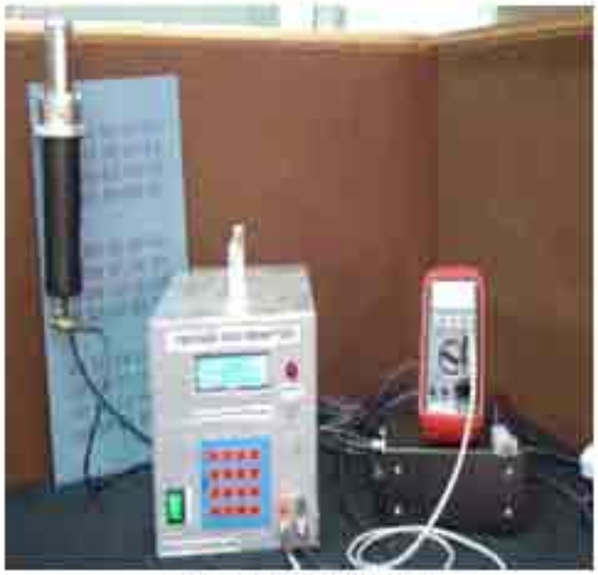
Radiation Detector System

Beta Gamma Hand and Foot Contamination Monitor

over 60 Mumbai police patrolling vehicles. Two days training programme was conducted for senior police officials about basic aspects of nuclear radiation, prevention and response to radiological emergencies in public domain arising out of unauthorized use of radioactive materials.

Nomogram software along with hand held tool was developed at BARC for defence applications related to nuclear disaster response. Large number of defence and security agencies including DAE security officials were trained on responding to nuclear/radiological incidents and emergencies. Aerial survey exercises were conducted as part of training to Indian Air Force personnel and officers for impact assessment and response to nuclear disasters.

Two additional DAE-Emergency Response Centres (DAE-ERCs) were commissioned to augment the National level Radiological Emergency Preparedness, one each at OSCOM, Chatarpur and IRE, Manavalakurichi. With this a total of 22 DAE-ERCs were established.



Tritium in Gas Monitor

Large area multi-wire gas flow proportional counting system

Large area multi-wire gas flow proportional counting system was established as a primary standard for calibration of large area sources. For calibration of contamination monitors, large area sources of $Sr^{90}/Y^{90}$ of different dimensions were prepared, calibrated and supplied. Radioactivity standards were

established for $^{177}$Lu and $^{18}$F which will be disseminated to hospitals and nuclear medicine centres, where these are used as radiopharmaceuticals.

Development of hand and foot monitor using large area thin plastic scintillator and high concentration tritium in air monitor for special monitoring applications were completed.

Hydrogeochemical studies and speciation analyses were carried out in connection with the monitoring of uranium in drinking water sources in Punjab. The uranium speciation in ground water was investigated by an equilibrium model under various redox conditions and complexant concentration.

Rapid and reliable radiochemical methods were developed for the separation of Pu, Am and U from urine matrix using solid extraction chromatographic resins for the quick estimation of excretion rates and help in taking appropriate protection measures.

A prototype automated radiochemical analysis system containing multiple columns was developed by BARC for the separation of Pu/Am from urine and fecal samples. A chair type Thyroid monitoring system, capable of utilizing multiple detectors such as HPGe, thick and thin

Automated bioassay system

NaI(Tl) was developed and commissioned. The system was used to measure internal contamination due to isotopes of radioiodine ($^{125}$I, $^{131}$I, $^{129}$I) on a single platform.

Non-linear least square regression based inverse modelling technique was developed to estimate the releases of different radionuclides into Pacific ocean which had resulted due to the discharge of highly radioactive liquid effluent from affected Daiichi Nuclear Power Station (DNPS) at Fukushima in Japan. The measured concentrations of these radionuclides in seawater samples collected from two sampling points near Fukushima were used for the estimation.

Inverse modelling was carried out to estimate the releases of different radionuclides into the atmosphere which had resulted due to the nuclear accident at the Daiichi Nuclear Power Station at Fukushima in Japan. The releases of $^{131}$I and $^{137}$Cs were estimated as a function of time by comparing the computed concentrations of these nuclides in the air and their deposited activities per unit release rate with the observations. The results were in good agreement with those published by NISA, TEPCO and IRSN.

The concentrations of U-238 in groundwater as a function of distance from a hypothetical mine due to leaching were estimated using a decay chain transport model.

About 350 Environmental Radiation Monitors (ERMs) were manufactured, calibrated and field tested and around 180 ERMs were installed under the countrywide "Indian Environmental Radiation Monitoring Network (IERMON)". These ERMs uses multiple detectors and have provisions for redundant communications. As a part of creating a dense network of radiation monitors in metropolitan cities, 50 units of IERMON systems were installed at police stations in Mumbai. To have redundancy in availability of IERMON data, geographically

Photograph of IERMON system installed at site

distributed IERMON Data Centres at two locations of the country were established.

Environmental Radiation Monitor (ERM) system developed by BARC was integrated with the Automatic Weather System (AWS) developed by ISRO, to have a realtime radiation monitoring system along with meteorological parameters. 10 such hybrid ERM-AWS stations were manufactured and installation of 5 units was completed under a BARC-ISRO, MoU.

Radiological safety surveillance was provided for the Thorium Retrieval Uranium Recovery and Restorage (THRUST) project of IREL at Udyogamandal for recovery of uranium from thorium concentrate and other materials. Average annual doses to workers in these plants were 4.56 mSv at Udyogamandal, 0.42 mSv at Chavara and 5.75 mSv at Manavalakurichi, respectively.

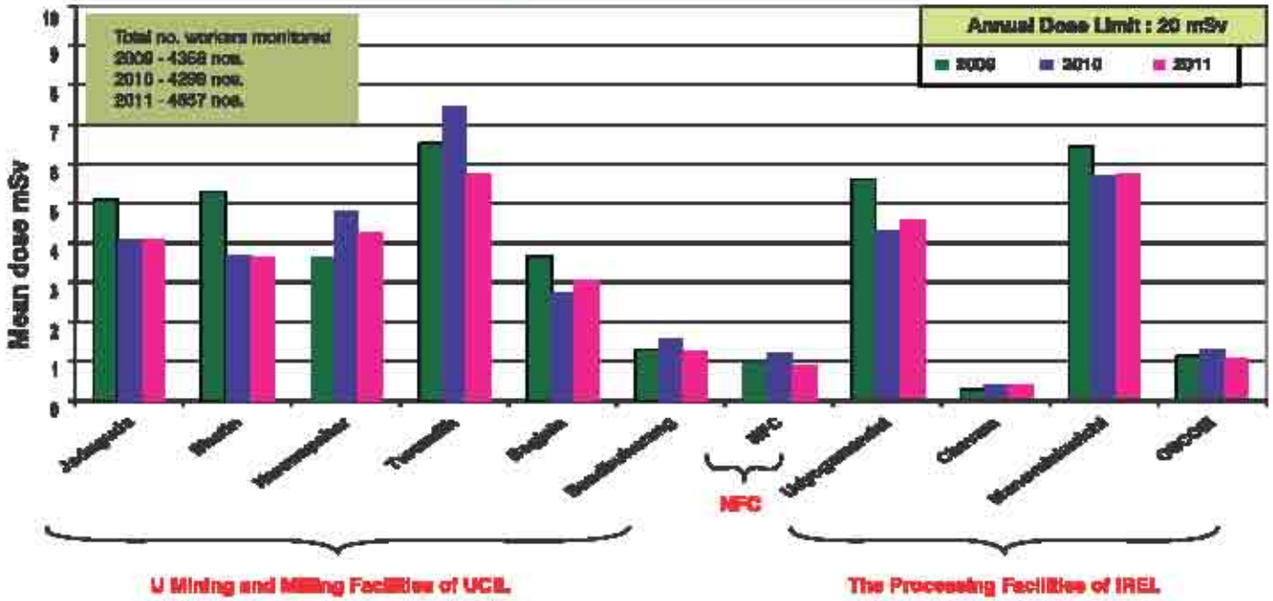
Average dose to thorium plant workers at OSCOM was 1.08 mSv and all exposure were below 20 mSv. Environmental surveillance was carried out around all thorium processing plants and the concentration of all concerned radionuclides in environmental samples were

Installation of ERM-AWS system

found to be well within the respective limits. Personnal monitoring services to about 85,000 occupational radiation workers were provided by accredited laboratories and NPCIL laboratories. Personnel monitoring support was also provided to radiological emergency response centers (ERCs) in the country.

Towards harmonization of personnal monitoring services, an integrated software called TLD Badge Management (TLDBM) system was developed at BARC. The software performs all the procedures of personnel monitoring like usual dosimetric calculations, report generation etc. The software also analyzes and identifies the badges with abnormal glow curve, performs pattern check and maintains the control background data, etc. This software after rigorous field tests is expected to be incorporated in the entire PMS system in the country soon.

**Annual Average Individual Effective Dose to Occupational Workers of UCIL, NFC and IREL Plants in India**




Integrated software– Glow curve check window

An Online Radon Monitoring Network (ORMoN) was established at Underground Uranium Mine, UCIL, Turamdih. The network consists of 10 number of in-house developed radon ($^{222}$Rn) monitors along with pollutant gas sensors, installed at 10 selected locations in the mine. Online data communication is being carried out, from individual monitors to a control room situated at the surface level, through a five thousand meter long cable established inside the mine.

An Industrial PC, loaded with custom designed software was placed in the control room for online data visualization and data logging into an excel file. Parameters that were continuously monitored included $^{222}$Rn, $CO_2$, CO, $NO_x$, $SO_x$, Temp and RH (%).

In vitro experiments were carried out to establish the premature chromosome condensation (PCC) assay and response curves were evaluated to estimate the coefficients for dose calculations. Standard Operating Procedure (SOP) for the assay was developed and validated for accidental high-dose radiation biodosimetry.

Six Gamma Low sensors and four Gamma High sensors were supplied as spares by BARC to PRP Kalpakkam.

## RESEARCH & DEVELOPMENT

Technology Development (TD) activities in NPCIL were focused on: setting up a Research

Successful Qualification/Validationof design through Containment Spray System (CSS) full header test

and Development facilities for carrying out performance testing and verification of new designs of systems and components for nuclear power plants, environmental qualification of components and validation of safety study codes; Indigenization of hitherto imported equipment, components and materials; developing / deploying remote tools for inspection, repair and refurbishment of reactor core components and primary system equipment; development /deployment of latest available technology for construction time minimization of new projects.

The above activities were aimed at achieving continual enhancement of nuclear and radiation safety, reliable operation and reduction in operational costs of nuclear power plants, Indigenization, construction time reduction and development of new reactor systems.

Major achievements and ongoing activities during the financial year-2012-13 were:

Qualification/validation of design through Containment spray system (CSS) full header test for 700MWe PHWRs was completed. Integrated Test Facility Tarapur (ITFT) was in advanced stage

Successfully developed indigenous Electrical Penetration Assemblies (EPAs) for 700MW Project

of erection. Several tests on 2% H2 injection with indigenous Passive Catalytic Recombiner Device (PCRDs) developed by BARC were carried out in Hydrogen Recombiner Test Facility (HRTF). Orders were placed for different modules of 700 MWe Fuelling Machine Test Facility (FMTF). Some of the FMTF equipment was delivered/ in advanced stage of manufacturing. Significant Environmental Qualification (EQ) tests were carried out utilizing the Loss of Coolant Accident (LOCA) chamber facility.

Several types of Modular Electrical Penetration Assemblies (EPAs) with greater leak-tightness were successfully developed and were undergoing qualification tests. Order was placed for development of steam generator forgings. Indigenous vendor capability evaluation for development of critical components of primary coolant pumps (PCPs) with adequate quality assurance was carried out and prima facie feasibility was established. Design of 3-pitch platinum clad inconel Self Powered Neutron Detectors (SPNDs) were completed and their fabrication reached advanced stage. Design of cobalt absorber rods assembly completed and proto-type manufacturing was initiated at Nuclear Fuel Complex (NFC). Some fuel handling components like aluminium bronze bar, round way bearing and control and instrumentation devices/equipment were under fabrication and at various stages of development.

BARCIS (BARC Channel Inspection System) campaigns were carried out in several 220 MWe reactors of the country. Steam generators (SG) lancing were carried out by remote tools which helped in achieving longer trouble free life of SGs. TAPS-1&2 Reactor Pressure Vessel (RPV) weld inspection was successfully carried out by Ultrasonic Testing.

Several initiatives to reduce the construction time of on-going 700 MWe Projects were conceptualized and developed. These

include, design of Preformed Ring Liner (PRL) handling arrangement for 700 MWe PHWRs; auto welding performance was evaluated towards its adoption by piping contractors in the projects; several other approaches in this regard made progress.

### R&D relating to PHWR

BARC provided R&D support for ageing management of existing PHWRs. Some of the developments for coolant channels carried out included Fuelling machine operated Remote Inner Diameter Measurement tool (FRIDM) which measured inside diameter of the operating pressure tubes of 220 MWe PHWRs; Wet scraping tool–III (WEST-III) for 220 MWe PHWR; Replica tools for 540 MWe and 220 MWe PHWRs and sag measurement tool for pressure tubes of PHWRs.

As a part of containment safety studies of PHWRs, experimental and analytical studies concerning various aspects of hydrogen management were carried out. The Hydrogen Recombiner Test Facility (HRTF) developed at BARC was commissioned at Tarapur in collaboration with NPCIL and experiments for performance evaluation of the device were pursued. Three important parameters namely the hydrogen concentration, inlet and outlet temperatures of the recombiner along with the maximum temperature developed in the catalyst plate were monitored.

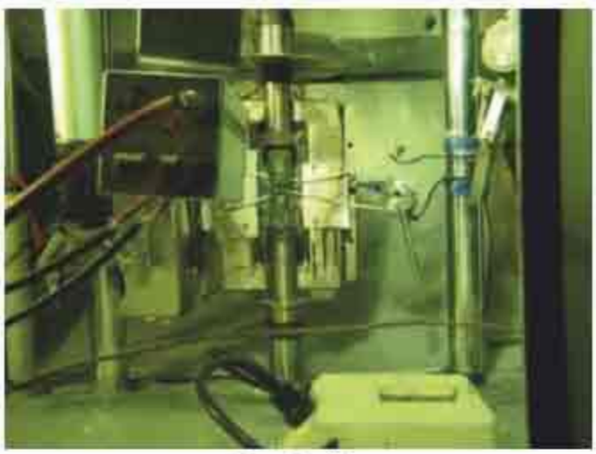
A patent has been awarded to BARC by Canadian Intellectual Property Office (CIPO) and Korean Intellectual Property Office (KIPO) for the innovative 'Emergency Leakage Arresting Device for a Collared Ended Pipe'. The device was deployed at all PHWR sites of NPCIL in the country.

A vibration test was carried out at R&D Centre Tarapur to study the possible fretting

Leakage Arresting Device developed by BARC

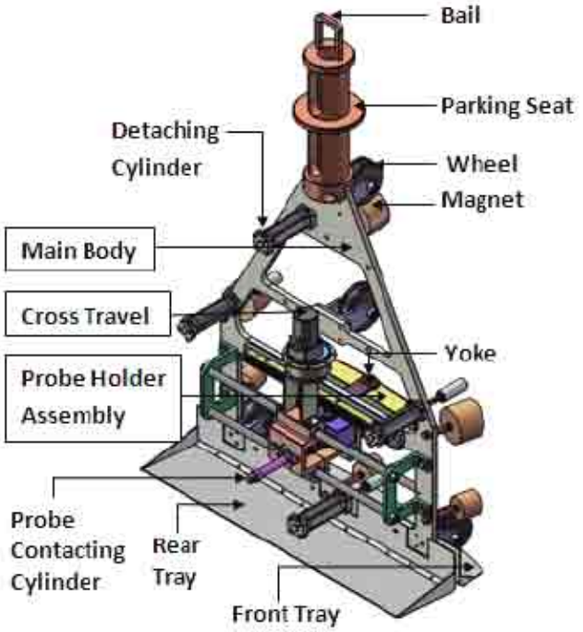
damage on feeder pipes due to differential creep in coolant channels.

Assessment of progressive degradation of fracture toughness of Zr-2.5Nb pressure tube material due to reactor service was implemented through a structured pressure tube surveillance programme for assurance of leak before break criterion to ensure safe operation of PHWR's. The pressure tube removed from a channel of KAPS-2 after around 8 years of operation was investigated for the degradation of fracture toughness and it was found to be within expected values and thus ensuring the safety of the reactor. The fracture toughness was evaluated by remote preparation of test specimens and tests in hot cells were carried out.



Test Facility

Specimen




Weld Inspection Manipulator

**R&D relating to LWR**

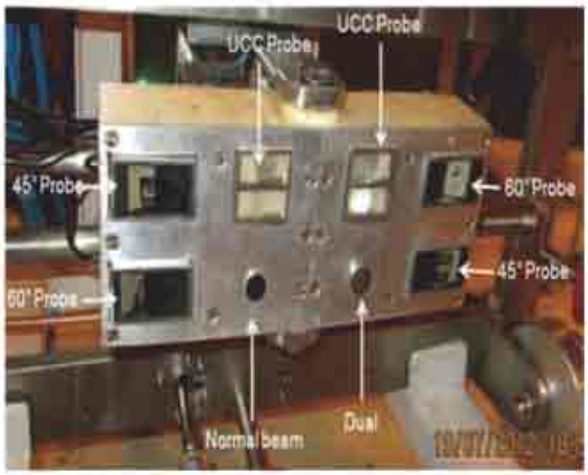
The longitudinal and circumferential welds of Reactor Pressure Vessel (RPV) of TAPS-1 were examined by ultrasonic testing (UT) using BARC developed Weld Inspection Manipulator (WIM).

Structural integrity assessment of RPV was performed for the observed flaws as well as for the postulated flaws in uninspected areas and existence of adequate factor of safety was demonstrated. The inspection data from all the sensors was logged and analysed for arriving at the length and depth of the indications and characterizing them as volumetric or planar type of defects. The probe holder developed for the purpose is shown in the figure.

Implementation of WIM in TAPS-1 RPV

Source term evaluation of Fukushima reactor Unit-1 has been carried out for 24 hours simulating Initial Isolation Condenser (IC)cooling for one hour, Reactor Pressure Vessel(RPV) inventory loss through steam relief valves, fuel uncovery, fuel melting, RPV failure, relocation to lower plenum, containment thermal hydraulic behaviour and molten corium concrete interaction following the prolonged Station Black Outs (SBO) condition. Event timings for vessel failure and core melting are comparable with predictions of Japanese safety authority.

In response to Fukushima event, enveloping extended station blackout scenario was analysed for TAPS-BWR simulating emergency condenser, different core and structural components, reactor coolant loop and power distributions. Predictions for important




Probe Holder Assembly

Compensated Ionization Chambers

Semi Portable Whole Body Counter

parameters was made for about 4 days simulating various severe accident phenomena like core heat up, core uncovery, oxidation, material interaction, material relocation, molten pool formation, hydrogen generation and fission product release.

Detailed calculations have been performed to obtain the decay heat, concentrations and radioactivity of important actinides and fission products for Fukushima-I core immediately at shutdown and also as a function of the cooling period.

In post Fukushima scenario, sea water was injected in the core to quench the heat. Possibility of re-criticality in case of sea-water injection was studied. Calculations were carried out based on the fresh core of TAPS design assuming that shutdown system is not available.

Proton induced gamma emission (PIGE) was used for the chemical quality control of structure rods made of Zr-1% Nb to ascertain the absence of boron. 4 MeV proton beam from Folded Tandem Ion Accelerator (FOTIA) was used with beam current of 50 nA.

A new test method for measurement of KIH by load shedding technique coupled with Direct Current Potential Drop and Crack Opening Displacement to monitor crack growth with time has been standardised. $K_{IH}$ for Zircaloy clad for PWR was determined and for PHWR cladding the determination was under progress.

Handling cum shielding assembly with $^{10}B$ lined gamma compensated ionization chambers was developed to monitor neutron flux in intermediate power range of reactor operation. Detectors are located inside the shield tank in identical SS hanger assemblies. Each hanger assembly consists of detector subassembly, leaf spring subassembly, shielding plug-II subassembly, flexible node subassembly, shielding plug-I subassembly, top cover subassembly, outer housing sub assembly and height adjustment subassembly.

Hanger Assembly

The hanger assembly has been qualified for shock and vibration tests and exposure to steam at 10 kg/cm$^2$ pressure and 180° C temperature.

Four beta gaseous activity monitors consisting of detection unit, intermediate unit and signal interface unit have been developed and supplied for use in LWR. Semi portable whole body counter for LWR has been developed for quick measurement of radioactivity within the thyroid, lungs and body of the victims of radiological accident.

# CHAPTER -2

# NUCLEAR POWER PROGRAMME STAGE-II

Inside view of PFBR reactor vessel with loaded Sub-assemblies

Top view of PFBR reactor vault with rotatable plugs in position

CHAPTER 2

# NUCLEAR POWER PROGRAMME STAGE-II

## FAST REACTORS

The second stage of the nuclear power generation programme is geared towards setting up of fast breeder reactors. These reactors produce more fuel than what they consume. The DAE organisations that are involved in the implementation of the Fast Reactor Programme are the Indira Gandhi Centre for Atomic Research (IGCAR), Bhartiya Nabhikiya Vidyut Nigam Ltd. (Bhavini) and Bhabha Atomic Research Centre (BARC).

IGCAR is engaged in the design and development of liquid sodium cooled fast breeder reactors, with associated fuel cycle technologies. This programme is supported by a strong research and development endeavour of IGCAR in disciplines such as reactor engineering, chemistry, metallurgy, material science safety reprocessing and instrumentation.

BHAVINI, a public sector company of DAE, was incorporated on 22 October, 2003 at Chennai, Tamil Nadu, as a Special Purpose Agency, for implementing India's first prototype 500 MWe Fast Breeder Reactor project.

BARC contributes towards the research and development of fuels for fast reactors, technology for reprocessing of fuels, waste management and health and safety of the work force.

## PROTOTYPE FAST BREEDER REACTOR

Prototype Fast Breeder Reactor (PFBR) is a pool type reactor using mixed oxide of uranium and plutonium as fuel and sodium as coolant.

Nuclear Island Connected Buildings (NICB) of PFBR

Construction and commissioning of the project is implemented by BHAVINI (Bharatiya Nabhikiya Vidyut Nigam Limited). PFBR is located 500m south of the existing Madras Atomic Power Station.

The Reactor Vault (RV) is the critical civil structure in PFBR which houses all the reactor assembly components. The erection of major nuclear steam supply system equipments was completed and the reactor roof was closed with roof slab. The erection of Large and small rotatable plug on roof slab was also completed.

The insertion of equipment into reactor core from top of roof slab was commenced. All four nos. of decay heat exchangers, one hot pool level detector housing and one cold pool level detector housing was erected in the roof slab penetrations.

Erection of outer shielding with boron carbide, dummy fuel as well as blanket subassemblies on the grid plate was completed. Erection of the primary ramp and primary tilting mechanism that forms a part of inclined fuel transfer machine used for fuel transfer, which were received at site after successful completion of testing in sodium from IGCAR was completed.

The civil structural works of steam generator building 1&2 was completed and all the eight steam generators were erected. The secondary sodium pump outer shell and shaft was erected.

The entire civil structural works of electrical building 1&2 was completed and ten 6.6kV switchgear boards were charged and four diesel generator sets were commissioned.

The construction of fuel building and erection of major fuel handling components was completed and pre-commissioning works are under progress for the erected systems.

The balance of plant houses the turbine building, raw-water & fire-water pump house, De-Mineralization plant (DM plant), auxiliary boiler plant, effluent treatment plant and open reservoir.

The civil construction work of turbine building was completed. Erection of turbine equipments was nearing completion and erection of all auxiliary equipments was also completed. Major equipments like generator stator & rotor, live steam re-heater, steam water separator lower & upper drum, high and low pressure turbines modules etc. were erected. Condenser tube insertion and expansion of Auxiliary Boiler plant was completed.

PFBR Turbine floor, BHAVINI

Raw water reservoir was commissioned and filling of water in reservoir was completed. Further raw water was transferred from reservoir to DM plant through pump house and both the streams of DM plant were commissioned successfully. Pre-commissioning works for other auxiliary service system was under progress.

Main control room, back-up control room and handling control room panels were erected in control building.

The construction of 220KV indoor switchyard (GIS) building was completed and commissioned. Entire 13 bays of switchyard and associated station transformer (ST), generator transformer (GT) and SCADA supervisory protection system was fully commissioned through MAPS tie line. Three 230kV double circuit line from BHAVINI switchyard to arani, sirucheri and Kancheepuram were energized. Four 4500kVA emergency diesel generators were commissioned successfully.

Pre-commissioning of various conventional system equipments like compressors and air receivers for compressed air generation system, air handling units and chillers for air conditioning and ventilation system was under progress.

The project has achieved an overall physical progress of over 91%.

## RESEARCH & DEVELOPMENT FOR FAST REACTORS

### Fast Breeder Test Reactor (FBTR)

The reactor was operated up to a maximum power level of 20.3 MWt with the Turbo Generator (TG) synchronized to the grid generating a maximum power of 3.5 MWe. Duration of high power operation of the reactor

was about 880 hours and TG operation was 700 hours. The total thermal energy developed during the period was 16843 Mwh

In the nineteenth irradiation campaign, low power physics experiments were carried out and power was raised to target power of 20.3 MWt and the Turbo Generator (TG) was connected to grid. The campaign was completed when the MK II fuel subassembly attained the target burnup of 100 GWd/t which was transferred to periphery.

In-service inspection of critical weld joints of one of the secondary sodium systems was carried out and the loop was normalized. The Industrial version of Kalman reactivity meter, developed by BARC for PFBR, was tested. The Switchover Logic Circuit (SOLC) in the Central Data Processing System was replaced and functional testing was completed.

Twentieth irradiation campaign was commenced. The Industrial version of High Temperature Fission Counter (0.1 cps) being developed by BARC for in-core neutron flux measurement in PFBR was tested at various power levels up to a maximum power of 10MWt.

Review of 'Periodic Safety Review' document was completed and periodic safety report was submitted to AERB for relicensing of FBTR.

Post Irradiation Examination (PIE) was carried out on PFBR MOX test fuel subassembly irradiated in FBTR to a burnup of 112 GWd/t.

### R&D relating to PFBR

Inclined Fuel Transfer Machine (IFTM) of PFBR exchanges core sub-assemblies between reactor vessel and fuel building during fuel handling operation in reactor shutdown condition. IFTM was designed by BARC to meet stringent requirements that are demanded by

Inclined Fuel Transfer Machine for PFBR designed by BARC

Facility for testing componentsat IGCAR

argon/sodium environment, high operating temperature, sealing, shielding, alignment at fuel handling temperature etc. Integrated IFTM assembly was manufactured, assembled and

leak testing of assembly was successfully completed. The sequence of fuel handling operation was also successfully tested.

High Temperature Boron-10 Coated Proportional Counters which can work upto 250°C, were developed at BARC for PFBR. An eight channel ultrasonic imaging system for under-sodium viewing of fuel sub-assemblies of PFBR was developed to view the fuel assemblies of the Fast Breeder Reactor and check for defects.

Absorber Rod Drive Mechanisms and the portions of inclined fuel transfer machine (IFTM) were tested and qualified in air & sodium. Performance tests on Transfer Arm and Integrated testing of IFTM in air were completed. Testing of the secondary sodium pump was completed, while that for the primary sodium pump, the same was continued. Seismic qualification tests on various components and systems were completed.

Sodium piping, IGCAR

Many advanced thermal hydraulics and structural mechanics analyses were completed towards the issues that have arisen post Fukushima. Commissioning sequence and procedure were finalized and commissioning of the system was commenced.

Erection of Turbine IP rotor

The irradiation performance of D9 cladding and wrapper of PFBR MOX test assembly irradiated in FBTR was assessed through swelling and mechanical property measurements carried out in the hot cells.

Post Fukushima analysis activities included assessment of safety margins of reactor components and safety of civil structures under sever earthquakes beyond limits, flood levels higher than 2004 Tsunami levels including issues of flooding of power island, sequential leakage of main and safety vessels, simultaneous double ended guillotine rupture of two primary pipes, multiple failure of Safety Grade Decay Heat Removal heat exchangers (SGDHRs), hydrogen generation need for hydrogen recombiners.

Thermal analysis of spent fuel storage bay under a prolonged station blackout condition was carried out for two different decay power load conditions of the water storage pool.

Mutual Inductance based level probes for continuous measurement of sodium level at discrete locations, manufactured by Indian Industries were calibrated at different temperatures ranging from 453 to 823K, before deployment in the reactor. About 58 probes were calibrated and delivered to BHAVINI for installation towards monitoring the level of sodium in the reactor vessel of PFBR.

High temp detectors for initial fuel loading

High temp detectors for use after long shutdown

PFBR Continuous Level Probe with pocket

Calibration facility for Level probes

**R&D for Future FBRs**

At IGCAR, an integrated top shield test facility was successfully constructed & commissioned to validate the thermal design of the top shield. Experimental studies were carried out with the facility simulating normal operation of the reactor as well as fuel handling condition.

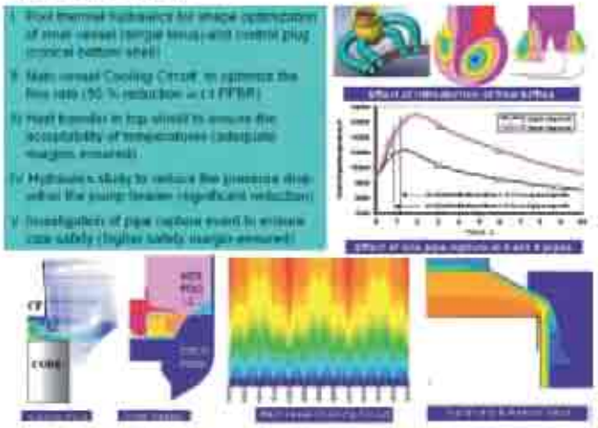
Top shield test Facility, IGCAR

To realize the full potential of indigenous nuclear resources through FBRs, Department has plans to build one twin unit each of 500 MWe capacity oxide fuelled fast breeder reactors (CFBR) in the vicinity of PFBR site at Kalpakkam and also to introduce metallic FBR at the earliest. R&D activities on fuel development including fabrication and irradiation aspects were carried out on priority. IGCAR is planning to construct a 120 MWe Metallic Fuel Test Reactor (MFTR) at Kalpakkam to get complete power plant experience including associated closed fuel cycle (pyro-processing) and manufacturing technologies.

The design modifications introduced in the reactor assembly of CFBR were confirmed with respect to thermal hydraulics design aspects through multi-dimensional thermal hydraulic studies.

Baffle plate configuration was incorporated inside the spherical header of the

primary sodium pump to reduce the pressure loss significantly. Higher safety margins in meeting the design safety limits for the core safety, with four primary pipes per pump compared to two pipes per pump were demonstrated.



Thermal hydraulics design confirmation of CFBR

Tri-junction forging for roof slab

Large diameter bearing for top shield

Thick plate welding for rotatable plug

R&D on manufacturing development technology was essentially called for certain key components that govern the economy, for which major conceptual changes were incorporated and many major and medium Indian industries

Welded Grid Plate

Inner vessel with single torus

were involved with a focus on total indigenization. This exercise provided many important feedbacks for the commercial deployment of CFBR in near future.

Eddy Current Position Sensor (ECPS) based technique was adopted to detect the position of DSR in the dashpot and measurement of free fall time of DSR after the de-energisation of the holding electromagnet and it was integrated with DSRDM for testing in air / water.

## Thermal Hydraulics, Component Testing and Validation

Laboratory scale studies on plutonium bearing alloys and engineering scale studies on alloys of natural uranium upto 1 kg per batch scale were carried out. Facilities were planned to set up for scaled up studies on alloys of natural uranium at 10 kg per batch scale in the next few

Ambient Temperature Electro Refiner facility

years so that experience can be generated for designing a pyro-process plant for the Metal Fuelled Test Reactor (MFTR). As a first step, an Ambient Temperature Electro Refiner (ATER) was commissioned to carry out validation of mechanical engineering design, automation and remote handling.

## Steam Generator Test Facility

Plugged tube experiment was carried out in the SG of Steam Generator Test Facility (SGTF) by plugging a healthy tube. Experiment was repeated for four tubes which are at different orientations at the nominal power of 5.5 MWt.

The material of construction of PFBR SG was modified to 9Cr-1Mo and the same material was used for the model of SG in SGTF too. Experiments were carried out in SGTF to estimate hydrogen flux through SG tube walls.

Experiments were carried out to study the tube damage (impingement wastage as well as self wastage) phenomenon to understand the wastage resistance of 9Cr 1Mo tube materials, in Sodium Water Reaction Test Facility. Two experiments were carried out in IGCAR in collaboration with CEA France under a bilateral agreement and the results are being analysed.

Impingement wastage during steam generator tube damage studies

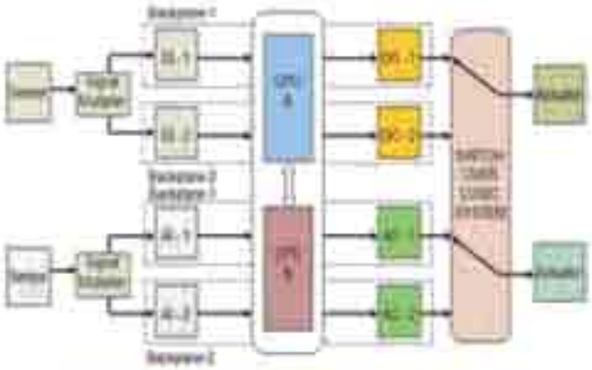
Self Wastage during the steam generator tube damage studies

## Control systems & sensors

Soft-Core Processor based single board Data Acquisition and Control systems called Remote Terminal Units (RTU) were developed for acquiring analog/digital signals, sending/receiving digitized data packets over Ethernet using TCP/IP protocol and generating control outputs (digital/analog) during all states of plant operation for reading the surface thermocouple & leak detectors mounted on sodium lines and control heaters in FBRs.

A fault tolerant PLC for safety related applications in fast reactor fuel reprocessing plant, using Commercial Off The Shelf (COTS) Schneider PLC, with redundant CPU, Input/Output, Ethernet Communication & Power supply modules, was implemented with in-house developed Switch Over Logic System (SOLS).


Soft-Core Processor based RTU for FBRs



Architecture of Fault Tolerant PLC with CPU & I/O redundancy and SOLS

Simultaneous calibration of thermal conductivity detector and semiconductor based hydrogen sensor systems for argon cover gas was carried out in the Sodium Water Reaction Test facility by simulating low power operation of reactor.

The fabrication and testing of electrochemical hydrogen meters (ECHM) for the online determination of hydrogen in liquid sodium in PFBR was in progress. One such system was sent to Cadarache, France, for its assembly in a sodium loop facility for testing and comparing the performance with conventional diffusion type meters, as part of an IGCAR-CEA collaborative programme.

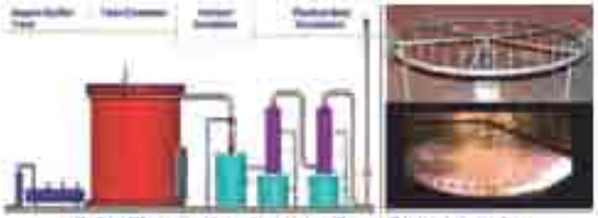
System with an online plot recorded during conductivity measurement of sample

Fault tolerant PLC

## Reactor Safety

The design evaluation & performance of Leak Collection Tray (LCT) (a passive sodium fire suppression device to mitigate sodium fire) was done in Sodium Fire Experimental Facility. Further improvement and optimization of LCT design was planned.

Sodium Leak Collection Tray experiment



A facility to simulate sodium fire scenario on top shield platform

An integrated experimental facility was commissioned to investigate the possible scenarios of sodium fire and followed by cable fire on the top shield platform, consequent to core disruptive accident and also to assess the structural integrity of Safety Grade Decay Heat Removal (SGDHR) piping passing through platform.

A series of tests were performed with Woods metal in water, simulating hydrodynamic and thermal characteristics of molten UO2 towards confirming the availability of natural convection path for the post accident heat removal purpose.

Grid Plate melt through tests

The important data collection for the validation of code through digital imaging and processing with high speed photography was under development.

Non-Contact Ultrasonic Inspection System developed by BARC for Health Check of Radioactively Contaminated Ultrasonic-

Transducers of Under Sodium Ultrasonic Scanner (USUSS) of PFBR was used before every "under-sodium" viewing campaign in PFBR, to test proper functioning of the ultrasonic transducers of the under-sodium viewing system.

Under Sodium Ultrasonic Scanner

High temperature Ultrasonic transducers for Under Sodium Ultrasonic Scanner (USUSS) of PFBR were developed. Eight Downward Viewing Transducers and four Side Viewing Transducers were qualified for use in PFBR USUSS.

### Reactor Physics and Shielding

A test capsule containing Ferroboron was fabricated and introduced in FBTR core to simulate neutron fluence seen by the Ferroboron over its lifetime in CFBR.

### Radiological Safety

An indigenous D-D Neutron Generator consisting of an ion source, an accelerating column, a DC High Voltage unit and a frozen D2O stationary target assembly was developed for neutron shielding related studies.

D-D Neutron Generator

Gene Expression Analysis was carried out for estimating individual absorbed doses in case of accidental scenarios. A numerical modeling study for examining the atmospheric dispersion pattern from all the facilities at Kalpakkam were carried out. A CFD code was used for detailed modeling.

### Environmental Safety

Effective and uninterrupted radiological surveillance for normal and special operations were provided to Radiochemistry laboratory, Fast Breeder Test Reactor, Post Irradiation Examination facility, CORAL and KAMINI. Processing of 1600 badges per month for TLD personnel monitoring services for 8 facilities and the whole body counting and bioassay programs covering on an average about 1000 radiation workers and over 200 occupational workers were completed. Counting facilities and calibration facilities were also extended to various institutions involved in BRNS projects and industries in southern region. Radiation awareness training programs on a periodic basis for the staff, general public and students were also conducted.

## Studies on materials for FBRs

During the year following studies were conducted on various aspects of materials for fast breeder reactors:

- Tensile and creep properties of modified 9Cr-1Mo steel clad tube for metallic fuelled fast reactor
- Long-term creep life prediction of modified 9Cr-1Mo 91 steel
- Establishment of resisting stress approach for constitutive analysis in hot working of modified 9Cr-1Mo steel
- Ratchetting behaviour of 316LN stainless steel in the dynamic strain aging regime
- Indigenous development of thermo-mechanical axial torsion testing machine
- Design, development and testing of high temperature in-sodium pin-on-disc tribometer
- Fabrication of 304L stainless steel pipes by activated tungsten inert gas (A-TIG) welding process for their evaluation under flowing sodium
- Corrosion studies in a bimetallic loop
- Development of Alloy D9 to Alloy D9 weld joints

High-temperature combined axial and torsion testing system

## FBR - Front End Fuel Cycle

During the year, mixed carbide fuel pins for FBTR at Kalpakkam were supplied by BARC as per requirement. Regular dispatch of (U-Pu) $O_2$ mixed oxide (MOX) fuel pins for the 500 MWe Prototype Fast Breeder Reactor (PFBR) of BHAVINI was commenced and the target to supply 50 % of the requirement of fuel pins for achieving criticality is expected to be met shortly. To enhance the production, second line with automation for manufacturing of the MOX fuel was made operational. The third line with Pu for fabrication of MOX fuel for PFBR is expected to be activated shortly.

Fuel pins in Pin Storage

Second glove box line for manufacture of MOX fuel

For the development of metallic fuel for fast reactor applications, U-6.33 wt.% Zr was produced in kg scale for preparation of U-19 % Pu-6.0 % Zr alloy fuel slugs. These slugs will be

utilized for fabrication of sodium bonded metallic fuel for irradiation trials in FBTR.

As a part of fuel development program, metallic fuels and blanket material of compositions U-15 wt.% Pu and U-6 wt.% Zr respectively were prepared. X-ray diffraction, microstructure, phase stability, co-efficient of thermal expansion, hot hardness and fuel-clad (T91 steel) chemical compatibility were studied. The temperature for eutectic formation between U–15 wt.% Pu fuel and T91 was established as 948 K and the input was provided to the designers.

CERMET fuel development program continued with fabrication and characterization of cermets of different compositions viz. uranium containing 15, 20, 25 and 30 wt.% $UO_2$. Compatibility of the CERMET fuel with T91 steel cladding with and without Zr liner was established.

Ten enriched U-6 wt.% Zr alloy slugs, meeting required specifications, were produced and supplied to IGCAR, Kalpakkam for fabrication of test fuel pins for irradiation trials in Fast Breeder Test Reactor (FBTR). Eddy current tests (ET) were used to confirm that the slugs were free of defects. Natural U-6wt%Zr alloy slugs were produced and supplied to IGCAR, Kalpakkam for standardization of pin fabrication, sodium bonding, pin characterization and pyro-processing studies.

A calorimetric study of the high temperature phase equilibria of iron-uranium binary system important for understanding the interaction between the steel clad materials and the metallic fuel was carried out with supporting metallographic investigation.

Ferro boron capsule used for irradiation

To determine the in-reactor performance of ferro-boron, an irradiation capsule was designed and fabricated and is being tested in FBTR

Studies on the sol-gel vibrocompaction method of fuel fabrication were in progress and two test fuel pins, to be irradiated in FBTR were fabricated at BARC for the first time, using the fuel materials in the form of micro spheres produced through sol-gel route.

Studies on coolant included thermochemistry of fission product systems and Radwaste immobilization matrices.

Electrodeposition of boron from molten salt bath was studied. Boron equilibrium potentials were also measured from the open circuit potentials of the electrodeposited boron on platinum electrode in the salt bath.

## FBR- Back End Fuel Cycle

The development studies on pyrochemical reprocessing for spent metallic fuels from FBRs are in progress. Sodium bonded metal fuel pins were chopped in the engineering scale facility for pyro process studies and electro refining was carried out.

A laboratory-scale set-up incorporated inside an argon atmosphere glove box was commissioned. A V-shaped mixing set up was fabricated and used for equilibration of molten salt.

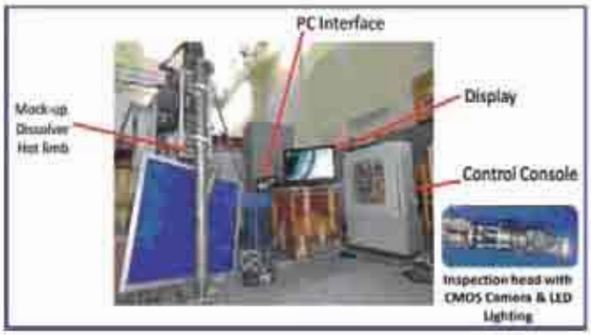
Separation of minor actinides from lanthanides was carried out for the first time using a 16-stage mixer settler in a hot cell and the product solution from a Carbamoyl Methyl

Phosphine Oxide (CMPO) run with High Level Waste (HLW) solution from reprocessing of FBTR fuel as the feed. Diglycolamic acid was used for the extraction of minor actinides into the organic phase and Diethylene Triamine Pentacetic Acid (DTPA) for stripping them back to aqueous phase. The flow sheet optimization was done using a 20 stage mixer- settler in a glove box using europium and americium tracers.

The recovery of plutonium from various polymeric matrices such as neoprene, polyvinyl chloride (PVC) and surgical gloves was demonstrated using supercritical carbon dioxide (Sc-$CO_2$) modified with n-octylphenyl N,N-diisobutyl Carbamoyl Methyl Phosphine Oxide (CMPO) in methanol. The plutonium recovery was found to be 97-99 % from the actual waste i.e. PVC waste containing plutonium. Super–critical Fluid Extraction technique developed offered a potential method for the recovery of actinides with generation of minimum secondary waste.

Separation of U(VI) and Pu(IV) from a simulated mixture containing Am(III) and trivalent lanthanide fission products was successfully carried out with ejector mixer-settler.

A novel approach towards detection of third phase during reprocessing of fast breeder reactor fuel was developed. Corrosion behaviour of carbon allotropes exposed to molten lithium chloride – potassium chloride salt were studied.




Mock-up dissolver vessel mounted with three-axis scanner

Mock up dissolver image acquired during trials

Ceramic coatings on crucibles and samples for pyro-chemical reprocessing applications were found to be highly corrosion resistant. A remote 3-axis scanner was developed for in-service inspection of DFRP dissolver vessel. Mock-up trials and validation of the device for underwater visual examination were conducted successfully in a test vessel made of 304L stainless steel.

The reprocessing of spent fuel of FBTR mixed carbide fuel in the CORAL pilot plant facility was carried out successfully. The recovered plutonium was re-fabricated into fuel subassembly and put back in FBTR this provided valuable inputs for the design and operation of future plants of fast reactor fuel reprocessing. Several of the feed backs were incorporated in the Demonstration Fast Reactor Fuel Reprocessing Plant, designed for closing the fuel cycle of FBTR and for demonstrating the reprocessing of PFBR spent fuel assemblies, which is in advanced stage of construction.

A view of piping and process vessels inside the hot cell in DFRP

A modified electrolytic dissolver with salient features such as improved agitation arrangement of hull to reduce Pu loss and provision of separate dissolver and electrolyser units, was designed for the dissolution of Pu-rich mixed carbide or oxide fuel of FBTR at DFRP.

A view of the transmitter gallery for the C&I of DFRP

High temp detectors for use after long shutdown

## R&D for Reprocessing

In order to reduce the number of solvent extraction cycles for FBR fuels containing high plutonium, formulation & validation of extraction flowsheet was carried out. Computer code was developed to incorporate the prediction of extraction equilibria of all the forms of troublesome nuclides. A flowsheets were designed one with a single cycle extraction, followed by partitioning of uranium and plutonium with the judicial reduction of plutonium from the

A 20 Stage Airpulsed mini mixer-settler to carrying out simulated flowsheet runs in a glove box

Centrifugal extractor bank in glove box for solvent extraction flowsheet studies

organic phase for the target recovery of plutonium and another for complete separation of uranium and plutonium with the required decontamination.

The flowsheet was analysed by the computer code and validated by simulated runs with an air-pulsed mixer settler and the same flowsheet were tested in centrifugal extractor to study the impact of low residence times in the extractors.

A fiber optic aided spectrophotometric (FOS) technique was developed for the determination of ruthenium (III) in nitric acid medium. Effect of nitric acid concentrations was also investigated.

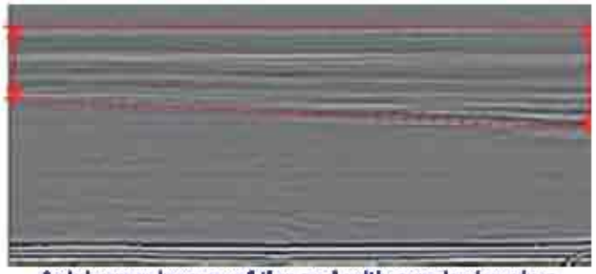
### Fast Reactor Fuel Cycle Facility

Detailed design of the Fast Reactor Fuel Cycle Facility to close the fuel cycle of PFBR was completed. Clearance from the project design safety committee was received for launch of the project.

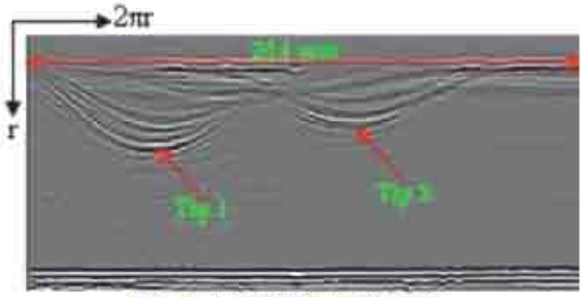
### Inspection Technologies

Innovative developments achieved in the field of Inspection technologies were as follows:

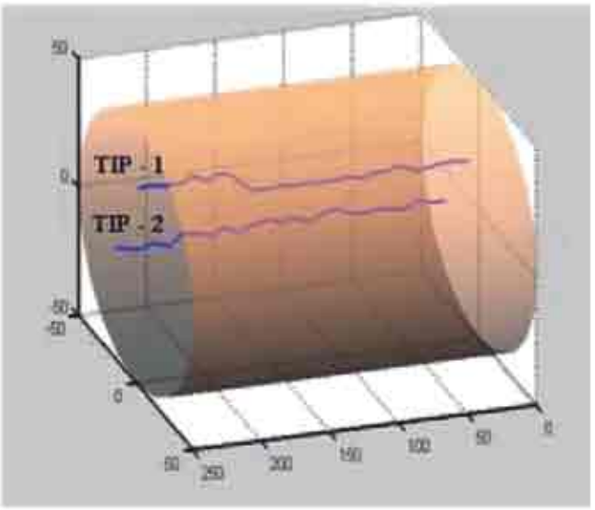
- Development of data fusion methodology for enhanced detection of defects in alloy D9 cladding tubes
- Study of crack growth behaviour in concrete using acoustic emission technique
- Innovative Application of Ultrasonic Time of Flight Diffraction Technique for Accurate Determination of Cracks inside Metallic Rods



Axial scan image of the rod with crack showing extend of the crack along the length of the rod




Circumferential scan image shows the tips of the crack




3D view of the crack profile in the rod

# CHAPTER -3

# NUCLEAR POWER PROGRAMME STAGE-III

C-C composite prototype tubes for CHTR

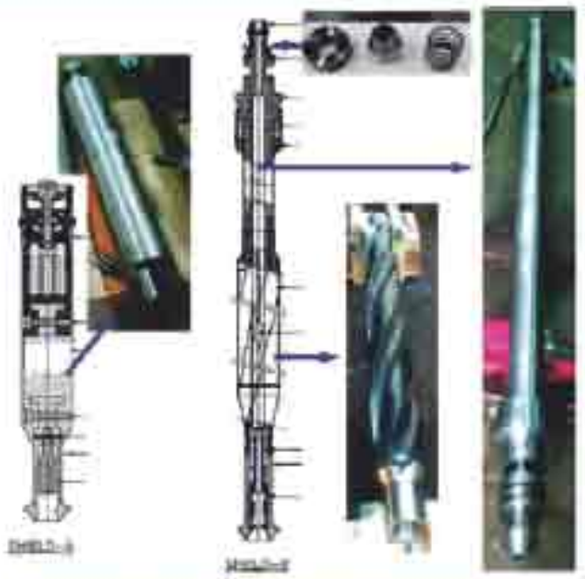
Machining Setup for CHTR Fuel Tubes

CHAPTER 3

# NUCLEAR POWER PROGRAMME STAGE-III

## THORIUM BASED REACTORS

The Indian Nuclear Power Programme Stage-3 aims at using thorium as fuel for power generation on a commercial scale. In the thorium fuel cycle, thorium-232 is transmuted into the fissile isotope uranium-233 which is a nuclear fuel. As a part of this programme, BARC has been developing a 300 MWe Advanced Heavy Water Reactor (AHWR). Fuelled by thorium and using light water as coolant and heavy water as moderator, this reactor will have several advanced passive safety features.



Structural components for AHWR fuel assembly

## ADVANCED HEAVY WATER REACTOR

AHWR Thermal-hydraulic Test Facility (ATTF), Tarapur is a twin channel scaled integrated test facility simulating AHWR thermal-hydraulics. Specifically it simulates the Main Heat Transport (MHT) system, steam and feed system, Emergency Core Cooling System (ECCS) and associated controls. The main building of facility and annex building housing the control systems and power supplies were readied for equipment installation. All ATTF vessels and heat exchangers were installed at site and piping prefabrication was in progress.


ATTF Tarapur

The structural components for AHWR fuel assembly were manufactured for carrying out the full-scale experimental/handling trials to be carried out at Fuelling Machine Test Facility, Tarapur. Manufacturing of components for the Shield-A and helically grooved Shield-B for AHWR fuel assembly was completed.

Fuel Rod Cluster Simulator (FRCS) was used for the investigation of the thermal hydraulic behaviour of reactor fuel elements under normal and accidental conditions. Nuclear heat generation was simulated by electrical heating in FRCS, which was used for out-of-pile experiments. Development of an indirect resistance heating type FRCS was also completed.

A novel buckling pin type passive valve was developed and demonstrated for Emergency Core Cooling System (ECCS) of AHWR. Under normal condition, the valve is closed with the buckling pin holding a piston / plug in place.

Based on designs, operational considerations, stability aspects and safety analyses for different Postulated Initiating Events (PIEs) various trip and setback parameters were finalized for AHWR. Availability of primary, alternate and backup trip parameters for different Postulated Initiated Events (PIEs) in all categories, avoiding spurious trip and overlapping of settings of the reactor trip parameters for shut down systems 1&2 (SDS-1 & 2) and Passive Poison Injection system (PPIS), online testing of safety systems and two group philosophy were taken into consideration. A number of trip coverage analyses were done to arrive at different trip parameters. Prediction for an enveloping scenario of station blackout with failure of wired shutdown system for deciding PIPS setting was given.

A prototype Fuelling Machine (FM) was designed and fabricated to validate its design. To enable X-Y positioning during the testing of FM at Integrated Test Facility, Tarapur (ITFT) and to take care of load and stability of entire FM assembly a Fuelling Machine Test Carriage Assembly was designed. Test carriage was manufactured, installed, load tested and commissioned in FM Test Facility.

Test Carriage Assembly in ITFT Building

Several equilibrium core clusters were studied for the on-power refuelling of AHWR-LEU core. Different refuelling strategies were tried to bring the maximum channel power close to the design limit such that the reactor could be operated at the rated power. Several refuelling strategies like single channel, mini batch, mini batch refuelling scheme mixed with reshuffling etc. were used.

The in-house 3-D space-time neutronics code ARCH (Analysis of Reactor transients in Cylindrical & Hexagonal Geometries) was coupled with thermal hydraulics code RELAP5 (Reactor Excursion and Leak Analysis Program 5) to simulate the reactor transients with the feedback effect at each feedback time step.

Coolant density and fuel temperature feedbacks were introduced into the coupled code and it was tested. Rod withdrawal scenarios and Loss of Regulation Accident (LORA) were simulated with coupled neutronics and thermal hydraulics code ARCH-RELAP5 as part of the testing and validation.

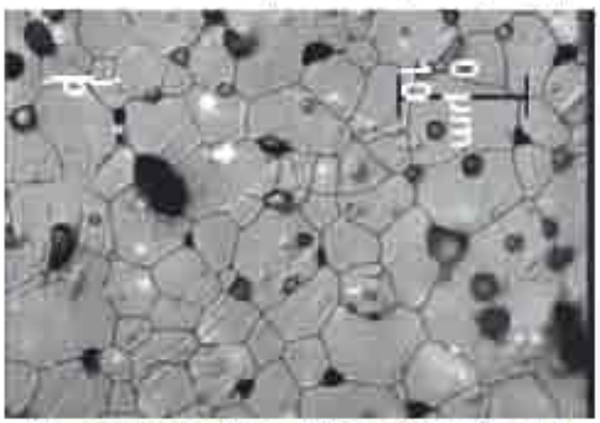
Detailed experimental and numerical studies were performed to study the liquid


Experimental Investigation Setup at BARC

behaviour in Gravity Driven Water Pool (GDWP) of AHWR and for evaluation of hydrodynamic effects. A setup was fabricated for the experimental investigation and tested on shake table. Pressure transducers were installed on the tank to capture pressure variations and the results were validated with numerical investigation.

Critical Facility for AHWR and 540 MWe PHWR was operated for various experiments. Experiments for estimation of Westcott neutron spectrum parameters by irradiating bare and cadmium coated copper and lutetium foils and estimation of the effective "shielding factor" for the yield (betas) of delayed photo-neutron groups for reference core fuel assembly by photo neutron decay were carried out. An integral experiment was carried out by observing critical height with one (Th-LEU) mixed pin cluster loaded in the centre and five other core locations. Use of Critical Facility was continued for testing of nuclear detectors and irradiations of large volume samples for Neutron Activation Analysis.

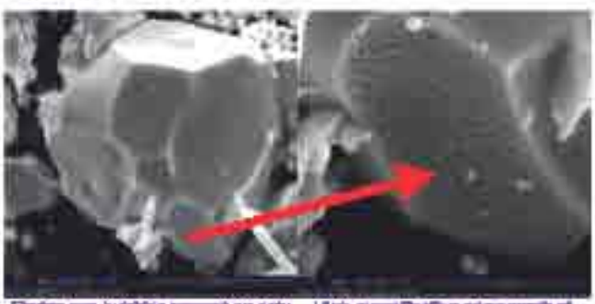
Microstructures of as polished $ThO_2$-22.5% $UO_2$



Microstructures of sintered $ThO_2$-18% $UO_2$ pellet

Fuel fabrication process flow sheet for AHWR300 LEU was established using natural $UO_2$ in laboratory (kg) scale. Evaluation of the fuel in terms of the thermo-physical properties was carried out. The work was extended to include simulated high burn-up nuclear fuel (SIM fuel) simulating different burn-ups. Work was in progress for re-cycling and recovery of process rejects using both dry and wet routes. Conceptual plant design, in line with the regulatory requirement was completed and the layout of the plant was optimized.

Post Irradiation Examination (PIE) of fuel pins from an experimental fuel cluster BC-8, comprising of twelve fuel pins of PHWR design with fuel pellets of different chemical composition, irradiated to a nominal burn up of 10,000 MWd/t (heavy metal) was carried out. Microstructures of Thoria-Plutonia mixed oxide (MOX) fuel confirmed the low fission gas releases observed in the fuel pin during fission gas analysis.



Fission gas bubbles present on only one of the faces of grain of the Thoria-plutonia MOX fuel

High magnification micrograph of the fission gas bubbles on the face of a grain

## Thorium Fuel Cycle

Studies on the validation of process flow-sheet for AHWR spent fuel reprocessing using simulated feed solution of known burn up (43

GWd/te, 5 year cooled) was completed. A solvent extraction based flow-sheet to recover Pu, Am and Ag was developed using TBP and TEHDGA for these dissolved effluents thereby completing the entire process flowsheet.

Uranium Thorium Separation Facility (UTSF) was operated for recovery of thorium from thorex process raffinate generated during reprocessing of irradiated thoria rods.

Four pieces of prototype fuel tube made of high-density carbon-carbon composite was prepared in collaboration with National Physical Laboratory (NPL), New Delhi.

The interface in all the extractors and strippers were detected and maintained as required. Periodic samples were collected and analyzed by ICP-AES. Overall results indicated separation efficiency of more than 99.8% for uranium and rare earths.

Fuel compacts containing 25 volume % TRISO coated $ZrO_2$, as surrogate fuel kernels, blended with graphite powder were fabricated by wet and dry routes using powder metallurgical techniques. The distribution of coated particles in the graphite matrix was studied by radiography.

CHTR fuel compacts with 25 vol% TRISO coated $ZrO_2$ surrogate kernel

X-ray radiograph of compact showing the distribution of kernels in the matrix

Parameters were optimized for making CHTR dummy fuel pellets up to 47 % packing density. A scheme for automation of large scale production of pellets was also made.

Some of the components like fuel tube, reflector blocks, moderator blocks and upper plenum for CHTR were successfully machined. Jigs and tools for machining and inspection of these components were also designed and fabricated.

Tool for convex profile


Moderator blocks

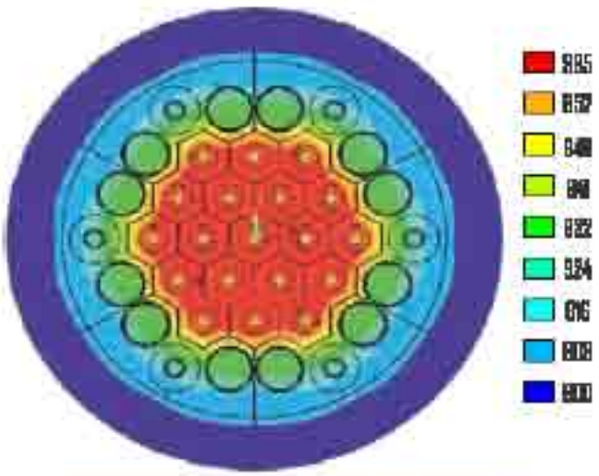
Tool for concave profile

Tool for hexagonal profile

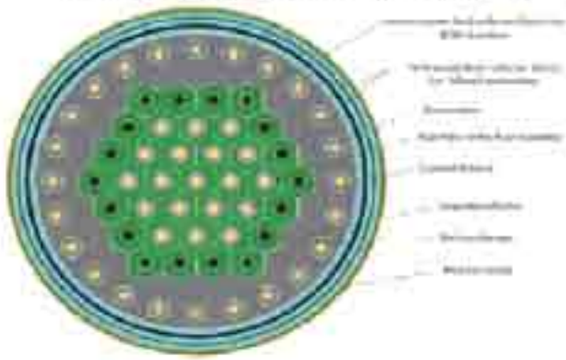
In order to maximize the yield and minimize rejections for production of uranium castings for special applications, a centrifugal casting machine has been designed, fabricated and installed. Centrifugal casting trials for producing two hemispherical casting with copper were carried out in order to optimize process parameters. The necessary modifications for use in vacuum are being carried out.

## Other Reactor Systems

For the Compact High Temperature Reactor (CHTR) critical facility, alternative design of the SDS-2 system, based on liquid poison injection was worked out. Reactor physics analysis and layout related studies were carried out.



Temperature within CHTR core under NOC



Compact High Temperature Reactor

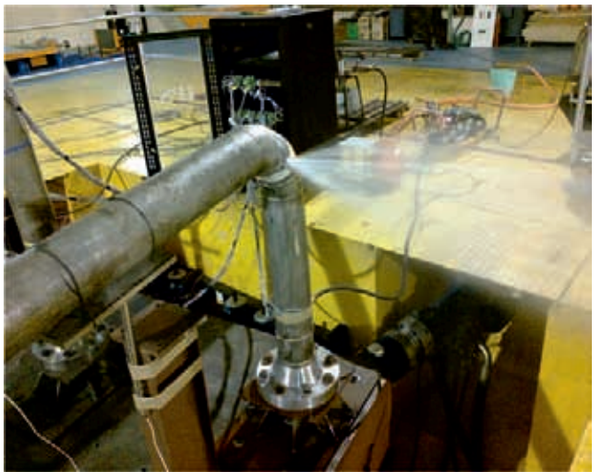
Computational Fluid Dynamics (CFD) based thermal hydraulic analysis of the reactor and detailed thermal analysis of the core of the reactor under normal and postulated accident conditions were carried out. Alternative SDS-2 system based on liquid Indium and spherical B4C absorber particles were analyzed for the CHTR core. Reactivity worth of twelve reflector holes filled with liquid Indium as secondary shutdown system was found to be adequate to shutdown the reactor in case of most reactive core condition.

Detailed project report for construction of a 30 MW High Flux Research Reactor (HFRR) and a new thermal research reactor of 125 MW at new BARC campus Vizag were prepared.

### Accelerator Driven Sub Critical systems

Experimental and analytical studies were carried out on pressurized piping system pressurized with water up to designed pressure. The pressurized piping system was subjected to a series of seismic waves. Extensive tests were carried out on the wires and device made of Shape Memory Alloys (SMAs) at various frequencies and amplitudes to understand pseudo-elastic effect and energy dissipation.

Test Set of Piping System



Strain accumulation at mid anchor

Extensive tests were carried out on the wires and device made of Shape Memory Alloys (SMAs) at various frequencies and amplitudes to understand pseudo-elastic effect and energy dissipation. The results were validated using a thermo-mechanical model of SMA taking into account the residual martensite accumulation and reduced apparent modulus of elasticity of the austenite while unloading.

Model of steel frame connected with dampers

Effect of SMA damper was also demonstrated considering the case of steel structure subjected to earthquake loads.

## Materials

Hexagonal shaped beryllium blocks were fabricated for BHAVINI for neutron source applications. The beryllium blocks were consolidated through vacuum hot pressing

followed by machining to achieve the specified dimension. To make one stack, 15.6 kg of beryllium powder was used. About 23.5 kg of beryllium metal pebble was produced and stock piled to be used to produce remaining two stacks for post acceptance of the first stack.

About 171 stacks from 7355 pellets (CSR), along with an additional batch of 500 pellets, were prepared, qualified and supplied to BHAVINI, Kalpakkam.

Separation of high purity erbium from its concentrate containing 4% $Er_2O_3$ was carried out in two cycle process. Pure yttrium of more than 99.5 % was obtained in the raffinate phase while erbium was upgraded to 15 % in the strip liquor. The strip solution was further processed to upgrade erbium content to more than 90 %.

Rare earth-transition metal based alloy powders, such as $Sm_2Co_{17}$, $SmCo_5$ and $Nd_2Fe_{14}B$ have been prepared by reduction-diffusion method. $Sm_2Co_{17}$ production was scaled up and 1 kg of purified $Sm_2Co_{17}$ was supplied to DMRL for evaluation of magnetic properties. Besides this La, Ce, Pr metals and La-Mg and Nd-Fe alloys were synthesised by fused salt electrolysis process.

In continuation of the developmental activity of TRISO-coated fuel further work was carried out with uranium oxide material. The existing coating unit was re-engineered to achieve spouting for uranium oxide kernels and commissioned in accordance with the guidelines of the safety committee. Trial experiments on $UO_2$ kernel was carried out. Existing centrifugal fluidization facility was modified to achieve carbon overcoat on surrogate alumina particles to develop a carbon overcoat on the TRISO fuel particles so as to ensure that TRISO layers were not damaged during compaction of fuel particles.

Beryllium Blocks for BHAVINI reactor

Carbon-Carbon composite tubes were developed following a fabrication route involving multiple cycles of resin impregnation and graphitization for possible use in Compact High Temperature Reactor. This development work was a collaborative effort with NFL (Delhi) and the developed tubes were subjected to detailed characterization.

Two different techniques namely cold solution spray and chemical vapour deposition were developed to coat silicon carbide on graphite. In cold solution spray deposition technique silicon powder was suspended in ethanol and the solution was sprayed on graphite. In chemical vapor deposition technique, Hexamethyldisilane (HMDS) was used and good coating of SiC was found to form on graphite.

Oxidation resistive properties of the uncoated, dense SiC and nanostructured SiC coated carbon fibers were examined. Chemical vapor deposition process was used for the preparation of dense and nanostructured silicon carbide (SiC) coating on carbon fiber using methyltrichlorosilane (MTS). Oxidation behaviour of the coated specimen was conducted using thermo gravimetric equipment.

## Hydrogen Energy

A technique has been developed for fabrication of Ni-YSZ cermet supported single Solid Oxide Fuel Cell (SOFC) in tubular configuration. In order to improve the cell performance, fabrication and testing of 60 mm long tubes has been taken up. Sealing technique

has also been perfected with different commercially available sealing materials. Tubular cells of 100 mm active cell length were fabricated.

Modeling of vapor phase HI decomposition on catalyst in a packed bed reactor were completed and validated with low pressure experimental results. Design of all the equipments and optimization of process parameters for high pressure SS $HI_x$ reactive distillation facility was also completed.

Catalyst performance test setup

## Materials and Technologies related to Fusion Reactor

Corrosion behaviour of SS316L in lead-lithium eutectic in the presence of oxygen was investigated by setting up a thermal driven buoyancy system with a thermal gradient of 100K.

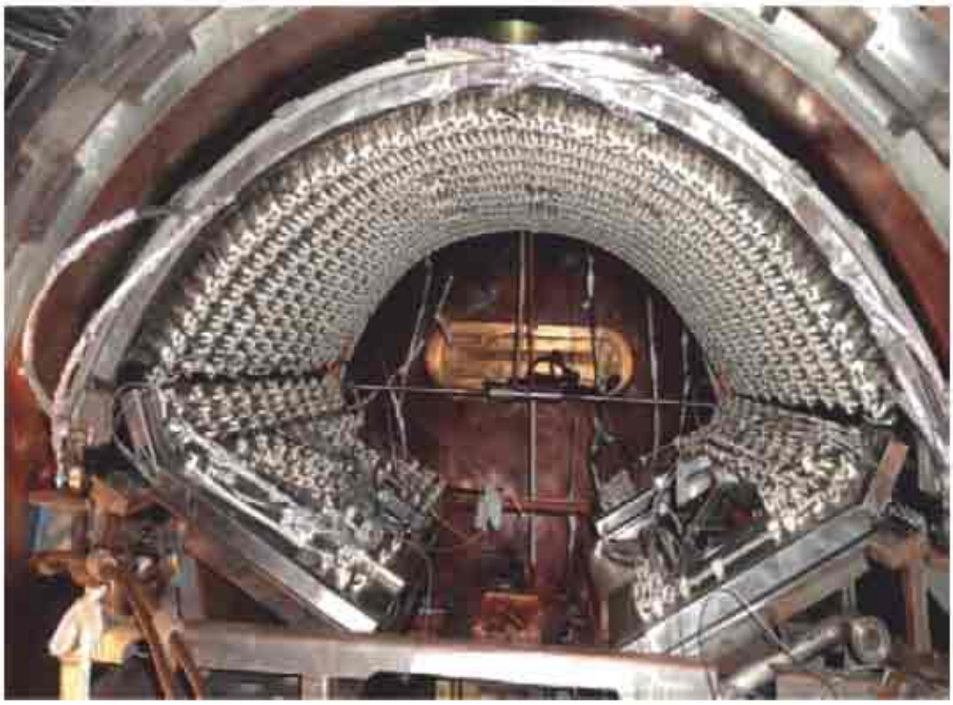
Besides, static corrosion behaviour of SS316L material in lead-lithium eutectic was studied up to 3200 h in a temperature gradient of 550 - 350°C in the presence of other metals like nickel or aluminium.

Solid solubility of hydrogen in the Pb83Li17 was studied between 300-500°C and hydrogen partial pressure of 80 - 105 kPa. The absorption behaviour of V, $LaNi_5$ and vanadium was investigated.

# CHAPTER -4

# ADVANCED TECHNOLOGIES AND RADIATION TECHNOLOGIES AND THEIR APPLICATIONS

1kJ Rep rate Marx system with Reflex developed at BARC



Hot Zone developed by BARC showing heater elements

CHAPTER 4

# ADVANCED TECHNOLOGIES AND RADIATION TECHNOLOGIES AND THEIR APPLICATIONS

Advanced technologies and radiation technologies development and their applications, is one of the major programmes of the Department of Atomic Energy's research organizations such as Bhabha Atomic Research Centre, Mumbai, Indira Gandhi Centre for Atomic Research, Kalpakkam, Raja Ramanna Centre for Advanced Technology, Indore, Variable Energy Cyclotron Centre, Kolkata and the industrial organization, Board of Radiation and Isotope Technology, Mumbai.

These organisations have developed a number of advanced technologies, hi-tech facilities and various sophisticated equipments over a period of time under this programme. This includes Research Reactors, Accelerators, Lasers and laser based equipment, special materials and others. These have many applications in the fields of medicine, industry, and research.

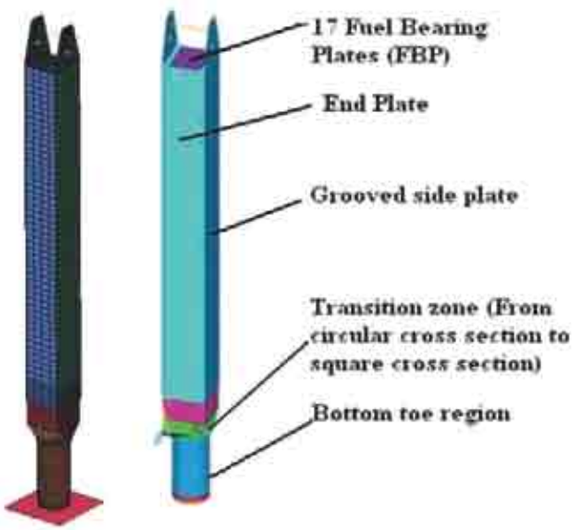
Remarkable contributions in the field of radioisotope production and applications of radiation technologies which are immensely beneficial in the areas of healthcare, nuclear agriculture, food preservation and industry have been made by the above organisations.

To widen the reach of these technologies for the benefit of common man, DAE has been working in close cooperation with other organizations of the Government of India. The major activities and achievements of DAE organizations during the report period were as follows.

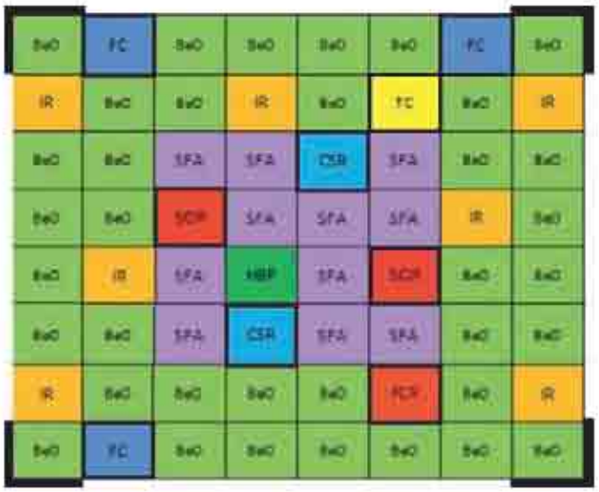
## RESEARCH REACTORS

### APSARA

At Trombay, preparations for demolition of the existing reactor pool block and reactor building were completed to enable up-gradation of APSARA reactor to a 2 MW reactor, with all regulatory approvals. Detailed sampling of the pool block concrete for waste categorization was done. Detailed engineering of the 2 MW upgraded APSARA reactor was in progress. Shielding design of reactor was completed. Safety review of various reactor systems was in progress. Design stage Level 1 Probabilistic Safety analysis (PSA) for the reactor, involving safety system and process system reliability analysis and quantification of the model by generic data was completed.




Schematic of Standard Fuel Assembly and FE Mo



Upgraded Apsara Reactor Core

Impact analysis was carried out for the postulated 300 mm drop in different orientations to find the force experienced by the Fuel Bearing Plates (FBP) of the standard fuel assembly of upgraded APSARA reactor.

## CIRUS

Cirus reactor remained in permanently shut down state. Reactor auxiliary systems were maintained in a preservation mode. Spent fuel discharged from core after permanent shutdown was transferred to Fuel Reprocessing Division. Periodic recirculation of water in the primary coolant and auxiliary systems were done to preserve the systems till decommissioning is taken up. Surveillance was in place as per the "Technical Specifications for Permanently Shutting down Cirus".

## DHRUVA

Research reactor Dhruva continued to operate with a high level of safety and an availability factor close to 80%. Radioisotope production continued at BARC and over 1100 samples were irradiated during the year. About 90 samples were irradiated in Pneumatic Carrier Facility for neutron activation analysis.

Controlled Temperature Irradiation Facility (CTIF)

Platform for Self Serve facility with sample unloading shielded cask

Dhruva continued to be the only facility for radioisotope production and served as a national facility for neutron beam research. A number of research scholars from various academic institutions in the country utilized the reactor under the aegis of the UGC-DAE Consortium for Scientific Research. As part of enhancing reactor utilization following work was carried out.

- Pre-commissioning trials for Self Serve Facility, internal inspection of self serve

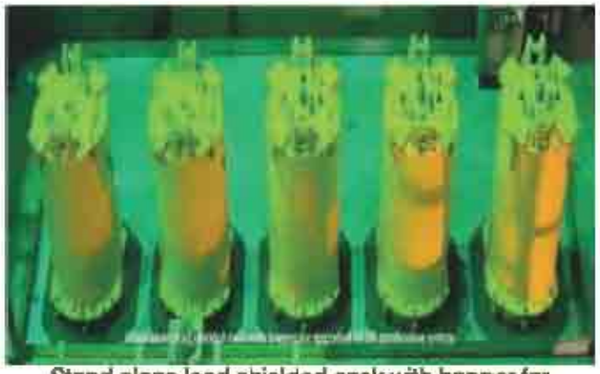
tray positions through loading and unloading tubes was carried out

- A seismically qualified operating platform was designed and fabricated and further commissioning trials were in progress.
- Controlled Temperature Irradiation Facility (CTIF) was commissioned after successful demonstration of motorized withdrawal of the cage assembly.
- Rectification of leak from surge tank (observed during trial hot operation), installation of ECS piping, etc. were in progress.
- Safety assessment of proposed irradiation of gaseous targets ($^{40}$Argon and $^{78}$Krypton) in Dhruva to produce radioactive tracers was completed and necessary clearance from safety committees was obtained.
- Feasibility for production of special isotope in Dhruva by irradiating absorber rods in peripheral locations of the core was studied.
- System modifications for tackling obsolescence and for safety improvement were carried out.

Paperless recorders along with P to I converters and instrumentation for hot operation of In Pile Loop (IPL) were installed and commissioned. Trip, alarm and interlock settings were checked and commissioned. To reduce the dose consumption in the Spent Fuel Storage Bay (SFSB) of Dhruva, up-gradation of the same is being carried out.

The instrument panel for the new purification system was upgraded. Fabrication of the piping system was in advanced stage. Mock up handling were carried out, the system is expected to be commissioned shortly.

IPL Control &Instrumentation Panel



Stand alone lead shielded cask with hopper for upgraded SFSB purification

Automatic Controlled Voltage Rectifiers

All the six Automatic Controlled Voltage Rectifiers (ACVR) were replaced with new generation Silicon Controlled Rectifier (SCR)-based ACVRs for providing power supply. Twelve numbers of 3.3 KV Minimum Oil Circuit Breakers

(MOCB) were replaced with Vacuum Circuit Breakers (VCB). Commissioning work for three numbers of 20 kVA Inverters as replacement for two number of 20 kVA Inverters was under progress.

Newly developed Reactor Regulating System Data Acquisition System (RRSDAS) was commissioned to monitor Reactor Regulating System (RRS) channel-A parameters. Relay based control instrumentation of Main Air Compressor (MAC) #3 & 4 was replaced with PLC based logic.

Overhauling of main Diesel Generator set 1 & 3 was done and performance test of the engines were successfully carried out at full load for one full day.

Replacement of 5 nos. of 20 MW capacity (each) Process water/Seawater shell & tube Heat-exchangers, due to tube thinning, progressed well. Carbon steel pipelines of effluent transfer system were replaced with SS-316 pipelines and successfully commissioned as these lines had started showing degradation due to external corrosion.

Process-water/Seawater heat exchanger replacement

The Fire Alarm System for Dhruva was developed and commissioned. A dummy fuel cluster assembly has been designed for carrying out flow tests and other experimental trials in the IPL test section loop of Dhruva reactor. The

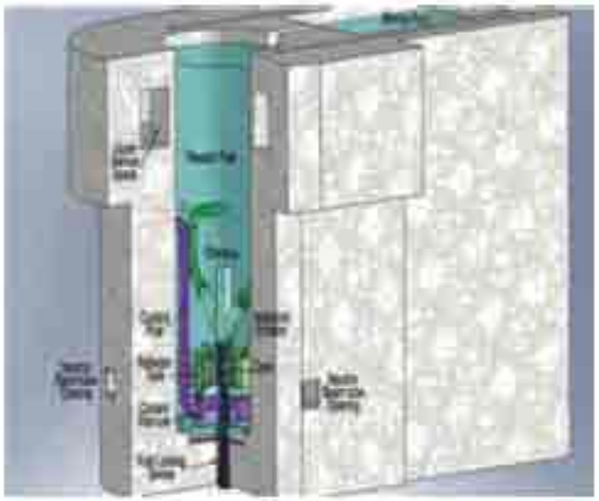
Dummy cluster for DHRUVA 2 MW In-Pile Loop

design of the structural components, the hanging arrangement and the cluster assembly has been completed. The assembly with fuel pins and tie rods is completed.

Development work on a Risk-based In Sink Inspection (ISI) document for Dhruva Reactor has been completed.

### High Flux Research Reactor

Detailed project report for construction of a 30 MW High Flux Research Reactor (HFRR) at



HFRR Reactor Block

new BARC campus Vizag was prepared and submitted for approval.

The proposed HFRR is expected to meet the requirements of high specific activity radio-isotopes and provide enhanced facilities for basic research in frontier areas of science and for applied research related to development and testing of nuclear fuel and reactor materials.

Detailed project report (DPR) of a new thermal research reactor of 125 MW (Th), with identical design features of Dhruva, to be constructed as a XII plan project at BARC Vizag site, was prepared and physics design of the reactor was completed.

## ACCELERATORS

At BARC-TIFR Pelletron Linac Facility, around 50 experiments were performed and a variety of beams were accelerated. Indigenously developed MC-SNICS (Multi-Cathode Source of Negative Ions by Cesium Sputtering) source was tested for performance.

Various composite cathodes and gas feed sputter-cathodes were fabricated and tested at the ion source test bench. The design and development of a Field Programmable Gate Array (FPGA) based Computer Automated Measurement and Control (CAMAC) time-to-digital converter was carried out. The Peripheral Component Interconnect (PCI) modules were successfully used for acquiring detector pulses at a sampling rate of 1 GS/sec.

The 8 MeV linac was developed at Electron Beam Centre to operate in the dual mode, where alternate pulses of 6 & 3 MeV electrons with 1 kW power and beam size of less than 2mm were produced.

6/3 Mev linac System

A 20 kV, 40kJ EMM Machine was designed, fabricated, assembled and tested to its rated value. Electromagnetic manufacturing tools were developed for forming and welding applications. The whole system was accommodated in three racks easily deployable on a shop floor.

40kJ, EMM Equipment

A state-of-the-art superconducting Electron Cyclotron Resonance (ECR) Ion Source was commissioned at Van-de-Graff lab capable of producing large beam currents for almost all elements at high ionic charges. The prototype heavy-ion RFQ was tested up to 1 kW RF power.

The design and development of LIA-400 (400kV, 2-4kA, 100ns, 1-300Hz) repetitive pulsed power system was completed. All the components of LIA–400 were assembled and integrated with 70 kW capacitor charging power supply and load.

Linear Induction Accelerator: LIA-400

A compact repetitive Marx generator rated at 1 kJ, 300 kV, 12 kA, 10 Hz rep-rate suitable to drive the reflex triode configuration for High Power Microwave (HPM) generation has been developed and characterized using an aqueous resistive load and the reflex triode Vircator. A maximum estimated peak power of 48 MW was

60 kW RF Power system source

1 kW solid State Amplifier

obtained at the reflex triode at 35 kV charging voltage with 15 mm anode-cathode (AK) gap.

As a part of the accelerator development program for ADS, a 400 keV, 1 mA, 4 vane RFQ for D+ beam was fabricated and its cold testing was completed. A tetrode based 60 kW RF power system was developed and tested for 62 kW in continuous wave mode. Solid State RF power amplifiers 1kW & 3 kW were designed and developed with conversion efficiency of more than 65 %. Installation of the 20 MeV, 30 mA Low Energy High Intensity Proton Accelerator (LEHIPA) components was started in Common Facility Building (CFB).

A 400 keV, 4 vane RFQ

Klystron Cooling System Heat Exchangers

Klystron Cooling System Piping

The physics design of the 200 MeV superconducting linac for ADS (Phase II) progressed. Installation of equipment and components for klystron cooling system of LEHIPA was completed and the commissioning was in progress.

**Solid state RF amplifier at 31.6 MHz for Indus-1**

At RRCAT, the high power RF amplifier of Indus-1 RF System based on tetrode tube was replaced by an in house developed solid state high power amplifier at 31.6 MHz. Output power from eight MRF141G based 300 watt high power amplifier module was combined to get the required 2 kW of RF power. This solid state RF amplifier was integrated with the Indus-1 RF system on March 2012. The system performed efficiently and required lower maintenance.

31.6 MHz, 2 kW, Indus-1 solid state RF amplifier

**Deployment of 100 kW, 505.8 MHz solid state RF amplifiers at Indus-2**

The development of solid state high power amplifier at 505.8 MHz was expedited in a phased manner to replace Klystron amplifier for use in Indus-2 synchrotron radiation source. Two 50 kW solid state RF amplifiers were developed and integrated with two Indus-2 RF cavities. With the integration of these two high power amplifiers and the optimization of operating parameters of the RF system, Indus-2 is operated at 2.5 GeV/100 mA in round the clock mode.

50 kW, 505.8 MHz solid state RF amplifier

**Electromagnetic design of a multi cell superconducting radiofrequency (SCRF) cavity**

The electromagnetic design study of a

multi cell 650 MHz elliptic superconducting radiofrequency (SCRF) cavity was completed at RRCAT. Higher order mode studies as well as Lorentz force detuning studies on the above SCRF cavity have also been completed. The geometry of the cavity was optimized to obtain the maximum acceleration gradient for a maximum allowed surface field and a minimum power loss.

**Fast corrector power supply for Indus-2 fast orbit feedback system**

A prototype power supply for driving Indus-2 fast corrector magnets has been designed and developed for better stabilization of electron beam orbit which is in turn required to provide required photon flux stability to the users.

The prototype corrector power supply for Indus-2 fast orbit feedback system

TL2 dipole magnet power supply

**Up-gradation of Indus-1 magnet power supplies**

The power supplies for quadrupole magnets and the TL-2 dipole magnets for Indus-1 were upgraded using a full-bridge zero-voltage-switching converter for ease of maintenance, lighter weight and better immunity to mains transients.

**Indigenous development of Helium Liquefier**

Performance of Indigenous Helium Liquefier was further improved from helium liquefaction rate of 6 liters/ hr. to 20 lit/ hr.

Experimental setup of prototype multi-cusp filament based H- ion source

**H- Ion Injector Linac Sub-systems**

**Ion Source Development**

At RRCAT, a hydrogen ion beam current of 1 mA was successfully extracted from the ion source after proper adjustment of inter-electrode separation and varying the extraction voltages up to 14 kV. The 25 $\mu$Amp current H- ion beam was extracted at extraction voltage of -9.6 kV using 3-electrode extraction geometry.

**On-line Production and Acceleration of Radioactive Ion Beams at VECC RIB facility**

Radioactive Ion beams (RIB) of $^{11}$O, $^{42}$K, $^{43}$K and $^{41}$Ar were successfully produced at VECC, using a novel gas-jet recoil transport coupled Electron Cyclotron Resonance (ECR) Ion-source

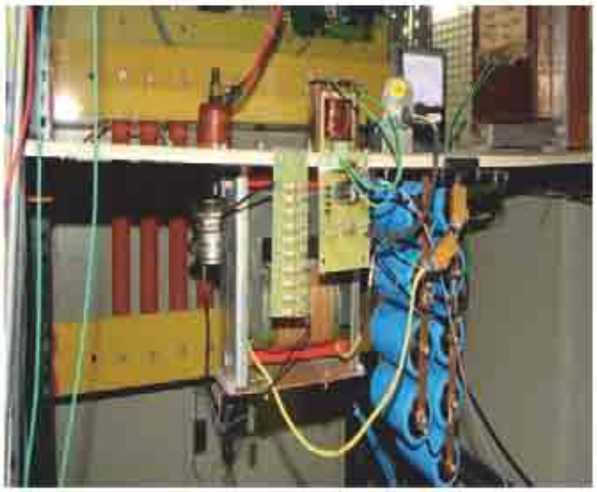
technique. The RIB of $^{14}O$ was further accelerated through the Radio Frequency Quadrupole (RFQ) accelerator to an energy of 1.4 MeV. Radioactive Ion beam of $^{14}O$ was produced on nitrogen gas target whereas $^{41}Ar$, $^{42}K$ and $^{43}K$ were produced on argon gas target.

**Development of high power IOT based RF amplifier along with its associated high voltage power supplies and associated protective devices for Superconducting RF cavity project**

The development of multi-cell medium-Superconducting RF linac cavity has been taken up at VECC. The state-of-the-art technology of IOT-based high power RF amplifier was designed, developed and tested at VECC is the first of its kind in India. The PC-PLC-based RF interlocks, control and monitoring of various parameters were developed indigenously. The IOT-based amplifier along with power supplies and interlocks etc. was installed and tested up to 40 kW with 50 ohm water-cooled dummy load at 704 MHz.

High power test of IOT based RF amplifier developed at VECC

The necessary high voltage power supply with fast crowbar protection circuit for biasing Cathode of the IOT was designed, installed, commissioned and tested at VECC. Other protections such as over current, over voltage, over temperature phase failure etc. were incorporated and tested with the IOT. A HV Deck has been specially designed in house to place these power supplies which are floating at 30KV.



Crow bar protection unit of Anode Power Supply for IOT

HV Deck housing the rest of the Power Supplies

## LASER TECHNOLOGY

### Laser welding of superconducting radiofrequency (SCRF) cavities

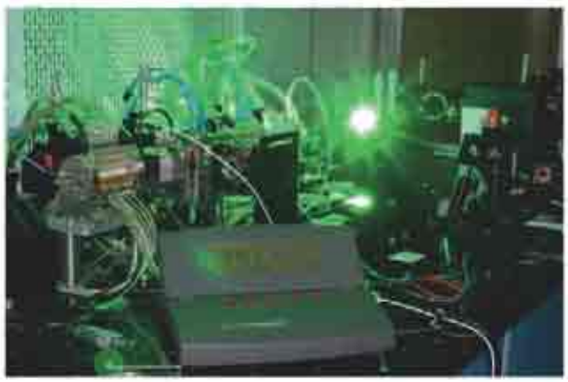
The technology for laser welding of niobium (Nb) was developed and used for welding of a prototype 1.3 GHz SCRF cavity. The welding of Nb half cells was done using a 500 W average power indigenously developed Nd:YAG industrial laser. The advantages were no vacuum required for welding , smaller energy deposition and hence less shrinkage and less distortion, less post welding cleaning requirements and finally much lower capital cost of the equipment . Laser welding of a 9-cell 1.3 GHz copper cavity for tuner studies was also carried out for the first time. A in house developed Nd:YAG laser with 1 kW average pulsed power was used to carry out this welding.

Laser welded prototype 1.3 GHz SCRF cavity made of niobium half cells

Laser welded 9-cell copper cavity

### Development of high beam quality Nd:YAG green laser of 100W output power

A high beam quality, high repetition rate, Q-switched, diode-pumped, intra-cavity frequency doubled Nd:YAG green laser system with an average output power of 100 W was developed for various applications.



The 100W, high beam quality Nd:YAG green laser

CuBr oscillator power amplifier set-up laser

### Master oscillator power amplifier chain of CuBr lasers

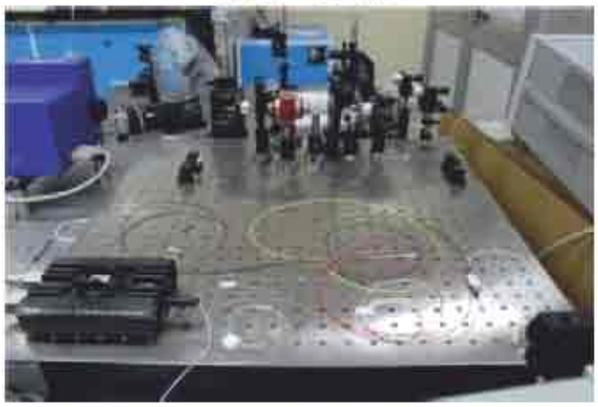
A master oscillator power amplifier chain of three in house made copper bromide (CuBr) laser units, delivering 100 W average laser power was developed. The optimum pulse repetition rate was in the range 18-22 kHz compared to 6-9 kHz for Copper Vapour Laser (CVL). Electrical efficiency of CuBr laser was almost twice that of the CVL.

### Development of 160 W CW Fiber Laser

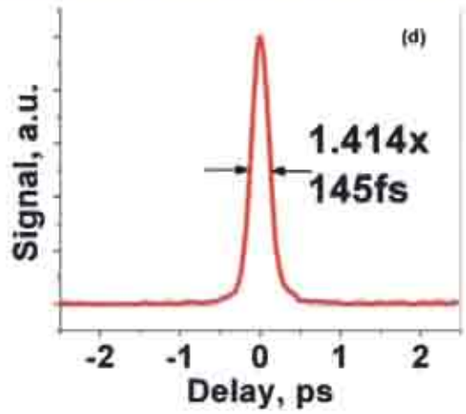
A 160 W single transverse mode Yb-doped fiber laser was developed using bulk

mirror components. The fiber laser was pumped in a double-end pumping configuration. The central wavelength of the output signal peaked at 1060 nm at full-width at half maximum (FWHM).

The in-house developed 160 W single transverse mode CW fiber laser



The Yb-doped femtosecond fiber laser and compressor




Autocorrelation trace of compressed pulses of Yb-doped fiber laser

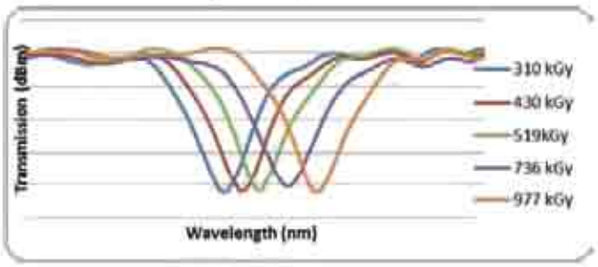
**Femtosecond fiber and crystal lasers**

An All-Normal-Dispersion mode-locked Yb-doped fiber laser was developed with compressed pulse and a clean temporal profile without any side-lobes. The average output power was 150 mW

Cr: Forsterite crystal based CW mode-locked femto-second laser with nearly Fourier transform limited pulses was demonstrated using a novel type of mechanism for femto-second laser generation known as self -shortening and transverse mode degeneracy driven mode locking (STDM).

**Optical fiber sensors for nuclear radiation dose measurement**

Long Period Grating (LPG) based wavelength encoded fiber sensors with a very high limit of integrated radiation dose were developed. The transmission spectra as per following figure show the dose dependent shifting of wavelength peaks after irradiation. The LPGs were inscribed in various commercially available B/Ge doped single mode fibers.




Transmission spectra of LPG based fiber gratings at different radiation doses

**Power conditioning system for multi-beam laser amplifiers**

A prototype power supply was developed for the power conditioning system for multi-beam laser amplifiers. This made use of a constant

current capacitor charging circuit based on LCL-T resonant dc-dc converter topology. The power supply included charging circuit, flash lamp trigger circuit and control unit. The supply was used to charge a 250 $\mu$F capacitor bank to 6 kV and discharge through flash lamps. The peak value of the current pulse was 6.2 kA at 10% of peak

At BARC, the work on the high average-power liquid dye laser systems based on water continued. For large-scale deployment of aqueous supramolecular dye laser operations, the indigenous synthesis of high purity cucurbit was optimized and the purity was verified by NMR, MS, and spectrophotometric titrations. The synthesized cucurbit was applied for generating an efficient and sustainable high-average power output from aqueous Rhodamine B dye laser, at 12.5 kHz pulse repetition frequency.

A non scanning atomic magnetometer with simultaneous frequency standard based on coherent population trapping has been developed.

BARC developed a 4 cubic meter hot zone operating at 1500 K temperature and 10-5 milli bar pressure for evaporation and recirculation of actinides. The heat shields were electro-polished

Hot Zone showing heater elements

to passivate the surface and to reduce the surface emissivity. The hot zone was efficiently operated for more than 400 hours in the commissioning runs.

A laser heating facility was setup using IR laser. The performance evaluation of the system was carried out by melting foils of different metals like Fe, Ta.

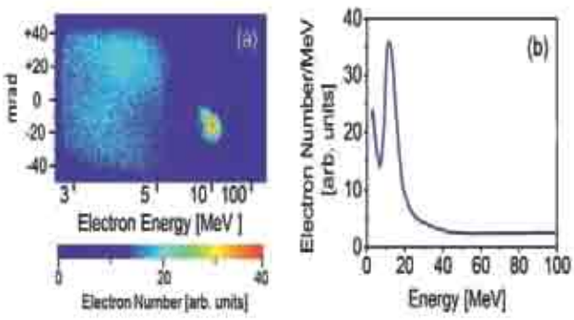
The Chirped Pulse Amplification (CPA) technique using Nd:Glass laser system consisting of one oscillator and three amplifiers with a pulse stretcher/ compressor yielding 80 GW peak power levels was designed for the development of ultra short pulse systems that can reach peak power levels in the range of petawatt.

A quasi-monochromatic x-ray source was developed with the existing 20J /300 - 900 ps Nd: Glass laser system for probing the laser shocked and isentropically compressed materials.

## Laser Applications

### Laser based electron acceleration in preformed plasma plumes

The experiments were carried out using plasma plume produced from the ablation of nylon target by focusing a second harmonic of Nd: YAG laser with 40 mJ energy, 12 ns duration to a peak intensity of $10^{16}$ W-cm-2. At the optimum

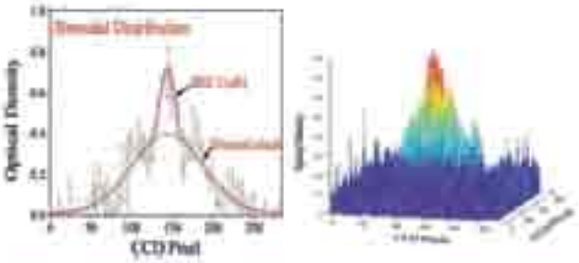



Energy spectrum of the electron beam accelerated in a plasma plume

Interaction conditions, a high quality electron beam with energy around 10 MeV with quasi-monoenergetic feature was produced.

**Bose Einstein Condensation of $^{87}$Rb Atoms**

Bose-Einstein Condensation (BEC) of atoms was observed in laser cooled $^{87}$Rb atoms and a double Magneto-Optical Trap (MOT) setup was developed for its study. BEC was observed by plotting the optical density profile of atom cloud by absorption probe imaging method.




The bimodal distribution shown in optical density profile is due to occurrence of Bose condensation in the central region of the atom cloud

## SPECIAL MATERIALS

**Titanium and chromium boride advanced control rod material**

Advanced control rod materials, made of titanium boride and chromium boride were test irradiated and examined in Dhruva reactor at BARC for performance evaluation.

**High mobility thin film organic conductors**

Development of high mobility thin films of organic conductors were carried out using cobalt phthalocyanine (CoPc) films deposited on flexible bi-axially oriented polyethylene terephthalate (BOPET) substrates. The high mobility observed is assigned to the good out-of-plane texturing of CoPc film on BOPET.

**Non destructive assay of $^{235}$U**

Pulsed neutrons emitted from a Plasma Focus (PF) device were used for non destructive assay of $^{235}$U content in different chemical forms (oxide, metal). Calibration of the Active Interrogation Delayed NEutron Counter (AIDNEC) system was carried out by irradiating $U_3O_8$ samples of varying amount containing enriched $^{235}$U in the device.

**Synthesis of Lithium orthosilicate**

Lithium orthosilicate was synthesized by Solid State Reaction Process (SSRP) through carbonate route as well as hydroxide route using extrusion and spheroidization technique. Grain sizes in the range of 100 microns were synthesized.

$Li_4SiO_4$ Pebbles

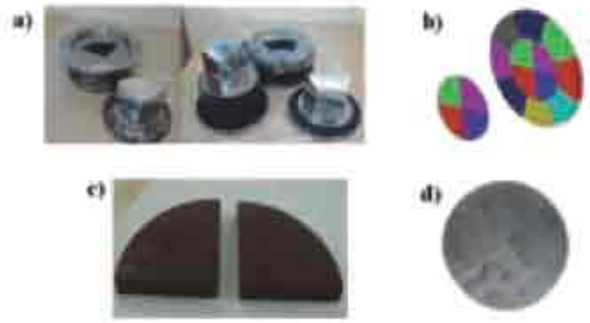
**Study of heat transfer with alumina pebbles**

Experiments to study the heat transfer with alumina pebbles of different sizes in pebble bed were carried out. Optimum parameters to enhance the effective thermal conductivity of pebble bed established. CFD modeling of the hydrodynamics of the pebble bed was initiated.

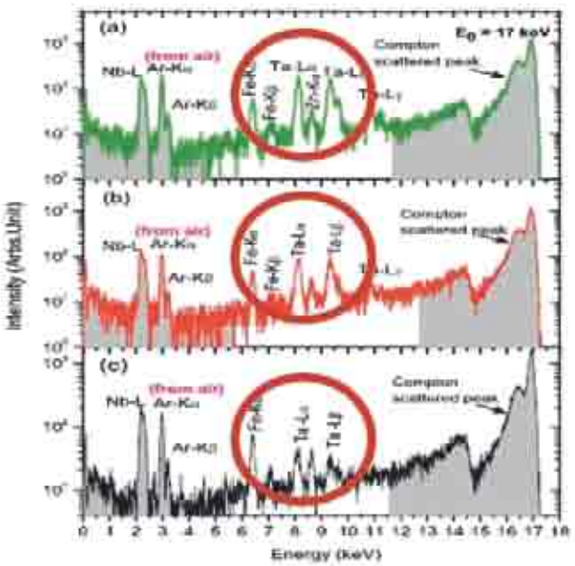
## Magnetic Materials

### Iron-deficient rare-earth garnets for high power circulator at 505.8 MHZ

High density, crack-free, large disks of Yttrium-Gadolinium-Indium Garnet, was developed by RRCAT for use in high power ferrite circulators. Material composition and process parameters were optimized to achieve desired magnetic characteristics.




(a) Die-sets for quadrant and segmented shape garnet components,
b) Design of quadrant-segment integrated garnet discs,
c) as pressed quadrant shape garnets and
d) Integrated large sintered garnet disc.




XRF spectra of tantalum impurity in niobium samples

### Superconducting properties of niobium materials

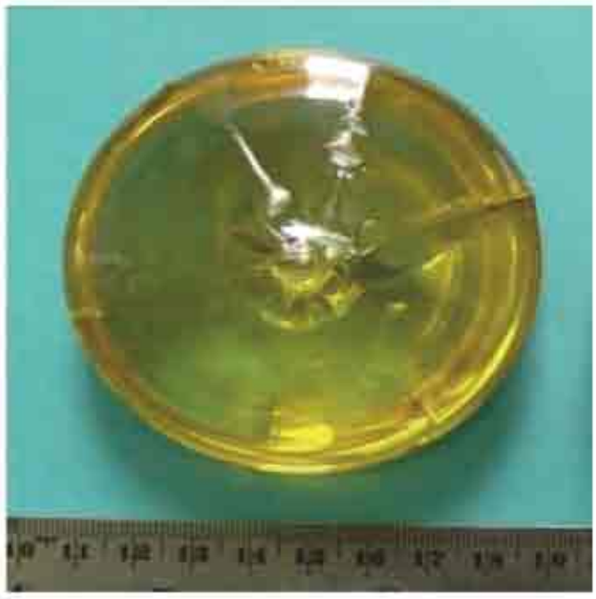
Superconducting properties of niobium materials have been investigated in detail after determining their tantalum (Ta) and other metallic impurity content based on x-ray fluorescence spectroscopy study using the Indus-2 beamlines.

### Platinum doped carbon aerogel catalyst for hydrogen isotope exchange

Work on the development of hydrophobic catalyst with platinum doped carbon aerogel as active material (Pt-CA) and poly-tetra-fluoro-ethylene (PTFE) as wet-proofing agent was further continued and efforts were made to achieve stable and consistent catalytic performance.

## Crystal Growth

Large diameter congruent lithium niobate crystals were grown by the Czochralski method.



Growth of 70 mm diameter congruent lithium niobate single crystal

## Photonic nano materials

Composites of Poly phenylene vinylene (MDMO-PPV) and lead sulfide (PbS) nanoparticles were fabricated for photovoltaic cell applications.

## ADVANCED TECHNOLOGIES

### Texture diffractometer

The Texture diffractometer consists of a four-circle goniometer with a translation axis. Motion control of the goniometer axes, implementation of scan algorithms and collection of diffraction data was carried out at BARC through a computer interface. The goniometer, collimation system and associated mechanical systems were fabricated and system integration was in progress.

### Waveform analysis software

The important task of uninterrupted online monitoring and reporting of global and in-country seismic events continued at BARC with the use of in-house developed waveform analysis software. Good progress was made in development of advanced techniques for seismic studies

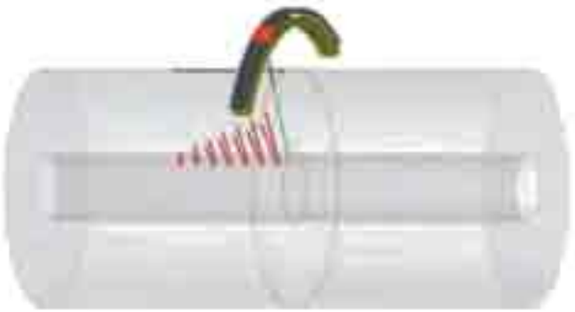
Texture Diffractometer

Tracked Robot with Tele-tector

Telepresence Interface for Master Slave Manipulation

### Telepresence

The technology, called Telepresence was developed and demonstrated in BARC using a stereo camera pair at the slave station and stereo viewing goggles at the master and a 3D immersive interface for telemanipulation. The salient points are 3D view of the slave robot and its work space, interactive telemanipulation using a haptic device, user friendly GUI guidance through cluttered space, recording and replay of previous movements to enhance operator's efficiency and any other PC in the same network.



Virtual billet inspection with encircling probe


Computed radiograph of NAPP RTD temp. sensors

LBE target loop being radiographed

**Advanced inspection techniques for reactor components**

Advanced inspection techniques like phased array Ultrasonic test probes for inspection of Zirconium billets and ingots, digital radiography were developed for inspection of reactor components.

**Pipeline Inspection Gauges**

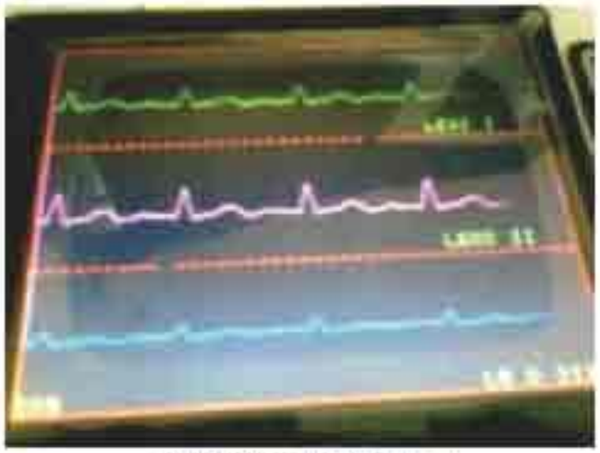
Pipeline Inspection Gauges (PIGs) for pipelines of several sizes ranging from 12" to 24", under an MoU with IOCL was developed by BARC. The tools were designed for inspection of oil pipelines without stopping the oil flow, and their capabilities were proved by physical verification.

24" Pipeline Inspection Gauge Tool

**Application-Specific Integrated Circuits (ASICs)**

Three application-specific integrated circuits (ASICs) – ANUSANSKAR, ANUSPANDAN, ANUSPARSH-II were designed, fabricated and tested in 0.35 um mixed Complementary Metal Oxide Semiconductors (CMOS) process. ANUSANSKAR was designed for readout of high density Silicon Position


ANUSANSKAR under test at ALICE PMD, CERN



ANUSPANDAN ECG display

Anusparsh-II ASIC interfaced with TDC ASIC

**Sensitive Detectors.** ANUSPANDAN, a low noise, low power, 12-channel analog ECG front end ASIC designed for portable ECG instrument capable of capturing ultra low frequencies of ECG spectrum required to detect myocardial infarction. ANUSPARSH, a fast 8-channel, low power front end ASIC for read out of Resistive Plate Chamber (RPC) detector of Indian Neutrino Observatory (INO)-Iron Calorimeter (ICAL) experiment.

**High Power solid state RF power amplifier**

High Power solid state RF power amplifier, at 13.56 MHz for use in plasma heating applications was developed at BARC and had more than 80 % efficiency.

RF Source

**Linear array detector**

Linear array detector with 16-element Positive-Intrinsic-Negative (PIN) photodiode coupled to a 16 element CsI array of geometry matching to the photodiode elements was indigenously developed.

Linear Array Detectors for X-ray

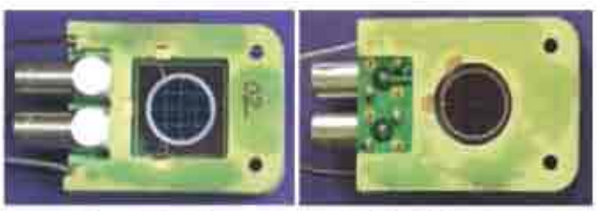
**Multi-channel high voltage system**

The multi-channel high voltage system was developed for biasing a charged particle detector array consisting of Si-pad detectors and CsI-PIN diodes for BARC-TIFR Pelletron-LINAC Facility.

A 48-channel High Voltage crate

### Silicon detector telescope

A novel silicon detector telescope for particle identification and measurement of their energy has been developed using double sided wafer processing technology with a common buried contact for nuclear physics experiments. The performance of this detector for light charged particles and fission fragments has been verified at FOTIA and Pelletron, BARC.



Front side E Back side E detector

### The PADMA System

The networked Monitoring and Assessment Centres (MACs) of the PADMA system having necessary infrastructure for data collection from seismic, micro barometer, IERMON, prompt gamma & EMP detection systems and fusion of these data to alert and authenticate the occurrence of any event were set up to provide round the clock authenticated information to designated authorities of an event anywhere within the Indian territory.

### Neutron optical devices

Novel neutron optical devices have been developed yielding many new experimental results. A high precision Bragg prism collimator has been fabricated and operated in conjunction with a matching, similarly designed Bragg prism analyser. Employing these, the most parallel neutron beam to date has been produced

Neutron Bragg Prisms

### Robotic goniometer

A robotic goniometer, operating remotely was developed that provides the unique capability to collect diffraction data on protein crystals in-situ, and will also act as a completely automated sample changer.

Robotic goniometer for protein crystallography

**Indigenously developed Diamond Anvil Cell (DAC)**

High pressure infrared studies of materials were carried out in an indigenously developed Diamond Anvil Cell (DAC) using Fourier Transform Infrared (FTIR) Spectrometer coupled to the Hyperion 2000 IR microscope set-up at IR-beamline, Indus-1, RRCAT.

**Synthesis of rare earth orthovanadates $RVO_4$ nanoparticles**

Technologically important compounds such as rare earth orthovanadates $RVO_4$ (R=La, Ce) nanoparticles were synthesized via microwave assisted heating. The measurements showed pressure induced insulator metal transition in $CeVO_4$ and structural phase changes in $HoVO_4$.

**Design and development of VSI-Chopper based Dynamic Voltage Restorer**

A 10kVA three-phase Voltage Source Inverter (VSI) was designed and developed at VECC. The power electronic device comprising of a Voltage Source Inverter (VSI) along with DC-DC Chopper was employed in the development of the Dynamic-Voltage-Restorer (DVR) using the SMES coil. A high current two-quadrant DC-DC chopper was designed and developed for charging the SMES coil

**Energization of 0.6MJ SMES Coil with the Two-Quadrant DC-DC chopper**

The NbTi based cryostable and solenoid type 0.6MJ SMES coil with HTS based current leads along with related instrumentations, quench detection and protection system, dump resistors and the data-logging systems were assembled, integrated and connected for energization of the SMES coil. The "Hysteresis Band Current Controller" based two-quadrant DC-DC chopper designed and developed in-house was used for charging the superconducting coil.

DC-DC Chopper

DSP based Voltage Source Inverter

**Conceptual Design Study of 5 MJ Toroidal SMES Coil**

Conceptual design study for the development of toroidal field magnet of 5 MJ/1 MW composed of modular solenoid coils connected in series and arranged in a toroidal symmetric were initiated. Detailed design study of

cryostat lay-out, quench protection, dynamic heatload, etc. made progress.

**Development of high-voltage power supply for electrostatic ion beam deflector**

High-voltage power supplies has been designed and developed for the electrostatic ion beam deflector. A novel topology of half-bridge parallel resonant DC-DC converter with high-voltage / high frequency step-up transformer followed by Cockroft-Walton multiplier stages has been used for the development of these power supplies. Output voltage regulation is achieved by changing the input DC bus voltage of DC-DC converter using a high control bandwidth series pass transistor working in the linear region.

## Cryogenics

**Experimental helium liquefier**

An experimental helium liquefier was built by BARC. The helium liquefaction process was based on a modified Collin's cycle consisting of one pre-cooler turbo-expander, a pair of by-pass turbo-expanders (warm and cold) and a series of 7 compact brazed plate and fin high effective heat exchangers.

The experimental helium liquefier with LN2 precooling facility

**Process design of a new 250 W at 4.5 K & a sub 4.5 K helium refrigerator**

Process design of a new 250 W at 4.5 K and a sub 4.5 K helium refrigerator was completed. The sub 4.5 K helium refrigerator was developed as an extension of the earlier described 4.5 K refrigerator to finally develop into an integrated cryogenic facility with 4.5 K as well as sub-4.5 K loads.

In the year 2012, operation of superconducting cyclotron at VECC at rated cryogenic loads with the old liquefier/refrigerator 250W at 4.6K was successful.

**Prototype development of an experimental variable temperature setup suitable from 2.2K to 325K for temperature sensor calibration at VECC, Kolkata**

A prototype of variable temperature set-up has been developed in-house using a glass cryostat for calibration of different temperature sensors. The temperature of Variable Temperature Insert (VTI) is controlled by the cryogenic process. The calibration was performed by comparing with a Lakeshore make Calibrated Silicon Diode DT470.

Photograph of thermal block and capillary coil placed in VTI

Photograph of Vacuum Feed-through of the sensors and heater

Experimental Set-up for sensor calibration

**4K Cryo-cooler based Cryogenic Test Set-up**

The 4K cryo-cooler based cryogenic test set-up is a general purpose test facility which allows to cool the samples/devices to 4.2K without the inconvenience and expense of liquid helium. The cryostat was designed, fabricated and successfully integrated with two Sumitomo Made 4K Cryo-coolers. The thermal performance of the system was tested successfully and different measurements were carried out. Several Niobium (Nb) samples from BARC, Mumbai were characterised for purity through RRR measurements. The phase measurement was carried out from 320 K-4 K of Cobalt-Tin samples of different compositions from SN Bose Institute, Kolkata.

Test set-up mounted on a movable table Cryogenics

Sample mounting centre stick Cryogenics

Helium Evaporator placed inside the cryostat

1K Helium Evaporator

## Robotics

**Mobile robot with on-board articulated arm**

Portable wireless controlled, rugged mobile robot with on-board articulated arm was developed by BARC. The salient features of the mobile robot included a vehicle payload 150 Kg, arm load 5 Kg, arm reach 1250 mm, rugged, maintenance free brushless motors used for all movements, powerful self protection by very fast "stop-on-hit" through touch sensitive bumpers, intelligent hit state recovery support through multiple body sensors, long campaign range supported by heavy duty battery, fully 3D model supported human-machine interface at operator console, on-line tracking of mobile robot's position and wide range of applications in the nuclear and hazardous materials industry.

Mobile robot moving under remote control

The heavy duty arm being maneuvered from remote console

Wrist, integrated with long arm

**Compact Wrist**

Compact wrist for Tele-robotics which is an electrically operated wrist with 2-finger gripper for pick and place as well as part assembly task execution through remote robot agents in active environment was developed. Compact low voltage (24 V) actuators for operator safety, full roll, tilt and grip functionality, all motions closed loop servo controlled with integrated sensors, light construction, pay load up to 700 gm, easily integrated with articulated arms for longer reach and wide range of applications in the handling of radioactive materials are some of the important features of the unit.

**Mobile robot based online radiation mapping system in K-130 cyclotron facility**

A mobile robot based radiation dose-rate mapping system was developed at VECC in collaboration with DRHR, BARC and HPU, Kolkata. Experiments were carried out with 30 MeV alpha beam at 12 pre-decided locations. The significant results obtained included complete neutron and gamma radiation field mapping for different conditions for accidental exposure estimation; Locating the maximum beam loss positions and thereby improving beam optics resulting in increase of beam transmission efficiency; Optimization of beam internal parameters to reduce the ambient dose rate inside vault and pit areas and reduction of

Mobile Robot at High Intensity Cave-I

radiation damage to components and accidental radiation exposure; Significant reduction of induced activity produced at different parts of the machine components.

## SPECIAL PROGRAMMES

### Access control system

A separate RFID type card was used for access control in different zones in VECC campus. RFID type attendance cards were introduced for VECC employees. These were programmed for access control, replacing the older cards. The system was monitored by the Health Physics Division, BARC. For Visitors, Trainees, Junior Research Fellow and Senior Research Fellow separate temporary cards were issued which were configured for the required zone only.

Access Control Card Reader

Access Display System

## ISOTOPE PROCESSING

The radioisotopes in India are produced in research reactors at Trombay, power reactors of NPCIL and accelerators at VECC. These radioisotopes are processed by BARC, and a vast array of high quality radioisotope based products and equipment is commercially produced by BRIT. All these products and services have wide applications in the fields of medicine, agriculture, industry and research.

The activities and achievements of this programme segment of DAE during the report period, are listed below.

A method was developed by BARC for the separation of fission 99Mo from irradiated uranium aluminium alloy. 99Mo was obtained with an overall recovery of 80% and the purity was found to be in agreement with the US and European pharmacopoeia.

A facility for processing spent ammonia cracker catalyst to recover high purity cobalt powder was set up. A multi-cavity die assembly has been designed and fabricated for compacting the cobalt powder into pellet/slugs of required dimensions for use as 60Co source. The multicavity die assembly set can produce 100 green cobalt pellets of dimension 1.2(dia)x1.2 (height) mm at a time and about 600 in an hour.

At BRIT Regional Center, RAPPCOF, KOTA, a total Cobalt-60 activity of 861 kCi in 17 sub assemblies was processed. About 1170 kCi of activity was transported in 12 consignments.

Fifteen numbers of W-91 sources were fabricated at RAPPCOF. Two teams of RAPPCOF successfully carried out source loadings at OGFL and JCPL, Bhiwadi.

Radiation Sources of Co-60, Cs-137 and Tm-170 for Nucleonic Gauges and other various applications were made. GC-4000 unit supplied to Urugway brought from USA in two numbers of Type A lead pots were sent back to them after removal of sources.

## AGRICULTURE

### Crop Improvement

A large seed Trombay groundnut variety, TG-47 (Bheema) was released and notified as RARS T1 for commercial cultivation for early kharif and rabi under irrigated conditions in all agro-climatic zones of Andhra Pradesh by the Central Sub-Committee on Crop Standards, Release and Notification of Varieties, Ministry of Agriculture, Government of India.

In groundnut, TG-67, TG-68, TG-69, TG-70 and TG-71 were evaluated at the Agricultural Universities of Navsari, Vyara, Raichur, Dharwad, Marathwada and Latur in kharif season. To disseminate new Trombay groundnut varieties and to reach groundnut farming community with quality seeds, large scale breeder seed production was undertaken at Farms at BARC.

About 372 quintals of breeder seed of Trombay groundnut varieties, TAG-24, TG-37A, TG-38, TPG-41, TLG-45 and TG-51 were multiplied and distributed to different seed agencies and farmers for further foundation seed production. In Rare Materials Project, BARC, Mysore, more than one acre of area was cultivated successfully with TG variety TG 37A in rainy season and around 1400 kg of quality seeds were obtained

A farmer from Karnataka with bunch of TG Variety

BARC scientists on visit to various farms

Groundnut mutant, TGM 112 with white to light orange flowers isolated with gamma ray (250 Gy) treatment of TAG 24 was deposited and registered with National Bureau of Plant Genetic Resources, New Delhi. Electron beam irradiation was standardized for absorbed dose in five Trombay groundnut genotypes using both the 750 KeV DC accelerators and 8.5 MeV linear accelerators at RRCAT, Indore.

Two recessive genes governing resistance to yellow mosaic virus MYMV were identified in mungbean. Thirty five transgressive segregants and recombinants with desirable characters were developed. A new source of resistance for bruchid storage pest was identified in wild mungbean.

Breeding programme on development of yellow mosaic virus and powdery mildew disease resistant black gram variety was undertaken for uradbean.

Soybean lines TLPM-14, TLPM-20, TLPM-34, TLPM-47 and TLPM-52 having higher inorganic phosphorous concentration and low phytic acid content were isolated through induced mutagenesis. High yielding soybean lines TS-46, 48, 69, 72, 80, 121 and TS-2 were entered into evaluation and multiplication.

Two cowpea selections TC 2-12-10 and TC 3-25-26 were identified having combined resistance against cowpea mosaic and leaf crinkle viruses. Eight germplasm lines and 11 mutants including TC201, TCM1-26-E, TCM503, TCM418SDT, TCM501-1-4, TC 99-1 and TCM 1-8-10 were also identified with resistance to cowpea mosaic virus. The cowpea mutant derivative TC-601 was identified with high protein and high albumin content. Multiplication of breeder seed of the Trombay pigeonpea variety TT401 was taken up.

A selection of rice involving mutant as a parent was tested and found high yielding and will be advanced to further yield evaluation trial. In wheat, early mutants of Cv. C306 were tested at IARI, Indore.

About 369 germplasm lines in chickpea were collected from different national and international institutes.

A protocol for extraction and HPLC separation of various sugars in blackgram was standardised. Twenty four blackgram genotypes were analysed for sucrose and raffinose family of oligosaccharides (RFO) content to identify genotype with high sucrose and low RFOs content. Investigations on banana somatic embryogenesis continued. Two new cell lines of Rasthali were initiated.

Investigations on the indigenous medicinal plant Ophiorrhiza species were pursued for the production of the Camptotheca alkaloids used in cancer therapy. Plant tissue and organ cultures of Ophiorrhiza were established and mass cultivated for the extraction and isolation of bioactive constituents.

Multiple shoot cultures and immobilised cultures of medicinal plant Ophiorrhiza

A novel plasma membrane aquaporin (MusaPIP-2) was identified from banana Expressed Sequence Tag (EST) database and used to transform embryogenic suspension cultures of banana. Stably transformed banana plants showed improved tolerance to salt, drought and cold stress.

Two important fungal proteins namely Velvet protein and a Fungal Transcription Factor (ftf1) in FOC involved in spore germination and mycelial growth in filamentous fungi of fusarium disease, were identified.

Molecular characterization of grapevine stress related gene SDIR1, VvbZIP23 and Ku70 was carried out using tobacco transgenic plants. Musa genome sequence was explored for putative bromodomain proteins, which are a group of important regulatory proteins.

Studies on the application of thiourea (TU) were continued. The efficient activation of alternate oxidase pathway was demonstrated under NaCl+TU treatment that helps to avoid the over-reduction of mitochondrial ETC,

The potential of Calotropis gigantean for phytoremediation of Pu-239 and Am-241 as well as nonradioactive Cs and Sr was demonstrated. Plants of Calotropis gigantea were found to tolerate up to 20 ppm of Cs and Sr.

Studies were continued on the field evaluation of sustained release biopolymer based formulation for mosquito control. Several Culex breeding sites were identified

To test antifungal activities of bioactive components towards serious diseases of rice caused by M. oryzae, 96-well microtiter plate growth method was developed which led to the identification of β-basrubrin peptide with killing activities towards blast pathogen.

Fruit fly infestation on fruit and vegetables crops was analyzed with the help of National Research Institutes and Agricultural Universities using different designs of pheromones based on methyal eugenol and Cue-lure traps.

A novel protocol was designed for immobilization of cells of Streptococcus lactis expressing β- Galactosidase activity using silica nanoparticles, by spray drying technique. The immobilized enzyme was found to be more thermostable than the free enzyme.

Enhancment of lipolytic activity for selected strains of Aspergillus sp. RBD-01 and RBD-02 that produce lipase were subjected to γ-irradiation for different time intervals.

An amperometric bienzymatic cholesterol biosensor based on functionalized graphene modified electrode was developed for total cholesterol determination. Cholesterol oxidase (ChOx) and cholesterol esterase (ChEt) were covalently immobilized onto functionalized grapheme (FG) modified graphite electrode.

Factors influencing the uptake of U (VI) ions such as solution pH, temperature, contact time and initial metal ion concentration were investigated systematically by batch experiments using doughnuts which contain S. lactis cells as adsorbent. More than 65% of U (VI) ions uptake was observed over pH range of 3-7 with optimum uptake at pH 5.0.

Floating magnetite-cryobeads were designed for the recovery of uranium from aqueous medium by integrating the properties of magnetism into cryogelation technology. Degradation of Tri-butyl phosphate was investigated using Klebsiella sp. S3 isolated from soil.

Electron beam irradiation of seeds for phyto-sanitary treatment

**Electron beam irradiation for phyto-sanitary treatment**

The DC accelerator at RRCAT was utilized for exploiting the potential of electron beam irradiation as phyto-sanitary treatment against pulse beetles in seeds of various grain legumes. Collaborative research and development work is being done with National Bureau of Plant Genetic Resources, New Delhi to issue Import Permits and Phyto-sanitary Certificates for radiation processed food in our country.

## FOOD PROCESSING

At BARC, a combination of nisin (1000 U) and low dose radiation treatment (1kGy) to improve microbiological quality of minced meat using packed inoculum studies was investigated. The treatment completely eliminated both Gram negative and Gram positive bacteria inoculated into meat when stored at chilled temperatures.

Large scale storage studies of irradiated semi-dried prawns demonstrated that the product could be stored up to 3 months at ambient temperature without significant changes in the microbiological, biochemical and sensory quality.

Protocols were standardized for determining the optimum dose for extension of shelf life of Ready-To-Cook (RTC) pumpkin at an optimum radiation dose of 1 kGy.

Raw carrot juice was demonstrated to have high antimutagenic activity while boiling was shown to increase the antimutagenicity of pigweed considerably.

In jackfruit, during storage, an increase in ethyl acetate content and formation of ethanol and valeraldehyde was noted. The possible use of veratraldehyde as a marker for detection of spoilage was under investigation.

A biochemical approach involving chemotaxonomic markers was adopted to determine the traceability of litchi fruits grown in India.

A process was developed for preparation of Ready-To-Cook (RTC) kidney bean (Rajma) by precooking and drying. Methods were standardized for identification of marker volatiles in food packaging for early detection of food spoilage.

A process for preventing browning and extending shelf life of litchi fruits for 45-60 days by a sequential dip treatment using GRAS chemicals and the technology transfer was developed by BARC. Dosimetry protocols were standardized at KRUSHAK facility for application of radiation processing as a quarantine requirement for export of pomegranate to USA.

Studies were carried out to evaluate effect of gamma radiation on composite films prepared from Carboxy Methyl Cellulose (CMC) and Poly Vinyl Alcohol (PVA). Biodegradable nano composite films prepared using bentonite nano clay (10%) and guar gum showed an enhancement in tensile strength by 83% and a decrease in Water Vapor Transmission Rate (WVTR) by 25%. Effect of gamma radiation on soybean trypsin inhibitor was evaluated.

The effect of various food-related stress events on general stress response and virulence gene expression in A. hydrophila CECT 839T and A. hydrophila A331 food isolate was studied using real-time PCR.

Studies on radiation (40 kGy) induced Maillard reaction between various sugars like maltose, ribose, sorbose and xylose with lysine or glycine showed that maximum MRPs were formed in ribose-lysine mixture.

A process was developed to improve shelf life of a regional Indian food preparation- 'Litti' or 'Bati' by use of gamma/electron beam irradiation (10 kGy) in combination with other preservatives for immune-compromised patients and other target groups.

Cinnamon, ajowain and clove oils (1 mg/ml) were found to inhibit biofilm growth of Aeromonas by 80 - 87%.

Studies on the characterization of polyphenol oxidase (PPO) from eggplant indicated the presence of two isoforms of PPO in brinjal that were confirmed as true PPOs.

Cloning, expression, purification and characterization of bifunctional aminoacylase/carboxypeptidase of Burkholderia cepacia was carried out.

Routine dosimetry and radiological safety assessments of Food Package Irradiator (FPI) and Gamma Chambers were performed at regular intervals. Radiation levels at all the occupied area were within permissible limit of 1-10 $\mu$Sv/h. TBP samples supplied by NRG, compensated Ion chambers (For testing) by ECIL Hyderabad and raisins from M/s Cadbury (Kraft India) were also irradiated. A Process Flow Sheet for Litchi Preservation by Dip Technology was prepared.

## Radiation Processing Services

### Radiation Processing Plant, Vashi

The Radiation Processing Plant, Vashi continued to provide gamma radiation processing services for Spices, Ayurvedic raw material, healthcare products and pet feed etc. to more than 200 customers from all over the country.

During the current financial year, about 2800 MT of spices and other products were processed till December 2012 which is more than the quantity processed during the corresponding period last year. This year the plant is expected to process around 3500 MT spices and allied products yielding revenue of about 250 lakhs. Since its inception, this facility has processed about 23000 tonnes of products realizing revenue of about Rs. 1400 lakhs.

To meet with the increased demand for radiation processing, source replenishment was carried out to enhance source strength from 400 kCi to 600 kCi. to cope up with the increased demand for radiation processing. Re-certification Audit for Quality Management Systems was completed successfully and facility was certified for three more years. Surveillance Audit for Food Safety Management Systems was carried out by certified agency and was found to be in full compliance with standard's requirements. Facility of e-payment has been provided to customers for payment of processing charges.

### Radiation Processing Plants in Private Sector

Two Radiation Processing Plants namely, M/s Hindustan Agro Co-Operative Ltd., Rahuri,


Radiation Processing Plant at Nipro India Corpn. Ltd., Pune is commissioned

MoU signed with M/s Isorad, Chennai

Maharashtra with source loading of 65 kCi and M/s Nipro India Corporation Pvt. Ltd, Pune with source loading of 275 kCi were commissioned.

Mou was signed with M/s Isorad Tech Pvt Ltd, Chennai, M/s Divyakiran Agro Processing Pvt. Ltd, Anand, Gujarat and M/s Radura Irradiators, Nashik, Maharashtra for setting up of Radiation Processing plants.

## HEALTH

Radioisotope based formulations, techniques and equipment are widely used in the diagnosis and treatment of various diseases. BARC, BRIT, RRCAT and VECC are major contributors in this field.

Radioisotopes are produced, processed and technologies are developed at Trombay for varied applications in the medical field. BARC's Radiation Medicine Centre, a premier centre in the field of radio-diagnosis and radiotherapy in Mumbai, is a regional referral centre of the World Health Organization (WHO) for South East Asia.

BRIT produces and supplies radio-pharmaceuticals for diagnosis and treatment of diseases, teletherapy and brachytherapy sources, radioisotope based kits, various instruments, and radio processing services. Jonaki Laboratory at Hyderabad produces and supplies P-32 labelled nucleotides for research in biology, biotechnology and drug discovery. Jonaki also markets S- 35 labelled amino acids produced by labelled compounds at Vashi.

Radioisotopes for medical applications are also manufactured at VECC. The Regional Radiation Medicine Centre in Kolkata meets the radio-diagnostic and radiotherapy requirements of the eastern region of the country.

## RADIOPHARMACEUTICALS

During the year, BRIT supplied more than 60,000 cold kits for formulation of $^{99m}$Tc radiopharmaceuticals (11 products under the code of TCK) to various nuclear medicine centers. 200 Ci of $^{99}$Mo (TCM-2) for solvent extraction and around 200 Ci of Mo-99 as alumina column generator (New product-COLTECH) and Gel Generators were supplied to hospitals for separation of $^{99m}$Tc. various accessories of $^{99m}$Tc Generator systems and other products were supplied. Nearly 20,000 Consignments of ready to use radiopharmaceuticals of $^{131}$I , $^{32}$P, $^{51}$Cr and $^{153}$Sm were supplied to various Nuclear Medicine Centers in India. The production and supply of injectable products $^{153}$Sm-EDTMP and $^{131}$I MIBG was increased during the year 2012-13.

Two new products $^{99}$Mo-$^{99m}$Tc alumina column generator (Brand name "COLTECH") and ready to use radiopharmaceutical Colloidal Samarium [$^{32}$P] Phosphate (SMPC) Code PHM-4 have been launched this year successfully.

The commissioning of the column generator production facility at BRIT and

$^{99m}$Tc - COLTECH Generator

availability of generator "COLTECH" has made a great impact on the market. The prices of the same capacity imported products have dropped considerably. At present the capacity of BRIT's COLTECH generator production facility is limited due to initial approval of upto 20 Ci of $^{99}$Mo-99 from AERB.

The introduction of colloidal Samarium [$^{32}$P] Phosphate as a therapeutic radiopharmaceutical for radiation synovectomy has filled a major requirement in the treatment plan of hospitals across the country.

Sterile pyrogen free, white colloidal solution an indigenous alternative at economical prices was supplied to hospitals by BRIT as an injection for administration by intraarticular instillation.

A new facility for production of I-131 capsules consisting of shielded mini hot cell and fume hoods has been set up at BRIT. The new facility will enable BRIT to enhance the volume of I-131 capsules production and also manufacture capsules containing higher than 25 mCi I-131 radioactivity for the treatment of thyroid cancer.

Radiopharmaceutical Production Facility

$^{99m}$Tc-tetrafosmin, a radiopharmaceutical for myocardial perfusion studies was developed and clinical studies of $^{99m}$Tc-TRODAT for diagnosis of Parkinson's disease and $^{99m}$Tc-Hynic-TOC for neuro-endocrine diseases was undertaken at BARC. A radiopharmaceutical, $^{131}$I-rituximab used for treating Non-Hodgkin's lymphoma was developed and a clinical study was planned with the Tata Memorial Centre.

About 3000 Ci of medical radionuclides ($^{99}$Mo, $^{131}$I, $^{177}$Lu, $^{153}$Sm, $^{32}$P, $^{51}$Cr etc) were produced for formulation of radiopharmaceuticals at BRIT. Production of $^{60}$Co (30,000 Ci per annum) suitable for blood irradiator and Gamma Chambers; and high specific activity $^{192}$Ir using enriched $^{191}$Ir started in the Dhruva reactor.

1200 reference sources of different radionuclides ($^{22}$Na, $^{54}$Mn, $^{60}$Co, $^{90}$Sr, $^{133}$Ba, $^{137}$Cs, $^{141}$Ce, $^{147}$Pm, $^{152}$Eu, $^{203}$Hg, $^{204}$Tl) were prepared and supplied to users including industry and academic institutions. Eighty two custom made sources were fabricated for various users for specific applications such as QA of fuels, as ionization source for dust monitors etc.

A flood phantom using $^{141}$Ce needed for the QA/QC of SPECT and planar cameras used in the nuclear medicine was developed, evaluated in Radiation Medicine Centre and found to perform as good as imported $^{57}$Co based phantoms.

The treatment of prostate cancer using 'BARC I-125 Occu-prosta seeds' was started in collaboration with a local hospital.

## RADIATION TECHNOLOGY EQUIPMENT

### A bio-chip arrayer & imaging system

A bio-chip arrayer & imaging system is an

automatic process stage to produce the antibody based bio-chip for in vitro simultaneous quantitative detection of a combination of cancer related hormones using polycarbonate (PC) track-etched membranes (TEM) as a novel substrate.

The system is equipped with real time imaging system to detect the falling of antibodies spots on the membrane chip and their quantification. The cleaning and shaking of all the samples simultaneously in a single stand is carried out with the help of a customized shaker and vacuum based membrane cassette holder.

Biochip Arrayer & Imaging System

**A metrological system**

A metrological system has been designed to measure the co-ordinates of a point in space.

Serial Mechanism for Metrology (SMM)

The metrological system is fabricated and the computer interface is developed for registration and data storage. The system is portable and has high manipulability as compared to conventional Cartesian type coordinate measuring machines.

Experiments were conducted to evaluate the performance characteristics of the Serial Mechanism for Metrology (SMM).

**Multileaf collimator**

A 46 pair secondary multileaf collimator with multileaf trimmers (MLC+MLT) was developed for integration into the Bhabhatron telecobalt machine. A specially designed ball screw with actuators was provided for driving the leaves of the MLC. The end of the collimating leaves was extended by incorporating the built-in trimmers to maintain an optimum source to diaphragm distance to minimize the radiation beam penumbra.

The electronic/ electrical components are DC geared motors with encoders for driving the leaves, position sensors (potentiometers) and other support electronics for operation and control of the leaves. Graphical user interface (GUI) was also provided. This MLC was integrated into the Bhabhatron-II telecobalt machine at ACTREC, Navi Mumbai for testing its mechanical, electrical and radiological performance.

Tungsten based MLC developed for Bhabhatron-II telecobalt machine

**Digital Radiotherapy Simulator**

BARC has developed the technology for indigenous Digital Radiotherapy Simulator for localization of tumor, radiotherapy planning and treatment plan verification. Recently, one unit was installed at TMH, Parel. The commissioning QA tests were performed satisfactorily. AERB has given clearance for clinical use of the machine.

Digital Radiotherapy Simulator

**Research Irradiators:**

During the current financial year the various gamma chambers supplied by BRIT included: Gamma Chamber GC 1200 to National Botanical Research Institute, Lucknow and a Low dose irradiator supplied to INMAS, New Delhi. Others that are to be supplied are: A Gamma Chamber 5000 unit through M/s. Denver Hydromatics, Kolkata to Bangladesh Institute of Nuclear Agricultural, Mymensingh, Bangladesh for US$ 169,000 FOB; Gamma Chamber (GC 5000) for RSD, BARC, Gamma Chamber GC 1200 for Dr. Ambedkar University, Lucknow.

Ten units of GC 900, GC 4000A and a Gamma Cell GC-1200 units were decommissioned and another 2 units from IIT, Chennai and IMRL Jammu is likely to be decommissioned soon. A new source extraction tool was developed for removing and transferring the decayed source from Gamma Chambers to type B(U) packages and the same was used at Kandy, Sri Lanka for transferring GC 900 to BLC 100.

**Install & Operate Irradiator**

Install and Irradiate operator was installed and functional tests were carried out successfully.

**Blood Irradiator**

Blood Irradiator BI-2000 units were supplied and installed at Rajeev Gandhi Cancer Institute, Delhi; Surat Raktadan Kendra, Surat; Apollo Hospital, Hyderabad. Another 2 units are expected to be supplied by the end of February to L&T Channel-unit to be installed at JIPMER, Pondicherry and IMS & SUM Hospital, Bhubaneswar.

**Radiography Camera ROLI-1 & II**

BRIT supplied 58 radiography exposure devices till December 2012 and another 30 cameras are expected to be sold by March 2013. 500 ROLI cameras were serviced, nearly 1000 decayed sources were removed and 600 imported cameras were inspected for approval of source replenishment. A new radiography camera model ROLI-2 was introduced in November 2012.

**Radiodiagnostic & Treatment Services**

A total number of about 7000 radioimmunoassay (RIA) and immunoradiometric assay (IRMA) kits were produced and supplied to various hospitals, research centres and immunoassay laboratories in India. RIA Laboratory at BRIT Vashi Complex achieved UKAS (United Kingdom Accreditation Services) accreditation and International Quality Standards and certification.

BRIT Vashi Complex and Jai Research Foundation (JRF) facilities, Valvada Gujarat jointly carried out a contract research service pertaining to Chromium Release Assay. About 600 samples were analyzed for Immunotoxicity studies using chromium release assay using in-house 51Cr. Development of IRMA procedure for human C-peptide initiated last year was continued. A prototype kit was designed and evaluated for its performance.

Regional Center, Delhi carried out production and supply of around 52,000 mCi of various ready-to-use $^{99m}$Tc Radiopharmaceuticals injections in compliance with GMP and RPC for diagnostic nuclear medicine studies in 21 hospitals in Delhi and NCR region. Retail outlet for radiopharmaceuticals (ROR) Delhi supplied 1300 cold kits for preparation of various $^{99m}$Tc Radiopharmaceuticals. Developmental work on $^{99m}$Tc alendronate as an alternative bone imaging agent and reinduction of $^{99m}$Tc- Ciprofloxacin was in progress. A renovated class 10000 laboratory for production of radiopharmaceuticals and labeled compounds was nearing completion.

Regional centre, Bangalore supplied 72000 mCi of ready-to-use $^{99m}$Tc formulations. Around 600 TCK cold kits were sold through retail outlet for radiopharmaceuticals. 1700 Blood bags were irradiated using BI 2000.

Regional Centre of BRIT at Kolkata worked in collaboration with Radiopharmaceutical section, BARC, VECC, Kolkata and Indian Institute of Chemical Biology (IICB), Jadavpur. Natural Mo foil stacks (25-100 micron thick) were irradiated at 15-18 MeV proton for 5 min, 1 h, 3 h and 6 h to study $^{99m}$Tc production through 100Mo (p,2n) reaction in the cyclotron. Overall yield of $^{99m}$Tc was about 80%. The purified $^{99m}$Tc was found to be suitable for preparation of $^{99m}$Tc-radiopharmaceuticals after quality assessment. The work was carried under the IAEA CRP.

An automated closed cyclic module TCM-AUTOSOLEX for separation and recovery of various isotopes radioactive or non-radioactive using solvent extraction technique in particular, for separation and recovery of $^{99m}$Tc from low-medium specific activity $^{99}$Mo obtained in the research reactor was indigenously developed jointly by VECC and BRIT, Kolkata. A 16-bit microcontroller based embedded system was designed indigenously to automate the entire process. A PC based Graphical User Interface (GUI) was also developed. A prototype was installed in BRIT, Kolkata and several cold runs were carried out and demonstrations done.

The AUTOSOLEX radiochemical process assembly inside furnoid Screenshot of PC base GUI for AUTOSOLEX control
AUTOSOLEX electronics assembly inside 19" rack

$^{68}$Ge-$^{68}$Ga generator - $^{68}$Ge was produced by internal irradiation of natural zinc target using an α beam of variable energy cyclotron. $^{68}$Ge production yield was 0.86 µCi/ µAh. The suitability of $^{68}$Ga was assessed by labeling EDTMP with it. The radiochemical purity of the labeled $^{68}$Ga-EDTMP was about 95%.

$^{99m}$Tc-HYNIC-HIS3-TATE – octreotide analogs of peptides find increased interest in nuclear oncology for targeted tumor diagnosis and therapy. New cyclic octapeptides conjugated with HYNIC were prepared using Fmoc solid-phase peptide synthesis. The purified analogs were labeled with $^{99m}$Tc using Tricine and EDDA. Bio-distribution and Image studies showed very high uptake in kidney which can be useful for developing $^{99m}$Tc-radiopharmaceuticals for imaging somatostatin receptor-positive tumors. The work was done in collaboration with IICB, Jadavpur, Kolkata. Retail outlet for cold kits for radiopharmaceuticals at Regional Centre, Kolkata was inaugurated in October 2012.

The Regional Centre Dibrugarh located at Assam Medical College and Hospital rendered the RIA and IRMA diagnostic services for the benefit of patients of the entire North-Eastern Region. More than 10,000 patients availed the services offered by the centre for analysis of hormones like T3, T4, TSH, LH, FSH, PRL, beta-HCG, Ferritin and insulin.

**Labelled Compounds and Diagnostic Kits**

Labelled Compounds Programme of BRIT is involved in the synthesis and supply of a variety of $^{14}$C, $^{3}$H and $^{35}$S-labelled products, which are powerful and versatile tools and are used as radiotracers in diverse investigations in the fields of biology, agriculture, medicine and chemistry.

The production and supply of tritium filled light sources of various types for defence applications met the desired requirements in military gadgets and instruments. Custom-synthesis of a few compounds was carried out for some R&D organizations. Carbon-14 labelling of Tulsi and Brahmi plants were carried out using 14C- urea for a DST project sanctioned to Haffkine Institute of Research, Training & Testing, Mumbai

A gel based PCR diagnostic kit for detection of M tuberculosis was developed in collaboration with RMC, BARC, Mumbai. Real time PCR based M tuberculosis detection kit developed at Jonaki will shortly go for evaluation on clinical samples. Additional Real time PCR kits for determination of load of viruses like Hepatitis B and C, and a few cancer markers like EGFR, BCR-

Labelling tulsi with $^{14}$C- urea for Haffkine Research Institute

ABL are in the process of development. A thorough validation of the Real time PCR chemistry developed at BRIT is also approaching completion.

Total of 1508 consignments were supplied which comprised mainly $^{32}$P nucleotides, $^{33}$P orthophosphoric acid, $^{35}$S amino acids, LCK Kits, Taq Polymerase and PCR Product, radiopharmaceuticals cold kits (TCK products) and Rs. 208 Lacs was earned as revenue. Food items were monitored for the presence of $^{137}$Cs and $^{134}$Cs. Water samples were routinely analysed for gross alpha/gross beta, uranium, $^{228}$Ra and $^{226}$Ra content, depending upon the requirement. BRIT also carried out 12 surveys for certification of surface radiation dose of steel consignments.

**Radio Analysis**

The measurement and certification of residual radioactivity in commodities such as food samples, animal feed supplements, steel, water and soil samples and other miscellaneous items were carried out at the Radioanalytical Laboratory of BRIT at Vashi. Setting up of Radioanalytical laboratory at BRIT Regional Centre, Bangalore was completed and AERB accreditation procedure was in progress. Work related to setting up of Radioanalytical laboratories at BRIT Project House, Deonar and BRIT Regional Centre, Hyderabad were also initiated by BRIT.

**Radiation Sterilization Services for Medical Products: ISOMED**

About 62000 boxes admeasuring approx 7000 Cubic Metre were processed in the facility. In respect of terminal sterilization of healthcare products, the average plant utilization and load availability was 96% and 100% respectively. The facility operated round the clock and ensured full compliance to the requisite statutory requirements of the regulators / certification agencies. An average customer feedback rating during the course of gamma radiation processing services was maintained above 85%. Source Strength in the facility was augmented by 66% in November 2012, to facilitate swift radiation processing of the customer's consignments. The current Source Strength in the facility is around 400 kCis.

## New Projects

**Integrator Irradiator Development Project**

The Objectives of the Project is to upgrade safety and security features in the RPP, Vashi and ISOMED facilities and to set up an Irradiator Training Facility for training of personnel for operation of irradiator. The project saw completion.

**Production Facility for $^{99}$Mo/ $^{99m}$Tc Column Generators**

The project objective is to set up a new automated facility for production of $^{99}$Mo – $^{99m}$Tc Column Generators using high specific activity Mo-99. The installation of the facility was done and the project was completed as per schedule. The cold runs were also completed and AERB approval was obtained. As planned, the new product Coltech was successfully launched in the market.

**State-of-the-Art Immunoassay Facility**

Procurement of following equipments such as Spectrophotometer, Dehumidifier, Multi-well RIA counter, BT reader, RO water system, T3 antibody needed for development of Isotopic/non-Isotopic assays was done and the Laboratory was partly refurbished. The project is expected to be completed by March 2013.

**Indigenous HDR Brachytherapy Equipment (IHDR)**

The progress made in this project includes making of second prototype of KARKNIDON, HDR treatment unit which underwent more than 50,000 cycle of operations. Reliabilities and robustness of stepper drive, safety interlocks, linear accuracy, repeatability, hardware and software were tested and recorded. Weaker components and software corrections are incorporated to ensure conformance to code. The second machine was upgraded systematically and it was found to be much superior in technology.

A suitable steel applicator was developed for the treatment of cervical cancer and

Prototype of Karkinidon – HDR Treatment unit for cancer

development of Treatment planning software for KARKNIDON was initiated.

**Facility for production of medical grade Fission Molybdenum**

The project consists of setting up of a State-of-the Art GMP compliant facility capable of producing 300 Ci (6 day pre-calibrated) per week $^{99}$Mo utilizing LEU targets. The scope includes commissioning of modern hot cells equipped with manipulators, in cell equipments, radiation surveillance instrumentation and data logging system, special AC & ventilation system, waste management equipments, civil construction of building and setting up of world class quality control labs, modern security system, construction of new building at approved site in ISOMED Complex, BRIT near South Gate BARC.

Work on procurement of the production plant, on turnkey basis reached advanced tender processing stage.

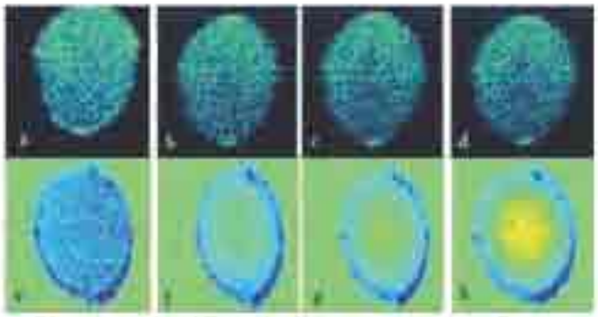
Main Laboratory Building under construction

Boundary wall under construction

**Biomedical applications**

**Prototype Doppler Optical Coherence Tomography (OCT) setup for studies on non-invasive monitoring of the healing of wounds**

At RRCAT, a Fourier-Domain Doppler Optical Coherence Tomography (OCT) set-up for simultaneous depth resolved imaging of the tissue morphology and blood flow velocity was



Phase resolved Doppler images corresponding to figures a-d :OCT scattering images of a flow phantom, e-h

developed. The system was validated on flow phantoms and was capable of measuring flow velocities similar to blood flow velocities in perfusion.

**Polarization-Sensitive Optical Coherence Tomography (PSOCT) subjected to photodynamic treatment**

Effect of Photodynamic Treatment (PDT) with poly-lysine-conjugated chlorin p6 (plcp6) on healing of murine excisional wounds infected with Methicillin resistant Staphylococcus aureus (MRSA) and Pseudomonas Aeruginosa (PAO) was studied noninvasively using PSOCT.

**Optical trapping using optically induced dielectrophoretic trapping set-up**

In optically induced dielectrophoretic trapping set-up the problem of stability of the coated amorphous silicon layer was overcome by using organic photo-conducting material Titanium Oxide Phthalocyanine (TiOPc). The results were in good agreement with the literature.

**Development of novel optical techniques for sorting of microscopic samples**

Several new techniques based on manipulation of optical trap arrays were developed to sort heterogeneous samples.

**Development of eye-safe fiber laser for potential medical applications**

A 13.5 W, single-transverse mode Continuous Wave (CW) fiber laser operating at 1560 nm was developed using commercially available Er:Yb co-doped fibers.

**Production of Oxygen-18 enriched water**

Oxygen-18 is one of the isotopes of oxygen having applications in nuclear medicine and biochemical research. HWB is entrusted for production of $H_2{}^{18}O$ water. HWB has embarked on distillation route for production of $H_2{}^{18}O$ at 96.5% purity

Process development for production of stable isotopes was initiated for separation of 18O from natural/heavy water. Basic cascade design was carried out for industrial scale facility.

Engineering, was carried out for the Small Scale Prototype Facility for upgrading off-grade $H_2{}^{18}O$ water available at RMC which will also be used to generate further data for designing the full fledged commercial plant. Procurement activity for prototype distillation system was completed. Facility is expected to be available shortly.

Procurement of equipments/systems for $^{18}O$ water production facility (Main Plant) was initiated in phased manner.

**Cancer Diagnostics and Treatment Services**

The Tata Memorial Centre (TMC), a grant-in-aid institution of DAE, is engaged in research, education and comprehensive care of cancer patients. The Tata Memorial Centre (TMC) comprising Tata Memorial Hospital (TMH) and the Advanced Centre for Treatment, Research and Education in Cancer (ACTREC) continued its activities in diagnosis, treatment and research in cancer as well as in training and education to provide the highest standard of patient care.

During the report period, at the Tata Memorial Hospital, about 56,000 cases of conventional radiography and over 9300 cases of mammography were handled. Around 20,200 cancer surgeries were done at TMH & ACTREC.

Clinical Research Secretariat (CRS) along with Department of Atomic Energy Clinical trials unit (DAE-CTC) facilitates and promotes high quality research at TMH. During the year it provided support in the form of infrastructure, trained manpower, study design, statistical assistance, data management and analysis, data monitoring etc. It also supported 15 new clinical trials through DAE-CTC funds.

**Co-60 Teletherapy Sources:**

BRIT supplied five teletherapy sources to different hospitals with total activity of 58 and 200 RMM. Eleven, decayed sources were unloaded from the teletherapy units and stored for fabrication of irradiator source. 172 kCi of high specific activity Cobalt-60 for the fabrication of Cobalt Teletherapy sources were imported from M/s Reviss.

Coblat-60 flask for Cobalt teletherapy Source

**Brachytherapy Applications:**

BRIT supplied 100 cm of ( Ir-192 + Pt Wire) with total activity of 644.67 mCi for various brachytherapy applications.

**Cancer Awareness & Prevention**

The Tata Memorial Centre Rural Outreach Program conducted around 8,600 household surveys in villages and town areas of Ratnagiri District, Maharashtra and about 3,500 eligible individuals were given health awareness programmes and about 2000 eligible individuals were screened for Oral, Breast and Cervical cancers.

The TMC-Urban Outreach Program was conducted in slums of eastern suburbs of Mumbai viz. Mankhurd, Paylipada, etc. Tobacco users were screened by house to house visits by TMC's trained paramedical staff. Awareness sessions were conducted in the community itself with the help of local NGOs, Corporators, etc. Counseling through Tobacco Cessation Clinic were offered to the needy. Persons having some premalignant / malignant lesion were referred to Tata Memorial Hospital for further management.

As part of its Information Education and Communication activities, about 50 cancer awareness programmes for general population were conducted benefitting around 11,000 people. Around 12,000 Cancer Education pamphlets in regional languages were distributed through various cancer awareness programs. Other cancer education materials in the form of Posters, Flip Charts, Audio Visual cancer education clips and Cancer Exhibition aids were also distributed to Government and Non Government Organisation after appropriate Training.

Under its Training and Capacity Building programs, about 10 Capacity Building workshops for Medical and Para medical health professionals were conducted and 30 observers were trained in Cancer Prevention Control and Early Detection activities.

Future Collaborations for undertaking Training in Cancer Control and Prevention was planned with Maharashtra State Public Health Department and Navi Mumbai Municipal Corporation (NMMC) to establish Cancer Control, Prevention and Early Detection Programs for Cervical, Oral and Breast cancers which are to be

integrated with the National Non Communicable Diseases (NCD) and National Rural Health Mission (NRHM) were in progress with respective organizations.

## WATER

### DESALINATION OF WATER

An isotope hydrology laboratory has been set-up at HESCO, Dehrdun under a tripartite MOU between BARC, HESCO and BRNS to train the local people as in-house facility for spring recharge related studies being carried out at BARC. The laboratory is equipped with advanced equipment related to isotope hydrology investigations such as Mass Spectrometer, Liquid Scintillation Counter, Ion-Chromatograph etc.

Isotope hydrology laboratory, Dehradun

A combination of environmental and injected tracer techniques was adopted to identify the source of salinity and understand the flow dynamics of the groundwater system in and around Kelwa and Mahim villages of Palghar taluka, Thane district.

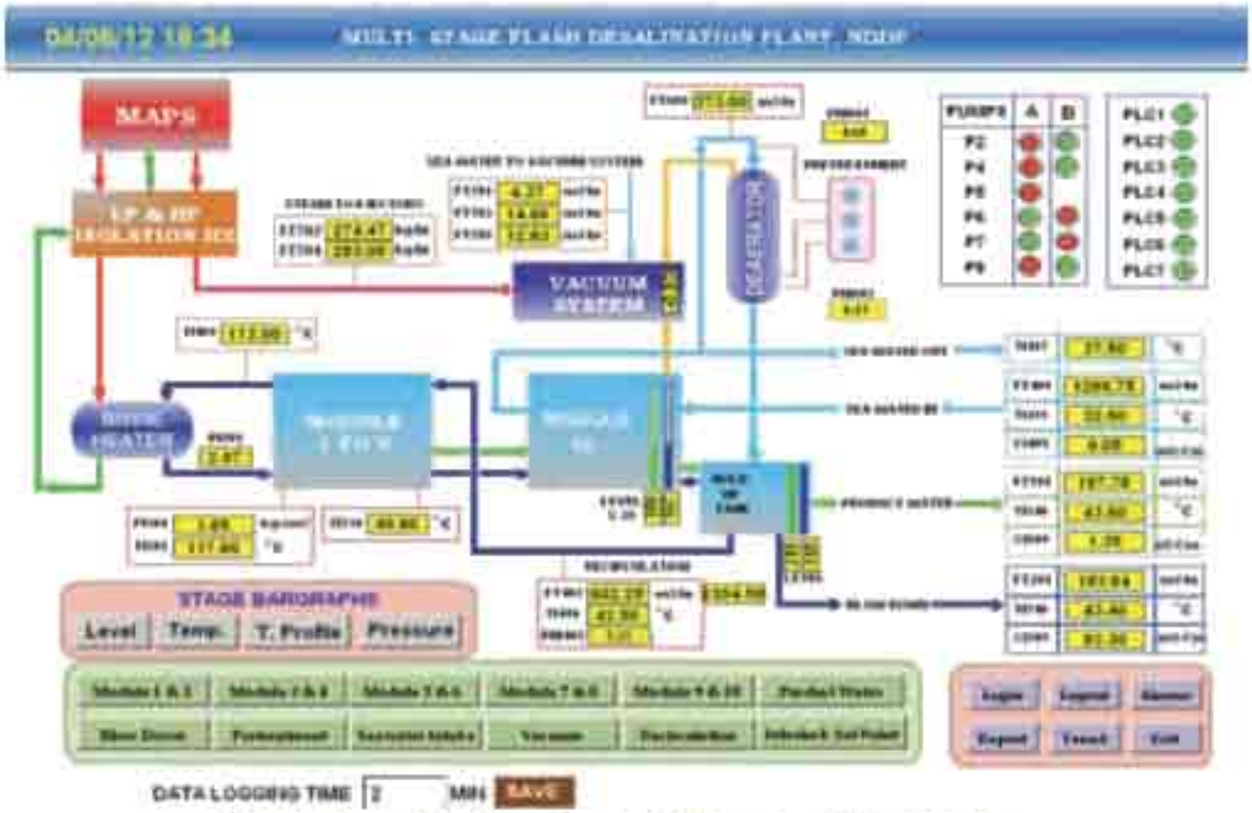
A feasibility study on the problems related to water resources management using environmental isotopes and hydrochemistry was carried out in at Chiplun, Khed and Guhagar Taluks in Ratnagiri, Maharashtra in collaboration with the Parivartan, a Non-Governmental Organization, Chiplun. An isotope hydrological investigation was carried out to understand groundwater recharge to shallow groundwaters at Dharnanavne village, Chiplun and at Madhal village in Guhagar Taluk.

Experiments to identify the source of salinity

BARC's Nuclear Desalination Demonstration Plant (NDDP) at Kalpakkam, which consists of Multi-Stage Flash (MSF) and Reverse Osmosis (RO) sections of 4.5 million litres per day (MLD) and 1.8 MLD capacities respectively was operated round the clock producing two qualities of product water. NDDP was coupled to Madras Atomic Power Station (MAPS). Multi-Stage Flash (MSF) produces demineralised (DM) quality product water (1-2 micro-siemens/cm) satisfying the stringent requirement of MAPS for high end applications.

A project proposal was put up for the field applications of Indigenous desalination technologies in DAE units. It consists of setting up a hybrid RO-MED sea water desalination plant of 5000 m3/d at OSCOM (IREL) Chattarpur, Orissa.

High salt rejecting RO membranes were developed in laboratory test cell size. Nano Filtration (NF) membranes were also prepared suitable for rolling in 4040 spiral module, which gave close to 90 % Solute Rejection (SR) and 1000 LMD flux for salts like $Na_2SO_4$ and $MgSO_4$.




Operation Data at Name Plate Capacity of MSF section of NDDP Kalpakkam

Anti - biofouling membranes prepared with silver impregnation and membrane candles coated with the nanocomposite membrane developed in-house showed good performance with respect to bacteria rejection from water.

The brackish water RO unit installed at Pharare fisher hamlet of Ratnagiri district Chiplun

Brackish water RO unit installed at Pharare fisher hamlet in Ratnagiri

(Maharashtra), as a part of AKRUTI programme for field testing of RO system in rural areas was rectified for voltage fluctuation and pump tripping.

**Development of indigenous membrane and membrane elements**

BARC carried out the development of indigenous membrane and membrane elements for desalination and water purification. Integrating water purification unit with renewable energy source is important for remote areas, where scarcity of power and water co-exists. For such remote areas, BARC has developed a solar energy driven membrane based desalination/ water purification system. The technologies of (a) solar energy driven portable domestic brackish water RO technology and (b) stand-alone solar photovoltaic (PV) driven battery-less ultrafiltration

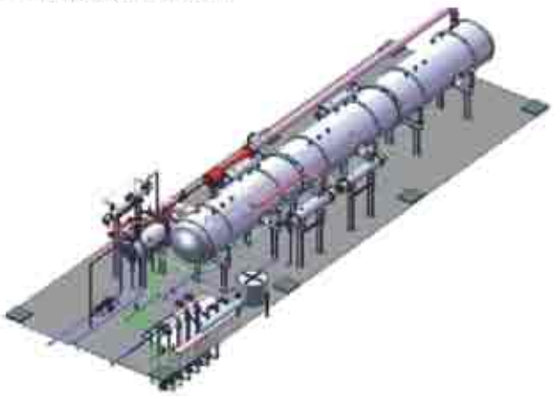
(UF) unit for water purification have been released for know-how transfer to interested parties for wider deployment.

**Bicycle mounted mobile solar PV based Ultra-Filtration (UF) water purification unit**

A bicycle mounted mobile solar PV based Ultra-Filtration (UF) water purification unit (80 LPH capacity) and Brackish Water Reverse Osmosis (BWRO) unit of (10 LPH capacity) was developed. Skid mounted Electro-De-Ionisation (EDI) unit was operated on regular basis for performance evaluation and supplying ultra pure water to users for high end water quality requirement. De-Ionized water of about 17 mega ohm cm resistivity was supplied to different laboratories for high end applications.

**Multi-Effect Distillation Mechanical Vapor Compression (MED-MVC)**

Multi-Effect Distillation Mechanical Vapor Compression (MED-MVC) sea water desalination plant was operated on regular basis. Average product water flow of 2.3 m3/hr and conductivity of 3-5 µS/cm was obtained providing valuable design inputs for larger plants. The installation of Multi-Effect Distillation Thermal Vapor compression (MED-TVC) sea water desalination plant was taken up.



3D model of MED-TVC System

## INDUSTRIAL APPLICATIONS

BARC made available specialized industrial radiometry and radiography testing services to different units of the DAE and outside organizations. These included Radiometry Testing of SHC mock-up blocks of 700 MWe PHWR-KAPP-3&4 for NPCIL; Radiometric Testing of the Cell walls of Advanced Vitrification System-II (AVS-II), Tarapur; Radiometry Testing of process cells of Waste Immobilization Plant at Kalpakkam; Radiometric Testing of Shielding Blocks for the Nuclear Submarine project manufactured under Advanced Technology Vessel Program (ATVP), Ministry of Defense, Govt. of India and specialized radiography testing of indigenous neutron detector probes for High Temperature Fission Counters, developed by the Electronics Division, BARC for detection of possible defects developed as a result of in-plant use.

Flow rate measurements using radiotracer (Iodine-131) techniques in Saurashtra Branch Canal (SBC) at Surendranagar, Gujarat were carried out to validate pumping efficiency of the Concrete Volute Pumps used for pumping. The discharge rate was measured to be 20.3 m3/s against the designed value of 20 m3/s.

A radiotracer investigation was carried out at Kolkata Port Trust, Kolkata to examine the suitability of a dumping site for dredged sediment located at south of shipping channel. Scandium-46 (8Ci) as scandium glass powder having a particle size distribution ranging from 40-100 microns was used as a radiotracer.

Experiments were conducted in fluidized and packed fluidized beds of silica particles in the interstices of large size alumina pebbles and lithium-titanate pebbles. The quality of fluidization was better in packed fluidized than the conventional.

SHRI Facility of Radiation Technology Development Division continued to treat the sewage sludge in round the clock shifts for hygeinisation of municipal sewage sludge at Vadodara. About 500 tons of dried hygeinised sludge was supplied to local farmers for use in agriculture. Several state governments have shown interest and are in the process of evaluating feasibility of replicating this technology.

Radiation processed flexible polymer-elastomer based polymer matrices were developed for sensing volatile organic compounds (VOC) to cover entire spectrum of toxic VOCs, ranging from non-polar toxic benzene to highly polar formic acid

**Development of laser based cutting techniques for applications in nuclear reactors**

At RRCAT, a manipulator with two laser cutting nozzles was developed for laser cutting in congested environment. This manipulator was successfully deployed for cutting of Q-10 coolant channel bellow lips of KAPS-2 reactor and an enormous reduction in radiation dose, time and cost was achieved.

**Development of a water jet assisted laser cutting technique**

A water jet assisted laser cutting technique was developed for underwater cutting

Demonstration of water jet assisted underwater laser cutting process

of SS and aluminium nuclear reactor components with high radioactivity level. With this cutting technique, no turbulence was generated in the water and it minimised the probablity of airborne activity.

**Laser for cleaning and decontamination applications**

A flash lamp pumped fiber coupled Nd:YAG laser with 55 $\mu$s pulse duration, 1.25 J pulse energy and upto 25 W average power was developed.

Laser cleaned samples of marble, zircaloy and inconel

**Recovery of gold coated optics by RF-Plasma based cleaning**

A RF plasma cleaning setup to clean metal coated expensive optics was developed. This has made possible reuse of the costly optics, which is otherwise rendered useless due to deposition of carbon on the metal coated surface.

Pulse compressor grating, a) before and b) after RF plasma cleaning

**Prototype light emitting diode (LED) based system for cancer diagnosis**

A LED based, USB powered, portable diagnostic system capable of sequentially


LED based portable diagnostic system developed for cancer diagnosis

acquiring fluorescence and diffuse reflectance spectra from tissue was developed. A miniaturized electronic data acquisition card was made for the automated sequential acquisition of reflectance and fluorescence spectra. The system is more compact, cheaper and rugged compared to the nitrogen laser based system that was used earlier for the same purpose.

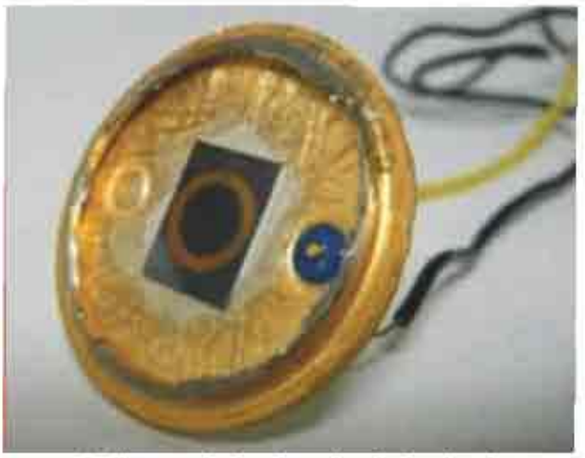
### Fluorescence lifetime measurement probe

A handheld probe has been designed and fabricated for the measurement of fluorescence lifetime of Nd doped laser materials by the phase lag technique and tested using a high stability function generator and Nd doped glass samples.

Fluorescence lifetime measurement probe prototype

### Development of radiation hard GaAs based photodetectors

GaAs based photodetectors with good spectral response in the wavelength range of 300–860 nm have been developed indigenously using the MOCVD semiconductor growth facility. The developed photodetectors have potential applications in high radiation zones



Indigenously developed radiation hard GaAs photodetector

### Inspection systems for Nuclear Fuel fabrication process

A prototype imaging setup for pellet inspection has been designed and developed

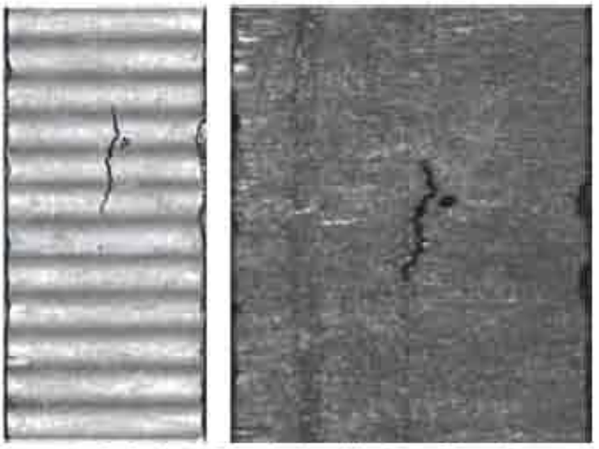


Image of a faulty pellet obtained by Area Scan Camera (L) with Line Scan Camera (R)

using a line scan camera with GigE Interface. A white LED based line light illumination is used to uniformly illuminate a narrow width of the pellet surface. This unit provides synchronized pulses for the stepper motor control electronics and also provides trigger for the line scan camera.

**Radioisotope Sources supplied by BRIT**

**Industrial Irradiator Sources**

Ninety three numbers of Irradiator sources were supplied to various Irradiators with total activity of 1100 kCi of which 34 nos. of sealed sources were supplied for the first time to NIPRO, Satara in BC-188 type pencils.

Source Loading at Radiation Processing Plant NIPRO Satara

Cobalt-60 Rack Design of NIPRO Irradiator

**Radiography Sources**

Radiography Sources of 900 Ir-192; 7 Co-60 and 1 Tm-170 with a total activity of 40 kCi; 400 Ci and 10 Ci respectively, were fabricated and supplied to various NDT users in the country. Radiation Sources custom made for Nucleonic Gauges and uses were: Co-60: 32 sources with activity of 2287 mCi; Cs-137: 3 sources with 214 mCi ; Tm-170: 1 source of 10 Ci.

**Gamma Chambers**

Fifteen numbers of GC-4000 pencils unloaded from GC-4000 unit supplied to Uruguay have been brought to India , The sources were brought from USA in two numbers of Type A lead pots. Both the packages were sent back to USA after removal of sources.

**Blood Irradiators**

Five Blood Irradiators (BI 2000) were loaded with approx. 808 Ci of 60Co-Cobalt activity in each. A total number of 47 pencils were loaded in these units. For the first time, 3 Ci Ir-192 HDR source was fabricated for the indigenous HDR unit. Newly installed 3 port laser system was

Radiometry of HDR Flask

used for the radiometry of the HDR transport flasks.

At Regional Center, RAPPCOF, KOTA a total activity of 691 kCi in 17 sub assemblies was processed and 1170 kCi of activity was transported in 12 consignments. Another 6 consignments with 600 kCi are expected to be transported in March 2013.

Special permission for the transportation of the absorber rods were taken from AERB and eight Co-60 absorber rods were transported from KAIGA to RAPPCOF. During the year four absorber rods from RAPS-2, eight absorber rods from RAPS-3 were unloaded for the fabrication of the Irradiator sources. Fifteen, W-91 sources were fabricated at RAPPCOF. Two teams of RAPPCOF successfully carried out source loadings at OGFL and JCPL, Bhiwadi

**Isotope Application Services**

Various radioisotopes, in sealed form and open sources were used for several troubleshooting applications in industries. Radiotracer technique was successfully used for leak detection in series of heat exchangers at Chennai Petroleum Corporation Limited (CPCL), Chennai and Bharat Petroleum Corporation Limited (BPCL), Mumbai.

Placement of detectors in heat exchangers for leak detection at CPCL, Chennai

Tangential pipe profiling in progress at HPCL, Mahul, Mumbai

The leaky heat exchangers were identified by on-line radioisotope techniques using 82Br as radiotracer.

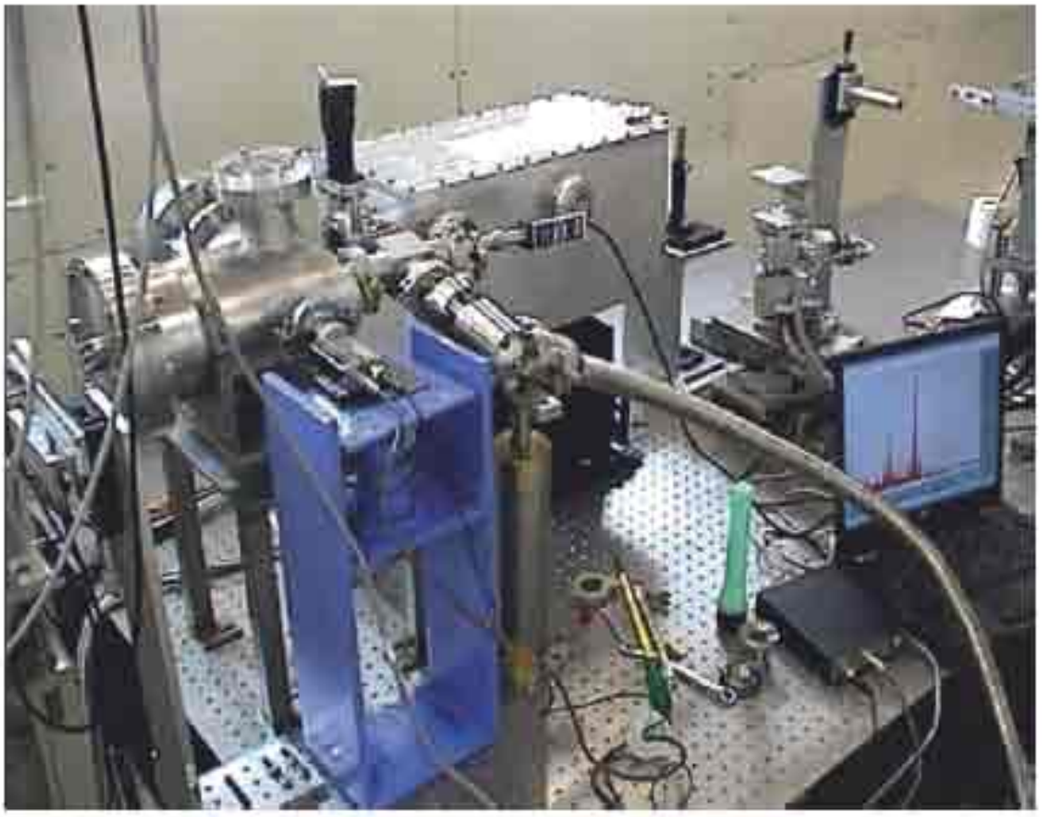
Gamma scanning of process columns was carried out by using sealed source 60Co in various refineries and chemical industries for troubleshooting. The technique provided on-line and fast identification of problematic zones in the process columns.

Interface detection of hydrofluoric acid (density 0.98 g/cc) and hydrocarbons (density 0.84 g/cc) was successfully carried out in a closed hydrofluoric settler tank for Reliance Industries Limited, Patalganga.

Interface detection for HF settler Tank settler at Reliance Industries Ltd.

# CHAPTER -5

# BASIC RESEARCH



Vacuum assisted experimental station on the x-ray fluorescence beamline

400 kV accelerator dome and accelerating tube

## CHAPTER 5
# BASIC RESEARCH

The Department of Atomic Energy has contributed significantly towards strengthening basic research in India. The Department pursues basic research in its R&D centres that ranges from mathematics to computers, physics to astronomy and biology to cancers. It also provides grants-in-aid to eight Institutes of national eminence. Following were the major activities and achievements of DAE in basic research, during the period of report.

## MATHEMATICS & COMPUTATIONAL SCIENCES

VECC, in collaboration with Webel Mediatronics Limited, Kolkata continued the development of software for the hearing-impaired persons. The software "Mounisara 1.0" that translates input Bangla text to sign language was released. The present version is "Mounisara 2.1".

The software was distributed free-of-cost to several deaf schools within West Bengal. Based on feedback the scope of the software was enhanced. Similar translator software with the input text in Hindi was also developed to extend


Graphical user interface of the Hindi version of Mounisara 1.0.

Graphical user interface of e-book (Text Book: Barnaparichay–II).

the usefulness of such software in the national level. E-books for the primary school children based on sign language were developed. Barnaparichay-II, Kishalaya and Sahaj Patha have been developed till now. A lesson on conversation in sign language was also developed.

At TIFR, the famous Zariski-Lipman Conjecture was proved in many cases by a global approach, different from all the previous methods. Representation equivalent lattices in products of real and p-adic Lie groups were investigated. Monodromy groups were shown to be Arithmetic in many cases.

The power of sequential decoding for channels with classical input and quantum output was studied, and a strategy for achieving existing capacity bounds was developed. An online algorithm for throughput maximization in green communication with energy harvesting nodes was explored. The Concert Queuing Game with Random Arrivals was analyzed. A characterization of automata and decision

complexities for unary un-timed and timed temporal logics was obtained.

At SINP, the eigenvalue problem of the DN type of Calogero model was solved by mapping it to a set of decoupled quantum harmonic oscillators through a singular similarity transformation. It was shown that the eigenfunctions of such Calogero model can be constructed from those of bosonic harmonic oscillators having either all even parity or all odd parity.

The level density distributions for a class of 1-dimensional classical vertex models related to Haldane-Shastry like spin chains were studied. Work was done on topological defects in graphene in the presence of an external charge. Both the sub and supercritical regimes of gapless and gapped graphene were studied and their properties were investigated.

Phases of matter at the Planck scale, where quantum effect of gravity are important were studied. The twisted statistics of quantum fields in the vicinity of a noncommutative black hole at the Planck scale were investigated.

In quantum field, the on-going work included the study of correlators of the topological charge density and the autocorrelations of a host of observables like gauge plaquette, Wilson loop, pion and nucleon propagator, and topological charge and susceptibility, with the Domain-Decomposed Hybrid Monte Carlo algorithm.

At HRI, the research work spanned the domains of number theory, algebraic number theory and analysis and geometry.

Research on L-functions associated to Maass forms was in progress. Work was continued on some zero-sum problems with weights. Progress was made in some Ramsey-type problems for finite colourings of the Euclidean plane.

Norm form Diophantine equations over a ring of integers of a quadratic number field was studied and some new results in this direction were obtained.

Work was done on geometric quantization of compact Kahler manifolds ; obtaining new identities from Ramanujan's identities using the theory of minimal surfaces; interpolation between two real analytic curves by minimal surfaces. Work was done on geometric prequantization of path spaces of a geometrically prequantized manifold.

Institute of Mathematical Sciences continued its ongoing projects of Mathematics Education on Mathematical Sciences without Walls; developing tools for dynamical modelling of C elegans neuronal network activity; Interplay of non-linearity with quantum effects and curve geometry; INO Project and Potential Theory on Infinite Networks and Trees.

The School of Mathematical Sciences at NISER continued its teaching and research activities and conducted seminars regularly. NISER has academic expertise in harmonic analysis, operator theory, representations of geometries, number theory, cryptography, algebraic graph theory and probability theory. Outstanding mathematicians from across the world presented their latest research findings in various fields of mathematics in the seminars. School of Mathematical Sciences introduced strong curriculum in the fields of applied mathematics, financial mathematics and computer science.

## PHYSICS

An experiment to quantify the damping of

the nuclear shell effect on the nuclear level density with temperature was carried out at BARC by using a large plastic detector array to measure neutron time-of-flight spectra from $^{206}$Pb and $^{184}$W using the transfer–fusion ($^{7}$Li,) reaction.

The evolution of the GDR built on excited states over a wide range of angular momentum and temperature in $^{100}$Mo+$^{28}$Si fusion was studied to investigate the applicability of the thermal shape fluctuation model.

A program to measure neutron induced fission cross sections for various unstable actinide isotopes which are produced in Th-U or U-Pu fuel cycles by the surrogate reaction method using $^{6,7}$Li induced transfer fusion on stable Th and U targets was pursued. The fission cross sections for $^{231,233}$Pa, $^{236,238}$Np, and $^{241}$Pu, in the neutron energy range of 10 - 16 MeV were measured and compared with statistical model predictions.

Gamma-ray spectroscopy of neutron rich nuclei, populated in thermal neutron induced fission of $^{235}$U at CIRUS/Dhruva reactor facilities was taken up. Off-line decay spectroscopy was carried out. The decay of $^{140}$Ba to levels of $^{140}$La was studied using 4 Compton suppressed high purity Ge clover detectors. Fission dynamics of excited, heavy nuclei was studied from the measurement of near-scission α-particle energy spectra.

The National Facility for Neutron Beam Research at the Dhruva nuclear reactor was utilized by both DAE and external users supported by UGC-DAE-CSR and BRNS. The underlying physics of the spintronics behaviour was understood by studying their core-shell structure employing the small-angle- neutron scattering technique.

BARC is a major collaborator in the Compact Muon Solenoid (CMS) heavy ion experiment at CERN, Large Hadron Collider (LHC), and has participated in the Pb+Pb and p+p data analysis. Using Pb+Pb collision data, the signals from the dimuon channels were extracted for the analysis of various quarkonium states.

The first instance of reciprocity and unitarity in the scattering from a non-Hermitian complex PT-symmetric potential was found.

High pressure phase stability and equation of state of actinides and their compounds (Am, Cm and PaN), as well as Molecular Dynamics (MD) simulations to understand high pressure high temperature polymorphism and melting in tantalum were carried out. Extensive studies of the structural, electronic, vibrational and elastic properties of diamond in the Mbar pressure range were carried out. Similar studies of a variety of condensed phase systems such as crystalline amino acids, alanine and glycine under pressure were also carried out to elucidate the variations in the hydrogen bonding in these compounds.

A systematic Raman spectroscopic study of thorium based nuclear fuels was carried out to demonstrate non-destructive composition analyses of proposed nuclear fuels like $ThO_2$-$UO_2$ mixture and Simulated high-burnup nuclear fuel (SIMFUEL). Raman spectroscopic studies of TNT based explosives were carried out to investigate melting and decomposition.

Single crystals of Ag doped $Li_2B_4O_7$ were grown for a possible use in sensitive thermoluminescence and optically stimulated luminescence based dosimeters

A new process was developed to prepare optically transparent ceramics (OTC) of the $CaF_2$:Mn and $CaF_2$:Mn+Ce. These ceramics have

shown good sensitivity and linearity as thermoluminescent dosimeters.

The TACTIC gamma ray telescope at Mt. Abu was deployed for observation of a number of Active Galactic Nuclei to monitor their flaring activity in the TeV (1 TeV=$10^{12}$ eV) energy range.

Manufacturing activities related to the various sub-systems of the 21m diameter Major Atmospheric Cerenkov Experiment (MACE) gamma-ray telescope progressed well. The trial assembly of its mechanical structure which started at Hyderabad was at an advanced stage of completion. A prototype of the 16-channel detector module was assembled and is presently undergoing detailed testing. Around 970 mirror facets were manufactured and qualified for deployment on the MACE telescope.

At RRCAT, the experiments were carried out using plasma plume produced from the ablation of nylon target by focusing a second harmonic of Nd: YAG laser with 40 mJ energy, 12 ns duration to a peak intensity of $10^{10}$ W-cm$^{-2}$. At the optimum interaction conditions, a high quality electron beam, with energy around 10 MeV with quasi-monoenergetic feature was produced.

Bose-Einstein condensation (BEC) of atoms has been observed in laser cooled $^{208}$Pb atoms. A double Magneto-Optical Trap (MOT) setup was developed for this study.

The first experimental giant dipole resonance (GDR) width systematics, in the temperature region 0.8–1.2 MeV for $^{207}$Tl, a near Pb nucleus was carried out at VECC to investigate the evolution of the GDR width in shell effect and pairing dominated region.

The low lying states of odd-odd $^{126}$I having three proton particles and three neutron holes with respect to the closed shell configuration of $^{132}$Sn were characterized from decay spectroscopy. The life times of excited states of $^{126}$I were measured using scintillators.

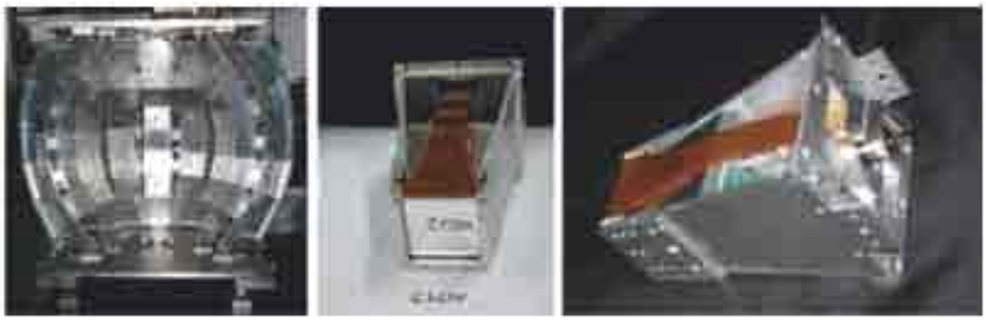
The picosecond lifetimes of the excited levels of odd-odd $^{156}$Eu were measured following the mirror symmetric centroid difference technique utilizing the unique combination of moderate energy resolution and a very good time resolution of a $LaBr_3$ detector. Excited states of $^{156}$Eu were produced by (a, 2n) reaction with 32 MeV alpha beams.

The beta gamma coincidence technique utilizing the beta response of a thin window planar segmented Ge LEPS detector for the measurement of endpoint energies, even for very weak beta branching was achieved successfully.

A new laboratory for fabrication of neutron detector was developed at VECC. Several neutron time of flight (TOF) detectors of dimension 7"x 5" were developed and a detector with new design was fabricated on the basis of R&D carried out on various design aspects of neutron detector made of liquid scintillators.

New design of neutron detectors developed at VECC

For the Charged particle detector array (CPDA), a clean room facility of class 100000 was developed for Storage and mounting of silicon detectors and CsI(Tl) crystals. The mechanical structure of the forward part of the array was completed.



Mechanical structure of the forward part and forward Array telescope with housing

The Magnet-Cryostat of Penning Ion Trap housing the Penning trap assembly was commissioned at VECC. It was kept at liquid helium temperature for quite some time and cryostat stability was tested for quenching effect. The 6 Tesla superconducting magnet operated successfully in persistent mode. Electrode assembly designed as per simulation studies was fabricated and high precision machining of copper electrodes and MACOR rings was achieved.

Penning Ion Trap Electrode Assembly fabricated at VECC

Heavy quark energy loss in a decorrlined medium and its effect on azimuthal anisotropy was investigated further a detailed investigation of system size dependence of nuclear modification factor and azimuthal anisotropy of jet quenching was studied.

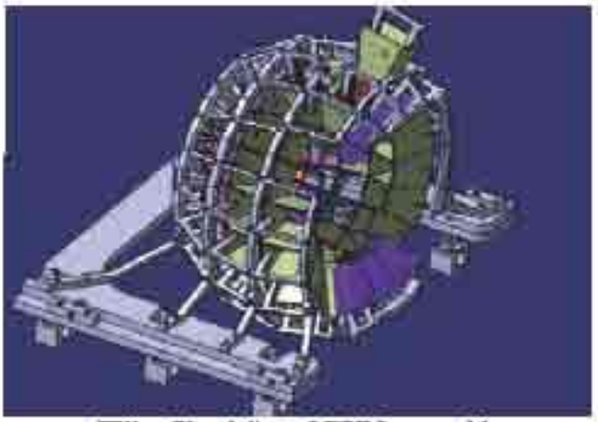
Laser welding of copper wire to electrode

A model for projectile fragmentation was developed. In an important study, equivalence between the canonical and grand canonical ensembles was established for fragmentation of finite nuclei. In another investigation, the ratio of symmetry energy coefficient to temperature was extracted from different prescriptions using the isotopic as well as the isobaric yield distributions.

Considerable progress was made in developing advanced detector systems. The silicon detectors as the detecting elements of the Forward Calorimeter (FOCAL) in ALICE upgrade, developed in collaboration with BARC and BEL were tested at VECC and CERN successfully. Two types of readout system one based on MANAS and the other based on ANUSANSKAR ASIC developed at BARC, were used.

Test beam setup for a prototype FOCAL detector at VECC

A 4π Charged Particle Detector Array (CPDA) was developed at VECC to understand basic properties using superconducting cyclotron beam.



Fitting Simulation of CPDA assembly

CPDA backward part assembly

A support structure was designed for mounting the detectors for the required orientation. Simulation for dismantling a single housing was carried out with CAD modelling software. Support ring cross sections were designed such that the rings were contained entirely within the non interference zone. The base plates and stands were also designed with the same principle.

TIFR continued its research activities in physics and new signals for SUSY were proposed and evaluated using inputs from existing Tevatron and B-factory data.

A nano-electromechanical system fashioned out of an incommensurate charge density wave (CDW) system was studied theoretically and experimentally, resulting in a a new way of studying CDW materials on the nanoscale. A theoretical model of proportionate growth of baby animals was also studied.

Chern-Simons Theories were analyzed and their gravity duals were explored. Various aspects of the AdS/CFT in condensed matter physics were also studied.

The first observationally determined velocity distribution function of galactic Dark Matter (DM) was obtained. Observations of X-Ray clusters were used to estimate the amount of feedback energy in cluster gas. Detailed comparison of Monte Carlo and Fisher method of forecasting cosmology constraints was done.

In Astronomy and Astrophysics, instruments for ASTROSAT were fabricated. Detectors for hard X-ray astronomy were developed. An Infrared Spectroscopic Imaging Survey (IRSIS) payload for an Indian Small Satellite was developed. Near Infrared Imager

and spectrometer camera fabrication was completed. Near Infrared Imaging camera developed in-house, was successfully used for science observations. A wide variety of problems related to solar physics, seismology, high energy astrophysics, black holes and other compact objects were investigated.

Long-term, systematic observations of the solar wind using interplanetary scintillation of the 3-D evolution of the solar wind density and speed were allowed investigations. GMRT was used to place stringent limits on the radio emission from extra solar planets, as well as to carry out a survey for supernovae remnants and pulsars in the plane of the galaxy. Several new and exotic pulsars have been discovered by searching for pulsations associated with sources identified by the LAT instrument aboard the Fermi satellite.

Observations of the neutral hydrogen in a large, systematically selected sample of extremely small, nearby galaxies were used to understand the connections between star formation and gas in the closest analogs to primordial galaxies. Sensitive, high resolution radio continuum observations of nearby spiral galaxies were used to study the radio-FIR correlation on small scales and the diffusion of cosmic rays in these spiral galaxy disks.

Studies of neutral hydrogen absorption arising from galaxies in the distant universe were used to determine the evolution of the cold gas content of galaxies with cosmic redshift. Accurate measurements of the red-shifted frequencies of multiple absorbing species were also used to place constraints on the evolution of fundamental constants with redshift. The major upgrades of various sub-systems of Giant Metrewave Radio Telescope (GMRT) progressed further.

CMS Experiment at the Large Hadron Collider in CERN, Geneva, Switzerland collected 20 fb-1 of integrated luminosity. Evidence for the Standard Model Higgs boson was presented. D0 Experiment at the Tevatron proton-antiproton collider, Fermi National Accelerator Lab in Batavia, Illinois, USA completed 30 years of running. There was also an evidence of the Higgs boson in the mass range 115-140 GeV.

In nuclear physics, a time-dependent bond-hardening process was discovered in a polyatomic molecule using few-cycle pulses of intense 800 nm light. It was demonstrated that aligned carbon-nanotube arrays are efficient transporters of laser-generated mega-ampere electron currents over distances as large as a millimeter. A compact laser-driven plasma accelerator for MeV energetic neutral atoms was demonstrated. A neutral atom source was built based on laser generated cluster plasmas, with 100% fast atom conversion efficiency, enabled by Rydberg excited clusters.

In Condensed Matter Physics, the THz spectroscopy setup was redesigned to enhance the emitted radiation. Direct evidence of intercalation in a topological insulator turned superconductor was presented. The effects of Tm3+ Additions on the Crystallization of LaF3 Nanocrystals in Oxyfluoride Glasses were investigated. The Au nanoparticle uptake (with different capping agents), interaction and accumulation on normal and cancerous human cell were also studied.

The experimental activities at SINP added new data acquisition system to the tokamak and a new microwave source was procured for the MaPLE device. Some interesting results were obtained on the plasma propulsion experiment.

The correlations between electric dipole polarizability & the neutron-skin in 208Pb nucleus have been studied using several non-relativistic and relativistic mean-field models.

Thermodynamic properties of such matter based on field theory at finite temperature and baryon density, and also other phenomenological aspects of very hot and dense matter created in heavy-ion collisions are being pursued. The strangeness −2 sector has been investigated by studies of the (K−,K+) reactions on proton and heavier nuclei.

At HRI the research activities were carried out in five major areas of Physics and they were Astrophysics, Condensed Matter Physics, High Energy Physics, Quantum Information and Computing and String Theory. The astrophysics group carried out measurement of the power spectrum and the bi-spectrum for various inflationary models were carried out and in general relativity, various aspects of quantum fields in curved space time were studied.

The Condensed Matter Physics group works in many areas such as Statistical Mechanics and Chaos, Strongly correlated Systems and Cold Atoms, Mesoscopic Systems and Spintronics, and Electronic Structure and Clusters. During the year the quantum information and computation group at HRI produced 15 research papers. The members of the string group undertook a study of the decay of massive fields in de Sitter space.

The High Energy Physics group continued to focus on systematic studies of physics signals at the Large Hadron Collider (LHC), the biggest ever international experiment in the history of fundamental science. Work on supersymmetric extensions of the Standard Model and the implications of a non-standard Higgs sector and extra space-time dimensions were also carried out.

The Institute of Physics (IOP) continued to pursue research in String theory, Cosmology and Particle physics. Some of the topics of recent interest are gauge / gravity duality, black hole Physics, anisotropic power law inflation, different aspects of relativistic heavy ion collisions, and dual superconductor model of Hadronization. Connection between phase transition in cosmology and Condensed matter suystem such as liquid crystal being investigated. In high energy phenomenology, cross section processes of one loop which are important for analysis of LHC data were studied.

IOP also focused research on nuclear structure and nuclear reaction. The mechanism for the formation of super heavy elements in astrophysical objects, nucleon-nucleus and nucleus-nucleus reaction, and study of cluster decay properties were pursued. Studies on quantum information were also carried out.

Major activities on experimental side included studies of accelerator based material science, surface and interface physics and nano systems. Analysis of valence band electronic structure and band mapping of transition metal-oxide compounds using photoelectron spectroscopy was undertaken. New facilities like SQUID-VSM and spectral response system for studies of magnetic and optical properties of materials were also added.

At NISER, The School of Physical Sciences continued to provide research activities and the areas covered included High-energy physics, Condensed-matter physics, Bose-Einstein condensation, nonlinear optics, Laser Physics and Nano-photonics. The five year integrated post graduate programme and one research work included courses from core areas of physics such as Classical Mechanics, Quantum Mechanics, Electromagnetism, Statistical Mechanics etc.

## CHEMISTRY

A procedure was developed at BARC to

prepare stable composite beads containing $TiO_2$ by preparing cross linked chitosan-$TiO_2$ composite beads. These composite beads were prepared using locally available titanium oxide and natural polymer chitosan (derived from shrimp shells), making it highly cost effective. Both nano-$TiO_2$ and the chitosan-$TiO_2$ beads showed excellent antimony pickup under wide range of solution pH (initial).

A two dimensional Infrared (2D-IR) spectrometer was developed around a 1 kHz amplified femto-second (fs) laser system. The infrared laser pulse used for the excitation of the sample was generated in two optical parametric amplifiers (OPA).

Two dimensional Infrared (2D-IR) spectrometer

For developing single source molecular precursors for semiconductor nano-materials and thin films, the chemistry of 2-seleno and 2-telluropyridines was explored.

Organotin pyridylselenolates were synthesized for the preparation of tin selenide nano-structures and thin films.

Luminescence from complexes of group 13 metals was exploited for organic light emitting diodes. Organo-gallium and -Indium complexes with dianionic tridentate Schiff bases and benzoazole ligands were prepared.

Zinc oxide (ZnO) nanoparticles were synthesized by pyrolytic and gel combustion methods and characterized using different techniques. The efficiency of the nanoparticles with respect to sorption of different toxic species like chromate ions and rhodamine 6G was evaluated.

A detailed investigation of nature of order-disorder transition in the $Nd_{2-y}Ho_yZr_2O_7$ system, over the entire composition range using diffraction and spectroscopic analysis techniques was undertaken. Comprehensive studies were performed to investigate the ionic conductivity behaviour of these solid-solutions in correlation with the structural transformations using AC impedance spectroscopy.

The quest for a G-quadruplex specific fluorescent sensor amongst other DNA forms under physiological salt conditions was addressed. Application of Thioflavin T (ThT), a water soluble fluorogenic dye, in dual role of exclusively inducing quadruplex folding in the 22AG human telomeric DNA, both in the presence and absence of Tris buffer/salt was demonstrated.

Interfacial modification of materials for diverse applications such as drug delivery, sensors and energy conversion was carried out. Peptide functionalized magnetic nanoparticles were prepared for pH dependant binding of drug molecules and its implications in anticancer drug delivery was investigated. Porous silicon interfaces were modified with nitrided TiO2 (TiON) nanoparticles to develop highly efficient photoelectrodes.

The radio-protective effect of extracellular melanin, a naturally occurring pigment, isolated from the fungus Gliocephalotrichum simplex was examined in BALB/C mice.

Heterocyclic ligands such as triazinylphenanthroline (TPhen) and bistriazinylphenanthroline (BTPhen), consisting of a triazinyl moiety on phenanthroline backbone were synthesized for separation of Ln(III) and An(III) ions from the high level nuclear wastes.

Using the synthetic alkaloid, corolyne as a photosensitizer in conjunction with UVA light, a new Photo dynamic Therapy (PDT) regime was developed.

Several enantio-selective chemical and enzymatic asymmetric protocols were formulated and used for the syntheses of a diverse array of anti-cancer and immuno-modulatory compounds.

New protocols for D-labeling were developed and used for the synthesis of D-labeled tributyl phosphates and deuteriated-drugs.

Nano - crystalline oxide powders of manganese were formed by the radiolytic reduction of permanganate ($MnO_4^-$) at ambient temperature and pressure in acid, neutral and alkali mediums and were analyzed by X- ray powder diffraction, Raman spectroscopy, X-ray Photoelectron Spectroscopy (XPS), Atomic Force Microscopy (AFM) and Scanning Electron Microscopy (SEM).

To explore new biocides for bio-fouling and microbial control, a wound dressing that works on the principle of release of nitrogen oxides from acidified sodium nitrite was developed.

Thermodynamic parameters of complexation of Eu(III) with pyridine carboxylates were studied by potentiometry, fluorescence spectroscopy and calorimetry. Results revealed formation of four complexes, in case of picolinate whereas only meta-ligand complexes were formed in case of nicotinate and isonicotinate.

Otracer studies were carried out to understand mechanism of formation of Ag nanostructures in ionomer matrix, and reorganizations in nano-composites in different counterion forms.

In TIFR, a facility for femtosecond transient spectroscopy was setup and studies of reaction mechanism in ultrafast photo induced ET were initiated along with work in carotenoid metabolism and molecular photo catalyst development.

A conformation change of the Alzheimer's disease-causing amyloid beta peptide was identified. Mechanism of action of GTP aptamer RNA was elucidated. Several mutants of thermostable cytochrome P450 enzyme were rationally designed to metabolise steroids and aromatic hydrocarbons.

HIV-1 protease (PR) and its mutant, PRD25N was found to undergo different folding transitions at lower acetic acid concentration. This has implications for emergence of drug-resistant mutations in the protein. The studies on the mechanical properties of a ubiquitin-like protein SUMO2 were completed.

The School of Chemical Sciences, NISER embarked on teaching and research activity in the traditional organic, inorganic, physical and theoretical chemistry areas as well as in the interface areas of Biology, Material Sciences and Medicine. It also imparted high quality undergraduate and postgraduate level of knowledge to students. It offered one of the best integrated postgraduate programme and the syllabus was designed not only to teach basic principles but also to have hands on practical experience.

## BIOLOGY

At BARC, the activities were focused on basic and applied research aimed at understanding mechanisms underlying cellular responses to radiation, oxidative and other stresses in Deinococcus radiodurans, Anabaena, E. coli and rice at molecular and structural level using recombinant DNA techniques and TEM facilities. Successful efforts were also made to generate recombinant organisms for precipitation of uranium from dilute acidic/alkaline solutions and for TBP biodegradation.

Surface Plasmon Resonance and Atomic Force Microscope procured under XIth plan were installed and made functional.

Matrix-assisted Laser Desorption/Ionization-Time of Flight Mass Spectroscopy facility was used to identify about 400 proteins from cyanobacteria native to Indian soils to generate proteomic maps and understand their response to oxidative stress.

The 30 kDa MnSOD protein of Anabaena 7120 was found to be post-translationally processed to generate multiple functionally active forms.

At TIFR, insights on enzyme active site geometries that relate to promiscuity of catalysis were obtained. Chromosome movements during DNA damage response in mammalian cells were uncovered. A module of physically interacting proteins involved in endocytosis was identified. Molecular mechanisms of kinesin-2 dependent axonal transport of choline acetyltransferase, and the kinesins-2 motor subunit assembly were established. Unknown role of Myosin Vb and Wnt signalling in cell size and cell shape regulation, respectively was unravelled. The basis of the generation and spatial propagation of cell shape oscillations was uncovered. Optical trapping methodology to precisely measure the force generated by motor-proteins on single organelles of unknown size in cell extract was developed. The regulation of axonal transport using the C. elegans model was studied. TIFR, made progress in experiments aimed at identifying downstream targets of Lhx2 and the binding site of Lhx2 on the regulator sequences of some candidate genes. A novel stream that contributes neurons to the accessory olfactory bulb was identified.

Glycolytic enzyme Enolase, a novel drug target and vaccine candidate for Plasmodium species that cause malaria in humans and are increasingly becoming resistant to existing drugs was identified by TIFR.

At TIFR's National Centre of Biological Sciences, genomes of clinical isolates of E. coli was undertaken. Computational modeling studies of a variety of biological response systems were carried out. These studies have provided understanding of how phage integrate and process diverse information from the environment. Insights into lac and sRNA regulation, transition to stationary phase and principles to predict the dynamics of combinations of feedback loops was achieved. An Ecosystem ecology laboratory and Greenhouse facility was set up and genetic sequencing and genotype services were initiated with the addition of more NGS instruments.

SINP scientists took active initiative in structural genomics and proteomics research in hematological and neurodegenerative diseases. Gene therapy of chronic myeloid leukemia and structural elucidation of two important hemoglobin variants, implicated in thalassemia were done.

Experimental approaches to understand the biomolecular recognition process in different intracellular phenomena and bioinformatics

based theoretical approaches employing quantum mechanical calculations to understand the structure-function correlation in nucleic acids (DNA and different types of RNA) were the major activities in biophysics at SINP. In addition, the biophysical properties of lamins to understand their roles as intermediary filaments were also studied.

In chemical sciences attempts were made to unravel the mechanistic pathways of various photoinduced charge-transfer processes using steady-state and time-resolved absorption and fluorescence, magnetic field effect and theoretical modeling. The effects of some NSAIDs and similar molecules on different biochemical processes and external agents and factors on protein folding and misfolding were investigated. A new method for label free and rapid impedimetric sensing of Escherichia coli using antibody antigen bound on conducting polyaniline film was reported.

The School of Biological Sciences, NISER is one of the leading international centres for research and teaching with harmonious synthesis of classical and modern biology. Interdisciplinary learning through extensive subjects covering all fields of modern biology and inter-phasing with other scientific disciplines and undertaking high quality research activities in defined areas of biosciences was the focus of the school.

## CANCER

Regular operation of Medical Cyclotron and production of $^{18}F$ and its conversion to $^{18}F$-FDG, $^{18}F$-NaF, $^{18}F$-FLT and $^{18}F$-FMISO was carried out to meet the in-house as well as the nearby hospital requirements. A large number of patients attended RMC for diagnosis and therapy of their ailments. The diagnostic investigations were related to almost all organs of the body.

A large number of Thyroid patients were diagnosed and advised during the year. In addition to this 18F- FDG- PET scans and $^{99m}Tc$-radiopharmaceutical based scanning like whole body bone studies, renal studies, myocardial perfusion studies and thyroid studies were carried out during this year. Over 300 patients diagnosed as thyrotoxic and requiring [$^{131}I$] radioactive iodine therapy were treated at RMC during this period.

ACTREC provided public interface to cancer research through its focus on nationally relevant research on common cancers, outstanding clinical outcome in a large volume Bone Marrow Transplantation programme and by developing and disseminating indigenous technology such as Bhabhatron in collaboration with BARC.

The Clinical Research Centre programs continued to show an upward trend during 2012, particularly in terms of the patient services provided. Over 4400 new patients were referred to the Centre for investigation or treatment as a part of various IRB approved translational or clinical research projects. A Dental Clinic and Pediatric OPD were set up and made fully functional to meet patient requirements. A new Digital Subtraction Angiography (DSA) facility was donated to the Centre by a philanthropic organization.

The new investigations at the Cancer Research Institute included study of the structure, function and specificity of proapoptotic proteins and their role in cancer; examination of infra red absorption, Raman and fluorescence spectroscopy methods; development of imaging protocols for human cancer; early detection of molecular changes in ovarian cancer cells; use of biophysical techniques, macromolecular crystallography, structural biology and bioinformatics tools to visualize cancer susceptibility genes and proteins; study of

molecular and cellular mechanisms governing stem cell regulation and their perturbation during oncogenesis. Assessment of the anti-metastatic activity of drugs and other complexes and a detailed study of the aberrant expression in cancer of the intermediate filament proteins keratin and vimentin made progress.

Quality initiatives undertaken during the year in order to improve patient care were: analysis of incident reporting with root cause analysis; patient feedback redressal with response from the respective areas with regard to patient suggestions and complaints; registering patients at ACTREC and implementation of referral card facility.

DAE is planning to establish a cancer care facility in Chandigarh on the framework of Tata Memorial Centre (TMC), Mumbai. As of now there is no major cancer hospital for the population in this region.

## SYNCHROTRON & THEIR UTILISATION

The synchrotron radiation sources Indus-1 at 450 MeV energy, 100 mA current and Indus-2 at 2.5 GeV energy, 100 mA current were operated in round-the-clock mode at RRCAT. A number of improvements were carried out in the various subsystems including Indus beamlines that are part of the Indus synchrotron radiation sources. Salient among these are mentioned below:

Operation of Indus-2 at 2.5 GeV with beam current of about 125 mA was achieved using indigenously developed solid state RF amplifiers with a power of 125 kW, at 505.8 MHz; experiments to improve the beam lifetime at 2.5 GeV were done; a multi-variable active feedback control system has been installed to actively keep the electron orbit within ± 30 μm band over reference orbit both in horizontal and vertical planes; implementation of betatron tune feedback system at injection energy.

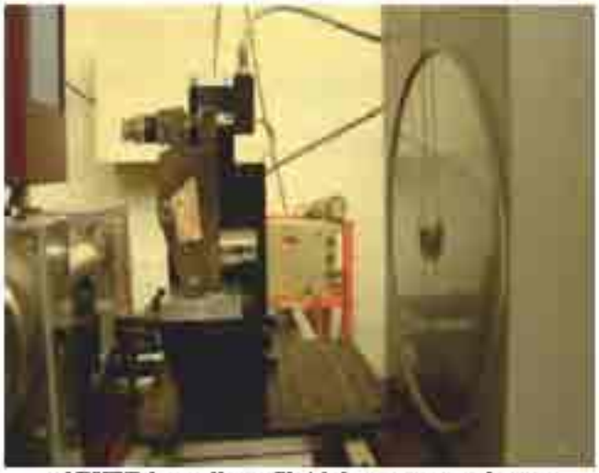
The experimental facilities installed on the beamlines of Indus-1 and Indus-2 were used by user groups from universities, national laboratories, academic institutes and DAE units in the country.

Eight beamlines on Indus-2 are now operational with the commissioning of three new beamlines during the year 2012 The data of the Indus-2 bunch pattern has been recorded using streak camera on the visible diagnostic beamline.


The x-ray photoelectron spectroscopy (XPES) beamline

The earlier commissioned Indus-2 beamlines were upgraded with new experimental facilities. The angle dispersive x-ray diffraction beamline was upgraded with the addition of low temperature and high-pressure facility. The high

ADXRD beamline with low temperature facility

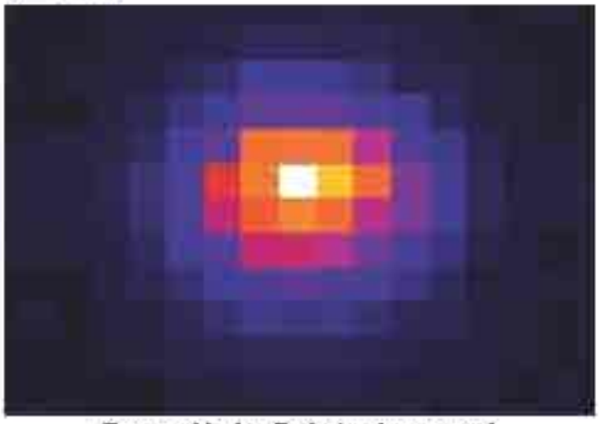


ADXRD beamline with high- pressure stage, attached to the Image plate

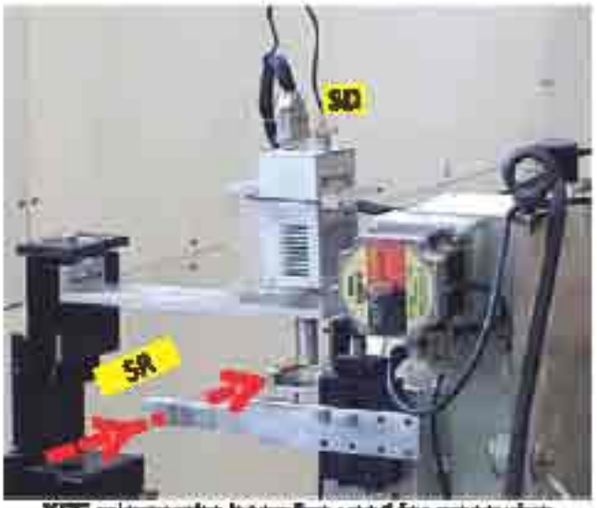
pressure setup on the ADXRD beamline was used by researchers from IGCAR and JNCASR. Experiments on $Tm_2O_3$ systems were carried out.

The x-ray fluorescence (XRF) beamline was upgraded with a sample vacuum environment for XRF measurements on low Z elements. XRF measurements on the lunar soil simulant samples from ISRO related to the Chandrayan mission were carried out on this system.

The spatial distribution of thorium and uranium in mixed oxide fuel pellets being developed for the advanced heavy water reactors has been studied using the XRF beamline.



Focused Indus-2 photon beam spot




XRF-microprobe beamline used for measuring spot size of the focused Indus-2 photon beam

Indus-2 photon beam has been focused to a spot size of 7.5 μm (H) x 4.3 μm (V) using the Kirkpatrick-Baez mirror optics installed on the X-ray fluorescence beamline. The spot size has been measured by the wire/edge scan method across the focused photon beam.

The soft and deep x-ray lithography beamline has been used for fabrication of high aspect ratio test microstructures for making different types of sensors, x-ray optics, microfluidic structures and micro-engineering micro-structures.

All the 5 beamlines on Indus-1 are fully operational. A low temperature (upto 80K) facility has been added to the angle integrated photoelectron spectroscopy (AIPES) beamline.

Measurements related to the studies of valence band offsets on heterostructures were done and experiments on the manganese (Mn) charge state modification in Manganite systems were studied.

The dispersive extended x-ray absorption fine structure (EXAFS) beamline has been upgraded with a low temperature facility. The photo-physics beamline has been upgraded with

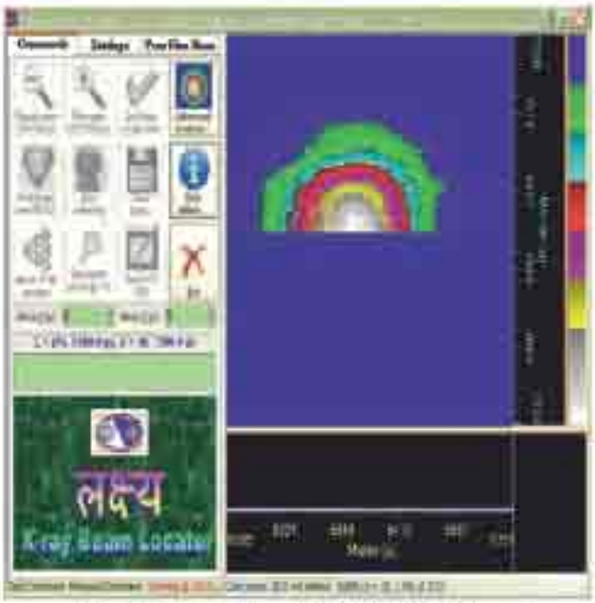
VUV absorption spectrum of acetone in argon matrix

a facility for matrix isolation spectroscopy. The VUV absorption spectrum of acetone in argon matrix at 10K taken using the matrix isolation setup on the photo-physics beamline on Indus-1.

Research work carried out using Indus-1 beamlines resulted in 41 publications in high impact factor journals and peer reviewed conference proceedings. Several user groups from IIT Delhi and Mumbai, PRL Ahmedabad, SINP Kolkata, UGC-DAE-CSR Indore, BARC Mumbai are using the beamlines on Indus-1.

**Data acquisition and controls for Indus beam lines**

At RRCAT a 2-dimensional X-Y beam scanner/ locater was developed for location of the X-ray beam in Indus-2 beamlines. An area of 10 x 10 mm2 was scanned with a resolution of 2.5 $\mu$m to 100 $\mu$m in different scan modes. The x-ray intensity was plotted in perpendicular plane using a Si-photodiode with a developed ultra low noise amplifier. The final unit with master computer



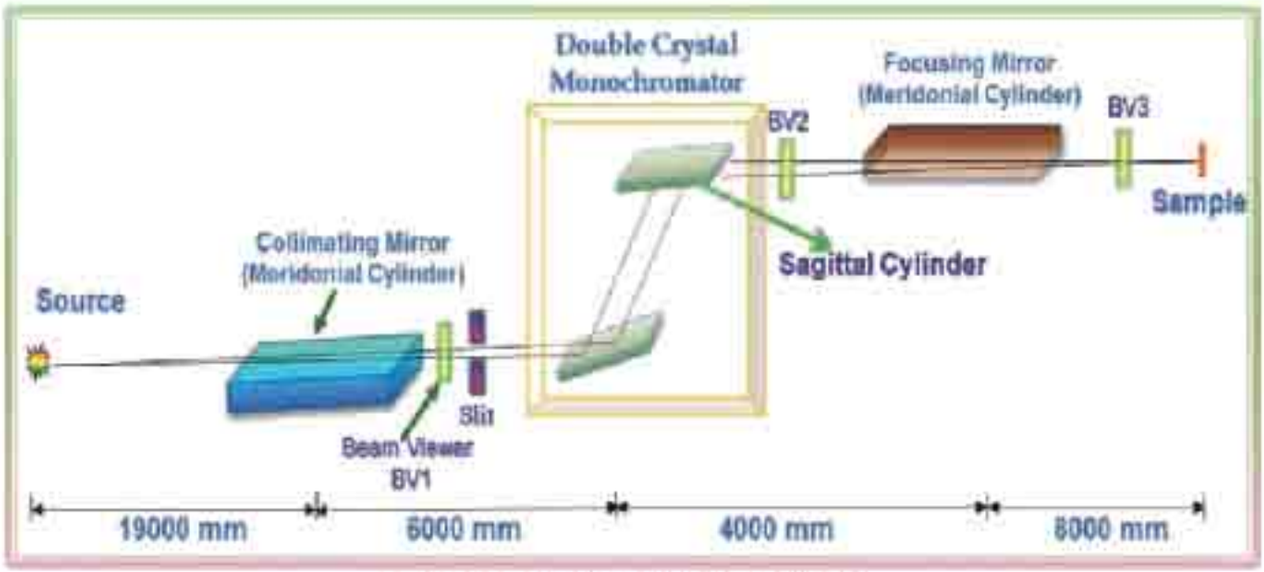

Indus-2 x-ray beam location with software "LAKSHYA"

controlled software "LAKSHYA" and an optical serial communication was installed and tested in high pressure physics experiments in the ADXRD beamline.

SINP has developed an Indian Beamline at Photon Factory Synchrotron, KEK, Japan and fifteen research institutes from India have already used this beamline. The beamline is expected to be opened for international on March 2013.

The beamline enables carrying out powder diffraction from nano materials as a function of temperature and high-pressure to perform phase transition studies; reflectivity and diffuse scattering from solid and liquid surfaces decorated with nanoparticles and buried interfaces of nano-structured materials and small angle x-ray scattering (SAXS) experiments – both in transmission and reflection geometry.

X-ray absorption fine structure (XAFS) technique has emerged as a powerful technique for probing the local structure around the atom of almost any element in the periodic table. XAFS studies can even be performed at trace levels




Optical layout of Scanning EXAFS beamline

which are very useful in the study of metal complexes on surfaces, catalysis and metal sites in bioinorganic samples.

BARC helped setup a state of the art energy scanning EXAFS beamline BL-09, where measurements can be carried out both in transmission and fluorescence mode at Indus-2.


Various sections of the scanning EXAFS beamline

This beamline uses a high resolution double crystal monochromator (DCM) for energy selection from the white synchrotron beam while two cylindrical mirrors with meridonial curvatures were used for collimation and focussing. Dispersive and scanning EXAFS BL-08 & BL-09, together offered a comprehensive X-ray absorption measurement facility over a wide variety of samples of current technological importance. This will cater to a large community of users across India.

A protein crystallography beamline was commissioned at Indus-2 and is now available for the experimental studies. A new workstation for

Protein Crystallography beamline

matrix isolation spectroscopy using synchrotron radiation was indigenously developed and installed at photophysics beamline.

Gas phase VUV photoabsorption studies of environmentally important molecules like sulphur dioxide, acetone, chloroform and trimethyl phosphate were carried out using photophysics and HRVUV beamlines at Indus-1.

An imaging beam line at Indus-2 is in advanced stage of installation at RRCAT. This beamline will have facilities for advanced material science research, medical imaging for cancer application as well as for NDT. It will incorporate several new imaging modality such as Phase contrast imaging, diffraction enhanced imaging as well as microtomography with micron and submicron resolution.

Conceptual Layout of Imaging Beamline

Optics hutch components of Imaging beamline

## CYCLOTRONS & THEIR UTILISATION

One of the major achievements at VECC in the superconducting cyclotron was improvement of RF phase stability. The direct measurement of RF voltage using Bremsstrahlung technique was also done.

Another remarkable development was the development of beam phase measurement setup using BC418 plastic scintillator detector. This set up provided a very useful tool for isochronisms tuning of the beam. The most important development was installation of a new spiral inflector assembly which can be remotely rotated and vertically moved to optimize its position with respect to the RF system. It was very effective as it accelerated more than 550 nA of beam current.

Other various developments at VECC in the field of superconducting cyclotron included the followings:

### High temperature superconducting magnet for beam line

A project for developing high temperature superconducting magnets was started at VECC. Detailed magnetic design of X-Y steering magnet for external beam line of K500 cyclotron was carried out with commercial finite element code ANSYS.

### Inductively coupled plasma for generating high intensity proton beam

An inductively coupled plasma ion source without using any magnetic field, operating at 13.56 MHZ with external antenna for producing high current CW proton beam was developed. The ion beam extraction system comprised of two parallel electrodes with single aperture.

### Development of Spiral Inflector

To improve the performance of the inflector in respect of the width of the electrode surface, reduction of joints, stability of

RF Shield, Electrodes & Insulator base of the Inflector

construction and positioning accuracy modifications were implemented.

Fabrication of the integrated stem electrodes was carried out from single stock of Aluminium 2024 in a 4 axis CNC milling machine by adopting proper machining strategies and simulations in CAM softwares.

The electrodes and other components were fabricated very precisely and it was possible to achieve the electrode gap within 60 micron accuracy in the final assembly.

**Design and fabrication of innovative neutron shutter for beam lines of superconducting cyclotron**

Design of the neutron shutter was improved by placing the mild steel rotor blocks and other suitable attenuators in a sealed stainless steel pipe to form a single encapsulated rotor. The static plates in the shield wall plug supporting the rotary shaft have been totally eliminated.

Innovative neutron shutter for beam lines of superconducting cyclotron

The vacuum in the shield wall plug placed in the beam line was found to improve transmission of beam in the beam line. Radiation protection aspects were also evaluated to ensure suitability of the neutron shutter.

**Upgradation of Phase control loop for the 3-phase RF system of K500 Superconducting Cyclotron**

The existing phase control loop were replaced with the newly developed one based on Direct Digital Synthesis (DDS) technique. An automatic phase correction system was been designed, developed, installed and commissioned using this DDS module and a programmable digital controller. There were significant advantages like 3600 phase rotation, constant amplitude irrespective of phase variation, linearity etc. of new control system over the analog phase controller. The performance of this new phase regulator was remarkably improved for the RF system of K500 Superconducting cyclotron.

**Design & Development of Low temperature Refrigeration Machine for Diffusion Pump Baffle cooling using two stage Vapor Compression Refrigeration (VCR) cycles**

The effort has been taken to design and manufacture low temperature two stage (cascade type) refrigeration units utilizing the combination of R-404A & R23 refrigerants. Details analysis of

Two stage cascade type Low temperature Refrigeration Machine

Low Temperature Machine connected with testing chamber

refrigeration cycle, cascade design, control logics have been worked out for approaching towards a theoretical system. An indegenous development has been materialized after the total inhouse fabrication of machine, which has been commissioned and being tested under the simulated load condition.

## PLASMA & FUSION TECHNOLOGIES

At the Institute of Plasma Research the experiments on Aditya tokamak continued to remain focused on breakdown and startup for generating necessary inputs for first plasma operation inSuperconducting Steadystate Tokamak (SST-1). In the refurbished SST-1 machine, engineering validations of various subsystems commenced. The assembled SST-1 Toroidal Field Magnet system was successfully charged to 1.1T after the system became superconducting. The diagnostics needed for the first plasma were integrated and tested for plasma operation. Ion Cyclotron RF (ICRF) systems based gas breakdown was achieved with low toroidal magnetic fields. The initiation of tokamak like plasma production was in progress.

The 42GHz Electron Cyclotron Resonance Heating system (ECRH) was commissioned to carry out ECRH assisted breakdown experiments in both SST-1 and Aditya tokamaks. Tungsten coating technology was developed for first wall components of tokamak with the collaboration of ARCI, Hyderabad.

High Power (200kW) Electron Beam System required for high heat flux facility was commissioned at the institute. A pump driven Lead-Lithium loop with indigenously developed components for corrosion experiment was successfully commissioned and set for operation in IPR.

Development of large cryogenic systems was undertaken. Remote handling (RH) and robotics technologies related activities were also initiated.

An accelerator based 14Mev neutron generator was developed for neutronics diagnostics and to study tritium breeding. Characterization of polycrystalline chemical vapor deposited (CVD) diamond detector was done. Experiments on tritium extraction studies on irradiated Lithium Titanate ($Li_2TiO_3$) powder were in progress. MCNP code analysis necessary for shielding design of the proposed laboratory was completed.

At Facilitation Center for Industrial Plasma Technology (FCIPT), IPR while completing and executing the committed projects, various new projects were also accepted.

**International Thermonuclear Experimental Reactor (ITER)**

For ITER project, five more procurement arrangements (PAs) were signed. A total credit worth 4600 IUA was received from IO for the in-kind contribution and 266.835 IUA for the credited Task Agreements. The building for ITER-India laboratory at IPR was completed and being used for various R&D activities.

At Center for Plasma Physics (CPP), Guwahati, the divertor simulator experiment

progressed well. Design of the magnets for the experiment along with the chamber was completed.

Towards development and fabrication of $Nb_3Sn$ based superconducting wire, a composite extrusion billet containing 1324 Niobium elements was assembled at BARC. Metallurgical characterisation of the product was carried out. An innovative space saving online fabrication facility was setup.

Reduced activation Ferritic-Martensitic steel for Test Blanket Module for ITER was developed at IGCAR by optimizing the content of tungsten and tantalum for achieving superior combination of ductile-to-brittle transition temperature and tensile and creep properties. Low cycle fatigue life of this steel was found to increase with increase in both tungsten and tantalum contents.

## MATERIAL SCIENCE

At Trombay, phase field modeling study was carried out to arrive at different microstructures in Zr-2.5 Nb alloy that gets evolved during isothermal holding.

Molten Salt Natural Circulation test Facility was setup in BARC. Effect of various orientations of heater and cooler can be studied in this experimental facility. 3D CFD simulation was performed to analyze the steady state characteristics of molten salt natural circulation test facility.

Molten Salt Natural Circulation Test Facility

A test facility to study the in situ corrosion in the molten salt environment was setup. The corrosion study was performed in the temperature range of 550–750°C using electrochemical polarization technique.

To quantify the Main Heat Transport system's material degradation under prolonged exposure to high temperature. Two important life limiting mechanisms identified were Low Temperature Sensitization (LTS) and Low Temperature Embrittlement (LTE). Initial assessment concluded that LTS may not be of concern for 100 years life of the piping material selected for AHWR.

Effect of irradiation induced defects on load displacement curves of nano-indentation in simulation was investigated. As a part of indigeneous development of Scanning Electron Microscopy (SEM), fabrication of the filament support assembly was accomplished in BARC. Fabrication of single and multiple joint ceramic-to-metal (Kovar) seals up to 60mm diameter by active alloy brazing technique was successfully done.

Various types of glass based devices like ionization vacuum gauge (BA Type), glass-to-metal and ceramic-to-metal seals were produced.

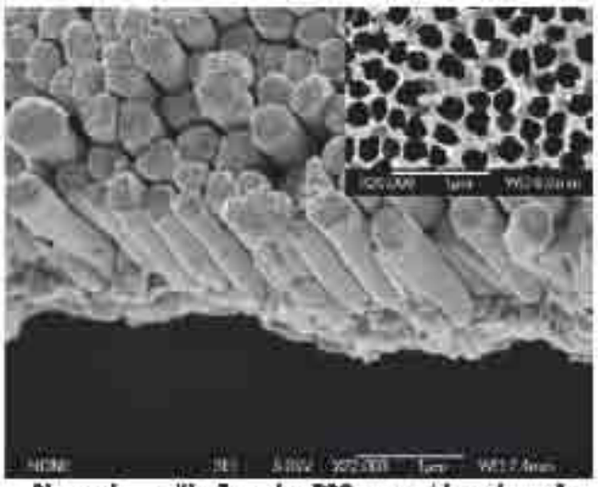
Several Fe and Co based amorphous and nanocrystalline metallic glasses were synthesized using rapid solidification technique. A detailed work was carried out to understand the kinetics and evolution microstructure to control the magnetic properties. For correlating the magnetic properties with microstructure of these nano-composites, several characterization techniques were employed.

An investigation on formation of aluminide coatings on Ni-based superalloy 690 substrate by low Al-containing pack aluminization process followed by its characterization have been undertaken.

At IGACR, Miedema's model was applied to identify the composition ranges of phase stability, particularly in ternary extensions of Fe-based Laves phases. The study of grain boundary character distribution was carried out, using a TEM-based orientation imaging microscopy (OIM), technique.

A 400 kV accelerator which would transact helium and other gaseous ions to the UHV irradiation system of the 1.7 MV tandetron accelerator together forming a dual beam facility, was developed indigenously.

Other studies carried out in the field of material science at IGCAR included: Prediction of mass transfer using emerging methodologies; Molecular dynamics simulation of deformation and fracture behaviour of body-centred-cubic (bcc) iron and face-centred-cubic(fcc) copper single crystals under tensile loading; Nano-fluid fluid based optical sensor; Understanding of the complexation of magnetic nano-particles and tri-block-copolymers in presence of surfactants; Detection of pathogenic gram negative bacteria using infrared thermography; Pressure induced metallization of $BaMn_2As_2$; Synthesis of novel $Ru_2C$ under high pressure and high temperature; Raman spectroscopy studies of negative thermal expansion materials; Tilt rotation distortion in cubic sesquioxide $Dy_2O_3$: A high pressure X-ray diffraction study; Stability of iron phosphate glass; Improved tribological properties of modified NiCrB coatings; Development of anti-fogging coating for hot cell glass windows; Indigenous repair and servicing high purity Germanium detectors.



Nanowires with diameter 200nm and top view of the membrane (inset) developed at VECC

The materials were developed in different nanostructured forms like nanowires, nanotubes, nanorods etc. through simple cost effective electrochemical and chemical means at VECC. Co and Ni nanowires with pore sizes up to 200nm were developed by electrochemical deposition using Anodised Alumina templates.

Superconducting properties of niobium materials were investigated at RRCAT. High density, crack-free large disks of Yttrium-Gadolinium-Indium Garnet was developed for use in high power ferrite circulator fabrication.

A Detailed study of the physical properties of a quasi-two dimensional structural modification of elemental Silver was made at TIFR. Study of inducing metal-insulator transition in VO2 using an electrolyte gate, wide bandwidth actuation and detection of nanowire NEMS was made.

In Plasmonic quasi-crystals TIFR studied incidence angle and polarization independent plasmon excitation and second harmonic generation. Highly oriented films of $TiO_2$ aligned nanorods were successfully grown directly on FTO. $ZnTiO_3$, a novel titanate was synthesised with phase purity and shown to be photocatalytic

under visible light. Hollow nanotubes of $BiFeO_3$ were also synthesised.

## INTERDISCIPLINARY AREAS

At BARC, the crystal structure of drosophila melanogaster (common fruit fly) was solved using 4.2 Å resolution synchrotron data which would provide useful information on human proteins as well. The low-resolution X-ray diffraction data acquired from methylated drosophila protein crystals showed clearly that ssDNA-binding competent drosophila protein is an octamer.

The structure of drosophila Transfin octamer with ssDNA-binding activity marked as spheres

For Indian Lattice Gauge Theory initiative the QCD critical point was obtained at a much finer lattice spacing at TIFR.

The cryogen free high cooling capacity dilution refrigerator was installed at TIFR for Neutrinoless Double Beta decay Experiment. A setup for measurement of specific heat at low temperatures was designed and tested. For development of NTD Ge sensors for mK thermometry, Ge samples were irradiated with different doses.

At Pelletron Linac Facility, the Pelletron and LINAC were operated for user cycles which delivered a variety of beams as per user requirement. Extension of LINAC operations to lighter beams was tested with Li beam. Indigenously developed digital control card was tested with a single superconducting cavity and gave excellent performance.

Development of Resistive Plate Chambers (RPCs) for the India based Neutrino Observatory (INO) experiment got completed and the design and prototyping of electronics trigger and data acquisition systems progressed well. For gravity wave detection, R & D activities regarding PRC detectors as well as construction of an interferometer were carried out.

## INTERNATIONAL RESEARCH COLLABORATION

BARC is a major collaborator in the Compact Muon Solenoid (CMS) heavy ion experiment at Large Hadron Collider (LHC) at CERN.

Under DAE-JHR bilateral collaboration, conceptual design of sample carrier for high temperature irradiation in Jules Horowitz Reactor (JHR) was carried out at BARC. Detailed thermal analysis of the device was done and the design was optimised as regards geometry of the capsules, ducts for carrying the coolants, coolant circuit, etc.

Advanced research was carried out on application of Physics-of-Failure methods to prognostics and health management of electronic components and R&D collaborative programme was under taken with Center for Advanced Life Cycle Engineering, University of Maryland, USA. Work on 12th Plan project entitled "Prognostics and Health Management of Electronic Component" was initiated.

Life Cycle Reliability engineering laboratory was set up to facilitate reliability and life prediction of components.

International Atomic Energy Agency awarded a project to BARC on 'Development of an IAEA Safety Series on Application of Probabilistic Assessment for Research Reactor'.

Under CEA–IGCAR cooperation on LMFBR safety, eleven collaborative projects were in progress. Based on design experience and feedback derived from construction experience of PFBR, IGCAR recommended revisions / new rules for the design and construction code RCC-MR (2010). AFCEN is discussing them with IGCAR on the recommendations.

Under Indian Institution Fermilab Collaboration (IIFC), RRCAT fabricated a 1.3 GHz 9-cell SCRF cavity and the pre-processing qualification tests for the cavity were carried out. A Prototype power extraction and transfer structure components (PETS bars) were fabricated in India and supplied to CERN.

The participation of VECC scientists at LHC-CERN for the quest of Quark Gluon Plasma (QGP) had borne fruits in terms of analyzing huge amount of data collected from p+p and Pb+Pb collisions. The Photon Multiplicity Detector (PMD) built by VECC was a strong partner in data taking. Dedicated efforts on data analyses made progress.

The prominent topics pursued by VECC collaborators included (a) collective flow using information from PMD (b) correlated particle production and formation of jets (c) production of resonances (d) fluctuations of net-charge, net-baryon numbers and strangeness.

VECC made significant contributions both in hardware and analysis in STAR experiment at BNL-USA. The first Multigap Resistive Plate Chamber (MRPC) module built at VECC was installed in the STAR experiment after detailed testing and a prototype MRPC-based TOF system was installed to demonstrate the proof-of-principle of using MRPC.

Two smaller-size MRPCs were assembled with a provision of including more glass electrodes. The system using a Na-22 source which gives two anti-parallel photons.

Another future experiment, in which VECC researchers are playing a major role is the CBM experiment at FAIR. The progress made for the project included (a) simulation for the optimization of the setup (b) R&D on GEM detector for handling high data rate (c) development of radiation hard electronics (d) design of the mechanical and electronic systems of the chambers in muon system. The close-to-final simulated design was done based on the optimization of detector geometry. The detector R&D advanced one stage further and it was tested using X-rays and conventional NIM electronics for readout.

A GEM testing setup at CERN

An arrangement consisting of alternating layers of detectors and absorbers (mini-MUCH) resembling the muon setup for CBM has been employed for the first time. This consists of 5 GEM detectors to face the muon and pion beam at CERN.

The INO-prototype laboratory continued to work at VECC. Students from all over the country took part in data taking and data analysis.

In collaboration with IIT-Kharagpur, considerable progress was made on building a serializer ASIC to be used to transfer data at very high speed upto 2.5 GHz from self-triggered electronics of CBM.

TIFR continued research collaborations with the International Centre for Theoretical Sciences (ICTS), Belle Experiment, and CMS Experiment at the Large Hadron Cloilder. Major activities under these collaborations were as follows:

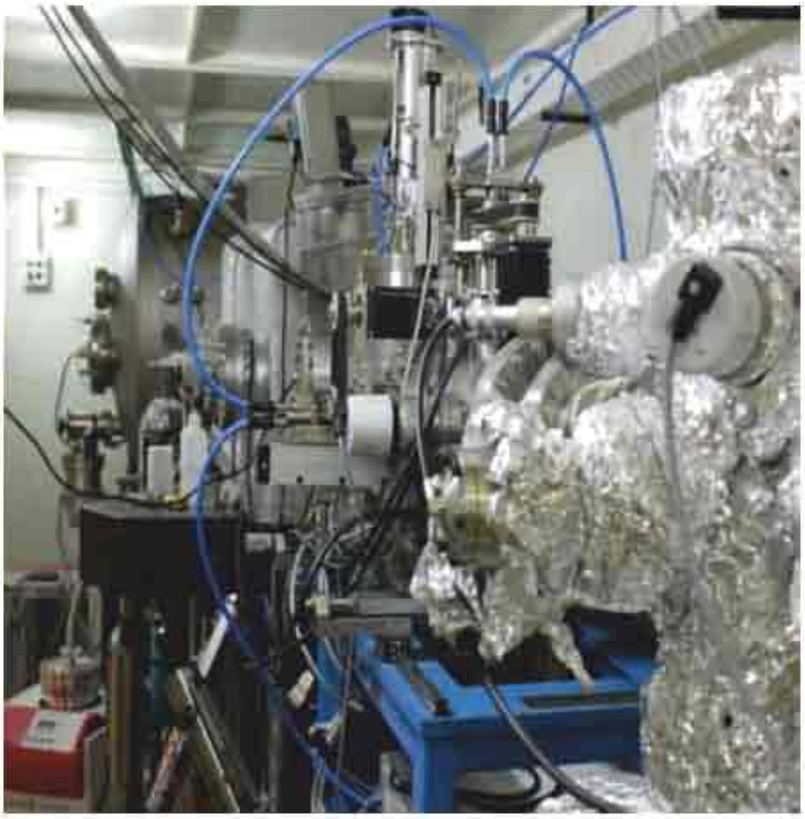
At ICTS, a masterplan for the campus was prepared by the architectural agency M/s Venkataramanan Associates, Bangalore. Lecture series on Srinivasa Ramanujan was also initiated.

Data recorded by the Belle experiment were analysed at TIFR and work on the upgrade of the silicon vertex detector (SVD) for the next phase of experiment called Belle II progressed.

Studies carried out for CMS experiments included studies of inclusive jet cross section, underlying events; Charge asymmetry in the W-boson production, W+gamma production; Search for Higgs boson in di-tau decay channel, charged Higgs boson; Performance of the Outer Hadron calorimeter (HO); and Monitoring the CMS detector.

# CHAPTER -6

# RESEARCH EDUCATION LINKAGES



The protein crystallography beamline at RRCAT

Induction training programme for the newly recruited security staff

CHAPTER 6

# RESEARCH EDUCATION LINKAGES

## HUMAN RESOURCE DEVELOPMENT AND KNOWLEDGE MANAGEMENT

### Homi Bhabha National Institute

Homi Bhabha National Institute (HBNI) continued to grow smoothly and steadily. At present, it has 7 Board of Studies – Physical Sciences, Chemical Sciences, Engineering Sciences, Mathematical Sciences, Strategic Studies and Health Sciences. Under these different disciplines, there are 25 types of degrees and diploma awarded by the HBNI. They include Ph.D, PG Diploma, M Phil, M.Tech, MSc (Engg.), Dip RP, DRM, DMRIT, DM, MD, MCh etc.

HBNI strengthened its linkages with premier research and academic institutes in the country and abroad. Two MoUs – one with Indian Institute of Science, Bangalore and the other with University of North Texas, Denton US were signed during the year in this direction. MoUs with Indian Institute of Technlogy, Bombay and the Institute of Chemical Technology, Mumbai were renewed. A general agreement for academic co-operation and exchange with Institute of fusion studies and Department of Physics at the University of Texas at Austin was also signed during the year.

About 82 new faculty members were inducted in HBNI during 2012.

### Training School

BARC continued the academic programme of Orientation Course for Engineering Graduates & Science Post-Graduates (OCES-2011) and conducted written tests. About 287 candidates were selected for OCES/DGFS 2011 across all disciplines. Courses consisting of foundation, nuclear engineering, core and electives were offered to TSOs.

A one day seminar on 'Role of Nuclear Energy in Development of the Nation' was organized. BARC officers delivered lectures on 'Career opportunities in DAE' to motivate young students. Coordination activities for providing practical training (1-2 months) and project work (2-12 months) to a very large number of BE/B.Tech/M.Tech/ME/Engg. Diploma/MSc/MCA students from all over the country on subjects related to nuclear energy were continued.

Four advanced courses from electrical sciences group were offered to the eligible employees under 'QUEST-Continuing Education Programme' scheme and six advanced courses were held under QUEST-3 and QUEST-4.

All aspects of Human Resource Management such as establishment, personnel and general administration, manpower planning, recruitment, providing statistical information based on personal data, software development for computerization of activities, issue of identity cards, vigilance, legal matters, transport, communication, canteens, public relations, staff relation & welfare and management of guest houses/hostels etc were carried out efficiently.

Personnel Information & Management Systems (PIMS) database was maintained. Online promotion proposal programme was developed and implemented. Enhanced website for recruitment section with more security features and facilities were developed and implemented. The existing Client-Server based pension processing system was re-developed on web based platform with more security features and facilities.

About 600 scientists were deputed abroad for participation in various International Meetings/Symposia/Conferences and other Government work, 40 scientists were deputed for Training/Workshops/Study Tours etc. under IAEA-Schemes, 73 scientists were deputed under various Bilateral Agreements and Collaboration Schemes and service of 6 scientists were placed at the disposal of the IAEA for expert assignments.

During the year CAT-I & II trainees, TSO's for OCES & DGFS, Junior Research Fellows & Research Associates were inducted. BARC also bagged the "Best Establishment Award for the 89th Regional Skill Competition for Apprentices held in September 2012 for western region.

The Radiation Medicine Centre (RMC) of BARC regularly conducted two year diploma course namely DRM for medical graduates under Homi Bhabha National Institute. These training courses were very useful in the propagation of Nuclear Medicine throughout the country. The course included lectures, practicals, apprentice programmes, demonstrations, scan review and reading sessions and dissertations on short projects. RMC also conducts one-year diploma course under HBNI for science graduates.

At IGCAR, the sixth batch of thirty five trainee scientific officers completed their training in six disciplines and were placed in various units of DAE. About 52 Trainee Scientific Officers were trained at the Training School. Twenty nine research scholars were inducted in the seventh batch to pursue their doctoral programmes and 24 employees pursued higher studies under the aegis of Homi Bhabha National Institute (HBNI).

BARC Training School AMD Campus, Hyderabad continued its activity in second year for Geology (12) and Geophysics (9) Trainee Scientific Officers (TSOs). AMD studentship programme was continued and 125 M.Sc./M.Tech. Students of different Universities completed their project. BRNS projects (43 nos.) were continued in collaboration with various Universities / Academic Institutions as R & D efforts of AMD.

At NPCIL the human resource initiatives were directed towards fulfilling NPCIL's mission and vision by attracting, motivating and retaining right talent. These measures included developing strategic and incremental packages from time to time for effective Human Resource Management and also to meet the aspirations of the employees. During the year, about 5056 man-days of training were imparted. Thirty seven employees were sponsored for acquiring higher education in Technology, Management etc. Training and development activities covered competency development for fresh as well as experienced manpower across hierarchy. Well developed internal training programs, customized management development programs with the involvement of professional training institutes and experts were also organized.

At present, NPCIL is having about 11,660 employees. Optimization of manpower, an important strategy towards best utilization of human resource was continued. During the year, 214 trainee engineers were inducted for NPCIL Batch-19 as a part of the annual program for induction of young talent into the organisation. Fourteen direct recruits in the scientific cadre and forty seven posts in the non-technical cadre were filled through the centralized recruitment process.

The Institute of Physics contributed in a significant way towards quality human resource development in the form of a one year pre-doctoral course followed by a Ph.D. program. Twelve post-doctoral fellows were attracted towards the research programs of the Institute. During the year, three doctoral scholars received

their Ph.D. degrees, while four scholars joined the pre-doctoral program. The Institute actively promoted interactions with colleges, universities, academic institutions and laboratories by means of visitor programs, workshops, symposia and other academic events.

IMSc continued its teaching programme and students were selected at the graduate and postgraduate level through an all India joint entrance screening test followed by an interview. They undergo two years of rigorous course-work followed by a doctoral thesis work for award of PhD degree by HBNI. Apart from this regular activity, IMSc also offered an opportunity of learning for few students during the summer vacation period. Several students visited the Institute for a semester working on short-time research projects. Institute members interacted extensively with their colleagues in the Universities and this interaction takes place via Faculty Associateship Programme, Refresher Courses for college teachers and Science Popularisation programmes.

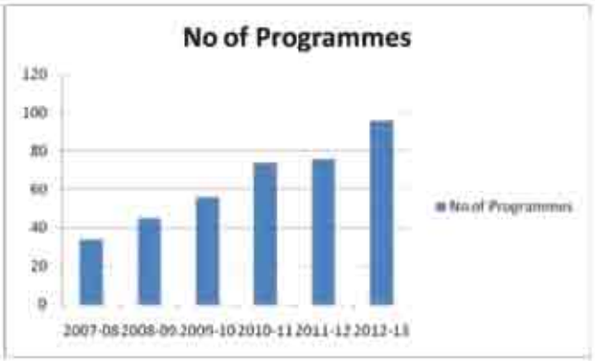
Tata Memorial Hospital (TMH) registered students for various postgraduate medical courses. A two year short term advanced diploma in Radio Imaging Technology was started. Training programmes were conducted for Doctors, Nurses and Technicians on continuing basis. Short term observership and summer training was provided to more than 500 Doctors, Nurses, Technicians, graduate and postgraduate science students.

With the aim of nurturing world class scientists for the country to take up challenging research and teaching assignments in universities, R&D laboratories and various Industries, National Institute of Science Education and Research (NISER) continued its excellence in science education and research in four basic sciences Biology, Chemistry, Mathematics and Physics.

### Administrative Training Institute

ATI arranges a wide range of training programmes for professional development of officials working in DAE. There has been a steady growth in the number of courses being conducted and number of employees being covered. About 380 programmes covering over 11000 employees have been organized till now by ATI and a growth of about 175% was achieved.

| Year | No of Programmes | No of Participants |
|---|---|---|
| 2007-08 | 34 | 1020 |
| 2008-09 | 45 | 1687 |
| 2009-10 | 56 | 1880 |
| 2010-11 | 74 | 2220 |
| 2011-12 | 76 | 2071 |
| 2012-13 | 96 | 2200 |
| Total | 381 | 11078 |




The training programmes catered to a wide spectrum starting from the Head of Units to the grass root level. During the year 96 programmes were organised that included: Induction training programme for the newly recruited administrative and security staff; Preparatory workshops for candidates appearing for various departmental examinations and personal interviews; Domain knowledge and skill enhancement series courses on different modules for various target groups with specific subjects based on functional requirement; Special workshops on land acquisition and motor

Induction training programme for the newly recruited security staff

vehicle accident matters, workshop on law and medicine, workshop on post retirement life management; Workshops on soft skills for various target groups; Programmes for Union / Association representatives on soft skills, computer applications, Reservation in services, RTI etc. Special workshops on handling projects, patent law, presentation skills were organized for scientific and technical officers; Faculty development programmes for building in-house resource persons; Management development programmes for Group A & B officers with the support of M/s. Yashwantarao Chavan Academy of Development Administration (YASHADA),Pune, Administrative Training Institute, Mysore and Mahatma Gandhi State Institute of Public Administration, Punjab.

In order to align with the National Training Policy, strategies such as "Training for All" and "Training at Doorstep" were used and training programmes were arranged in many languages at different localities like Shillong, Manuguru, Kalpakkam, Hyderabad, Baroda, etc.

As part of employee welfare a two day workshop on "Emotional Intelligence" and a one day workshop on "Security Awareness" were organised for the family members of employees.

A dedicated webpage was put under DAE website http://atl.dae.gov.in which contains the latest calendar, self learning materials, copies of presentations etc.

## SPONSORED RESEARCH

### Board of Research in Nuclear Sciences (BRNS)

The Board of Research in Nuclear Sciences (BRNS) an advisory body of the Department of Atomic Energy provides financial assistance to universities, academic institutions and national laboratories for encouraging and promoting scientific research in areas of relevance to the mandate of DAE..

It also plays a proactive role in tapping some of the highly talented young scientists and technologists by offering K.S. Krishnan Research Associateship (KSKRA). DAE Graduate Fellowship Scheme (DGFS) of BRNS identifies and encourages graduate level students doing M.Tech. at IITs and NITs to initiate them in a career to pursue scientific research. Selected young scientists are awarded fellowship under DGFS to work on research projects in any one of the DAE units, simultaneously pursuing Ph.D. degree through HBNI. Raja Ramanna Fellowship and Homi Bhabha Chair is also funded through BRNS. In addition BRNS provides partial support to DAE - Mumbai University Centre for Excellence in Basic Sciences and Homi-Bhabha Centre for Science Education.

During the financial year till January 2012, about 300 new research projects were sanctioned. In addition, three new CRPs (Co-

ordinated Research Projects) were sanctioned for coherent collaborative research work with various academic institutes. These are: (a) Uncertainty Analysis and Management in Engineering and Environmental Systems with IISc., Bangaluru (Rs 2.62 Cr. for three years), (b) Remote Sensing Technology for Beach Sand Placers for Thorium & Rare Earth Elements with Bharathidasan University, Trichy (Rs.2.71Cr. for three years) and (c) Upgradation and utilization of National Facility of Texture & Orientation imaging microscopy OIM: Extending the Scope & Usage (phase III) with IIT Bombay (Rs. 7 Cr. for five years). BRNS also renewed the MOU with University of Pune for Phase-III of the National Centre for Free Radical Research (NCFRR) for the year 2012-2016 (Rs. 1.28 Cr. for five years).

Fourteen new DAE-SRC fellowships amounting to Rs. 14Cr. were awarded to 7 DAE & 7 Non-DAE fellows. Five ongoing Prospective Research Fellowships (PRF) amounting to ` 0.48 Cr. were granted this year.

Twenty KSKRA fellows were selected during 2012. Under DAE Graduate Fellowship Scheme (DGFS), Nine M.Tech. in 6 different IIT's & Thirty-Six Ph.D students were offered/awarded fellowships.

Financial support to the tune of Rs. 3.4 Cr. was extended for funding 148 seminars, which were conducted by professional organizations on various topics of relevance to DAE. Out of these 19 symposia were solely organized by the DAE fraternity and they were fully funded by BRNS. Thirty-eight fellowships were offered/awarded under the Raja Ramanna Fellowship Scheme (Senior Scientists Scheme) & Homi Bhabha Chair.

## Promotion of Mathematics

The National Board for Higher Mathematics (NBHM) established under the aegis of DAE promotes excellence in higher mathematics education and research in the country.

NBHM took active part by extending its support to the 125th birth anniversary year of Ramnujan and celebrated the year long period December 22, 2011 - December 22 2012 as National Mathematics Year. Eminent mathematians across the globe delivered "Panorama Lectures" in various institutes of the country.

NBHM has been organizing the Mathematics Olympiad activity for talented young students at higher secondary (the plus two) level. This activity is conducted with the help of the Homi Bhabha Centre for Science Education (HBCSE). The six-member Indian team secured 2 Gold medals, 3 Silver medals and a Honorable mentions at the 53rd International Mathematical Olympiad held at Sao Paulo, Argentina.

Madhava Mathematical Competition for the undergraduate students is being conducted by NBHM. The competition is designed to generate interest in mathematics in early years of college. NBHM is in the process of creating suitable infrastructure, in the form of human resources, for this purpose.

NBHM supported 24 mathematicians to attend International Congress of Mathematics Education held at Seoul, South Korea, to acquire latest Information in the field of Mathematics Education.

NBHM gives grants to various mathematical centres engaged in activities of promoting higher mathematics. The Chennai Mathematical Institute that runs a high quality undergraduate programme in mathematics is a regular recipient of grants from NBHM. The Kerala School of Mathematics, Calicut the

Institute of Mathematics and Applications, Bhubaneswar and the Bhaskaracharya Pratishthana, Pune, are the other institutes that got grants from NBHM for their various programmes.

The Board provided scholarships and fellowships to the students selected through nationwide competitive tests, to pursue studies at the masters and Ph.D. levels. Mathematics Training and Talent Search programmes at undergraduate level and Advanced Training in Mathematics (ATM) programme for selected students at postgraduate level were undertaken.

NBHM provided grants for promotion of activities in pure and applied mathematics, under several schemes, including support to research projects, travel grants for participation in workshops, conferences, and undertaking collaborative research, funds for organizing conferences etc. It also provided grants to mathematics libraries around the country. Around 80 such libraries took advantage of this scheme and updated their collection. Selected books to various postgraduate institutions under its book distribution schemes were also distributed.

Financial support was provided to 65 national and international conferences held in India, and 17 Instructional Schools for advanced training in mathematics and 31 research projects. Travel grants were provided to 59 mathematicians to enable them to participate in conferences held in India and abroad.

Seven institutions were provided faculty support in the form of Visiting Professors, to strengthen the research and teaching potential at the institutions. Post Doctor Fellowships were awarded to 36 (including the ongoing ones) researchers for the period of 3 years.

Steps were taken to create a web-based interactive system for communication, evaluation of proposals. This will help researchers to obtain a prompt response from NBHM on their applications for grants.

## GRANTS-IN-AID

### Grants to Aided Institutions

The aided institutions of the Department of Atomic Energy are an integral part of the Department. There is frequent interaction between the academicians of the aided Institutions and the Scientists of the R&D Units. Several joint projects were undertaken between the Units and Aided Institutions. These institutions are growing at a faster pace in terms of the projects undertaken by them.

The Department has eight aided institutions and one education society fully funded in terms of their recurring and non-recurring expenditure. The funds (Plan & Non-Plan) allocated to these Aided Institutions by the Department of Atomic Energy during the financial year 2012-13 are as mentioned in the table:

### Grants to Cancer Hospitals

The Department of Atomic Energy (DAE) is releasing grant to Dr. B. Barooah Cancer Institute (BBCI), Guwahati through Tripartite Agreement [which was signed between DAE and the North-Eastern Council (NEC) and the Government of Assam]. This hospital is a Regional Cancer Centre (RCC) for cancer treatment and control in the North-Eastern Region (NER). The Department's total share as per the Tripartite agreement upto the year 2012-13 is approximately Rs.24.50 crore for revitalization of the BBCI which includes the cost of construction for expansion of the hospital as well as the procurement of major radiation related equipment during its Revitalization Project-III which has been started during the year 2004 – 05.

| Sl. No. | Name of the Institutions | Budget Provision BE 2012-13 (Rs. in crore) |
|---|---|---|
| 1. | Tata Institute of Fundamental Research (TIFR), Mumbai | 403.68 |
| 2. | Tata Memorial Centre (TMC), Mumbai. | 248.14 |
| 3. | Saha Institute of Nuclear Physics (SINP), Kolkata. | 153.50 |
| 4. | Institute of Physics (IOP), Bhubaneswar | 21.70 |
| 5. | Institute of Mathematical Sciences (IMS), Chennai. | 31.41 |
| 6. | Harish-Chandra Research Institute (HRI), Allahabad | 37.21 |
| 7. | Institute for Plasma Research (IPR), Gandhinagar. | 661.22 |
| 8. | Atomic Energy Education Society (AEES), Mumbai. | 83.92 |
| 9. | National Institute of Science Education and Research (NISER), Bhubaneswar. | 220.00 |

Department has also proposed to set up a Cancer Hospital at Punjab.

The Department also extended financial assistance to Cancer hospitals located in other parts of the country. The budget provision for the year 2012-13 for such partial financial assistance is to the tune of Rs.165.70 crore.

An increasing need was felt to use the expertise available in the DAE funded Tata Memorial Hospital for creating a better network between cancer institutions all over the country. This included research & development, training and preparation of protocols for treatment as well as incentives for indigenization of much of the radiation related equipment for cancer treatment. An Apex Committee was formed under the Chairpersonship of Director, TMC, for this purpose. The Apex Committee met several times and deliberated on indigenous development and manufacturing of equipment related to radiation oncology such as Cobalt 60 Teletherapy Machine, Low Energy Linear Accelerator, High Energy Linear Accelerator, simulator development, Brachytherapy.

The initiatives taken to achieve the above stated objectives would lead to further gains in DAE's outreach in the cancer care programme.

# CHAPTER -7

# TECHNOLOGY TRANSFER AND COLLABORATIVE PROGRAMMES

K-200 shock testing machine installed at BARC

MoU signed with M/s Divyakiran for Radiation Processing Plant at Anand, Gujarat

## CHAPTER 7
# TECHNOLOGY TRANSFER AND COLLABORATIVE PROGRAMMES

The spin-off technologies generated out of the core programmes of the Research and Development organizations of DAE are developed and transferred to industries for commercial exploitation. Over a period of time, a number of technologies were transferred to industries.

DAE organizations also entered into scientific collaborations with public and private sector organizations. This interaction has given beneficiary organizations a technological edge.

## TECHNOLOGY TRANSFER

During the year, BARC transferred about fifteen technologies to 28 private entrepreneurs. This included Nisarguna, Online domestic water purifier, Membrane assisted defluoridation process for safe drinking water, Preparation of composite polyamide reverse osmosis membrane for BWRO desalination technology, UF membrane assisted device for removal of iron from contaminated water for drinking purposes, Kvp meter, Dip N Drink, Glass to metal seals technology, Lascan Dia Gauge, Production of Dy Doped $CaSo_4$ TLD Phosphor Powder, Process for retaining pericarp colour and extending shelf life of litchi, Fresh Water Generator, Micro-propagation of Banana, Production of $CaSo_4$ : Dy Embedded Teflon Discs and TLD Cards and arsenic removal from drinking water by ultrafiltration membrane assisted process.

Thirteen technology licenses were renewed. Two patents were granted and one patent application was filed. BARC Technology Incubation Cells were ready for operation and handed over to respective divisions. Expression of interests was invited from industries for incubation of various technologies.

Facilitation Centre for Industrial Plasma Technology (FCIPT) at Institute for Plasma Research executed several projects and also signed new projects with various organisations, autonomous bodies and private sector companies.

## COLLABORATIVE PROGRAMMES

At BARC, four pieces of prototype fuel tube made of high-density carbon-carbon composite was prepared in collaboration with National Physical Laboratory (NPL), New Delhi. Under a MoU with IOCL, BARC developed Pipeline Inspection Gauges (PIGs) for pipelines of several sizes ranging from 12" to 24".

The BARC developed Environmental Radiation Monitor (ERM) system was integrated with the Automatic Weather System (AWS) developed by ISRO, under a BARC-ISRO, MoU.

Under a tripartite MoU between BARC, HESCO and BRNS, an isotope hydrology laboratory was set-up at HESCO, Dehradun to train the local people as an in-house facility for spring recharge related studies carried out at BARC.

BRIT signed a MoU with M/s Isorad Tech Pvt Ltd, Chennai, M/s Divyakiran Agro Processing Pvt. Ltd, Anand, Gujarat and M/s Radura Irradiators, Nashik, Maharashtra for setting up of Radiation Processing plants.

At IMSc, the collaborative research programmes included, CEFIPRA: Arithmetic circuits computing polynomials with University of Paris and an Indo-German research grant of the Humboldt Foundation for research on the graph isomorphism problem.

## SOCIETAL INITIATIVES

DAE has launched `DAE Societal Initiative' for utilization of non-power applications (NPAs) and spin-off technologies (Spin-offs) in the areas of water, land, agriculture, food processing and urban-rural waste management. Within this frame work, a structured programme called **'AKRUTI-KRUTIK-FORCE'** was formulated and is being implemented by BARC for techno-economic growth of the rural sector, as one of the many schemes for large scale deployment of NPAs and Spin-offs. During the report period under the DAE social initiative programme, AKRUTI Tech pack was transferred to 8 parties by BARC.

## INTELLECTUAL PROPERTY RIGHTS

DAE-IPR Cell constituted by the Department, works as a nodal agency for all Intellectual Property Rights (IPR) related matters including filing of patents within India and abroad for all the Units including Public Sector Undertakings and Autonomous Institutions under DAE.

During the calendar year 2012, four regular DAE-IPR cell meetings were held during which thirteen new inventions and two of the previously filed applications under Patents Cooperation Treaty (PCT) applications were reviewed for patentability and national phase entry respectively. DAE has filed twenty one new patent applications that includes nine in India, four in USA, three in the European Union, two in Japan, one each in China and Canada and one under PCT.

During the year 2012, eight of the previously filed patents have been granted to the Department. Seven out of the eight patents were in foreign countries.

1. Emergency leak arresting device for a collared pipe (Canada and South Korea) - BARC

2. A hydraulic micrometer system for remote measurement of inside diameter of pipes and tubes and a method of such measurement (Canada and USA) - BARC

3. A process for producing Body Centeric Cube (B2) Nickel Aluminium (NiAl) coating of controlled thickness on Nickel-base alloy surfaces (Russian Federation) - IGCAR

4. Single stage purification of Uranium refining (Australia) - BARC

5. Fluorescence correlation microscope with real time alignment readout (European Union) - TIFR

During the year, 80 patent applications were referred to the Department by the Controller General of Patents, Intellectual Property (IP) India, to screen for the applicability of section 20 (1) of Atomic Energy Act, 1962, i.e., whether the application is related to or useful for atomic energy, and give its opinion. Directions of the Department were communicated to the Controller of Patents in India.

As a part of the IP awareness activities, lectures were given to the 56th batch of the training school (OECS-2012) students covering all aspects of intellectual properties, protection and rights emanating thereof. The 47th DAR-IPR cell was held at RRCAT, Indore along with lectures on IP awareness. A Technology Information, Forecasting and Assessment Council (TIFAC)-BARC training program on IPR and WTO issues was conducted through DAE's Administrative Training Institute (ATI) at Vikram Bhavan, Mumbai for the benefit of officials associated with IP from various units of DAE. Lecture on IPR and its relevance to DAE was also delivered at the Administrative colloquium of BARC.

# CHAPTER -8

# INFRASTRUCTURE

Constructed Laboratory building for IOP Physics, Bhubaneshawar


Water Treatment Plant of GSO, Kalpakkam

## CONSTRUCTION, SERVICES & ESTATE MANAGEMENT

The Directorate of Construction, Services & Estate Management (DCSEM) is responsible to provide infrastructure support to various units of Department of Atomic Energy (DAE) including its aided institutions. DCSEM is involved in executing construction works for Housing, Schools, Hospitals, Laboratories, various Public Buildings & other infrastructure in support of the Science & Technology programme of DAE. This Directorate is responsible for operation and maintenance of various services, estate management and security for the housing colonies of DAE at Mumbai.

During the year, construction of RCCe underground water tank of 375 KL capacity with drywell pump room for CISF quarters at western Sector, Anushaktinagar, Mumbai, RCC Bridge over natural nallah near type III-C housing in western sector, Anushaktinagar and DAE Nodal Dispensary at Kharghar, Navi Mumbai were completed. Works relating to extension of School-4 for AEES at Anushaktinagar, Director's Bungalow, flat lets for Indian Institute of Geomagnetism (IIG) at Panvel and Apartments for QIP/ DRDO for IIT Bombay at Powai, Mumbai were also completed by DCSEM.

Construction of Type–II-B building for IIT, Powai, Mumbai

Construction works of Convention Centre / Sr. Officers Guest House and Administrative Training Institute Complex, Residential Quarters for CISF personnel, Restoration / Renovation of Old Houses more than 20 years old Phase–I, Creche Facility at Anushaktinagar, Upgradation of services, Construction of 356 nos. residential quarters and Hostel for trainees of BARC/HBNI at Anushaktinagar, Mumbai were in progress.

Construction of Nodal Dispensary works for BARC at Kharghar Navi Mumbai

Construction works of DAE Units / Autonomous Institutes such as Research and Training Block for FReT project TIFR, Hyderabad, Construction of Training School, Core Library,Hostel,Dining/Multipurpose Hall and staff quarters for Atomic Minerals Directorate (AMD) at Cherlapally, Hyderabad, Construction of Pre Engineered Multipurpose Hall at VECC Rajarhat, Kolkata, Construction of Medical Cyclotron building Kolkata, Computer & Information Centre at VECC, Kolkata, Construction of RIB (Radioactive Ion Beam) Building for VECC, Fire

Station and & Anunet substation Building at VECC, SINP Canteen, Kolkata, Academic Township, Sports complex and Residential Township for NISER, Bhubaneswar, Construction of a building for Fission based $^{99}$MO Production facility for BRIT adjacent to ISOMED plant near South Site gate of BARC at Trombay, Mumbai and Compound wall for GCNEP, Harayana also made progress.

Major work orders were issued by DCSEM for Construction of Extention of V.S.Bhavan at Anushaktinagar, Upgradation of Substation 5&6 at Anushaktinagar, Construction of Laboratory Building for IOP Bhubaneshawar, Construction of Academic Block and Residential Quarters along with infrastructure facility for ICTS (International Centre for Theoritical Sciences) Bangaluru.

The Engineering Services Division of DCSEM maintained DAE residential flats (9821 nos) and public buildings in Mumbai including execution of up-gradation works required for the buildings. The Directorate is also responsible for the operation and maintenance as well as up-gradation of electrical power distribution, lifts, water supply, sewer lines and sewage treatment plant, fire fighting system, rain water harvesting system and energy conservation of the services in the large Anushaktinagar township.

The Estate Management Section continued to manage the allotment of residential flats, shops including public buildings and the security for the DAE estate in Mumbai. Schemes worth Rs 281.32 Crores were executed for various DAE units and other departments, including the projects for DCSEM worth Rs. 110 Crores.

## PURCHASE & STORES

The mandate of DPS is to procure right material at right price, storing and issuing of the same to various constituent organisations of DAE. DPS also caters to the materials management needs of the R&D units and the Industrial units of DAE.

A gist of the quantum of work carried out by DPS during the financial year 2012-13 is given below:

### Uranium fuel imports

With the opening of nuclear trade to civil nuclear facilities it became expedient to leverage the enormous experience of DPS. Several short term as well as long term contracts for procurement of enriched uranium as well as uranium ore and pellets were entered and the supplies were received without any hurdle and delay. New sources were also explored and efforts were on for further procurement.

### IT activities

To meet new challenges of increasing departmental needs, DPS took initiative for introduction of information technology. Several parallel contracts for creating infrastructure for implementation of e-procurement were entered and e-tendering was initiated at Madras Regional Purchase Unit, Hyderabad Regional Purchase Unit and Local Purchase Section of DPS Headquarters. Till date about 11,000 tenders were issued and finalized. A new contract for e-tendering was entered into with M/s. ITI based on the MOU between DAE and M/s. ITI. Several other activities for implementation of end-to-end e-procurements were at progressing stage.

### Export of Heavy Water

As per the international packing requirements, DPS had undertaken tropical packing of all Heavy Water consignments exported by DAE and provided logistic and documentation support.

### Inventory Development

To ensure seamless flow of materials to users, the procurement of consumable stores, commonly used by Units in Mumbai was carried out by Central Stores Unit.

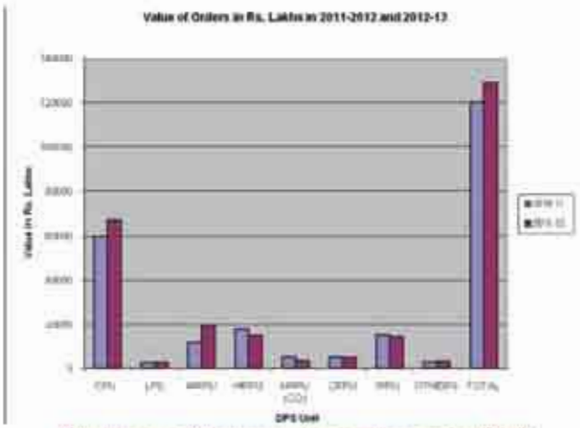
The comparative graph for the last two years for DPS Headquarters and major Regional Units depicts the increase in purchases.

Obsolete, unserviceable equipments & machineries, condemned vehicles and other scraps were disposed of by way of sale tenders and a revenue of about 6 crore was generated.

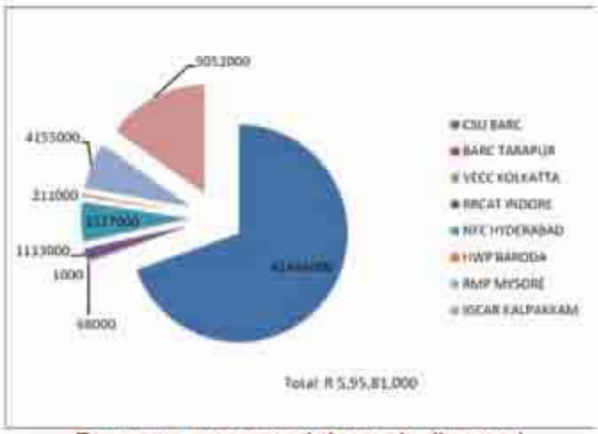
Stores also provided effective support to units in material handling activities like receiving, custody, preservation, accounting and issues in addition to physical distribution of materials between units located at various states and physical movements within units.

## GENERAL SERVICES ORGANISATION

General Services Organisation, Kalpakkam takes care of the common facilities such as Housing, Medical services, Office transport services, Water supply, Solid waste




Quantum of Increase in purchases by DPS during the financial year 2011-12




Revenue generated through disposal of materials during 2012-13

collection and disposal and all maintenance activities in the Atomic Energy Townships at Kalpakkam and Anupuram which cater to the needs of various DAE Organisations located at Kalpakkam Viz. IGCAR, MAPS, BARC and BHAVINI. GSO also provides administrative support to various common advisory committees constituted by Kalpakkam Management Committee (KMC).

GSO provides infrastructural facilities and administrative support to Kendriya Vidyalayas, Atomic Energy Central Schools and Atomic Energy Central Higher Secondary School. Infrastructure support was provided to Nuclear Employees Sports and Cultural Organization. All Departmental administrative work relating to Kalpakkam Nuclear Installation Local Authority (KNILA) was carried out by GSO.

The General Services Organisation was involved in the various activities under Neighbourhood Development Programme as part of social welfare in the villages around Kalpakkam.

GSO provided a clean and green environment with all essential amenities to the two townships Kalpakkam and Anupuram. Following were the highlights of various activities undertaken by GSO during the year 2012.

### Design and Construction

The Architectural & Structural engineering design was completed and drawings were released for construction of shopping complex (Phase-I) at Anupuram Township.

Construction of officer's hostel cum guest house and Phase-I of shopping centre at Anupuram Township was initiated and it made progress. To provide more consulting rooms for doctors, extension of first floor of hospital at Kalpakkam township was completed.

During the year, 1 MGD and 0.60 MGD water from Water Treatment Plants at Kalpakkam and at Anupuram township were supplied to the residents.

### Maintenance

GSO maintained uninterrupted power supply to both the townships. A computer section was setup to establish backbone Network for the Anupuram Township, automation of GSO activities, providing biometric attendance system, establishing e-tendering facilities and organizing the GSO website.

### Quality Circle

During the year, two quality circle teams from GSO viz. EDISON and SAKTHI participated in the regional level meet at Hosur and were awarded the gold and silver cup respectively. Two teams – PLEISTOCENE and SUSHRUTHA were nominated for the National meet.

### Energy Conservation Efforts

Root cause analysis for reducing power consumption by air conditioning systems was carried out. Automated energy saving devices


Quality Circle award winners of GSO

was introduced in the street lighting systems and pump operation systems.

### Industrial Safety

Industrial safety activities were initiated to ensure safe working conditions and practices during construction of high rise buildings that are planned to be built at Anupuram Township. Mandatory industrial safety training program was provided to each and every construction worker in GSO site.

### Auto Shop Activities

Preventive maintenance and repairs of all Light / Heavy vehicles and heavy equipment of GSO, IGCAR, MRPU, NDDP and BARC Facilities were carried out. A number of engine overhauls were undertaken to reduce exhaust pollution and improve mileage.

### Medical services

GSO conducted medical screening camps at the DAE schools and Tamil Nadu Government Schools at Kalpakkam.

# CHAPTER -9

# PUBLIC SECTOR UNDERTAKINGS
## (FINANCIAL PERFORMANCE)


Product launch of Carrier Ethernet Switch Router ECR-1000 series by Dr.R.Chidambaram, Principal Scientific Adviser to the Govt. of India

Product Launch of Programmable Logic Controller (MPROGICON 5000)
by Dr. Anil Kakodkar, Member, AEC and Shri Y.S. Mayya, C&MD, ECIL

**CHAPTER 9**

# PUBLIC SECTOR UNDERTAKINGS (FINANCIAL PERFORMANCE)

Financial performance of DAE's public sector undertakings namely, the Nuclear Power Corporation of India Ltd., Uranium Corporation of India Ltd., Indian Rare Earth Ltd. and Electronics Corporation of India Ltd. are given below. (BHAVINI is yet to commence commercial operations)

Operational highlights of these public sector undertakings, except ECIL, have been covered under the relevant major programme heads. Gist of the operational performance of ECIL is given here.

## NUCLEAR POWER CORPORATION OF INDIA LTD.

The provisional net profit after tax (PAT) for the year 2012-13 was Rs. 1525 crore (up to December 31, 2012) The net profit after tax for previous FY 2011-12 was Rs. 1906 crore.. The NPCIL bonds continued to be rated at AAA (Highest Safety) by CRISIL and CARE.

## URANIUM CORPORATION OF INDIA LTD.

The overall performance of the Company in terms of MoU signed with DAE was rated as "Very Good" for the year 2011-12. The total income of the Company during the year 2011-12 was Rs.707.28 crore as against Rs.750.26 crore in the previous year. The profit before tax during the year 2011-12 was Rs.86.27 crore.

## INDIAN RARE EARTHS LTD.

For the financial year 2011-12, the Sales Turnover (net off excise duty) was Rs. 622.40 crore and Profit Before Tax was Rs.249.84 crore. As against this, for the financial year 2010-11 the Sales Turnover and PBT were Rs. 388.50 crore and Rs. 52.44 crore respectively. During the year 2011-12 IREL had earned foreign exchange of Rs. 200.76 crore which is 119% more than the previous year. The Company paid Rs.34.50 crore as dividend for the financial year 2011-12 which amounts to 20% of profit after tax of the current year. IREL is expecting a total turnover of Rs. 538.00 crores for the year 2012-13.

## ELECTRONICS CORPORATION OF INDIA LIMITED

Electronics Corporation of India Limited (ECIL) is engaged in the design, development, manufacture, supply, installation and commissioning of a wide variety of electronic equipment for Atomic Energy, Defence, Aerospace, Security, Information Technology and e-Governance sectors. ECIL is also a key partner in the implementation of National Population Register (NPR) and socio-economic & caste census (SECC) projects of Govt. of India.

During the year, ECIL took major initiatives to introduce new products such as indigenously designed carrier switch routers, secure network access system (SNAS) and integrated threat management appliance (ITMA) to mitigate the information security concerns especially in strategic areas.

### Performance

During the financial year 2012-13, against an MoU target of Rs.1600 crore each of production and net sales, ECIL achieved a production of Rs 984 crore and a net sales of Rs.927 crore upto November 2012 as compared to Rs.581 crore and Rs.562 crore respectively for

the corresponding period during 2011-12. The company has sufficient orders on hand and is confident of meeting the targets set for the year.

The significant achievements during the year 2012-13 in the strategic sectors were as follows:

**I) Atomic Energy Sector**

- Supply Control & Instrumentation (C&I) equipment to PFBR project, B1/B2 and P3 A Project
- Field Engineering Services to Kudankulam Nuclear Power Project

**II) Defence Sector**

- Supply of M7, TR 3060 and TR 2400 adlos
- Supply of MSRS-II equipment
- Universal Fuzes
- Supply of Ground Control Systems for Akash and BrahMos Missiles
- Supply of Sensor Packages and Antenna Platform Units

**III) Space Sector**

- Supply of Communication equipment including antennas for establishing a Ground Station at Antarctica.

**Iv) Security Sector**

- Security Systems for Indian Embassy at Kabul
- Security Systems to Kudankulam Nuclear Power Project
- Jammers for Police Departments of various States

**Iv) Other Sectors**

- Automation of Maharashtra Sales Tax Department's operations.
- Supervisory Control and Data Acquisition Equipment to Oil and Steel Industries
- Project KAVERI for Govt. of Karnataka

**vi) National Population Register and Socio- Economic Caste Census Projects**

ECIL is associated with the creation of the National Population Register (NPR) project for digitization of census data and also to acquire biometric information relating to the population. The data digitization was completed and the biometric data capture was under progress.

ECIL is also associated with the Socio-economic and Caste Census (SECC) of Government of India. ECIL is executing SECC in 10 States and 90% of the data collection was completed during the year. The data verification was under progress and the project is expected to be completed by March 2013.

Flagging off of Antarctica Antenna by Shri D.S. Jain, Dy. Director, National RemoteSensing Centre (NRSC) and Maj. Gen. (Retd.) Sanjeev Loomba, acting Chairman &Managing Director, ECIL.

Signing of agreement with Bose Institute, Kolkata for supply of Power Converters to FAIR (Facility for Anti-proton and Ion Research)

## Research & Development

The In-house R&D programme of ECIL is guided and supported by the Technology Development Council. Work on the following projects was under progress:

- Carrier Switch Routers
- Development of Software for Intelligent Traffic Management System and Building Automation
- Design, development and production of Secure Router and Transporters
- DAMA Controller and Generic Command & Control System for EW applications
- Integration of ECSCADA software with ECIL's MPROGICON 5000 PLC
- Monitoring and search receivers with software for COMINT applications
- Microwave Signal Survey and Wide Band Analysis System including Spectrum Monitoring Software for EW applications
- Integrated V/UHF Search and Direction Finding System

## New Products Introduced

- BF3 based Drum Monitor, EC Router
- Voter Verifiable Paper Audit Trail (VVPAT)
- Group Command Post
- Software Defined Radio (SDRs)
- MPROGICON PLC System
- T-90 Gyro and Triggers

## Certification of the applicable Quality Management Systems

Surveillance audits of ISO 9001:2008, Safety, Health and Environment (SHE) and Calibration and Measurement Laboratory were completed.

## Collaborations

ECIL has entered into strategic tie-ups with the following companies to strengthen its activities:

- M/s. Toshiba, Japan for supply of Antennas for Weather Radars
- Bose Institute for supply of Ultra Stable Power Converters for FAIR, Germany.
- Institute of Plasma Research (IPR) for technical know-how and licensed production of HV Power Supplies
- M/s. Infronics, Hyderabad for supplying Electronic Voting Machines to the Election Commission of Indonesia.

## Outlook for 2013-14

The company is aiming to achieve a target of Rs.1800 crore during 2013-14 covering following supplies and services:

**Atomic Energy:**

- C&I equipment to various Nuclear Power Plants of NPCIL, PFBR & B1/B2 Projects
- Radiation Gas Monitoring Systems
- Radiation Detection Equipment for Seaports
- New range of Area Gamma Monitors
- Access Control Systems
- High Temperature Fission Counters, Boron Coated Counters

**Defence:**

- M7, TR 3060 and TR 2400 radios, MSRS-II
- Speech Secrecy Equipment, Signal Analyzing Systems
- Carrier Switch Routers and Secure Transport Routers
- Encryption Equipment, Mobile Command Post
- Command Control Centre, Seekers
- Mobile Automatic Surveillance Monitoring (MASM) & Direction Finding (DF) Systems

**Aero Space:**

- Actuators for Unmanned Aerial Vehicles
- Solid State Cockpit Voice Recorders

**Security:**

- Security Systems and Jammers

**Others:**

- EVM Mark-II, VVPAT (Voter Verifiable Paper Audit Trail) systems, multi-post and multi-vote Electronic Voting Machines to State Election Commissions
- SCADA Systems to Oil Pipelines and Steel Industries.
- NPR biometric enrolment, Network Routers

# CHAPTER -10

# OTHER ACTIVITIES

Dr. R K Sinha, Chairman, Atomic Energy Commission,being briefed by
Shri N Saibaba, Chief Executive, NFC,at India Nuclear Energy 2012, Mumbai

Participants of the 24th DAE All India Essay Contest
with the Officials of the Public Awareness Division, DAE

CHAPTER 10

# OTHER ACTIVITIES

## NATIONAL SECURITY

BARC continued implementation of the necessary research and development as well as manufacturing activities required for national security.

## CRISIS MANAGEMENT

The Crisis Management Group (CMG), a standing Committee of senior officials of the Department of Atomic Energy (DAE), is responsible for coordinating the Department's response to any radiation emergency in the public domain. Such an emergency could be due to events taking place either within a nuclear facility or at other facilities handling radioactive materials such as hospitals or industries, and due to an accident involving the transport of nuclear material or even due to any deliberate attempt.

With deployment of multiple safety systems and due to inherent design features, the possibility of any accident in a nuclear facility or during transport which might lead to a radiation emergency in the public domain is highly remote. However, in order to handle any unforeseen situation, formal emergency response systems are in place and are tested regularly to ensure that there would be no radiation hazard to the public. All these activities are overseen by an independent regulatory authority, which ensures that all radiological safety issues are adequately addressed. Further, in case, such an unlikely event does occur and leads to a radiation emergency in the public domain, a response system is in place to tackle such situations by mobilizing the expertise in the Department of Atomic Energy. The specialized technical support would enable public officials to effectively address the situation. The CMG also provides its expertise in various forums in the field of disaster management at both national and international levels.

The Crisis Management Group during its meetings, reviews the crisis management plans at different facilities, discusses on issues related to radiological incidence, if any, in the country and provide necessary guidance on matters related to radiological safety in the public domain to avoid the recurrence of such incidence.

A significant component of the emergency response system of DAE is the availability of two emergency communications rooms at Mumbai, which are manned on a round-the-clock basis throughout the year. These have multiple modes of communication and are in constant contact with various nuclear facilities in the country as well as with the International Atomic Energy Agency (IAEA) in Vienna. The Emergency Response System of DAE is also available to respond to any request from public official in the event of the reported presence or suspected presence of radioactive material. For this purpose, guidelines have been circulated to all State Governments and Union Territories.

To ensure that the emergency plans are in high state of readiness, major nuclear facilities like nuclear power stations and hydrogen sulphide based heavy water plants periodically carry out a variety of emergency exercises. The numbers of exercises carried out during the year 2012 were as follows:

- Communication Exercises (395)
- Fire Emergency Exercises (60)
- Plant Emergency Exercises (47)
- On-Site Emergency Exercises (9)
- Off-Site Emergency Exercises (3)

The off-site emergency exercises were carried out in the public domain in the vicinity of Heavy Water Plant, Kota on April 2012, at Kudankulam Nuclear Power Plant at Kudankulam, Tamil Nadu on June 2012, and at Heavy Water Plant, Manuguru on Oct 2012. These off-site exercises were conducted by the concerned district officials (the District Magistrate or Collector is the off-site emergency director) and information flows were established to the CMG as well as to the National Crisis Management Committee of the Union Government. In addition to these exercises, the National Disaster Management Authority (NDMA) had arranged special training workshops on 'Disaster Risk Reduction' at several Nuclear Power Plant sites to harmonize the procedure to conduct mock emergency exercises and to bring better awareness among the district officials on their roles and responsibilities.

During the year, an international tsunami alert was received on 11 April, 2012 at 1400 IST, with the 8.7 magnitude earthquake hitting the west coast of northern Sumatra. Emergency Response System of DAE effectively communicated the message to our NPPs which enabled them to promptly take the necessary measures.

## BARC SAFETY COUNCIL

BARC-Safety Council continued its regulatory function to ensure the safety of all the plants and facilities under its purview.

To comply with the requirement of licensing/authorization for operation of the variety of radiation installations in BARC, the BARC-Safety Council Secretariat had earlier prepared Regulatory Guidelines, which specify the requirements to be fulfilled for reauthorization of existing old facilities of BARC. It addresses the requirements for new radiation installations in BARC.

## SCIENCE RESEARCH COUNCIL

DAE-Science Research Council that comprises eminent scientists, continued with the peer reviews of basic research to ensure that highest possible level of excellence is maintained.

## INTERNATIONAL RELATIONS

India continued to contribute to policy management and programmes of the International Atomic Energy Agency (IAEA). There was also active involvement in collaboration projects of a multilateral nature. Discussions and engagement at the bilateral level continued with the principal partner countries.

In the field of international relations, the major activities and role that India had played are described as under:

### Bilateral Agreements

Intensive discussions were held with Russia, France and USA both in regard to R&D cooperation and Nuclear Power Plant Projects in India. The first meeting of the Joint Working Group under the Memorandum of Understanding between DAE and ROSATOM of Russia concerning broader scientific and technical cooperation in the field of peaceful uses of nuclear energy was held in Moscow on 4-6th July, 2012. Discussions with the USA relating to R&D projects under the civil nuclear cooperation framework were held under the aegis of the India-US Joint Working Group on basic and applied sciences and the India-US Joint Commission on Science and Technology Cooperation in Washington DC in January, 2012. A Joint Committee meeting of DAE and CEA of France was held in Mumbai in October, 2012.

The Atomic Energy Regulatory Board signed a MoU with the National Commission for Nuclear Activities Control of Romania for the exchange of information and cooperation in the field of regulation of nuclear activities for peaceful purposes on 19th September 2012. AERB also concluded an agreement with the State Nuclear Regulatory Inspectorate of Ukraine for exchange of technical information and cooperation on nuclear safety and radiation protection on 10th December 2012.

### Legislation

The Atomic Energy (Radiation Processing of Food and Allied Products) Rules, 2012 were notified on 30 June 2012.

### International Atomic Energy Agency (IAEA)

Chairman, AEC led Indian delegation to the 56th General Conference of IAEA in Vienna from 17-21st September, 2012. The Indian delegation called on Director General, IAEA and in the margins of the General Conference held bilateral meetings with the delegations of Russia, USA, France, Bangladesh, Canada, Argentina, Iran, Malaysia, Sri Lanka, Namibia, Ukraine, Vietnam and the NEA of OECD.

India hosted several IAEA workshops, technical meetings etc., and offered the services of its experts under the IAEA Technical Cooperation Scheme in a number of fields. India also participated in the various committees of IAEA related to safety, safeguards, nuclear engineering and application, nuclear law etc.

India made extra budgetary contributions of USD 1 million to the IAEA Nuclear Security Fund and USD 50,000 to the Innovative Nuclear Reactors and Fuel Cycles (INPRO) of IAEA. Operational Safety Review Team of IAEA undertook the first-ever mission to India in October - November, 2012. Units 3 & 4 of RAPS were offered for the review.

Principal Adviser, DAE led a delegation to the Fukushima Ministerial Conference on Nuclear Safety held in Japan on 15-17th December, 2012.

### Global Centre for Nuclear Energy Partnership (GCNEP)

A Memorandum of Understanding between the DAE and the Republic of France on cooperation with the Global Centre for Nuclear Energy Partnership of India was signed on March 2012. The Practical arrangements between the Global Centre for Nuclear Energy Partnership and the IAEA were also signed on 22nd March 2012.

A DAE delegation visited USA in July, 2012 to discuss possibilities of cooperation and interface between GCNEP and US laboratories and national training centres.

### Multilateral

India continued to participate in collaborative work in the European Organisation for Nuclear Research (CERN) and the International Thermo-nuclear Experimental Reactor (ITER) project. On 4th April 2012, AERB joined the Multinational Design Evaluation Programme as a full member.

### International Conferences, Symposia etc.

A large number of foreign and Indian scientists/engineers/experts participated in International symposia, workshops, conferences and meetings held in India under the auspices of the IAEA and various international/multinational organizations. Over 1200 Indian scientists were deputed abroad to attend international symposia, workshops, conferences and technical meetings conducted by IAEA and non-IAEA organisations.

## MANAGEMENT SERVICES

The Management Services Group managed the IT infrastructure in DAE headquarters that included round the clock local area network and internet access. It monitors DAE's Plan projects and programmes for preparing progress reports to the top management.

As part of the IT services it managed connectivity of DAE with all the three networks namely ANUNET connecting all DAE Units, NKN a state-of-the-art multi-gigabit pan-India network and Internet. MSG provided video conferencing facilities in DAE over these networks.

DAE's web site (http://www.dae.gov.in), a repository of various press releases, acts, rules, agreements, orders, publications, achievements of the department, downloadable forms for the benefit of the public and having links to all its constituent units was maintained by MSG.

Information Technology infrastructure in DAE Secretariat was continuously upgraded by MSG to keep pace with technology. A helpdesk enabling delivery of IT services to the users was operated.

MSG played an important role in framing guidelines on IT security. The Group coordinated the functioning of the Computer and Information Security Advisory Group (CISAG) of the Department constituted for the purpose of overseeing IT security in DAE and its units. It also coordinated quarterly internal IT security audits by all units of DAE and communicated the IT security guidelines for compliance. CISAG's quarterly magazine "Cyber Diligence", providing inputs on computer security was produced by MSG.

## VIGILANCE

The overall responsibility of vigilance activities rests with the Chief Vigilance Officer (CVO) of the Department of Atomic Energy. To facilitate proper functioning of the vigilance machinery and to establish effective co-ordination amongst the organizations, a senior officer in each unit has been designated as Vigilance Officer for vigilance functions. In the Public Sector Undertakings such as ECIL, IREL and NPCIL, full time CVOs are available to co-ordinate the vigilance activities.

Vigilance functions include timely transmission of various vigilance returns to the Central Bureau of Investigation (CBI), Department of Personnel and Training (DoPT), Central Vigilance Commission (CVC), issuance of prosecution sanctions, processing of vigilance & disciplinary cases, monitoring of the progress of inquiry proceedings, investigation of complaints and others. An Annual Action Plan was worked out by all DAE units. DAE prepared a compendium of CVC guidelines on tendering process and circulated it to all its units.

As per directives of CVC, Vigilance Awareness Week was observed in the Department of Atomic Energy, Mumbai from 29th October to 3rd November 2012. The week commenced with the administering of pledge by Secretary, DAE to all the officers and staff of the Secretariat in both English and Hindi. The key note address was delivered by Special Secretary/Chief Vigilance Officer, DAE. The programme was attended by all the officials of the Department. Vigilance Awareness Week was also observed in the constituent Units/PSUs and Aided Institutions of the Department.

## OFFICIAL LANGUAGE IMPLEMENTATION

DAE and its constituent units, PSUs and aided institutions continued to carry out their activities to promote the use of Rajbhasha Hindi in various disciplines of Nuclear Science and Technology. Some of the efforts made in this direction are highlighted below:

- DAE conducted 14th All India Rajbhasha Sammelan on 17th and 18th January, 2013 at AMD (Western Region), Jaipur. Various lectures and programmes were organized during the course of Sammelan. The souvenir in Hindi on the proceedings of the Sammelan was also brought out.

- The Headquarters of ECIL, Hyderabad and its regional offices located at Bangalore, Chennai, Kolkatta, Tirupati; and HRI, Allahabad were notified under Official Language Rule 10(4). Total 33 offices were notified under the said rule.

- The Parliamentary Committee on Official Language inspected ECIL, New Delhi and BARC, Mumbai offices.

- Five officers of DAE, BARC and NPCIL participated in the Ninth World Hindi Conference organized at Johannesburg city of South Africa in September, 2012 and submitted their presentations at the conference.

- The Department of Atomic Energy carried out hindi inspections at TIFR, TMC, AMD (Central Region), AEES, RRCAT, IPR, HWP, Baroda; BARC, IOP, and NISER. In addition to this, various units such as BARC, RRCAT, AMD, HWB, DCS&EM, DPS, NPCIL, ECIL, GSO, IRE, UCIL, BHAVINI, IPR, and IOP inspected their subordinate offices and sections.

- Thirty five seminars and forty eight talks in hindi on diverse subjects, mostly related to nuclear science were organized and the souvenirs in hindi on the proceedings of the seminars/talks were also brought out.

- All Gazette Notifications, Cabinet Notes, Annual Reports and other documents furnished to the various committees of the Parliament, and the agreements and MOUs were prepared bilingually.

- Training in hindi noting and drafting in hindi workshops was provided to about 1,800 officers and employees. 317 officers and employees under the incentive scheme for doing original noting and drafting in hindi, 92 typists under the incentive scheme for hindi typing and 44 stenographers under the incentive scheme for hindi stenography were awarded.

- 208 Officials, 39 Typists and 19 Stenographers were imparted training in Hindi, Hindi Typing and Hindi Stenography respectively. 251 Officials, 36 Typists and 35 Stenographers were given training in Hindi, Hindi Typing and Hindi Stenography respectively. 122 Officials, 42 Typists and 12 Stenographers were given cash awards and other incentives for successfully passing Hindi, Hindi Typing and Hindi Stenography examinations.

- Hindi books worth Rs. 5,80,973/- were purchased and books worth Rs. 2,88,819/- are proposed to be purchased.

- Quarterly meetings of OLICs were held regularly and the progress of implementation of Hindi was monitored regularly through OLIC meetings and review of the Quarterly Progress Reports.

- DAE and 22 of its establishments have their Websites in bilingual form and these are updated regularly. Presently, there are 19,414 bilingual computers and 591 bilingual computers are proposed to be purchased.

- The Hindi Vigyan Sahitya Parishad, a voluntary organization of BARC continued to publish a popular Hindi quarterly bulletin "Vaigyanik". Pamphlets on various subjects related to DAE's activities were also prepared in bilingual form.

- With a view to provide information in legal field, Legal Advisor delivered lectures in Hindi on legislation pertaining to DAE at Mumbai & Kalapakkam.

- Forty two house magazines and five newsletters were brought out by various establishments of DAE.

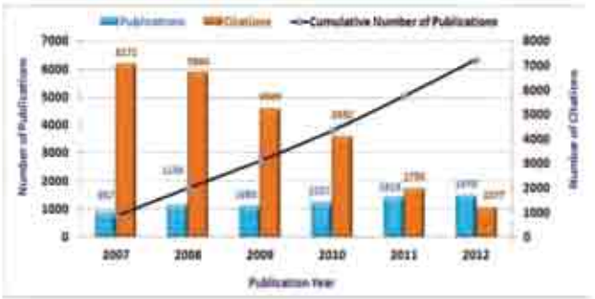
- The total strength of Hindi Staff in DAE and its constituent units was 125.

## SCIENTIFIC INFORMATION & RESOURCE MANAGEMENT

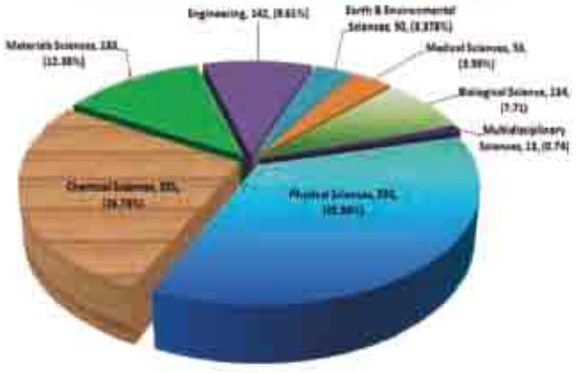
During the report period, the Scientific Information Resource Centre (SIRC) of Department of Atomic Energy procured many new books, periodicals and other audio-visual materials. User services such as Circulation, News Clipping Service called News Watch, Reference & Information, Reprography, Referrals etc. were continued.

The Publications Unit of the Department published many literatures for internal use as well as for general public. These included Annual Report, Outcome Budget, DAE perspective, Accounts at a glance, Achievement at a glance a XIIth plan document, DAE Diary, brochures, leaflets etc. The published literatures were disseminated to individuals, organisations through mass mailing.

Library facilities in BARC were continuously upgraded with the state-of art facilities and technology infrastructure to provide seamless access to information to the users and to extend its facilities to other DAE Institutions. A total of 7232 publications were published and 23,039 citations were received to these publications during 2007-2012. There were 1478 publications in 2012. The highlights are given below:




Year-wise Distribution of Publications and Citations of BARC during 2007-2012



Subject-wise Distribution of Publications of BARC in 2012

Research activities in Library & Information Science and Scientometrics on various topics related to nuclear science and technology as well as major thrust areas continued. Over 18 papers were published. BARC newsletter, Scientific Information Resource Bulletin, Pulse and several internal, external and restricted reports, brochures, printing of diaries, greeting cards, etc were brought out.

At IGCAR, a state-of-the-art live streaming facility of the events from the auditorium was implemented and made available across the user's desktops. Based on the research needs of the centre, the e-collections were augmented. The complete archives of Nature & Scientific American, ICDD-PDF database, Bureau of Indian Standards and Indian patents were added to the library collection. The library was equipped with CCTV base surveillance systems.

## PUBLIC AWARENESS

The Department of Atomic Energy (DAE) continued to promote the awareness about peaceful uses of atomic energy in the correct perspective with prime focus on benefits to the society and also keeping the public abreast with current trends and developments in the areas of power production, applications of radiation technologies, healthcare, food & agriculture, industry, water, environment, advanced technologies etc.,

The main objective of the public awareness activities is to elucidate the uses of atomic energy to the general public and alleviate unwarranted fears, misconceptions and address apprehensions harboured against nuclear energy. This was done on a mission mode in a structured manner through a multi-pronged approach by organising and participating in exhibitions; seminars for academicians, general public and the media in different regions of the country and organising essay and quiz contests etc.

**During the year, DAE participated in and organised several events as follows:**

The 100th Session of the Indian Science Congress was held at the University of Calcutta, Kolkata, during January 3-7, 2013. Pride of India, a Mega Expo, was held parallel to the Science Congress. The main theme of the Congress was "Science for the Shaping the Future of India". DAE participated in this exhibition by putting up a neoteric state-of-the-art multimedia display system. Video films and multimedia presentations on nuclear power, applications of radioisotopes in healthcare, agriculture, food processing, industry, hydrology, desalination and advanced technologies etc. were shown. The system proved to be a phenomenal success in evoking interest about atomic energy among the public. Other units of DAE viz. Atomic Minerals Directorate for Exploration and Research (AMD), Uranium Corporation of India Limited (UCIL), the Nuclear Fuel Complex (NFC), the Heavy Water Board (HWB), the Nuclear Power Corporation of India Limited (NPCIL), the Bhabha Atomic

Dr. R K Sinha, Chairman,
Atomic Energy Commission,
at the DAE pavilion during the
100th Indian Science Congress at Kolkata

Research Centre (BARC), Saha Institute of Nuclear Physics (SINP) and the Variable Energy Cyclotron Centre (VECC) also put up pavilions along with DAE.

The 24th All India Essay Contest on Nuclear Science & Technology was organised in October 2012. Essays were received in three languages and on three topics namely Relevance of Nuclear Power for Future Energy needs of India, Radioisotopes and Radiation Technology for Improving the Quality of Life, Role of Power Beams in Enabling Science and Technology in the Twenty-first Century – contributions to healthcare, materials processing, environment and energy sectors. About 190 essays were received out of which the authors of thirty two were selected for making the oral presentation at Mumbai.

Participants of the 24th DAE All India Essay Contest with the Officials of the Public Awareness Division, DAE

The selected participants were shown around various facilities of DAE. Certificates and cash prizes were awarded during the Founder's Day Celebrations on October 30, 2012.

DAE participated in the Haryana S&T Workshop Exhibition, held at Palwal, Haryana during April 26-28, 2012. The event was inaugurated by Shri Avtar Singh Bhadana, Hon'ble Member of Parliament (Lok Sabha) from Faridabad. The theme of the exhibition was 'Science & Technology Applications for the Betterment of life'. DAE exhibited all its activities for societal development. Several members of the local public benefitted from the DAE exhibition.

The 6th Science & Technology EX PO – 2012 was organised at Ranikhet, Uttarakhand during June 7-9, 2012 by the Creative Centre for Rural Development, New Delhi. DAE participated in this event at the instance of Shri K C Singh Baba, Member of Parliament (Lok Sabha) Nainital. The event was inaugurated by Shri Pradeep Tamata Hon'ble Member of Parliament (Lok Sabha). The objective of the event was to create awareness and knowledge among young scientists, students, general public, ex-servicemen, emerging entrepreneurs etc. The programme was well received by all the visitors who had several specific queries on nuclear power & safety related issues, applications of radiation technologies for healthcare and food processing.

Interaction with students during the 6th Science & Technology Expo-2012, Ranikhet, Uttarakhand

DAE took part in the 'Frontiers of Science 2012' held at Kolkata, during September 3-4, 2012. DAE exhibited its strengths, programmes and achievements in the area of various cutting edge technologies. Delegations from Facility for Antiproton and Ion Research, (FAIR) and CERN also participated in the event.

Participants during the Frontiers of Science event at Kolkata

The 16th National Exhibition with theme as 'India Marching towards an Advanced Nation was held during September 7-11, 2012 at Nazrul Maidan, Narayantala, Kolkata. VECC Kolkata, also participated with DAE in this exhibition. Information (in Bengali and English) and several working models were displayed in this expo. The DAE pavilion had as many as 30000 visitors.

Students being briefed at the DAE pavilion during the 16th National Exhibition at Kolkata

The Kerala State Industrial Development Corporation Ltd. organised Emerging Kerala 2012 during September 12-15, 2012 at Kochi, Kerala. DAE took part in the event and exhibited its achievements, contributions and current activities in the field of nuclear science and technology. Visitors to the pavilion comprised

Visitors at the DAE pavilion during Emerging Kerala 2012 event at Kochi

senior government officials, scientists, policy makers and leaders from industry.

DAE participated in the 'Ramnagar Scientific Literacy Festival 2012' at Ramnagar, Uttarakhand during October 4-6, 2012. The focus of the event was to educate and enlighten the general local public and the students on the positive and beneficial aspects of atomic energy so as to remove misunderstandings and fears about nuclear energy. Over 20000 members especially from the rural public and students visited the DAE pavilion. The event was inaugurated by Shri Satpal Maharaj, Member of

Shri Satpal Maharaj, Member of Parliament (Loksabha) and Chairman, Standing Committee on Defence, Member, Public Accounts Committee, taking keen interest in the exhibits at the DAE pavilion during the Ramnagar Scientific Literacy Festival 2012 at Ramnagar, Uttarakhand

Students taking notes during the Ramnagar Scientific Literacy Festival 2012 at Ramnagar, Uttarakhand

Parliament (Loksabha) and Chairman, Standing Committee on Defence, Member, Public Accounts Committee.

India Nuclear Energy 2012 – 4th International Exhibition and Conference was held at Mumbai during September 25 – 27, 2012. DAE exhibited all its achievements related to the Indian Nuclear Power Programme comprising the three stage programme, the closed nuclear fuel cycle, fuel reprocessing, nuclear waste management, safety etc. The event was a unique platform for showcasing latest cutting edge nuclear technology. Several other countries like France,

Dr. R K Sinha, Chairman, Atomic Energy Commission, being briefed by Shri N Saibaba, Chief Executive, NFC, at India Nuclear Energy 2012, Mumbai

Francois Richier, French Ambassador to India at the DAE pavilion during India Nuclear Energy 2012, Mumbai

Korea, USA, Russia etc. also participated in this event. In addition, many companies from the Indian industry supplying various components to our nuclear power programme also took part in the exhibition. Other units of DAE viz NPCIL, NFC, UCIL, HWB, BARC and BRIT also took part in the event.

The Uttarakhand State Council for Science & Technology, Dehradun organised the Uttarakhand State Science & Technology Congress at the Graphic Era University, Dehradun during November 21-23, 2012. The prime focus of the event was promotion of Nuclear Science & Technology and the strides made by India in this field. DAE put up an exhibition showcasing all its activities in various areas like nuclear power, applications of radioisotopes, desalination, advanced technologies etc. The DAE pavilion had over 20000 visitors mainly comprising college and school students from in and around Dehradun, faculty members etc. Parallel to the exhibition, a seminar on 'Nuclear Science & Technology' was organised which was attended by several young scientists wishing to pursue their career in the field. Experts from BARC and DAE addressed the scientists.

The Swadeshi Science Movement (SSM) Kerala, (A unit of Vijnana Bharati) organised a mega programme, the Swasraya Bharat – 2012, during November 30 – December 5, 2012 at Kochi, Kerala so as to inculcate the spirit of national self-reliance among students, youth and scientists. DAE participated in this event and

exhibited all the peaceful applications of atomic energy towards societal development. The DAE exhibition was visited by members of the general public, academia, students from schools and colleges in and around Kochi.

To teach and train farmers about new technologies, innovative methods to increase farm yield and bridge knowledge gaps, AGROVISION 2013 was held during January 24-27, 2013 at Nagpur. The event was organised under the guidance of eminent agricultural scientist Prof M.S. Swaminathan. DAE exhibited its activities and contributions in the areas of agriculture and food processing. Farmers from Vidarbha and adjoining districts of M.P, Chhattisgarh, Andhra Pradesh etc. visited the pavilion and took interest in knowing about the BARC crop varieties and radiation food processing technologies. Scientists from BARC interacted with the visitors and provided information.

DAE took part in the Bangalore India Bio 2013 held at Bangalore during February 4-6, 2013. The event was organised by the Department of IT, BT and S&T, Government of Karnataka & the Vision Group on Biotechnology. Achievements in the field of healthcare, agriculture, food processing and biotechnology were exhibited by DAE. Members of the academia, scientists, farmers, general public benefitted from the exhibition.

The Science Expo was held at the Nehru Science Centre, Mumbai during February 20-23, 2013. The focus of the programme was to bridge the gap between Science and Society. DAE participated in the expo through models and multimedia displays on the complete gamut of DAE's activities as in the fields of nuclear power, production and applications of radioisotopes in healthcare, agriculture & food, industry, hydrology, advanced technologies etc. The event was very well received by students, scientists and other members of the general public.

AGROVISION 2013, at Nagpur.
A view of the DAE Pavilion

The Nuclear Fuel Complex, Hyderabad organised the 9th DAE MEDI-MEET at Hyderabad during November 1-2, 2012. The theme of the event was Healthcare Services – "Challenges and Solutions". The programme provided a platform for medical professionals to deliberate and exchange present day advances taking place in the medical field. An exhibition on Radiation & Health was put up by DAE so as to propagate the peaceful applications of nuclear energy for the benefit of mankind. The event was attended medical professionals form various DAE Units.

The Atomic Power Evolution Awareness Foundation (APEAF), organised two Grand Mahotsavs – mass scale public awareness programmes on the uses of atomic energy- both in Haryana, one at the CCS Agricultural University, Hissar, Haryana during July 29-31,

Dr. Anil Kakodkar, Former Chairman Atomic Energy Commission at the DAE pavilion during the 6th Science Expo at Nehru Science Centre, Mumbai

2012 and the other at Bhivani, Haryana during January 22-23, 2013. The events were of particular significance especially in the wake of the proposed nuclear power station at Gorakhpur, Haryana. DAE participated in both the programmes and exhibited all its contributions to society with special focus on the need for electricity, emphasising the important role that nuclear power would play in the future. Large sections of the general and rural public interacted with departmental officials thereby getting their fears and apprehensions cleared about nuclear energy.

The Chinchni-Dandapada village is very close to the Tarapur Atomic Power Station (TAPS) and the happenings at Fukushima, Japan in 2011 instilled doubts and fear about TAPS. A seminar on 'Atomic Energy' was held at the Chinchni-Dandapada Jilha Parishad School in April 2012 at the request of the Sameer Seva Mandal, Thane. High school students and several villagers from in and around the locality attendee the seminar and found it very useful. Dr Anil Kakodkar, former Chairman of the Atomic Energy Commission was the Chief Guest and he also addressed the gathering and allayed their fears.

A seminar was on 'Trends in Nuclear Power – One Year after Fukushima' was organised by the Centre for Air Power Studies at Mumbai in April 2012. Over 200 participants comprising people from various academic institutes in Mumbai, representatives of Maharashtra Government and members from the media attended the seminar.

The National Association for Application of Radioisotopes and Radiation in Industry (NAARRI) organised an awareness programme on 'Application of Radioisotopes and Radiation Technology in Industry and Healthcare' at the Kalasalingam University near Madurai during August 17-18, 2012. Several post graduate students, faculty members from various universities and research organisations and NGOs participated in the seminar. The event bore specific relevance and importance in the wake of the nearby Kudankulam Nuclear Power Project.

In addition to all these events, throughout the year, several public awareness lectures on atomic energy were delivered in different regions of the country.

Nuclear Power Corporation of India Limited (NPCIL) carried out a gamut of public outreach activities over a period of time, conveying the facts on nuclear power in a simple transparent and credible manner. Following the Fukushima accident, the outreach activities were scaled manifold in a structured manner adopting a multi-pronged approach, to allay the apprehensions about nuclear power and its safety. An action plan was implemented with clear set of objectives and timelines including a review and monitoring mechanism. NPCIL Board also approved the scaled up outreach plans on a long term basis along with sizeable investment for these activities.

KAPS visit by local villagers

The public outreach programme of NPCIL comprised of regular visits by the senior officials to surrounding areas and enhanced interaction with locals, visits of villagers, students, media persons and other members of public to nuclear power plants and organizing awareness campaigns on nuclear power for various target groups.

Use of TV commercials, advertisements, digital cinema, radio jingles, single-sheet print

publications, innovative comic books and animated films, etc. in vernacular languages, enhanced interaction with press and media, e-public awareness campaigns, rallies in support of nuclear power are a few, among many, modules that were adopted to supplement the scaled up outreach activities.

NPCIL entered into partnership with several special agencies like Vigyan Prasar of the Department of Science & Technology, DAVP, UFO Movies, media facilitator etc. NPCIL entered into partnership with several special agencies like Vigyan Prasar of the Department of Science & Technology, DAVP, UFO Movies, media facilitator etc.

A view of Hall of Nuclear Power at Nehru Science Centre

As a part of capacity building for public outreach, a permanent exhibition centre called Hall of Nuclear Power at Nehru Science Centre, Mumbai was set up by NPCIL with Nehru Science Centre, Mumbai. The gallery inaugurated on August, 2011 comprises of latest and innovative technical backlit displays, touch screen kiosks, interactive games, panels, banners, placards, cut-outs, static/dynamic models, interactive models, audio/visual presentations, 2D/3D films, quiz, games etc. The main highlight and the USP of the entire gallery was Digital Walk-through. People, particularly students visited the gallery in lakhs. NPCIL is planning more of such permanent exhibition centres at its sites and at locations across the country.

To promote awareness among the public about the peaceful uses of atomic energy, several

Media Awareness Programme at BARC

Exhibition at BARC during the National Science Day

public awareness programmes for the benefit of students, teachers and farmers across the country were conducted by BARC. Over 30 public awareness progrmmes were conducted during the period. In addition, media coverage to the various events organized at BARC was also provided. As a part of this programme, students from various colleges in and around Mumbai and from other states visited BARC and interacted with the scientists.

"Nuclear Waste Management" exhibition was organized at BARC during the National Technology Day to provide a platform for better interaction amongst scientists and engineers. A week long programme on the theme 'Clean Energy Options and Nuclear' along with the National Science Day celebrations was organised.

An exhibition on 'Radioactive Waste Management' was inaugurated by the National Security Advisor. A photo exhibition on the theme "BARC-2011: The Year that Was" was organized during 26th -31st January 2012 at BARC.

A new informative BARC website was launched which is more users centric and provides interesting information related to various activities of BARC.

The public awareness programme was continued in a big way at AMD in various cities as well as in remote field areas.

## SOCIAL WELFARE

NPCIL continued its Corporate Social Responsibility and implemented 32 projects in education, 17 projects in healthcare and 67 projects in infrastructure development during the year 2011-12. For the year 2012-13 about 250 CSR projects were planned by NPCIL and Rs. 55 crores was allocated for CSR programme. An additional Rs. 125 crore was also allocated as additional CSR fund in the Silver Jubilee year of the Corporation to be used in next two years.

Computer education for women near Rawatbhata, Rajasthan

Limbarda Primary School near Kakrapar, Gujarat

Distribution of Educational Kits to Girl Students near Kudankulam in TN

CSR projects in education and skill development included various projects like construction of school buildings, financial assistance to schools, scholarships to students and sponsorship for higher education, development of aaganwadis etc. Support through distribution of educational aids was continued. School teachers in the area near all the units were also felicitated on Teachers Day for their contribution to the cause of education for the rural students.

Healthcare CSR projects included running primary health centres, providing mobile medical van services, organising medical camps,

Dormitory for Cancer Patients at Walewalkar Hospital, Chiplun, Ratnagiri near JNPP

Hall for Fishermen Constructed in Sadras near Kalpakkam, Tamilnadu

funding extension of hospitals, providing medical treatment and medicines, OPD services for villagers etc.

Under infrastructure development, the projects like laying of approach roads, development of drinking water facility, construction of community hall, construction of bus stop sheds, installation of street lights, providing fishing facility etc. were planned and implemented.

## EMPLOYEES' WELFARE

### Employees' Health Care

The employees of DAE organisations, along with their family members, are beneficiaries of the Contributory Health Service Scheme (CHSS) of the Department. The healthcare facilities of CHSS are also extended to the retired employees and their families.

During the year of report, medical facilities under CHSS were extended to the DAE employees and their dependents by the BARC Hospital through its 13 zonal dispensaries, 2 occupational health centres, pathology and radiology lab and pharmacy.

### Children's Education

The Atomic Energy Education Society (AEES) meets the educational needs of the children of the employees of DAE and its constituent units working at different centres in the country. AEES currently administers 30 schools/ Junior colleges at 15 centres located all over India and provides education to over 27, 500 students.

AEES achieved remarkable success in its quest for excellence in academic as well as sports, NCC and arts. Importance was given to strengthening of infrastructure facilities, enriching the school libraries, upgrading the computer education and providing better sports facilities. Regular in-service training programmes for the teachers as well as enrichment and educational programmes for the students were continued.

During the report period the performance of students in academic and non-academic areas of education brought laurels to AEES. Over 3800 students appeared for the All India Secondary School Examination and the Higher Secondary Examination and the pass percentage was 99.91% and 90.72% respectively. The overall Excellence Index stood at 69.45%. AEES Mumbai produced cent percent result.

Nineteen students of AEES Schools cleared the National Talent Search Examination. Twenty six students from AEES Tarapur, Kalpakkam, Hyderabad and Indore participated in the 54th Annual All India UN Information Test and secured above 60% marks. The AEES, Tarapur students bagged Gold Medal in the 61st Annual All India General Knowledge Test conducted by the All India Board of General Knowledge.

One student of AEES, Mumbai cleared Regional Mathematical Olympiad and was selected for Indian National Maths Olympiad. Two

students from AEES, Manuguru secured first position in the Regional Level Hindi Vignanik Prashna Manch held at Mysore. Four students of AEES Mumbai & three students of Tarapur topped in Physics at the National Standard Examination in Physics, Chemistry, Biology & Astronomy 2011-2012.

Six students from AEES, Tarapur won the first position in the Inter School One Act Play organized by BARC at Tarapur. One student from AEES, Mumbai was awarded Dhirubhai Ambani SSC Merit Reward Scheme for her outstanding performance in SSC Board Exam. A student of AEES, Tarapur secured 98.4% in AISSE. At the National Level Science Talent Search Examination two students of AEES, Rawatbhata secured national ranks.

Seven students from AEES, Tarapur received Gold medal at the 14th National Science Olympiad Contest conducted by All India Schools Science Teachers Association. Thirteen students from AEES, Rawatbhata secured gold medal in International Olympiad of Mathematics Exam organized by Mathematics Olympiad Foundation. Nine students won gold, eight students received silver and five students got bronze medals in the International Olympiad of Science conducted in December 2011.

A student from AEES, Narora received DST Scholarship for Higher Education (SHE) under Innovation in Science Pursuit for Inspired Research (INSPIRE). One student from AEES, Kudankulam was awarded Certificate of Merit in Australian National Chemistry Quiz conducted by Royal Australian Chemical Institute. The Inter AEES Hindi Vigyan Prashna Munch was held at Mysore, Rawatbhata, Oscom (Hyderabad) and Mumbai.

Atomic Energy Education Society in collaboration with the Department of Atomic Energy Sports & Cultural Council organized a summer sports coaching camp for school children for various games such as Football, Volleyball, Basketball, Lawn Tennis, Table Tennis, Badminton and Athletics.

Students of AEES schools participated in many sports events and competitions such as Athletics, Volleyball, Table Tennis, Karate, Badminton, Swimming, Chess, Skating etc. at district, state, national and international levels during the year. AEES, Mysore secured first place in International level Asian Open Karate Championship held at Kerela. AEES, Mumbai qualified for the International examination of the science of Go souk Ryu Karate-do. AEES, Anupuram secured Bronze medal in Kumite at National level Kofukan Shito-Ryu Karate Competition.

More than 370 and 230 students passed the Elementary & Intermediate Drawing Grade Exams respectively which was conducted by The Grade Examination of Directorate of Art, Maharashtra State Board.

### Talent Nurture Programme

Under Talent Nurture Programme (TNP), children were selected for admission in Class I. Ten centres of the AEES provided education to children admitted under the TNP and provided free education, monthly scholarship, medical facilities, school uniforms, textbooks and notebooks.

### UK India Education and Research Initiative (UKIERI)

As a part of this programme the teams from UK visited AEES schools and AEES Schools visited UK to gain learning experience, to share and communicate with the teachers and students.

### Science Parks

To create and sustain the interest of students in science, AEES had set up science parks in Hyderabad, Kaiga, Turamdih and Anupuram schools.

## DAE SPORTS & CULTURAL ACTIVITIES

The DAE Sports and Cultural Council (DAE S&CC) facilitates promotion of sports, physical fitness, yoga and cultural activities among DAE employees and their family members located at various units all over India.

The XXVIII Inter DAE sports & Cultural Meet has been scheduled in eleven different sports and cultural events at various locations. During this year, more than 2500 employees took part in the selection trials and 1000 employees participated in the final meets. The playing facilities at various units were upgraded.

Ajanta (BARC) Cricket Team receiving the Winners Trophy from Shri N. Saibaba, Chief Executive NFC and Shri Venkatapathi Raju Former Indian Cricketer & Vice President, Hyderabad Cricket Association Winners Trophy

The events were conducted in the best traditions of the department. Teams for participation in National events like ball badminton, kabbadi, football, bridge, Table Tennis, Badminton etc. were selected during the meet.

Every year Special Summer Coaching camps were organized jointly by DAE S&CC and Atomic Energy Education Society (AEES) as a regular annual event and more than 1500 children of DAE employees received coaching in various games and sports. Based on the performance and aptitude displayed in these camps, about 100 children were selected for advanced coaching scholarship in various games.

During the year, sports camps in badminton and table tennis were organized for highly talented youngsters and were trained by National level coaches. For creating competitive match environment and promoting competitiveness in employees and their children, a combined sports and cultural meet SPLASH-2012 was organized.


Shri A. P. Joshi, Special Secretary DAE at Opening Ceremony of SPLASH-2012

Under its Health and Fitness activities, regular yoga activities as well as camps were organized at different centers at various levels for employees as well as for their family members. Units of DAE were encouraged and financially supported to set up Fitness centers.

## OTHER ACTIVITIES

Every year, DAE S&CC organizes All India level painting competition this year the painting competition was held at AEES center at Kalpa.

DAE S&CC in collaboration with BARC staff Club's Nature and Adventure Circle organised Nature and Adventure Camp at Van Vihar, Ambivali village near Karjat Raigad district to promote the spirit of adventure among youngsters. The activities included Rock climbing, Rappelling, River Crossing, Rafting, Star gazing and a short Trek to Peth Fort.

The fourth Himalayan Trekking Expedition was organised in Hamta Pass region near Manali, Himachal Pradesh. All the participants successfully completed the trek.

DAE's annual all India trekking programme "Girisanchar-24" was organized with the approval of the Indian Mountaineering Federation in the picturesque and dense forest region of Bhimasankar sanctuary.

Trekkers of Girisanchar-24 at the Base Camp at Dhasai

As a part of Infrastructural development and promotional activities, DAE S&CC supported many residential colonies of the Department that included, BARC Staff club, NFC Hyderabad, NESCO IGCAR, AERB Staff Club, ARWA, Mumbai etc.

## AWARDS & PRIZES

Shri K. Balaramamoorthy, former Chief Executive, Nuclear Fuel Complex, Hyderabad; Prof. R. Balasubramanian, Director, Institute of Mathematical Sciences, Chennai; Dr. Ravi Bhushan Grover, Principal Adviser, Department of Atomic Energy, Mumbai and Dr. Satinder Kumar Sikka, Homi Bhabha Chair Professor, BARC, Mumbai were conferred with the DAE's Lifetime Achievement Award for the year 2011 by Dr. Manmohan Singh, The Prime Minister of India.

BARC bagged the "Best Establishment Award for the 89th Regional Skill Competition for Apprentices held in September 2012 for western region.

AMD officers were awarded DAEs medals and Hindi Sevi Samman during 2011-12.

NPCIL units received several awards during the year for performance in safety, environment protection and other areas. TAPS-1&2, TAPS-3&4, RAPS 1&2, RAPS-3&4, MAPS, APS 1&2 and KGS-1&2 bagged National Safety Council of India's various Safety Awards for the year 2011. AERB's Safety awards for the year 2011 for industrial safety, environment protection and fire safety were bagged by RAPP 7&8, KAPP 3&4 and KGS 3&4 respectively. NPCIL achieved excellent MoU rating for the year 2011-12.

The awards received by the Professors of Institute of Mathematical Sciences during the year were as follows: Prof. Ronojoy Adhikari received Google Research Award by Google Incorporation, USA on January 2011, Dr. Sanoli Gun won ICTP Associate Award for the year 2011 and Dr. Saket Saurabh was awarded with the Award of European Research Council.

Prof. Ashoke Sen of HRI was conferred with the prestigious "The Fundamental Physics Prize - 2012" by Milner foundation Established by Yuri Milner for his contribution to string theory which helped to show that multiple string theories are all different versions of a single underlying theory.

The Prime Minister, Dr. Manmohan Singh & Dr. R.K. Sinha, Chairman, Atomic Energy Commission with the recipients of DAE's Lifetime Achievement Award 2011 along with their family members in New Delhi on January 15, 2013.

Heavy Water Plant, Manuguru won "Golden Peacock Environment Management Award-2012" in recognition of sustainable and effective Environment Management system. HWP, Hazira was selected for National Safety Award for the year 2010 from Directorate General Factory Advice Services and Labour Institutes, Faridabad, Ministry of Labour & Employment. Plant also received "Certificate of Appreciation-2010" awarded by Gujarat Safety Council, Vadodara and Directorate of Industrial Safety & Health.

"Miniratna Category –I" status was granted to IREL on 11th October, 2011. OSCOM Unit received the 1st prize in the safety & training during the Odisha metalleferious mines safety week 2011-12. During the Mine Safety week organized by the Kerala Mine Safety Association, Chavara unit received three 1st prizes and five 2nd prizes.

Two quality circle teams from GSO viz. EDISON and SAKTHI participated in the Regional Level meet at Hosur during the year and were awarded the gold and silver cup respectively. Two teams – PLEISTOCENE and SUSHRUTHA were nominated for the National meet.

# CHAPTER -11

# IMPLEMENTATION OF PERSONS WITH DISABILITIES (EQUAL OPPORTUNITIES, PROTECTION OF RIGHTS & FULL PARTICIPATION) ACT, 1995

The Department of Atomic Energy has a mandate to develop peaceful uses of nuclear energy in areas like power generation and basic research in frontier areas of science and technology. In view of the nature of activities carried out by the Scientific and Technical persons in various Research Centres, Public Sector Undertakings, Industrial Units and Aided Institutions of the Department, this Department is not in a position to implement the provisions of reservation of posts fully as required under the "Persons with Disabilities (Equal Opportunities, Protection of Rights and Full Participation) Act, 1995". Therefore, this Department has already sought exemption for the Units like Heavy Water Boards and Nuclear Power Corporation of India Ltd. From the provisions of the said Act. No specific scheme under plan projects for the benefit of persons with disabilities has been introduced in the Department. In-spite of the constraints, all the Units/PSUs/Aided Institutions have attempted to identify posts, where persons with disabilities could be employed without impairing the activities or causing inconvenience.

The sanctioned strength and number of persons with disabilities in various posts in Group A, B, C & D against 3% vacancies to be reserved for them under Section 33 of the said Act is indicated in the pages that follow.

## ANNUAL STATEMENT SHOWING THE REPRESENTATION OF PERSONS WITH DISABILITIES AS 01.01.2013 AND NUMBER OF APPOINTMENTS MADE DURING THE PRECEDING CALENDAR YEAR 2012 IN RESPECT OF CONSTITUENT UNITS

| Group | Number of Employees | | | | Direct Recruitment | | | | | | | By Promotion | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | No. of vacancies reserved | | | No. of appointment made | | | | No. of vacancies reserved | | | No. of appointment made | | | |
| | Total | VH | HH | OH | VH | HH | OH | Total | VH | HH | OH | VH | HH | OH | Total | VH | HH | OH |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) | (18) | (19) |
| Group A | 7548 | 0 | 1 | 23 | 0 | 0 | 1 | 267 | 0 | 0 | 0 | NIL | NIL | NIL | 461 | 0 | 0 | 0 |
| Group B | 10458 | 7 | 7 | 42 | 1 | 1 | 2 | 336 | 0 | 0 | 0 | NIL | NIL | NIL | 565 | 0 | 0 | 0 |
| Group C | 11458 | 14 | 25 | 94 | 0 | 7 | 11 | 440 | 0 | 4 | 4 | 0 | 1 | 1 | 240 | 0 | 0 | 1 |
| TOTAL | 29464 | 21 | 33 | 159 | 1 | 8 | 14 | 1043 | 0 | 4 | 4 | 0 | 1 | 1 | 1266 | 0 | 0 | 1 |

Note 1 : (I) VH stands for Visually Handicapped (persons suffering from blindness or low visions)

(ii) HH stands for Hearing Handicapped (persons suffering from hearing impairment)

(iii) OH stands for Orthopaedically Handicapped (persons suffering from locomotor disability or cerebral palsy)

(iv) There is no reservation for persons with disabilities in case of promotion to Group A and B posts. However, persons with disabilities can be promoted to such posts, provided the concerned post is identified suitable for persons with disabilities provided the concerned post is identified suitable for persons with disabilities.

Note 2 : Column No. 9 and 16 show the sum total appointments made in the Department by way of Direct Recruitment and Promotion

## ANNUAL STATEMENT SHOWING THE REPRESENTATION OF PERSONS WITH DISABILITIES AS 01.01.2013 AND NUMBER OF APPOINTMENTS MADE DURING THE PRECEDING CALENDAR YEAR 2012 IN RESPECT OF AIDED INSTITUTIONS

| Group | Number of Employees | | | | Direct Recruitment | | | | | | | By Promotion | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | No. of vacancies reserved | | | No. of appointment made | | | | No. of vacancies reserved | | | No. of appointment made | | | |
| | Total | VH | HH | OH | VH | HH | OH | Total | VH | HH | OH | VH | HH | OH | Total | VH | HH | OH |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) | (18) | (19) |
| Group A | 1103 | 1 | 2 | 2 | 1 | 10 | 1 | 46 | 0 | 0 | 0 | NIL | NIL | NIL | 37 | 0 | 0 | 0 |
| Group B | 2798 | 4 | 0 | 15 | 1 | 5 | 0 | 44 | 0 | 0 | 0 | NIL | NIL | NIL | 10 | 0 | 0 | 0 |
| Group C | 2552 | 3 | 12 | 28 | 1 | 7 | 1 | 111 | 0 | 1 | 2 | 0 | 0 | 0 | 14 | 0 | 0 | 0 |
| TOTAL | 6453 | 8 | 14 | 45 | 3 | 22 | 2 | 201 | 0 | 1 | 2 | 0 | 0 | 0 | 61 | 0 | 0 | 0 |

Note 1 : (I) VH stands for Visually Handicapped (persons suffering from blindness or low visions)

(ii) HH stands for Hearing Handicapped (persons suffering from hearing impairment)

(iii) OH stands for Orthopaedically Handicapped (persons suffering from locomotor disability or cerebral palsy)

(iv) There is no reservation for persons with disabilities in case of promotion to Group A and B posts. However, persons with disabilities can be promoted to such posts, provided the concerned post is identified suitable for persons with disabilities provided the concerned post is identified suitable for persons with disabilities.

Note 2 : Column No. 9 and 16 show the sum total appointments made in the Department by way of Direct Recruitment and Promotion

## ANNUAL STATEMENT SHOWING THE REPRESENTATION OF PERSONS WITH DISABILITIES AS 01.01.2013 AND NUMBER OF APPOINTMENTS MADE DURING THE PRECEDING CALENDAR YEAR 2012 IN RESPECT OF PUBLIC SECTOR UNDERTAKINGS

| Group | Number of Employees | | | | Direct Recruitment | | | | | | | By Promotion | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | No. of vacancies reserved | | | No. of appointment made | | | | No. of vacancies reserved | | | No. of appointment made | | | |
| | Total | VH | HH | OH | VH | HH | OH | Total | VH | HH | OH | VH | HH | OH | Total | VH | HH | OH |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) | (18) | (19) |
| Group A | 6869 | 7 | 3 | 44 | 2 | 2 | 9 | 454 | 1 | 0 | 1 | NIL | NIL | NIL | 524 | 0 | 0 | 0 |
| Group B | 6120 | 12 | 3 | 59 | 1 | 1 | 3 | 171 | 1 | 0 | 3 | NIL | NIL | NIL | 1455 | 0 | 0 | 0 |
| Group C | 9757 | 9 | 8 | 62 | 6 | 3 | 1 | 83 | 0 | 1 | 3 | 0 | 0 | 0 | 1292 | 0 | 0 | 0 |
| TOTAL | 22746 | 28 | 14 | 165 | 9 | 6 | 13 | 708 | 2 | 1 | 7 | 0 | 0 | 0 | 3271 | 0 | 0 | 0 |

Note 1 : (i) VH stands for Visually Handicapped (persons suffering from blindness or low visions)

(ii) HH stands for Hearing Handicapped (persons suffering from hearing impairment)

(iii) OH stands for Orthopaedically Handicapped (persons suffering from locomotor disability or cerebral palsy)

(iv) There is no reservation for persons with disabilities in case of promotion to Group A and B posts. However, persons with disabilities can be promoted to such posts, provided the concerned post is identified suitable for persons with disabilities provided the concerned post is identified suitable for persons with disabilities.

Note 2 : Column No. 9 and 16 show the sum total appointments made in the Department by way of Direct Recruitment and Promotion

# CHAPTER -12

# CITIZEN'S CHARTER

CHAPTER 12

# CITIZEN'S CHARTER

## I) OUR VISION

The vision of the Department of Atomic Energy is to empower India through technology, creation of more wealth and providing better quality of life to its citizen. This is to be achieved by making India energy independent, contributing to provision of sufficient, safe and nutritious food and better health care to our people through development and deployment of nuclear and radiation technologies and their applications.

## II) OUR CLIENTS

- User Ministries/Departments of Central Govt. and State Govt. dealing with energy, agriculture, food, health, education, oil and petroleum, industry, science and technology etc.
- Quasi Govt. Organisations, NGOs, industrial organizations, educational institutes.
- Electricity Boards, Hospitals, Research / Medical / Educational / Academic Institutions, agriculturists etc.

## III) OUR ACTIVITIES

The Department is engaged in the design, construction and operation of nuclear power / research reactors and the supporting nuclear fuel cycle technologies covering exploration, mining and processing of nuclear minerals, production of heavy water, nuclear fuel fabrication, fuel reprocessing and nuclear waste management. It is also developing advanced technologies which contribute to the national prosperity. The human resource developed and technical services being rendered by the Department have been greatly helping the Indian industry.

The Department is also developing better crop varieties, techniques for control/eradication of insects thus protecting the crops, radiation based post harvest technologies, radiation based techniques for diagnosis and therapy of disease particularly cancer, technologies for safe drinking water, better environment and robust industry.

## IV) MANDATE

The mandate of the Department, on which its programmes are based, covers :

- Increasing share of nuclear power through deployment of indigenous and other proven technologies, along with development of fast breeder reactors and thorium reactors with associated fuel cycle facilities ;
- Building and operation of research reactors for production of radioisotopes and carrying out radiation technology applications in the field of medicine, agriculture and industry;
- Developing advanced technologies such as accelerators, lasers, supercomputers, advanced materials and instrumentation, and encouraging transfer of technology to industry;

- Support to basic research in nuclear energy and related frontier areas of science; interaction with universities and academic institutions; Support to research and development projects having a bearing in DAE's programmes, and international cooperation in related advanced areas of research, and
- Contribution to national security.

## V) DAE PROGRAMMES RELATING TO THE NATIONAL COMMON MINIMUM PROGRAMME

### HIGH POTENTIAL DOMAINS FOR DEVELOPMENTAL APPLICATIONS

**AGRICULTURE**

Enhanced production of oilseeds and pulses

**EDUCATION, HEALTH**

Homi Bhabha National Institute (HBNI)
National Initiative on Undergraduate Science (NIUS)
Countrywide Services in Cancer through Telemedicine

**FOOD & NUTRITION SECURITY**

Radiation Processing of Food & Agro Products

**WATER RESOURCES**

Desalination in water scarcity areas along the sea coast

**ENERGY SECURITY**

Electricity supply in near and long term ensuring long term sustainable development
Rule of Nuclear Power as Primary Energy Source in the years to come.

## VI) WHOM TO CONTACT

### I. Public Grievance and complaints

**Shri A.P. Joshi,** Special Secretary,
Public Grievances Officer & Chief
Vigilance Officer,
Department of Atomic Energy,
Anushakti Bhavan, C.S.M. Marg,
Mumbai – 400 001.
Tel. No. 022-22029328
Email I.D.: as@dae.gov.in
apj@dae.gov.in

### II. Public Relations

**Shri S.K. Malhotra,**
Head, Public Awareness Division,
Department of Atomic Energy,
Anushakti Bhavan, C.S.M. Marg,
Mumbai – 400 001.

Tel.No. 022-22823144
Email I.D.: skm@dae.gov.in

**Government of India**
**Department of Atomic Energy**
**Anushakti Bhavan, C.S.M. Marg,**
**Mumbai - 400 001**

# NOTICE

WE, THE PUBLIC SERVANTS OF INDIA DO HEREBY SOLEMNLY PLEDGE THAT WE SHALL CONTINUOUSLY STRIVE TO BRING ABOUT INTEGRITY AND TRANSPARENCY IN ALL SPHERES OF OUR ACTIVITIES. WE ALSO PLEDGE THAT WE SHALL WORK UNSTINTINGLY FOR ERADICATION OF CORRUPTION IN ALL SPEHERES OF LIFE. WE SHALL REMAIN VIGILANT AND WORK TOWARDS THE GROWTH AND REPUTATION OF OUR ORGANISATION. THROUGH OUR COLLECTIVE EFFORTS, WE SHALL BRING PRIDE TO OUR ORGANISATIONS AND PROVIDE VALUE BASED SERVICE TO OUR CONTRYMEN. WE SHALL DO OUR DUTY CONSCIENTIOUSLY AND ACT WITHOUT FEAR OR FAVOUR.

THIS OFFICE IS THUS COMMITTEED TO MAINTAINING THE HIGHEST LEVEL OF ETHICS IN ITS WORKING TOWARDS ACHIEVING THE ABOVE OBJECTIVE, ALL ARE REQUESTED :

- NOT TO PAY BRIBE
- IF ANYBODY IN THIS DEPARTMENT OR ITS OFFICES ASKS FOR BRIBE : OR
- IF YOU HAVE ANY INFORMATION ON CORRUPTION: OR IF YOU ARE A VICTIM OF CORRUPTION IN ANY OF OUR OFFICES.

## YOU MAY COMPLAIN TO:

**Shri A.P. Joshi,** Special Secretary,
Public Grievances Officer & Chief Vigilance Officer,
Department of Atomic Energy,
Anushakti Bhavan, C.S.M. Marg,
Mumbai – 400 001.

## YOU CAN ALSO COMPLAIN TO:

THE CENTRAL VIGILANCE COMMISSION,
SATARKTA BHAWAN, BLOCK 'A',
GPO COMPLEX, INA,
NEW DELHI – 110 023.

# ANNEX-I

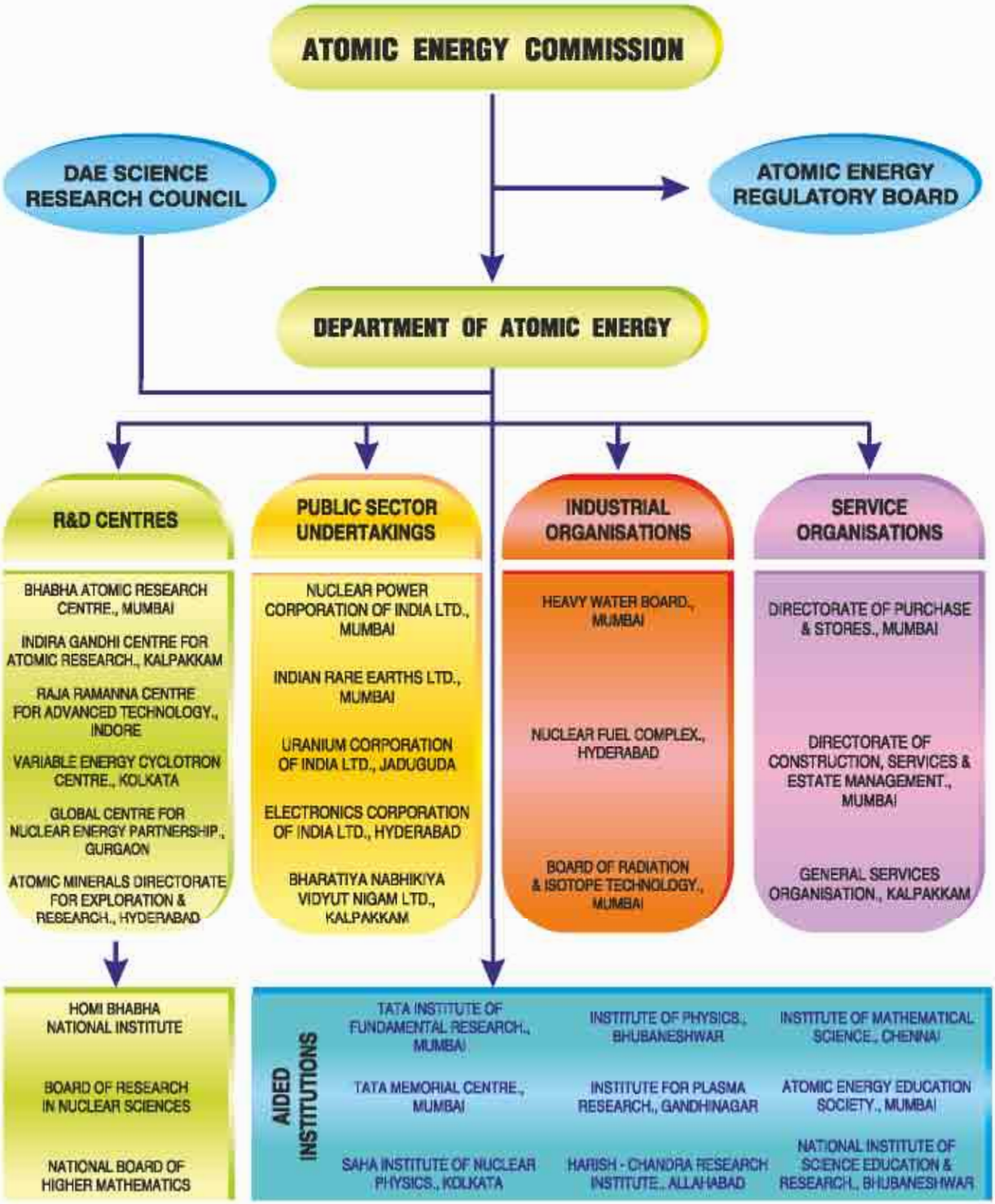
# THE ORGANISATION

## THE ORGANISATION

The Department of Atomic Energy (DAE), that came into being on August 3, 1954, has been engaged in the development of nuclear power technology, applications of radiation technologies in the fields of agriculture, medicine, industry, and basic research.

As integrated group of organizations, the Department comprises five Research Centres, three Industrial Organisations, five Public Sector Undertakings and three Service Organisations. It has under its aegis two Boards for promoting and funding extra-mural research in nuclear and allied fields, and mathematics, and a national institute (deemed university).

It also supports eight institutes of international repute engaged in research in basic sciences, astronomy, astrophysics, cancer research and education, etc., and a society that provides educational facilities to the children of DAE employees.


ATOMIC ENERGY COMMISSION
DAE SCIENCE RESEARCH COUNCIL
ATOMIC ENERGY REGULATORY BOARD
DEPARTMENT OF ATOMIC ENERGY
R&D CENTRES
PUBLIC SECTOR UNDERTAKINGS
INDUSTRIAL ORGANISATIONS
SERVICE ORGANISATIONS
BHABHA ATOMIC RESEARCH CENTRE., MUMBAI
INDIRA GANDHI CENTRE FOR ATOMIC RESEARCH., KALPAKKAM
RAJA RAMANNA CENTRE FOR ADVANCED TECHNOLOGY., INDORE
VARIABLE ENERGY CYCLOTRON CENTRE., KOLKATA
GLOBAL CENTRE FOR NUCLEAR ENERGY PARTNERSHIP., GURGAON
ATOMIC MINERALS DIRECTORATE FOR EXPLORATION & RESEARCH., HYDERABAD
NUCLEAR POWER CORPORATION OF INDIA LTD., MUMBAI
INDIAN RARE EARTHS LTD., MUMBAI
URANIUM CORPORATION OF INDIA LTD., JADUGUDA
ELECTRONICS CORPORATION OF INDIA LTD., HYDERABAD
BHARATIYA NABHIKIYA VIDYUT NIGAM LTD., KALPAKKAM
HEAVY WATER BOARD., MUMBAI
NUCLEAR FUEL COMPLEX., HYDERABAD
BOARD OF RADIATION & ISOTOPE TECHNOLOGY., MUMBAI
DIRECTORATE OF PURCHASE & STORES., MUMBAI
DIRECTORATE OF CONSTRUCTION, SERVICES & ESTATE MANAGEMENT., MUMBAI
GENERAL SERVICES ORGANISATION., KALPAKKAM
HOMI BHABHA NATIONAL INSTITUTE
BOARD OF RESEARCH IN NUCLEAR SCIENCES
NATIONAL BOARD OF HIGHER MATHEMATICS
AIDED INSTITUTIONS
TATA INSTITUTE OF FUNDAMENTAL RESEARCH., MUMBAI
TATA MEMORIAL CENTRE., MUMBAI
SAHA INSTITUTE OF NUCLEAR PHYSICS., KOLKATA
INSTITUTE OF PHYSICS., BHUBANESHWAR
INSTITUTE FOR PLASMA RESEARCH., GANDHINAGAR
HARISH - CHANDRA RESEARCH INSTITUTE., ALLAHABAD
INSTITUTE OF MATHEMATICAL SCIENCE., CHENNAI
ATOMIC ENERGY EDUCATION SOCIETY., MUMBAI
NATIONAL INSTITUTE OF SCIENCE EDUCATION & RESEARCH., BHUBANESHWAR

# Major Programmes and Sub-Programmes

| MP 1 | | MP 2 | | MP 3 | | MP 4 | | MP 5 | | MP 6 | | MP 7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.01 | PHWR | 2.01 | Fast Reactors | 3.01 | Advanced Heavy Water Reactor | 4.01 | Research Reactors | 5.01 | Mathematics & Computational Sciences | 6.01 | Human Resource Development | 7.01 | Infrastructure |
| 1.02 | LWR | 2.02 | Materials | 3.02 | Thorium Fuel Cycle | 4.02 | Isotope Processing | 5.02 | Physics | 6.02 | Sponsored Research | 7.02 | Housing |
| 1.03 | Front End Fuel Cycle | 2.03 | FBR-Front End Fuel Cycle | 3.03 | Other Thorium Reactor Systems | 4.03 | Agriculture | 5.03 | Chemistry | 6.03 | Prospective Research Fund | | |
| 1.04 | Back End Fuel Cycle | 2.04 | FBR-Back End Fuel Cycle | 3.04 | Accelerator Driven Sub-critical Systems | 4.04 | Food Processing | 5.04 | Biology | 6.04 | Homi Bhabha Centre for Science Education | | |
| 1.05 | Health, Safety & Environment | 2.05 | Repair and Inspection Technologies | 3.05 | Materials | 4.05 | Health | 5.05 | Cancer | 6.05 | Information Technology Application Development | | |
| 1.06 | PHWR | 2.06 | FBR-Health, Safety & Environment | 3.06 | Hydrogen Energy | 4.06 | Water | 5.06 | Synchrotrons & their Utilisation | | | | |
| | | | | 3.07 | Fusion Reactor | 4.07 | Industrial Applications | 5.07 | Cyclotrons & their Utilisation | | | | |
| | | | | | | 4.08 | Accelerators | 5.08 | Fusion & Other Plasma Technologies | | | | |
| | | | | | | 4.09 | Lasers | 5.09 | Material Science | | | | |
| | | | | | | 4.10 | Special Materials | 5.10 | Interdisciplinary Areas | | | | |
| | | | | | | 4.11 | Advanced Technologies | 5.11 | International Research Collaborations | | | | |
| | | | | | | 4.12 | Special Programmes | | | | | | |

**MAJOR PROGRAMMES**

**MP-1** : Nuclear Power Programme-Stage-1
**MP-2** : Nuclear Power Programme-Stage-2
**MP-3** : Nuclear Power Programme-Stage-3 and beyond
**MP-4** : Advanced Technologies and Radiation Technologies and their Applications
**4A** : Advanced Technologies and their Applications (Includes sub-programmes 4.01, 4.08 to 4.12)
**4B** : Radiation Technologies and their Applications (Includes sub programme 4.02 to 4.07)
**MP-5** : Basic Research
**MP-6** : Research Education Linkages
**MP-7** : Infrastructure & Housing

# ATOMIC ENERGY ESTABLISHMENTS IN INDIA

# ANNEX-II

## REPLY TO AUDIT OBSERVATION

**REPORT OF THE COMPTROLLER AND AUDITOR GENERAL OF INDIA FOR THE YEAR ENDED 31 MARCH 2012-NO.1 OF 2011-12 ON THE ACCOUNTS FOR THE YEAR 2010-11 OF THE UNION GOVERNMENT**

### The observations of the Audit are as follows:

***Para No. 4.2.1: Failure to obtain legislative approval for augmenting provision Augmentation of provision to object head 'Grants-in-aid'***

In accordance with instructions issued by the Ministry of Finance in May 2006, augmentation of provision by way of re-appropriation to the object head 'Grants-in-aid' to anybody or authority from the Consolidated Fund of India in all cases could only be made with the prior approval of Parliament.

Scrutiny of Appropriation Accounts revealed that Rs.0.30 Crore was augmented by the Department during the financial year 2010-11 under 'grants-in-aid' to a body/authority without obtaining the prior approval of the Parliament.

**Action Taken:**

There was overall saving of budgetary provision under the relevant subhead, the augmentation of Rs. 0.30 Crore under the detailed head 'Grants-in-aid" was considered subsumed in the overall savings which has the approval of Parliament.

# ANNEX-II

## Audit Report No 8 of 2012-13

### Electronics Corporation of India Limited

**I.1 Avoidable loss due to short/ excess payment of advance tax**

The Company incorrectly worked out the estimated profit resulting in excess/short payment of advance tax which resulted in loss of Rs.5.34 Crore

**Action Taken:**

Replies submitted to Audit

## Nuclear Power Corporation of India Limited

**1.2 Avoidable expenditure due to non-admittance of claim under defect liability period**

Failure to trip the generator resulted in damage to stator and non-admittance of claim under defect liability by supplier necessitating avoidable expenditure of Rs.31.08 Crore.

**Action Taken:**

Replies submitted to Audit

# ANNEX-II

**No. 13 of 2012-13 Union Government (Civil), Compliance Audit Observations,**

**Avoidable expenditure of Rs. 3.32 Crore**

Failure of the Directorate of Purchase and Stores under the Department of Atomic Energy in adhering to the purchase procedure and consequent delay in finalising a purchase proposal within the validity period resulted in avoidable expenditure of Rs. 3.32 Crores.

**Action Taken:**

Replies submitted to Audit

## ANNUAL STATEMENT SHOWING THE REPRESENTATION OF SCs, STs AND OBCs AS 01.01.2013 AND NUMBER OF APPOINTMENTS MADE DURING THE PRECEDING CALENDAR YEAR 2012 IN RESPECT OF CONSTITUENT UNITS

| Groups | Representation of ST/ST/OBC | | | | (as on 01-01-2013) Number of appointments made during the calendar year 2012 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | By Direct Recruitment | | | | By Promotion | | | By Deputation | | |
| | Total Emp | SCs | STs | OBCs | Total | SCs | STs | OBCs | Total | SCs | STs | Total | SCs | STs |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) |
| Group A | 7548 | 539 | 104 | 516 | 267 | 9 | 2 | 41 | 461 | 59 | 6 | 12 | 5 | 0 |
| Group B | 10458 | 1880 | 571 | 1605 | 336 | 51 | 8 | 140 | 565 | 128 | 16 | 12 | 2 | 0 |
| Group C | 11458 | 2441 | 1274 | 2511 | 440 | 65 | 28 | 187 | 240 | 59 | 32 | 9 | 0 | 1 |
| TOTAL | 29464 | 4860 | 1949 | 4632 | 1043 | 125 | 38 | 368 | 1266 | 246 | 54 | 33 | 7 | 1 |

## ANNUAL STATEMENT SHOWING THE REPRESENTATION OF SCs, STs AND OBCs AS 01.01.2013 AND NUMBER OF APPOINTMENTS MADEDURING THE PRECEDING CALENDAR YEAR 2012 IN RESPECT OF AIDED INSTITUTIONS

| Groups | Representation of ST/ST/OBC | | | | (as on 01-01-2013) Number of appointments made during the calendar year 2012 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | By Direct Recruitment | | | | By Promotion | | | By Deputation | | |
| | Total Emp | SCs | STs | OBCs | Total | SCs | STs | OBCs | Total | SCs | STs | Total | SCs | STs |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) |
| Group A | 1103 | 33 | 6 | 60 | 46 | 0 | 0 | 12 | 37 | 1 | 1 | 3 | 0 | 0 |
| Group B | 2798 | 369 | 75 | 318 | 44 | 9 | 0 | 13 | 10 | 0 | 0 | 0 | 0 | 0 |
| Group C | 2552 | 735 | 119 | 330 | 111 | 29 | 13 | 11 | 14 | 1 | 0 | 0 | 0 | 0 |
| TOTAL | 6453 | 1137 | 200 | 708 | 201 | 38 | 13 | 36 | 61 | 2 | 1 | 3 | 0 | 0 |

## ANNUAL STATEMENT SHOWING THE REPRESENTATION OF SCs, STs AND OBCs AS 01.01.2013 AND NUMBER OF APPOINTMENTS MADE DURING THE PRECEDING CALENDAR YEAR 2012 IN RESPECT OF CONSTITUENT UNITS

| Groups | Representation of ST/ST/OBC | | | | (as on 01-01-2013) Number of appointments made during the calendar year 2012 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | By Direct Recruitment | | | | By Promotion | | | By Deputation | | |
| | Total Emp | SCs | STs | OBCs | Total | SCs | STs | OBCs | Total | SCs | STs | Total | SCs | STs |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) |
| Group A | 6869 | 706 | 183 | 752 | 454 | 65 | 9 | 115 | 524 | 65 | 10 | 5 | 1 | 0 |
| Group B | 6120 | 991 | 410 | 1283 | 171 | 22 | 9 | 61 | 1455 | 270 | 84 | 1 | 0 | 0 |
| Group C | 9757 | 1603 | 2344 | 1869 | 83 | 15 | 20 | 38 | 1292 | 244 | 89 | 1 | 0 | 0 |
| TOTAL | 22746 | 3300 | 2937 | 3904 | 708 | 102 | 38 | 214 | 3271 | 579 | 183 | 7 | 1 | 0 |

# ABBREVIATIONS

| | |
|---|---|
| DAE | Department of Atomic Energy |
| HWB | Heavy Water Board |
| HWP | Heavy Water Plant |
| TBP | Tri-n-butyl phosphate |
| D2EHPA | Di-2-ethyl hexyl phosphoric acid |
| NFC | Nuclear Fuel Complex |
| BWR | Boiling Water Reactor |
| PHWR | Pressurised Heavy Water Reactor |
| NTPF | Niobium Thermit Production Facility |
| IGCAR | Indira Gandhi Centre for Atomic Research |
| BHAVINI | Bharatiya Nabhikiya Vidyut Nigam Limited |
| FBTR | Fast Breeder Test Reactor |
| NSSS | nuclear steam supply system |
| AERB | Atomic Energy Regulatory Board |
| FRFCF | Fast Reactor Fuel Cycle Facility |
| AHWR | Advanced Heavy Water Reactor |
| KAMINI | Kalpakkam Mini Reactor |
| ECIL | Electronics Corporation of India Limited |
| NPR | National Population Register |
| SECC | socio-economic & caste census |
| SNAS | secure network access system |
| ITMA | integrated threat management appliance |
| VVPAT | Voter Verifiable Paper Audit Trail |
| SDR | Software Defined Radio |
| C&I | Control & Instrumentation |
| NPCIL | Nuclear Power Corporation of India Limited |
| BRIT | Board of Radiation and Isotope Technology |
| DLW | Doubly Labeled Water |
| PET | Positron Emission Tomography |
| CDW | charge density wave |
| IRSIS | Infrared Spectroscopic Imaging Survey |
| GMRT | Giant Metrewave Radio Telescope |
| LHC | Large Hadron Collider |
| IOP | Institute of Physics |
| HBNI | Homi Bhabha National Institute |
| NBHM | National Board for Higher Mathematics |
| HBCSE | Homi Bhabha Centre for Science Education |
| TIFR | Tata Institute of Fundamental Research |
| TMC | Tata Memorial Centre |
| SINP | Saha Institute of Nuclear Physics |
| IMSc | Institute of Mathematical Sciences |
| HCRI | Harish-Chandra Research Institute |
| IPR | Institute for Plasma Research |
| AEES | Atomic Energy Education Society |
| NISER | National Institute of Science Education and Research |
| NEC | North-Eastern Council |
| RCC | Regional Cancer Centre |
| NER | North-Eastern Region |
| SVD | Silicon Vertex Detector |
| CDW | charge density wave |
| DM | Dark Matter |
| INO | India based Neutrino Observatory |
| RPC | Resistive Plate Chamber |
| RIA | Rradioimmunoassay |
| IRMA | Immunoradiometric assay |
| UKAS | United Kingdom Accreditation Services |
| IAEA | International Atomic Energy Agency |
| RMC | Radiation Medicine Centre |
| ALARA | As Low as Reasonably Achievable |
| EPRs | Evolutionary Pressurised Water Reactors |
| CRZ | Coastal Regulation Zone |
| PCRD | Passive Catalytic Recombiner Device |
| HRTF | Hydrogen Recombiner Test Facility |
| ITFT | Integrated Test Facility Tarapur |
| RPV | Reactor Pressure Vessel |
| BARCIS | BARC Channel Inspection System |
| IERMON | Indian Environmental Radiation Monitoring Network |
| INPRO | Innovative Nuclear Reactors and Fuel Cycles |

Edited and Pulished by S. K. Malhotra, Head Public Awareness Division, DAE
and printed by him at M/s Sundaram Art Printing Press, Wadala, Mumbai.