

Annual Report

2011-12



Government of India
Department of Atomic Energy

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Late Dr. P.K. Iyengar

“The most important foot print that a civilization leaves on history is the technology that it generates and uses. This is the most reliable index of how well developed a society had been. Technology which determines the basic life style of man is perhaps the most essential component in determining the rate of progress of a society.”

(Source: “Technology - Can it be borrowed and sustained?” by Dr. P.K. Iyengar, former Chairman, Atomic Energy Commission and Secretary, DAE at Tagore Endowment Lecture, University of Kerala, Trivandrum, April 29 1987)

EXECUTIVE SUMMARY

The vision of the Department of Atomic Energy (DAE) is to empower India through technology, creation of more wealth and providing better quality of life to its citizens.

To achieve this vision, DAE is engaged in the design, construction and operation of nuclear power/research reactors and the associated nuclear fuel cycle technologies.

It is developing advanced technologies such as accelerators, lasers, supercomputers, advanced materials and instrumentation, and encouraging transfer of technology to industry which contribute 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 pursuing 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.

The human resource developed and technical services being rendered by the Department have been greatly helping the academic institutions and Indian industry.

The year 2011-12 was an epoch-making period that saw several achievements and impressive growth of the Department in all its programme domains as described below.

NUCLEAR POWER PROGRAMME : STAGE 1

PRESSURISED HEAVY WATER REACTORS

Nuclear Power Corporation of India Ltd.

(NPCIL), a public sector undertaking of DAE, is responsible for the 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 is under construction that comprises two light water reactors of 1000 MWe each at Kudankulam in Tamilnadu, and four PHWRs of 700 MWe each - two at Kakrapar in Gujarat and two at Rawatbhata in Rajasthan.

Power Generation

During the calendar year 2011, the power generation was the highest ever with 32,400 million units, that was 39% more than the power generated during the previous calendar year due to increased fuel availability, both indigenous and imported.

The overall weighted availability factor for operating reactors was 90% and capacity factor was 78% up to December 2011 in the financial year 2011-12. Ten reactor units of NPCIL recorded a continuous run of more than a year with Unit-3 of TAPS setting a record of 465 days of continuous run as on January 18, 2012.

Reactors under construction

Six reactors, two each at Kudankulam (2x1000 MWe LWRs), Kakrapar (2x700 MWe PHWRs), and Rawatbhata (2x700 MWe PHWRs) were under different stages of construction. The two reactors at Kudankulam achieved 95% physical progress and its Unit-1 reached an advanced stage of commissioning. Currently, no physical activities were possible on these project due to the ongoing protest there. All efforts are being made by the Government, DAE and NPCIL to resolve the stalemate.

Construction of four 700 MWe PHWRs - two each at Kakrapar and Rawatbhata, was launched. The construction of the 500 MWe PFBR at Kalpakkam by Bhartiya Nabhikiya Vidyut Nigam

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Kudankulam Nuclear Power Project-1&2

has attained more than 81% completion.

New Projects

NPCIL will be setting up two new Nuclear Power Projects that comprise two 1000 MWe light water reactors at Kudankulam, Chennai and two 1650 MWe light water reactors at Jaitapur, Maharashtra. For the Kudankulam Power Project (Unit 3 & 4), environmental clearance from the Ministry of Environment & Forests (MoEF) and Siting consent from AERB were received. For the Jaitapur Projects, clearances from MoEF and Coastal Regulation Zone (CRZ) were received.

New Sites

For the new Nuclear Power Plants, land

acquisition process and pre-project activities were in progress at the sites namely Gorakhpur (Haryana), Chutka (Madhya Pradesh), Kovvada (Andhra Pradesh), Chhaya Mithi Viridi (Gujarat) and Haripur (West Bengal). Pre-project activities will be initiated at Mahi Banswara (Rajasthan), Bhimpur (Madhya Pradesh) and Kaiga-5&6 (Karnataka).

NPCIL obtained approval on Terms-of-Reference from the Ministry of Environment and Forests (MoEF) for environmental impact assessment of the projects in Gujarat, Madhya Pradesh and Andhra Pradesh. Studies for environmental impact assessment of new projects, including preliminary pre-operational radiological survey, were largely completed for Haryana, Gujarat, Madhya Pradesh and Andhra Pradesh sites.

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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 constitutes 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 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.

During the financial year, all the Heavy Water Plants performed very well and production of heavy water exceeded the targets. Focus also remained on reducing the specific energy consumption.

The overall safety standards of the heavy water plants were better than similar chemical industries in the country.

During the report period, the Board supplied heavy water to all the operating pressurized heavy water reactors. Export orders were executed for supply of heavy water to South Korea and United States. Many research institutions in France, US and UK approached HWB, for supply of heavy water, for non-nuclear applications. HWB bagged one more export order of 11,000 kg high purity heavy water from Linde Electronics and Speciality Gases, USA for use as raw material in the manufacture of deuterated compounds. Another export order for

supply of 15,000 kg heavy water to KHNP, Republic of Korea for make up requirement for their 700 MWe PHWR was under finalization.

Small quantities of heavy water were also supplied to some Indian research institutions for applications in life sciences and other technological developments.

Energy conservation schemes implemented at HWP-Manuguru gave positive results. The plant also installed & commissioned Dry Ash Collection /Segregation and Storage for supply of fly ash to cement industries, and for other uses.

Heavy Water Cleanup Facility

To achieve reduction in internal dose to occupational workers of Nuclear Power Stations, setting up of a Technology Demonstration Plant at HWP (Kota) for Heavy Water clean up was in progress. This plant is based on the design & engineering developed by HWB.

Deuterium Exchange Test Facility

Work continued on Hydrogen-Water bi-thermal Deuterium Exchange Test Facility at Baroda. Platinum doped carbon aerogel and Teflon based wet proof catalyst coated on Dixon rings suitable for Hydrogen-Water exchange process was under development in collaboration with RRCAT.

Diversification Activities

HWB made major progress towards the development and demonstration of technological feasibility of various processes for products required at the Front End as well as Back End of the Nuclear Fuel Cycle. Also, to seize the emerging new opportunities, the Board developed production capabilities in various other areas such as specialty chemicals and stable isotopes.

Solvent Technology

For setting up Versatile Solvent Synthesis Pilot plant (VSPP) at HWP, Tuticorin, syntheses of three

EXECUTIVE SUMMARY

solvents were carried out and erection of industrial scale facility for VSPP was in progress.

Boron enrichment

HWB took up development of suitable technology for Boron enrichment for fabrication of control rods and neutron detectors in fast breeder reactors. Different production routes for elemental Boron were successfully demonstrated at Talcher and Manuguru. About 2/3rd requirement of BHAVINI was already supplied to BARC for conversion to boron carbide and pellatisation. HWB is now looking forward to export opportunities in this field.

Sodium Metal

HWB started collaborative work with National Metallurgical Laboratory, Jamshedpur, on the development of safe and efficient closed cell for production of Sodium metal.

Depleted Uranium

Design, engineering and setting up of facility to convert Uranyl Nitrate solution from reprocessing plants to depleted uranium oxide powder, was taken up by HWB.

Mineral Exploration and Mining

Atomic Minerals Directorate for Exploration and Research (AMD) accelerated its exploration activities during the field season 2010-11. This resulted in establishing over 9620 tonnes of additional reserves of uranium oxide in areas in Andhra Pradesh, Rajasthan, Meghalaya and Jharkhand. The country's uranium resources now stand updated to about 1,72,400 tonnes of uranium oxide.

Promising uranium anomalies were discovered in parts of Andhra Pradesh, Chhattisgarh, Rajasthan, and Tamilnadu. About 2,04,000 m of drilling was carried out to establish additional uranium resources.

Under the exploratory mining at Gogi, Yadgir district, Karnataka, the Uranium Corporation of India Ltd., carried out shaft sinking upto 212 metre on behalf of AMD.

AMD also carried out geochemical surveys (2765 sq km), ground geophysical investigations (112 sq km), and electro-magnetic, magnetic and gamma ray spectrometric surveys (78,600 km) for detailed investigations. Airborne survey and remote sensing was also carried out.

The Rare Metal and Rare Earth investigations yielded location of new occurrences of columbite-tantalite and beryl bearing pegmatites in areas in the states of Odisha and Rajasthan.

AMD continued its surveys and exploration activities along the coastal tracts of Gujarat, Andhra Pradesh, West Bengal, Odisha, Tamilnadu and Karnataka, and identified new potential heavy mineral zones. The heavy mineral resources of the country were updated to 942.58 metric tonnes.

In India, mining and processing of uranium ore is done by the Uranium Corporation of India Ltd. (UCIL). This corporation operates in Jharkhand state, 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).

During the year of report, UCIL came out with an excellent performance both in ore mining and processing. Steady production was maintained at Jaduguda mine, additional ore blocks were added to the mining limits of the mine at Bhatin, production capacities of Narwapahar and Turamdih mines were under augmentation, and the mines at Bagjata and Banduhurang attained full capacities. The mine at Mohuldih will be commissioned shortly.

UCIL's Ore Processing Plant at Jaduguda completed the third phase of its expansion, and the new processing plant at Turamdih achieved full capacity.

The construction work of the mine and the processing plant at Tummalapalle was approaching completion and production will start shortly.

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UCIL also undertook exploratory mining in Gogi (Karnataka) on behalf of AMD.

The works relating to capacity expansion of the IRE's plants at Chavara, Manvalakuruchi and OSCOM progressed. Project work on the Monazite Processing Plant at OSCOM was in full swing. The plant is likely to be commissioned shortly. During the report period, IRE also pursued its activities towards recovery of uranium from secondary sources.

Fuel Fabrication

During the report period, the Nuclear Fuel Complex (NFC) fabricated and supplied fuel bundles for the reactors operated by NPCIL. Production of PHWR fuel bundles, zirconium sponge, PHWR fuel tubes & niobium metal was also the highest ever achieved. At NFC, manufacturing of critical components for various

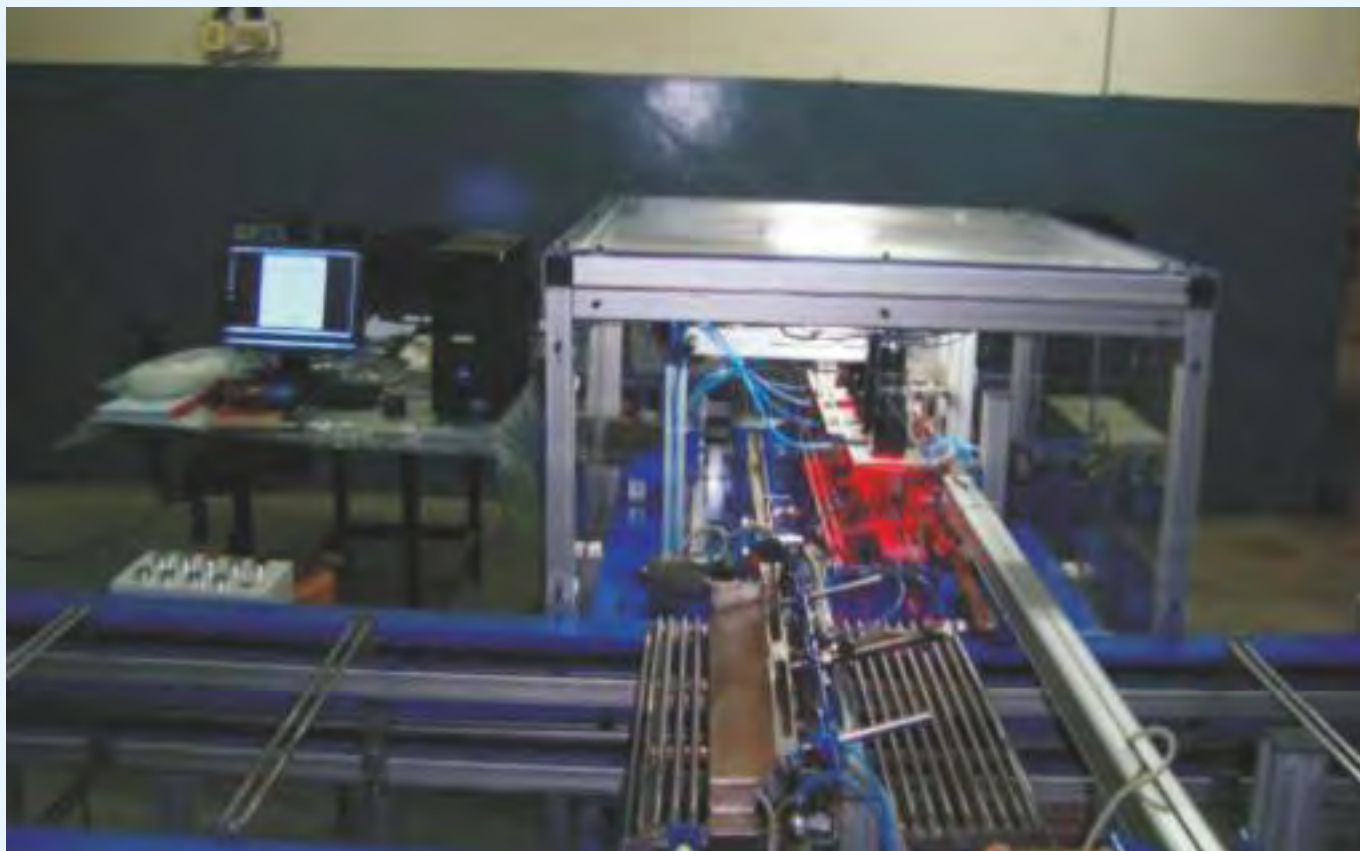
sub-assemblies for 500 MWe PFBR reached an advanced stage of completion. Special tubes for 700 MWe PHWRs, AHWR critical facility and TAPS 3 & 4 were also produced.

NFC took up bulk production of Incoloy-800 U-bend Steam Generator tubes for 700 MWe PHWRs. This is the first time that these tubes will be manufactured indigenously.

An automated PHWR fuel pellet visual inspection system was also developed successfully.

Atomic Energy Regulatory Board (AERB) issued licence for regular operation of Zirconium Complex, Pazhayakayal. This will strengthen the production of zirconium oxide and zirconium sponge.

Fuel for Research Reactors is fabricated at BARC. Production of natural uranium metal for research reactors, fuel fabrication and specific grade uranium metal powder for strategic use was continued.



Machine vision based automated pellet inspection system installed at NFC, Hyderabad

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BACK END FUEL CYCLE

Fuel Reprocessing and Waste Management

PREFRE II commenced production in April 2011 and the plant was in regular operation.

The Plutonium Plant at Trombay and Kalpakkam Reprocessing Plant (KARP) at Kalpakkam were in regular operation for recovery and purification of Plutonium and Uranium from spent fuels from the research reactors and PHWRs respectively. The throughput of KARP was highest ever.

Transfer of spent fuel from MAPS to Spent Fuel

Storage Facility (SFSF) at Kalpakkam was continued. Scheme was worked out to decontaminate and reuse the spent fuel transfer trays to reduce the active waste generation.

Waste Management Facilities at Trombay and Kalpakkam operated safely. Discharge of activity to the environment was kept well below the prescribed limits set by regulatory bodies.

The Waste Management Plant at Tarapur continued to provide service in management and safe disposal of radioactive waste materials in solid and liquid form obtained from BARC and NPCIL units at Tarapur.

Development studies for formulation of vitreous matrices for immobilization of futuristic high level waste containing thorium, aluminum & fluoride,



PREFRE-II Building

EXECUTIVE SUMMARY

were carried out.

An experimental facility was fabricated and erected by BARC at the Waste Immobilization Project to understand coolability of molten corium, and to devise effective strategy to terminate the progression of severe accident.

R&D SUPPORT TO POWER SECTOR

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

A facility was set up by BARC for evaluation of fracture toughness of irradiated pressure tubes. High temperature ballooning and deformation of PHWR fuel pins was studied and detailed

metallurgical evaluation of irradiated garter springs of the Unit-1 of Kakrapar Atomic Power Reactor was carried out.

A Boat Sampling system for cutting metal samples from core shroud of TAPS for metallurgical analysis and assessing mechanical properties of the core shroud was designed and fabricated.

An analytical methodology for precise quantification of various metallic impurities at trace levels in zirconium matrix was also developed.

HEALTH SAFETY & ENVIRONMENT

Following the events at Fukushima, Japan in March 2011, India had undertaken the stress test of its nuclear power reactors in operation and under construction to verify and validate their safety status. These tests conclusively brought out that the Indian reactors are safe against the extreme natural events. Additional safety measures, as recommended by the committees of NPCIL and AERB, were also in the process of implementation.

Environmental safety surveillance, radiation protection and industrial hygiene services were provided by BARC to all the DAE Units. Radiation dose to occupational workers was assessed. The radiation doses were well within the AERB prescribed limit. Technical support was provided to Uranium Corporation of India Ltd. and Indian Rare Earths Ltd. for environmental impact assessment, public hearing and AERB clearance of uranium mining project at Gogi, Karnataka and monazite processing plant at Chatrapur, Odisha.

Baseline environmental survey was carried out at BARC-Visakhapatnam, uranium mining project at Tummalpalle (AP) and Gogi (Karnataka).

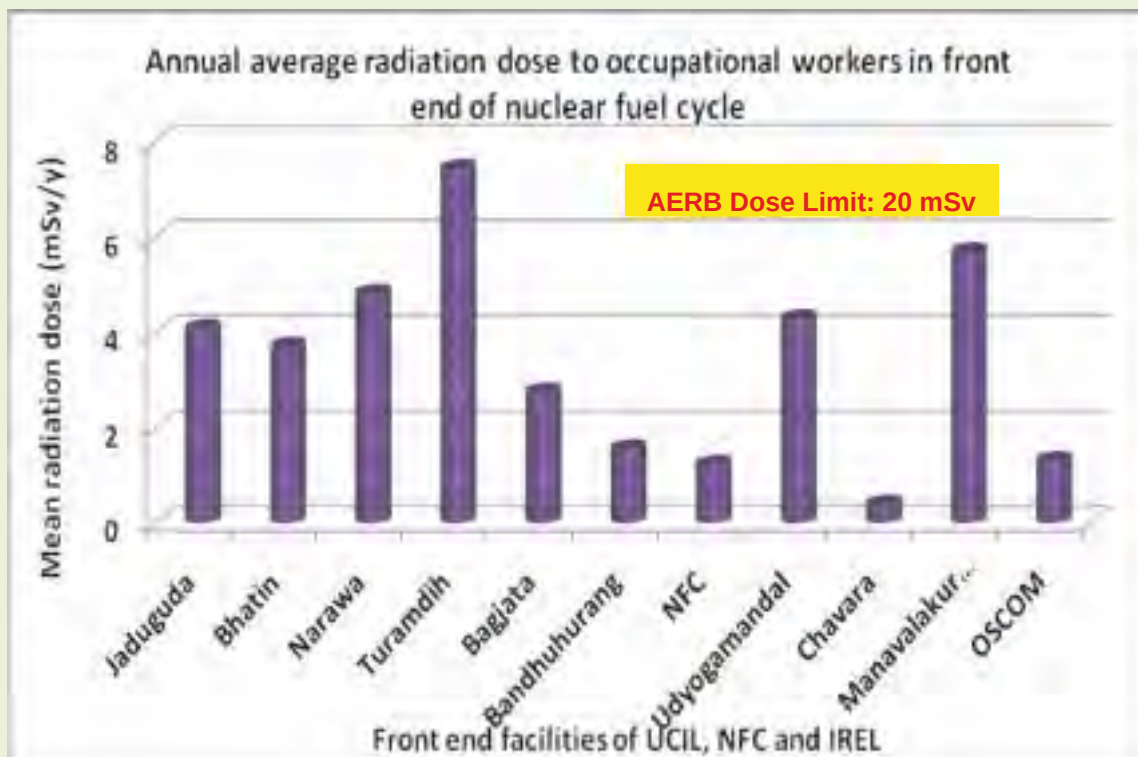
As a part of IERMON network, BARC installed 20 environmental radiation monitoring systems at different locations in India.

For personnel and environmental monitoring applications, a prototype smart 4-element Optically Stimulated Luminescence Dosimeter badge was designed and developed at Trombay to measure radiation doses in field conditions. A hand and foot beta-gamma contamination monitoring system was



*BARCIS-540 Drive Mechanism
developed at Trombay*

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also developed. This system uses large area thin plastic scintillator detectors.

Several natural molecules were screened at Trombay for their radio-protective effect using murine splenic lymphocytes.

In order to find out the effect of chronic natural background radiation at molecular level, BARC carried out transcriptome analysis on adult population living in coastal areas of Kerala.

NUCLEAR POWER PROGRAMME : STAGE-2

FAST BREEDER REACTORS

For the 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 manufacture of fuels for fast

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*Nuclear Island Connected Buildings
(NICB) of PFBR*

reactors, waste management and health and safety of the work force.

Prototype Fast Breeder Reactor

The construction of PFBR reached advanced stage. The civil structural works for the Nuclear Island Connected Building (NICB), that houses all the safety and safety related structures, and the buildings surrounding NICB, were completed.

Erection of major critical reactor components inside the reactor vault was completed earlier. This year, the Roof slab which forms as the top cover of reactor vault, was erected and welded with the main vessel. The construction of the Balance of Plant (BOP) was approaching completion. The construction of indoor gas insulated Switchyard was completed and commissioned successfully. The construction of Simulator Building (for training & licensing of operators) was also completed and commissioned. PFBR training simulator was ready for imparting training to plant operators.

Manufacture of major components such as Secondary Sodium Pumps, Steam Generators, and others, were completed and delivered at the site.

The project achieved an overall physical progress of more than 81%.

Fast Breeder Test Reactor

FBTR successfully completed two irradiation campaigns with maximum power of 20 MWt and peak linear heat rating of the Mark-I driver fuel. Turbo generator was rolled and synchronized to the grid, generating a power of 3.9 MWe.

The life extension studies indicated that FBTR can function for another ten power years.

FBR Fuels

Plutonium bearing fuels for the Fast Reactor Programme are supplied by BARC. For the first core of PFBR, manufacture of MOX fuel pins at BARC, made progress. Laser decontamination of MOX fuel pins for PFBR was successfully demonstrated and was in use. This decontamination system reduced the exposure to the operating personnel.

Fast Reactor Fuel Reprocessing

Reprocessing of the spent fuel from FBTR continued at CORAL facility, and the Demonstration Fast Reactor Reprocessing Plant (DFRP) at Kalpakkam reached an advanced stage of completion. A mobile robotic system for visual inspection of waste vault of DFRP was developed and its engineering scale pyro-processing facility was commissioned.

FBR Related Technologies

As a part of engineering development, a thermal shock test facility was commissioned by IGCAR. The augmented boron enrichment plant produced 91% enriched boron. A facility for studying the science of sodium fires was commissioned. Improved version of modified 9Cr-1Mo steel was developed for steam generator applications. A neutron flux monitoring system for PFBR was successfully developed at BARC. Fuel pin bird cages for transporting MOX fuel pins to Kalpakkam were fabricated as per IAEA safety standards.

Future FBRs

EXECUTIVE SUMMARY

At IGCAR, the reactor assembly components of future commercial fast breeder reactor were conceptualized and detailed analytical investigations were completed. Based on the analysis, optimization of the shapes of various components was carried out. This exercise paved the way for beginning of the detailed design of commercial fast breeder reactor, towards total indigenization for future FBRs.

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 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. Other advanced reactor systems are also under development at this Centre.

Advanced Heavy Water Reactor

The Advanced Heavy Water Reactor (AHWR) design involving compartmentalized inlet header and emergency core cooling system header, and connecting compartments of both in interleaving manner was evolved.

An experimental cluster having six AHWR type (Th-Low Enriched Uranium) MOX fuel pins was designed and fabricated for carrying out reactor physics experiments in AHWR-Critical Facility and for irradiation studies in Dhruva.

A number of AHWR type (Th-Pu)O₂ fuel pins containing varying Pu content were fabricated for experimental irradiation in DHRUVA and AHWR Critical Facility.



*(ThO₂-1%PuO₂)MOX cluster
for experimental irradiation*

As a part of development of fuel for AHWR-LEU 300, trials for fabrication of ThO₂UO₂ pellets with different UO₂ contents were carried out. Studies on reprocessing of spent fuel from AHWR were conducted at BARC. Critical Facility at Trombay was used for testing of nuclear detectors and irradiations of large volume samples for neutron activation analysis.

Other Reactor Systems

A Compact High Temperature Reactor (CHTR) uses graphite pellets containing a uniform distribution of TRISO coated particle fuels. For achieving a uniform distribution, an innovative scheme for pelletisation was developed at BARC. For CHTR critical facility, design of shielding system was worked out, and an alloy was developed for structural components of this reactor.

BARC carried out a conceptual design of the proposed High Flux Research Reactor. The Physics design of the reactor fuelled with low enriched uranium dispersion type silicide fuel, light water coolant & moderator and a square inner shell of heavy water reflector, was optimized.

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A Compact Prototype Electrolyser Plant was developed at Trombay for demonstration of a large scale hydrogen generation unit for hydrogen energy programme.

For future advanced reactors, research was carried out to generate an indigenous database on thermophysical properties of thorium based metallic alloy fuels.

Kalpakkam Mini Reactor (KAMINI)

At Kalpakkam, KAMINI reactor remained in regular operation for neutron radiography of pyro-devices, control rods, PFBR-MOX fuel pins and activation analysis of samples.

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 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.

Research Reactors

APSARA reactor at Trombay was de-commissioned to make way for its new and upgraded version that will have several advanced features and core capability to deliver 2MWt power. To enhance in-reactor performance of the modified APSARA reactor core, an innovative powder processing technique was developed for synthesis of uranium silicide. Design basis reports relating to the up-gradation of APSARA reactor to a 2 MW reactor were also prepared. These reports were undergoing safety review.

Research reactor Dhruva, a national facility for neutron beam research, continued to operate with a high level of safety

Accelerators

At VECC the Superconducting Cyclotron accelerated several light ion beams up to extraction radius, and the extraction system and the external beam line were installed. Computer control systems for different subsystem of the cyclotron were also upgraded.

The K-130 Variable Energy Cyclotron performed very well and delivered good quality beams of alpha and proton particles for nuclear physics, radio-chemistry and material science research.

During the period of report, at VECC, the experimental nuclear physics programmes were carried out extensively using the light ion beams from K-130 cyclotron, as well as using heavy ion beams from other accelerator facilities of India.

The energized feeder line for Radioactive Ion Beam Facility will serve as the primary accelerator for this Facility at the centre.

For the Superconducting Magnetic Energy Storage, a 12 Tesla Hybrid Magnet was developed.

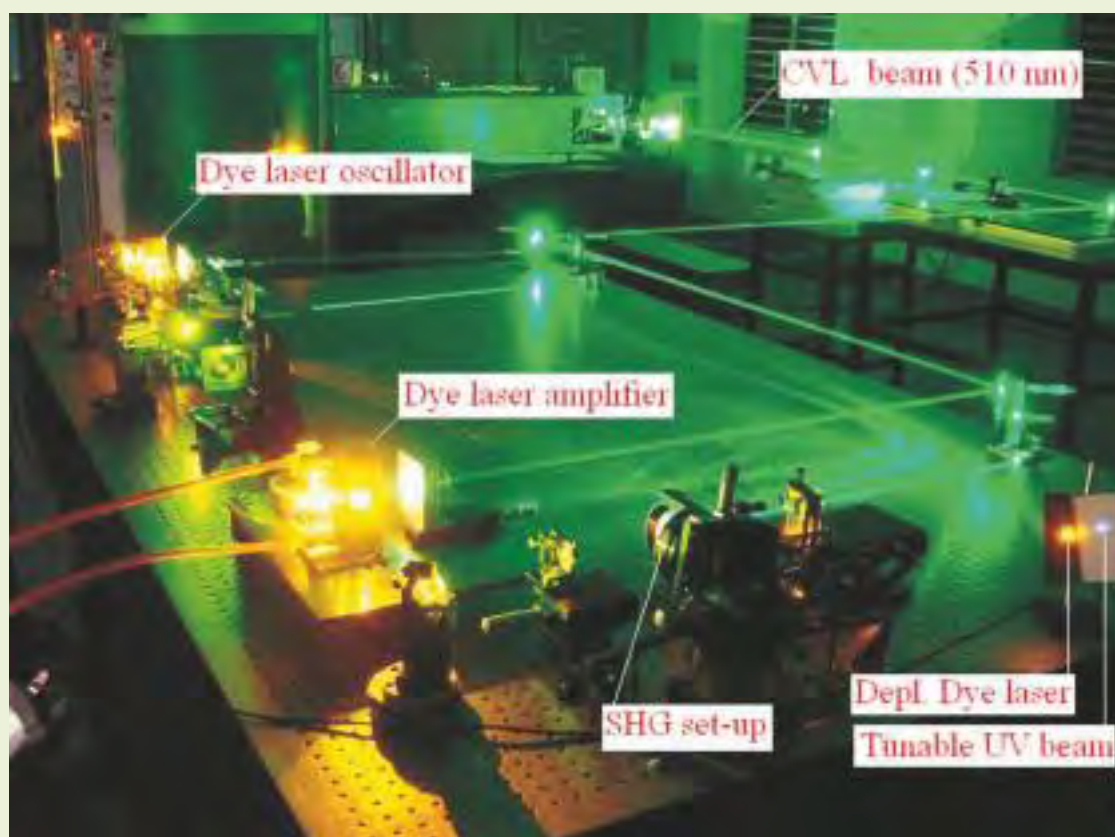
Indigenous development of high power solid state RF amplifiers of 50 kW power was carried out.

Laser Technology Development and Applications

During the period of report, RRCAT developed a number of lasers that find applications in the fields of medicine, industry and research. These included : A copper vapour laser pumped Dye Laser giving out tunable ultra-violet radiation; A 120 W continuous wave Fibre Laser with a very high optical-to-optical slope efficiency; A compact high power diode pumped solid state Green Laser; A narrow line-width Dye Laser using a novel coupled cavity configuration, and a water-cooled laser marker system for serial number marking on fuel elements. Other salient developments were : A 10 kW peak

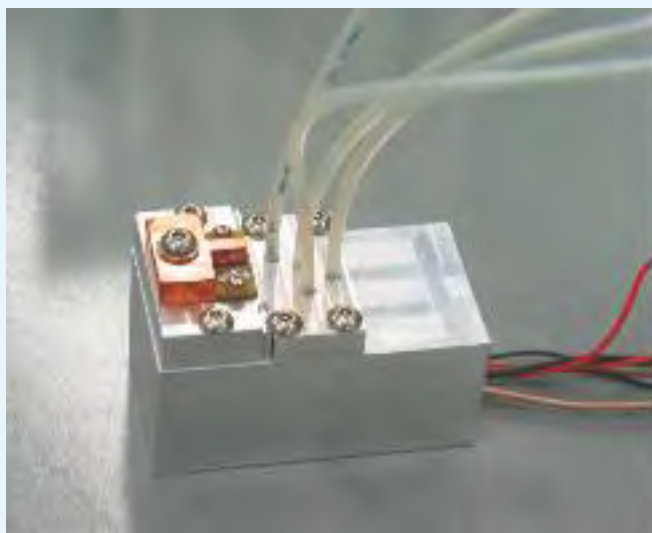


K-500 Superconducting Cyclotron with one of its external Beam Lines at VECC



Tunable UV generation from copper vapour laser pumped dye laser beam developed at RRCAT

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Uranium sensing chip bonded to fused silica

power pulsed industrial Nd:YAG Laser for drilling of holes, metal cutting and welding; A short pulse duration Nd:YAG Laser for surface cleaning applications, and a Copper-HyBrID laser with average laser power of 110 W.

At RRCAT, a number of laser based technologies were developed. Some of these were : Underwater laser cutting technique for nuclear applications; Polarization sensitive Optical Coherence Tomography setup for bio-imaging, and a Femtosecond pulse shaping setup. Applications of

laser technologies in biomedical field such as optical diagnosis of oral cancer and photodynamic treatment of infected wounds for faster re-epithelization and ordering of collagen in the wounds were notable successes of this Centre.

The technologies developed at RRCAT for industrial applications included 1kW average power long pulse Nd:YAG laser for cutting thick steel, TEA-CO₂ based paint stripping system for removal of enamel and epoxy based paints for surface cleaning applications, a micro-fluidic chip for uranium sensing applications, and machine vision system for PHWR fuel pellet inspection.

At BARC, an experimental setup for investigating pulse laser induced Photo-Physics Phenomena in thin films, multilayers and precision optics, was established. Good quality transparent single crystals of Lithium Gadolinium Borate and Sodium Yttrium Tungstate were also grown here.

Instrumentation

Indigenous and highly customized sensors for nuclear reactor applications were developed by BARC. For monitoring and protection of large rotating machines, a Machine Protection system was developed.

In a significant achievement towards



TEA CO₂ laser-based paint stripping system and (right) Paint stripping in progress

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development of diamond based alpha particle sensors for use in highly corrosive and radioactive liquid medium, a few detectors were fabricated indigenously using in-house developed highly pure electronic grade diamond thin films.

Three Application Specific Integrated Circuits (ASICs) - Anusparsh, Anudrishti and Anusuchak were designed, developed and tested successfully at Trombay.

The Electronics Corporation of India Limited (ECIL), is engaged in the design & development to commissioning of a wide variety of electronic equipment for atomic energy, defence, aerospace, security, information technology and e-governance sectors.

During the year 2011-12, ECIL completed Divyadrishti Project for Services. The company was a key partner in the implementation of National Population Register and Socio-Economic & Caste Census projects of the Government of India.

Supply of Control & Instrumentation (C&I) equipment and Operator Training Simulator to PFBR Project; Progressive proof assembly of 21M Telescope for MACE project and Integrated Security System for BARC, Ground Support Systems to BrahMos and Akash Projects for defence sector, e -Services to Government of Karnataka, and Supervisory Control and Data Acquisition Equipment to Oil and Steel industries were the significant achievements of ECIL in the strategic sectors.

ECIL introduced a number of new products that included indigenous routers, variety of crypto products and programmable logic controllers. The products developed during the year included Automatic Weather Station, S-band Feed System for Tracking Radar, Earth Station Antenna for Remote Sensing, Integrated IT solution for Border Check-post Automation covering needs of Road Transport and Commercial Tax Departments of State Governments.

Robotics

Hot cell Visual Metrics System Tele-Robot Operated Periscope was developed at Trombay, for



Non-cryogenic helium purification system developed by VECC

post-irradiation examination of irradiated hot components and structural materials. An all-terrain Robot was also designed and developed here.

Cryogenics

At BARC, performance of the indigenously designed and developed Helium Liquefier was improved to nearly its double the liquefaction rate and about 1,000 litres of Helium was liquefied.

A cryocooler producing a lowest temperature of 7K was indigenously designed and developed. It was installed in the Photophysics beamline at Indus-1 for Matrix Isolation Spectroscopy work. A cryogenic turbine impeller was designed and developed at BARC.

A very cost effective non-cryogenic helium purification system that works without any cryogen, was successfully designed and commissioned at VECC.

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. As a result of the consistent efforts of DAE, India is today one of the leading countries in the isotope technology.

Radioisotopes are produced in the research



*Hot cell Visual Metrics
System Tele-Robot
Operated Periscope
at Trombay*



*Helium liquefier
under commissioning
at Trombay*

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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

One of the important applications of atomic energy is the improvement of crop plants using ionizing radiation. Genetic improvement of crop plants is a continuing endeavour of BARC. Preservation of agro-products using Radiation is an important post-harvest technology that is now widely used on commercial scale. BARC, BRIT and RRCAT are the technology generators in this field.

During the report period, a confectionary large seed groundnut variety TG 47 (Bheema), developed at BARC, was released for commercial cultivation for early Kharif and Rabi, under irrigated conditions in all agro-climatic zones of Andhra Pradesh. Trombay Urd bean (Blackgram) variety TU-40 was identified for release in south zone by the Central Varietal Release Committee of Indian Council of

*Breeder seed plot of
Trombay groundnut variety
TG 38 near
Kolhapur, Maharashtra*



*Trombay Groundnut
variety TG 51*

EXECUTIVE SUMMARY

Agricultural Research (ICAR).

A Bruchid resistant Trombay wild Urd bean was registered with National Bureau of Plant Genetic Resources, New Delhi. Two high yielding Urd bean cultures and three high yielding Mung bean cultures made entry in the initial varietal trial of ICAR.

Large scale breeder seed production was undertaken at BARC, Gauribidanur and under contract farming at Kehal, Parbhani and Pattanakodoli, Kolhapur. About 466 quintals breeder seeds of six Trombay groundnut varieties were multiplied and distributed to different seed agencies and farmers for further foundation seed production.

Micropropagation of Banana was successfully carried out in the institutions collaborating with BARC. More than 26,000 plants were produced in

the Tissue Culture Lab at KVK Pondicherry and over 30,000 Banana plants were produced in AKRUTI-CARD Tissue Culture Lab at Anjangaon-Surji, Amaravati. Nisargruna biogas technology developed earlier at Trombay, was extended to treat the biological sludge generated in effluent treatment plants of textile industries.

Food Technology

Large scale studies were undertaken by BARC in collaboration with the Central Institute for Fisheries Education (CIFE), Versova, Mumbai. A joint IAEA-RCA project was also undertaken to develop irradiated foods for immuno-compromised patients.

At Trombay, various traditional Indian meat products selected for development of radappertized



Groundnut seeds irradiated with 8.5 MeV Linac for mutation breeding experiments

EXECUTIVE SUMMARY

(radiation sterilized) products, were found to be microbiologically sterile and had high sensory acceptability.

Studies conducted at Trombay on the effect of radiation processing on nutritional quality of vegetables demonstrated that the process does not affect their nutritional contents.

At RRCAT, fresh groundnuts were irradiated with electron beams from DC accelerator (700 keV) and Linear accelerator (8.5 MeV) for mutation breeding experiments in groundnuts. Soybean seeds were also irradiated with electron beams from the accelerator to study mutations in growth phases of soybean.

Nuclear Medicine and Healthcare

BARC continued to produce medically important isotopes such as I-131, Mo-99, Sm-153 and others, and processed 1,00,000 GBq of activity for supply to users.

The Medical Cyclotron at the Radiation Medicine Centre (RMC) of BARC was used to produce ^{18}F -radioisotope, and its conversion to the radioimaging compounds that are used in positron emission tomography (PET). These compounds were supplied to various hospitals in Mumbai and Pune.

About 1800 FDG PET scans and nearly 4000 other scans were carried out.

Thyroid hormone estimation by radioimmunoassay was routinely done on serum samples from patients at RMC, patients referred from BARC hospital and from other hospitals in Mumbai and outside. Routine radioiodine therapy for thyroid cancer cases, and diagnostic nuclear medicine operations using the various $^{99\text{m}}\text{Tc}$ -radiopharmaceuticals were continued.

Patients with neural crest tumours and bone metastases, were investigated and treated.

BRIT supplied more than 65,000 cold kits for formulation of Tc-99m radiopharmaceuticals and Mo-99 (500 Ci) for separation of Tc-99m. Nearly 15,000 consignments of various ready-to-use radiopharmaceuticals were also supplied. During

the report period, the supply of injectable products was considerably increased.

BRIT continued to produce and supply radioimmunoassay (RIA) and immune-radiometric assay (IRMA) kits. Two newly developed IRMA kits for human thyroid stimulating hormone and for human follicle stimulating hormone were approved for production and supply.

Regional Centres of BRIT in Delhi and Bangalore regularly supplied ready-to-use Tc-99m radiopharmaceuticals and cold kits in their regions; Regional Centre, BRIT in Dibrugarh continued to render RIA and IRMA diagnostic services for the benefit of North-Eastern region, and BRIT, in collaboration with BARC and VECC, successfully worked for the development of a new PET Bone imaging agent. A new infection imaging agent was also developed by BRIT.

The Regional Radiation Medicine Centre at Kolkata continued to provide nuclear diagnostics service and radionuclide therapy to patients. Imaging technologies for early detection of breast cancer were taken up at this centre. Jonaki improved its multiplex PCR based M. tuberculosis detection kit, and a real time PCR kit for detection of M. tuberculosis was in progress.

Alternative Applications of Heavy Water

In the field of medicine, alternative applications of heavy water are opening up new business opportunities. Keeping pace with these developments, the Heavy Water Board made significant progress. Oxygen-18 is one of the isotopes having application in medicine and biochemical research. At HWP (Tuticorin), a test facility for Oxygen-18 enrichment was set up.

In a collaboration between the Heavy Water Board and BRIT, developmental activities on deuterium labeled compounds and allied value added products, made progress. HWB also signed agreements with three Indian companies for development of deuterium labeled reagents, D-labeled APIs and NMR solvents and allied value added products. At HWP (Baroda), deuterated

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NMR (nuclear magnetic resonance) solvents were synthesized at laboratory scale.

Cancer Diagnostics & 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. TMC, that comprises the Tata Memorial Hospital (TMH) and Advanced Centre for Treatment, Research and Education in Cancer (ACTREC), continued to provide service in the diagnosis and treatment of cancer, and carryout cancer research. The Centre also enhanced training and education in the field of cancer.

At the Tata Memorial Hospital, during the report period, about 62,000 cases of conventional radiography, around 19,000 cancer surgeries and over 8500 cases of mammography were handled.

As a part of its societal initiative, TMC continued its outreach programmes such as 'TMC-Urban Outreach Programme' in the slums of Mumbai and the 'TMC-Rural Outreach Programme' in the districts of Ratnagiri and Sindhudurg, Maharashtra.

The TMH-Outreach Programme aims at reaching the slums and underserved areas of Mumbai, for early detection of oral, breast and uterine cervix cancers among women. Under the programme, women detected with cancers or pre-cancers were offered appropriate treatment free of cost. The project will cover 1,50,000 low socio-economic population residing in Mumbai.

As a part of Cancer Prevention Programme, TMC provided cancer screening services for common cancers and created a model for cancer control programmes.

Industrial Applications of Radioisotopes & Radiation

BRIT supplied 36 Industrial Irradiator sources containing 600 kCi of Cobalt-60 activity to the three Radiation Processing Plants in Delhi, Bangalore and Vadodara.

About 1000 Iridium Radiography Sources were

fabricated and supplied to various NDT users in the country. Two Gamma Chambers (GC-5000) and two Blood Irradiators were loaded with Cobalt-60 activity. Identification of Gamma Chamber pencils was carried out at SWRI San Antonio, USA. This unit was supplied to Uruguay in April 1972.

The Regional Centre of BRIT at Kota (RAPPCOF), continued to process Cobalt-60 for use in radiography and radioprocessing equipment. Two Cobalt Teletherapy Sources were prepared using indigenous pellets.

Radiation Processing

The ISOMED facility at Trombay continued to operate with an average load availability factor 99% and average utilization factor of 95%. A total of 4659 cubic metres of healthcare products were processed for terminal sterilization.

During the current financial year, about 2440 MT of spices and other products were processed at the Radiation Processing Plant at Vashi.

BRIT has been facilitating setting up of Radiation Processing Plants in private sector. Recently, a Radiation Processing Plant of Innova Agri BioPark, Malur was commissioned and a Radiation Processing Plant at Hindustan Agrotech,



*Radiation processing plant
at Hindustan Agrotech Rahuri,
Maharashtra*

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Rahuri, Maharashtra was inaugurated. Two more MoUs for setting up of Radiation Processing Plants were signed by BRIT with private parties.

Radiation Technology based Equipment & Services

BRIT exported Gamma Chamber-5000 to the National Institute for Physics & Nuclear Engineering, Bucharest, Romania for US\$ 140,000. The Board also strengthened its presence in the North-East India by supplying Low dose Irradiator at North Eastern Hill University (NEHU), Shillong for research purposes.

A new model of Roli radiography camera was added to the product range of BRIT. This is a remotely operated hybrid shield camera with a capacity of 65Ci of Iridium-192.

Gamma scanning of process columns was carried out by BRIT at the Hindustan Petroleum Corporation Ltd. (Vizag Refinery) for troubleshooting. Radiotracer study was also carried out in two oil wells of ONGC's Gandhar oil field.

At the Electron Beam Centre of BARC, the RF Linac was operated regularly at a beam energy of 10MeV and beam power of 3kW. For X-ray cargo scanning applications, a 3/6 MeV dual energy compact linear accelerator was designed.

The low energy heavy ion irradiation / implantation facility was in use for materials science and atomic physics research. A plasma ion source based Focused Ion Beam system was developed for micro-machining applications.

Isotope Hydrology & Water Desalination

An isotope hydrological investigation carried out by BARC resulted in discovering a huge groundwater sanctuary in Chinchona hill range in Maharashtra.

BARC's 6.3 million litres/day Nuclear Desalination Demonstration Plant at Kalpakkam, continued to produce potable water and water at a quality of about 5ppm of dissolved solids from sea water.

At Trombay Design of a Multiple Effect Distillation-Thermal Vapour Compression system (240cum/h) was cleared for fabrication. A Brackish Water Reverse Osmosis (BWRO) demonstration plant, integrated with a wind-based power unit, was commissioned. The first batch of indigenously developed Thin Film Composite Reverse Osmosis membranes was prepared and spirally rolled to commercial sizes.

BARC successfully developed a Water



*Brackish Water Reverse Osmosis unit at Trombay.
This unit is powered by wind energy*



Brackish Water Reverse Osmosis Plant at Chiplun, Maharashtra

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Purification System for removing uranium from the drinking water in villages of Punjab.

BASIC & APPLIED RESEARCH

Basic and applied research relevant to DAE's programme are carried out in the research centres of the department. The autonomous research institutes supported by the grant-in-aid and applied sciences.

Following are the notable developments in the fields of basic and applied research carried out during the report period, by these research institutes.

Mathematics & Computation

Profibus based communication system for nuclear plants was developed at Trombay which eliminated large amount of signal cabling, and direct connectivity to the field devices. Deterministic Fault Tolerant Communication Protocol board was developed at BARC that provided fault tolerant data communication.

TIFR remained involved in research in several areas of pure mathematics, and also in instructional and training programmes.

At SINP, successful application of the integrable perturbation was achieved for a wide range of nonlinear systems generating new nonlinear models. Noncommutative black holes and the behaviour of scalar fields in such backgrounds were investigated.

With the Cray Supercomputer at SINP, the lattice

QCD investigations got a boost. Several mass formulae were found for a local field with finite residue field.

In the field of mathematics, research work at HRI spanned the domains of algebraic geometry, arithmetic geometry, analytic and combinatorial number theory, group theory, harmonic analysis, mathematical physics and geometry.

The Institute of Mathematics continued with the projects : Mathematics Education : Mathematical Sciences without Walls; Interplay of Non-linearity with Quantum Effects and Curved Geometry, and Physical principles relevant to Nanoscale Devices and Biological Motors in the Brownian regime.

In the field of mathematics, NISER has academic expertise in harmonic analysis, operator theory, representations of geometries, theoretical computer science (cryptography), algebraic graph theory and probability theory. Recently 18 research papers were published by the School of Mathematical Sciences of NISER.

Physics

At BARC research work related to the study of spectroscopy of transition metal containing diatomic molecules, was carried out.

Experimental and theoretical work in nanophotonics resulted in several outcomes having important technological implications.

Neutron diffraction studies were performed on multiferroic core-shell nanoparticles of Bi-Fe-Mn-O. This work was found to have implications in designing magnetoelectric random access memory.

Raman spectroscopy was used for characterization of a variety of materials, particularly for non-destructive composition analyses of nuclear materials like ThO_2 - UO_2 mixture.

To carry out high pressure studies at very high temperatures (a few thousands K), a laser heated diamond cell facility employing a 100 W air cooled Ytterbium fibre was set up at Trombay.

A Charged Particle Detector Array was fabricated for BARC-TIFR Pelletron-LINAC Facility for investigations in fusion-fission



Profibus Master Card developed at BARC

EXECUTIVE SUMMARY



Laser heated diamond cell facility at Trombay

dynamics, nuclear structure, exotic nuclear clusters and related fields.

BARC's TACTIC gamma ray telescope at Mt. Abu was deployed for observation of a number of active galactic nuclei to monitor their flaring activity. The manufacturing activities related to the 21m diameter MACE gamma-ray telescope progressed well.

The Gulmarg Neutron Monitor continued recording of neutrons of cosmic-ray origin and also neutrons generated in the atmosphere by lightning discharges.

The notable studies carried out at RRCAT during the report period were the following : X-ray lasing in Argon capillary discharge plasma; Observation of Neutron generation in ultra-high intensity laser matter interaction, and Coherence measurement of high order harmonics from plasma plumes.

The studies conducted by TIFR included interplay between the diphoton events from Higgs decay and squark gluino production at the Large Hadron Collider (LHC) experiments and neutrino-neutrino interactions in a supernova and their effect on neutrino flavor conversions.

In the fields of Astronomy and Astrophysics, near Infrared Spectrometer and Imager for Large Aperture Indian Telescopes (TIRSPEC-1) reached completion stage. TIRSPEC-1 will be integrated with the 2-metre Himalayan Chandra Telescope at Hanle (Ladakh). The HAGAR array at Hanle remained in operation and pulsars, supernova remnants and Active Galactic Nuclei (AGNs) were

observed.

At the National Balloon Facility, Hyderabad, the Aethelometer payload of Space Physics Laboratory, Trivandrum along with Optical Particle Spectrometer & Ozonesonde payload of TIFR, were successfully launched, and in-situ measurements carried out. At the National Centre for Radio Astrophysics, Pune a modern, authenticated data archival and retrieval tool for GMRT data was developed.

The experimental activities at SINP were centred around the Tokamak, linear magnetized plasma machine (MaPLE), the Deep Space Plasma Propulsion experiment, Diamond Nanotechnology for Biological Applications and nonlinear dynamics experiments. Behaviour of runaway electrons in the Tokamak plasma was notable.

SINP carried out research in Astro Particle Physics that related to the experimental search for WIMP Dark Matter candidates; Work on various particle physics models of dark matter; Phase transitions in Neutron Star interiors; Neutrino mass and leptogenesis, and Black Hole spacetimes was carried out.

A theory developed at SINP within the effective Lagrangian framework, predicted that the dilepton production in proton-neutron collisions was three to four times larger than the corresponding rate in of the proton-proton collisions.

At HRI, the studies continued on string theory, quantum information and computation, condensed matter, and astrophysics. There was ongoing work on the role of geometric frustration on magnetic order and the Mott transition. A working scheme was set up to study superconductivity in disordered systems as well as trapped cold atomic systems. The other areas of research covered relativistic and high energy astrophysics, compact objects, reionization and the intergalactic medium, and inflationary cosmology.

The Institute of Physics continued to pursue research in String Theory, Cosmology and Particle Physics. Some of the topics in focus were Gauge/Gravity duality, anisotropic power law inflation, different aspects of relativistic heavy ion collisions, dual superconductor model of

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Hadronization. Research relating to nuclear structure and nuclear reactions was also pursued.

On the experimental side, the studies covered accelerator based material science, surface and interface physics and nano systems. Ion beams from Pelletron were used for modification and preparation of nanomaterials.

The research programme of NISER in physical sciences spanned high energy, condensed matter covering nano materials, magnetism and superconductivity, Bose-Einstein condensation, non-linear optics, and others.

Chemistry

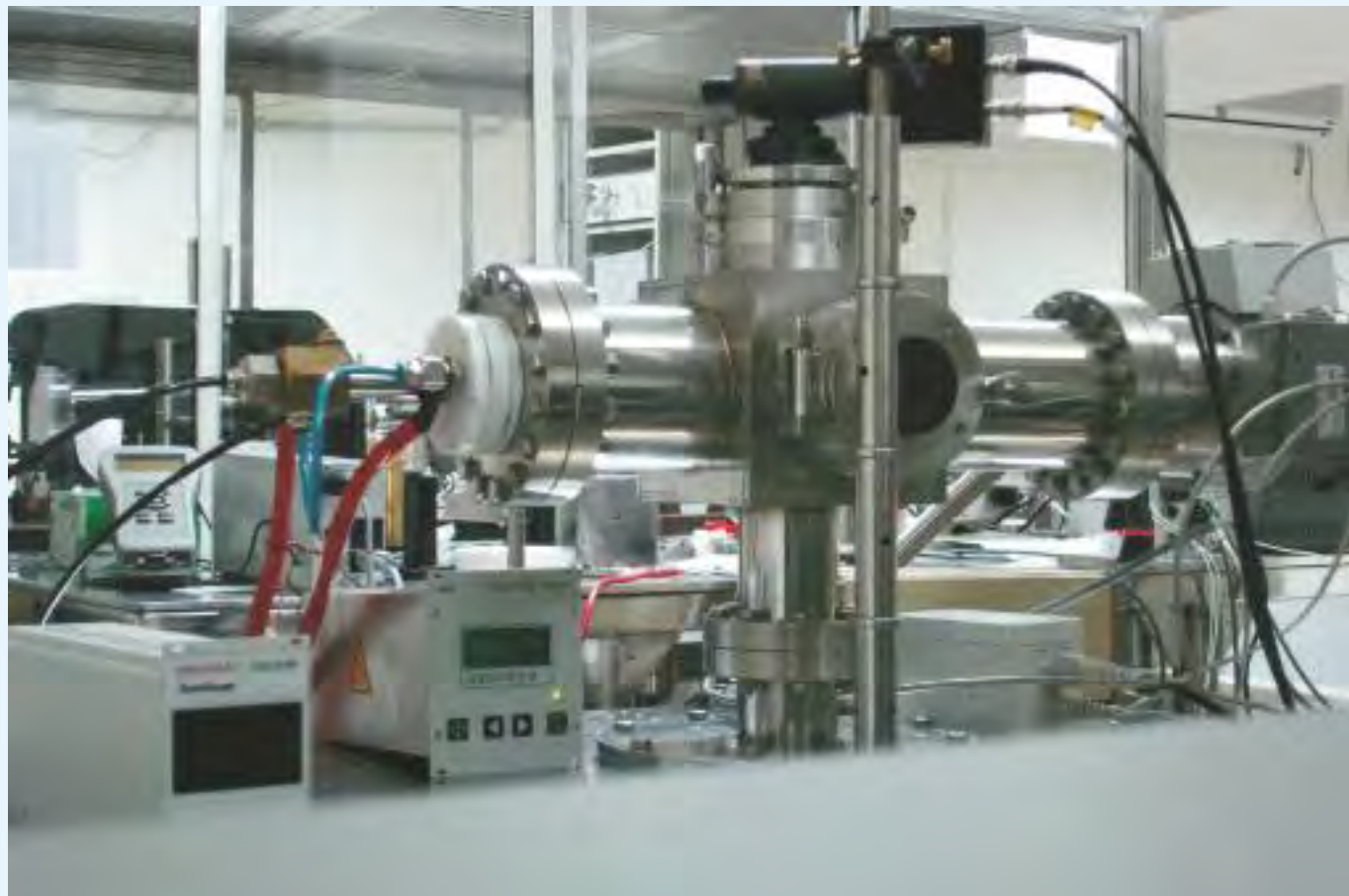
Synthesis of Magnesium silicate hollow spheres; development of an efficient method for the synthesis of a cationic resin for Pu(IV) ion



Diamond film based alpha particle detector developed at BARC

sequestration, and synthesis of a Cs^+ ion-selective calix-crown ether, were some of the notable achievements at BARC.

Isolation of a compound from the Indian spice,



Atomic beam fluorescence spectrometer developed at Trombay for high precision measurements of isotope shifts and hyperfine structure

EXECUTIVE SUMMARY

rampatri (false nutmeg) with good potency in inducing apoptosis to human breast cancer MCF-7 cells; Development of a novel solvent system for recovery of palladium from high level liquid waste solutions, and syntheses of non-lanthanide based host for doping lanthanide ions for making efficient luminescent materials were the other salient outcome of research at Trombay.

A diamond based alpha particle sensor was developed for use in corrosive and radioactive liquid medium, and a few detectors were fabricated.

Research was carried out to generate an indigenous database on thermophysical properties of thorium based metallic alloy fuels for future advanced reactors. Titanium metal based alloys were explored for their potential as hydrogen storage materials. S.S. wire gauze supported Pt-Pd catalyst was developed for hydrogen mitigation in a nuclear reactor. A work that can open up a new era for actinide speciation was the investigation on the interaction mechanism between carbon nanotubes and uranyl ions. A titanium alloy and a modified Incoloy-800 were evaluated for their corrosion property.

In the field of bio-chemistry, studies were conducted in BARC on the genes involved in biofilm development. In an effort to converge the biodegradation potential of granular biofilms aerobic microbial granules with self-integrated phototrophic components were developed.

At BARC, some of the other important developments included a gelatin based moist wound dressing capable of antimicrobial action; An accurate method for the quantification of fluorine in some important drugs, and a method for accurate determination of DNA content at microgram levels.

At TIFR, the studies on amyloid peptides provided a possible explanation for the mechanism of toxicity in Alzheimer's disease.

The work done at NISER generated research papers on studies relating to interaction of a nitrobenzoxadiazole derivative with metal ions, fluorescence behavior of Coumarin-153, and other topics.

Biology

BARC, in collaboration with Government of Kerala, conducted a hospital based programme at Kollam to screen newborns for congenital malformations. Also, a transcriptome analysis on adults was carried out to find the effect of chronic natural background radiation at molecular level. Several natural molecules were screened for their radioprotective effect using murine splenic lymphocytes.

At BARC, molecular mechanisms underlying tolerance to radiation and agricultural stresses in bacteria and plants were also explored.

The National Centre for Biological Sciences of TIFR continued to work on storage of memories in a pattern of connections between brain cells. The Institute achieved the identification of metabolites that are altered during the progress of Plasmodium berghei ANKA infection in murine model of malaria.

At SINP, small molecules with potentials as transcription inhibitors, encapsulation of therapeutically active plant flavonoids for drug delivery, understanding hematological disorders, and certain neurodegenerative diseases were the focus of research.

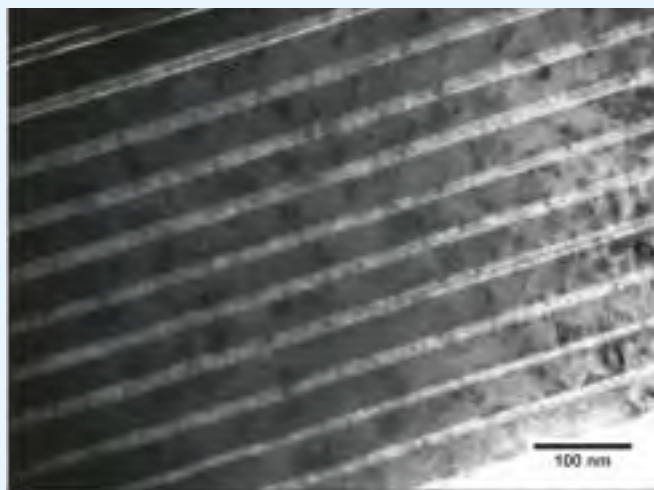
At NISER, the explorations in the field of Biological Sciences led to publication of research papers relating to binding of berberine with DNA G-quadruplex, and role of CART in spatial learning and memory, and other topics.

Materials Science

During the report period, the notable developments of BARC in materials science included Synthesis of oxide nano-powders; Initiation of indigenous production of Aluminium-Beryllium composites for inertial systems and satellite applications of ISRO; Development of dye-sensitized solar cells; A new process for preparation of optically transparent ceramics, and synthesis of nanocomposite microcapsules of silica and surfactants.

Study of phase stability and interfacial reactions

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Low magnification bright-field image showing cross-sectional view of multilayers of Yttria/Zirconia. Dark bands correspond to Zirconia while bright bands in between are Yttria layers

in Yttria/Zirconia systems, development of multifunctional smart nanofluid, demonstration of tunable magnetically polarisable soft matter system, molecular dynamics calculations towards thermo-physical properties of UO_2 , and recording of Raman spectrum of uranium, were some of the important basic research activities at IGCAR.

Properties of different nanostructures like graphene and nanowires were studied at TIFR. Relating to induced electron emission from nanorod arrays, enhancement of emission properties by tuning the geometry of the array was an interesting finding. The institute successfully designed and fabricated Photonic crystal micro-cavities with high-Q.

Cancer Research

The research at the Cancer Research Institute covered several new areas such as Stem cells in skin, solid and haematological malignancies; Complex vector systems to monitor chemo and radiation resistance, and imaging techniques for diagnosis and treatment. Monitoring of distribution of specific labelled molecules to evaluate their diagnostic and therapeutic potential; Characterization of somatic mutations in cancer were also the focus of research. The on-going molecular profiling investigations



Soft X-ray reflectivity beamline

moved forward in defining signatures for risk assessment and prognosis in various types of cancers.

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. During the report period, Indus-1 and Indus-2, remained in regular operation. All the five beamlines of Indus-1 were used by researchers. Operation of Indus-2 attained its design energy limit of 2.5 GeV, on December 6, 2011. The beam life time of Indus-2 was increased to 22 hours, reliability of the operation of Indus-2 was improved, and stored beam current was increased to 200 mA. It was utilized for extended X-ray Absorption Fine Structure Study of actinides adsorbed on mineral oxide surfaces to study the influence of colloids on migration of actinides from the deep geological repository to the nearby aquatic environment.

Fusion and Other Plasma Technologies

At the Institute for Plasma Research, Aditya Tokamak operated regularly and experiments related to breakdown and startup for generating necessary inputs for first plasma operation in Superconducting Steadystate Tokamak (SST-1) were carried out. Plasma production was conducted in Aditya with indigenously developed Ion-Cyclotron Resonance Heating system.

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SST-1 refurbishment activities progressed satisfactorily. Engineering validation of refurbished SST-1 will commence soon.

At IPR, experiments continued with the 'SYMPLE' (SYstem for Microwave - PLasma Experiments) for studying the interaction between plasma and high power microwave.

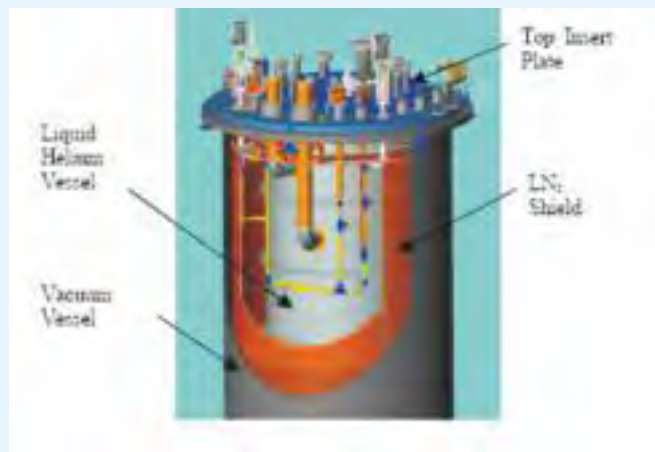
In the plasma theory and simulation, work continued at IPR on various aspects of electron magneto-hydrodynamics, wave breaking and phase mixing studies, particle acceleration studies, and others.

INTERNATIONAL RESEARCH COLLABORATIONS

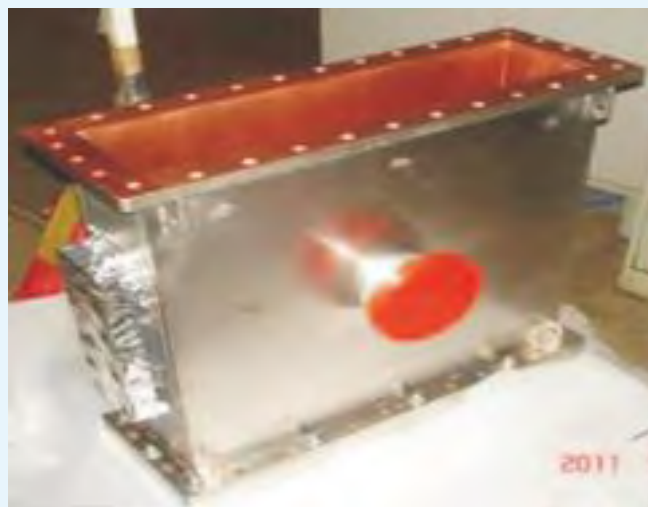
India is setting up the Global Centre for Nuclear Energy Partnership which will provide a forum for joint work with its international partners in development of proliferation resistant reactor technologies, nuclear security technologies, radiological safety and radiation technology application.

BARC has been participating in an IAEA initiative on Fuel Modeling at Extended Burn up (CRP FUMEX-III). As a part of this study fuel pins from pressurized water reactor and pressurized heavy water reactor were analyzed.

The International collaborations of IGCAR were



Schematic of Vertical Test Stand cryostat for testing superconducting RF cavities at 2K



Waveguide RF power coupler at 352.2 MHz for LINAC-4 project at CERN

enhanced through IAEA, by participating in the end-of-life-test programme performed on PHENIX reactor, and numerical simulation of pool thermal hydraulics experiments carried out in Japanese reactor MONJU.

Under the Indian Institution-Fermilab Collaboration, RRCAT successfully developed two 1.3 giga hertz (GHz) single cell Superconducting Radio Frequency (SCRF) cavities.

In collaboration with Fermilab, RRCAT designed and fabricated, a Vertical Test Stand Cryostat for testing SCRF cavities at 2K. Also, for LINAC-4 project at CERN, components of waveguide were developed here.

In the field of Quark Gluon Plasma, VECC's research collaboration continued in the STAR experiment at Brookhaven National Laboratory, USA. The Centre also continued its active participation in the ALICE experiment at CERN, Geneva and the Compressed Baryonic Matter (CBM) experiment at GSI, Germany. A dedicated centre for data monitoring and analysis for the ALICE experiment was setup at Kolkata to remotely monitor the detector components.

VECC fabricated Read-Out-Controller Boards for the in-beam test experiments at Juelich, Germany. These Boards or their later generation

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Read-Out-Controller Board

will be used in muon channels in the CBM experiments.

The international research programme of TIFR spanned a number of disciplines of science. These included studies under Belle collaboration relating to CP violation, rare B-meson decays and observation of new particle states, and Collection and analysis of quality data relating to CMS Experiment at the Large Hadron Collider (LHC) of CERN.

SINP was involved in experiments at the LHC at CERN. It remained engaged in the analysis of large amount of data from the ALICE experiment. The ALICE group of SINP constructed a part of the forward muon spectrometer which worked satisfactorily.

As a part of IMPECS -- a society that facilitates collaboration with Max Planck Institute of Germany, IMSc continued its participation in the collaborative projects in the theory of algorithms and complexity. It also remained engaged with the Indo-Austrian (DST Supported) project with Vienna University of Technology on Algorithms, and Indo-Tunisian joint project for theoretical investigation of Nano Science of Graphene.

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, one more procurement arrangement for Cryostat was signed during the report period. Till now a total of nine out of fifteen procurement arrangements were signed, and four Task Agreements were successfully completed. The sub-projects under various Task Agreements progressed well.

At Trombay, welding process and fixtures were developed for chromium-molybdenum steel for manufacture of Test Blanket Modules for ITER, and molybdenum alloy for the components of high temperature molten lead loop.

Indigenous reduced activation ferritic-martensitic steel for test blanket module to be tested in ITER was developed at IGCAR for achieving superior combination of ductile to brittle transition temperature and tensile and creep properties. At this centre, a welding technology was developed for welding reduced activation ferritic-martensitic steel plates of upto 10 mm thickness. The mechanical properties of the activated tungsten inert gas welded joints were found to be comparable to those of the weld joints made by electron beam welding process.

OTHER ACTIVITIES

Research Education Linkages

Interaction amongst the national laboratories and the university systems is supported by DAE mainly through grants-in-aid to institutes of national eminence, Funding of Extra-Mural Research, and DAE-UGC Consortium for Scientific Research. During the report period, the major activities relating to Research Education Linkages were the following.

Dhruva at Trombay 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.

Alumina Based Humidity Sensors were developed and tested by BARC in association with the Central Glass & Ceramic Research and

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*Humidity Sensors for leakage detection system
in main steam line for PHWRs*

Jadavpur University, Kolkata.

For validation of the nonlinear static pushover analysis for seismic assessment of reinforced concrete structures, tests were conducted at the Structural Engineering Research Centre, Chennai.

To strengthen the DAE-University linkages, practical training and project works for engineering and science students from different universities, were coordinated at Trombay. During the financial year 2011-12, about 475 students from all over India underwent practical training/project work in various divisions of BARC.

At RRCAT, the beamlines of the Synchrotron Radiation Sources Indus-1 and Indus-2, were offered to researchers from IITs, Universities and Research Institutes for experiments that ranged from investigations on lunar simulant samples for the Chandrayan project, development of microfluidic channels and high speed bearings related structures using the lithography beamline, and materials research involving thin films.

Several students working in the India-based Neutrino Observatory (INO) project took part in data-taking shifts at VECC. This provided an excellent environment for training students and

post-doctoral fellows, for work in the ALICE Control Room at CERN.

HUMAN RESOURCE DEVELOPMENT AND KNOWLEDGE MANAGEMENT

Homi Bhabha National Institute

The Homi Bhabha National Institute (HBNI) completed six years of its existence and it continued to grow steadily. Since 2006, the enrolments rose to nearly 2880, with Ph.D. enrolment alone being 1320.

During the period of report, HBNI further strengthened its linkages with premier research and academic institutes. MoUs were signed with the Jadavpur University and the Indian Statistical Institute. M.Tech and Ph.D programme requirements were completed by over 260 DAE officials and 105 scholars respectively. For the Post-Graduate Medical Programmes, the enrolment was close to 200. Two batches of a new scheme of DGFS-Ph.D students in engineering sciences with post-graduate qualification were inducted into the academic programmes of HBNI.

Training

The ongoing Orientation Course for the Engineering Graduates & Science Post-Graduates (OCES-2010) & DAE-Graduate Fellowship Scheme (DGFS-2010) courses, and placement of Trainee Scientific Officers of OCES-2010, were completed. To streamline the process due to the large number of applicants involved, an online screening test is proposed to be implemented from the current academic year.

Two year Post-Graduate Diploma in Nuclear Medicine for medical graduates, and one-year Diploma Course for science graduates were offered under HBNI.

QUEST, a continuing education programme of HBNI, offers advanced courses to the staff members of DAE units in Mumbai.

To strengthen the DAE-University linkages,

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short term training programmes were conducted for post-graduate students of different universities and institutions, in various divisions of BARC.

OCES programme of BARC-Training School at AMD Campus, Hyderabad was continued with geology (12) and geophysics (9) Trainee Scientific Officers. Under the AMD Studentship Programme, 104 M.Sc./M.Tech. Students of different Universities completed their project work till now.

At NPCIL, the human resource initiatives were directed towards achieving organizational goal of attracting, motivating and retaining the human resource. These measures covered developing strategic and incremental packages from time to time for effective Human Resource Management to meet the aspirations of the employees.

VECC provides an excellent training environment to new students and post-doctoral fellows, that prepares them to take up duties in the ALICE Control Room at CERN.

The Institute of Physics contributes towards quality human resource development by way of a one-year Pre-Doctoral Course followed by a Ph.D. programme. Interactions with academic institutions were also promoted during the report period.

Tata Memorial Hospital registered students for various postgraduate medical courses. Training programmes were conducted for doctors, nurses and technicians on continuing basis. Short term observership and summer training was provided to more than 350 doctors, nurses, technicians and graduate/post-graduate science students.

ACTREC offered clinical training in Radiation Biology, and short term training to science postgraduate students.

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

At IMSc, the students selected for the graduate and post-graduate levels, undergo course-work followed by a thesis work for PhD degrees. During the summer vacations, a few students were offered 6-week project work. Several students visited the institute for a semester working on mini-research projects. For working on various short and long

term projects, the Institute hosts a large number of visiting scientists from all over the world. The Institute members were also involved in joint projects. National and international conferences, workshops and instructional schools were regularly organized by IMSc. During the financial year more than 12 such events were organised.

The Administrative Training Institute (ATI) arranges training programmes for professional development of all levels and various cadres of officials working in DAE. Most of the programmes are arranged in-house. During the current financial year, ATI conducted 80 training programmes that included Management Development Programmes with the support of Dr MCR HRD Institute of AP and Administrative Training Institute, Mysore, Special Management Development programme for SC/ST officers, Programmes on accounts related subjects like Performance Audit, Cash and Accounts etc., and others.

With a view to build up an efficient team and match needs of specific operations, a large number of officers of DPS were imparted training.

For remote areas such as Shillong, Kota and Manuguru, programmes on computer applications were arranged at the door-step of these units.

Towards a better Work-life balance, a one day Workshop “Towards Healthy and Happy Life” for the female family members of employees, was organized by ATI.

To ensure overall development of the officials, apart from generic academic knowledge and skills, a variety of methodologies were used in these training programmes.

SPONSORED RESEARCH

Promotion of Extra-mural Research in Nuclear Science

The Board of Research in Nuclear Sciences (BRNS), an advisory body of DAE, provides financial assistance to universities, academic institutions and national laboratories for encouraging and promoting scientific research in

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areas of relevance to the mandate of DAE. It also plays a proactive role in tapping 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 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 current financial year till January 2011, over 200 new research projects were sanctioned. In addition, BRNS also entered into three new MoUs for collaborative research work with various academic institutes. Nine fellowships were awarded under the Raja Ramanna Fellowship Scheme (Senior Scientists Scheme) and Homi Bhabha Chair, 16 new DAE-SRC fellowships were awarded, and 4 new Prospective Research Fellowships (PRF) were granted. Eleven KSKRA fellows were selected, 20 M.Tech. and 34 Ph.D students were offered fellowships under DGFS. Financial support was extended for funding 275 seminars.

Promotion of Mathematics

The National Board for Higher Mathematics (NBHM) promotes education and research in higher mathematics in the country.

To mark the 125th birth anniversary of great Indian mathematician Ramanujam, the National Mathematics Year is being celebrated during Dec 22, 2011 to Dec 22, 2012. NBHM is providing support to these programmes.

During the current fiscal, NBHM continued its efforts of promotion of mathematics in the country. This endeavour included award of scholarships to

undergraduate students to pursue studies at Masters and Ph.D. levels and fellowships were offered to teachers at universities to undertake Ph.D. studies. NBHM also supported the programme of providing supplementary training to undergraduate and postgraduate level students. It also extended financial support to research projects, collaborative research, travel grants for participation in workshops, conferences, and for organising conferences etc. Post-Doctoral Fellowships were awarded to 39 (including the ongoing ones) researchers for a period of 3 years.

NBHM, with the help of HBCSE, organises activities relating to Mathematics Olympiad for talented young students at the higher secondary level.

For promotion of mathematics, the other major activities of NBHM included conducting of Madhava Mathematical Competition for the undergraduate students; grant to 80 mathematics libraries in the country for purchase of books and journals in mathematics and grants to various mathematical centres engaged in activities of promoting higher mathematics.

During the report period, NBHM also provided support to 34 mathematicians to attend an International conference in Vancouver, Canada.

GRANTS-IN-AID

Grants to Aided Institutions

Several joint projects were undertaken by the research organizations of DAE and the Aided Institutions under its aegis.

The Department has following 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 DAE, during the financial year 2011-12, were as follows :

Tata Institute of Fundamental Research, Mumbai (510.38cr.); Tata Memorial Centre, Mumbai (277.56cr.); Saha Institute of Nuclear Physics,

EXECUTIVE SUMMARY

Kolkata (117.05cr.); Institute of Physics, Bhubaneswar (29.60cr.); Institute of Mathematical Sciences, Chennai (28cr.); Harish-Chandra Research Institute, Allahabad (25.80 cr.); Institute for Plasma Research, Gandhinagar (564.48 cr.); Atomic Energy Education Society, Mumbai (54 cr.), and National Institute of Science Education and Research, Bhubaneswar (210 cr.).

Grants to Cancer Hospitals

DAE has been releasing grant to Dr. B Barooah Cancer Institute (BBCI), Guwahati through a Tripartite Agreement signed among DAE, the North-Eastern Council 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 2011-12 was approximately Rs.24.49 crore for revitalization of the BBCI which had commenced during the year 2004-05.

The Department also extended financial assistance to Cancer Hospitals located in other parts of the country. The budget provision for the year 2011-12 for such partial financial assistance, has been to the tune of Rs.11 crore.

An increasing need was also 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. For this purpose, an Apex Committee was formed that has met 19 times so far and deliberated on indigenous development and manufacturing of the equipment related to radiation oncology such as Bhabhatron, Cobalt-60 Teletherapy, Low Energy Linear Accelerator, High Energy Linear Accelerator, Simulator development, Brachytherapy etc.

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, 24 medals were won including 9 gold, 9 silver, and 4 bronze medals besides the 2 honorary mention.

For School and College teachers, several Resource Generation Camps and Exposure Camps were organised by the Homi Bhabha Centre for Science Education, Mumbai. Academic support in experiments and theory is being provided for Asian Physics Olympiad (APhO) 2012.

TECHNOLOGY TRANSFER

During the report period, the technologies transferred by BARC to industries were : Vibro Thermal Disinfector, Dip-N-Drink Membrane Pouch, Quadrupole Mass spectrometer, and Digital Radiotherapy Simulator.

Technologies in the process for transfer were : On-line domestic water purifier based on ultrafiltration (UF) polysulfone membrane, Membrane Assisted Defluoridation Process for Safe Drinking Water, and UF Membrane Assisted Device for removal of Iron from contaminated water for drinking purposes,

Licenses for the technologies transferred earlier, were renewed for a period of five years as follows : Auto TLD Badge Reader, Impedance Cardio Vasograph and Cardiac Output Monitor, High resolution 8K MCA with USB interface, Production of dysprosium doped Calcium Sulphate Thermoluminescence Dosimetry Phosphor Powder, Production of CaSO₄: Dy Embedded Teflon Discs, TLD-Cards technologies, Fluoride Detection Kit for groundwater, On-Line domestic Water Purifier based on UF polysulfone membrane, and Medical Analyser Software.

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BARC renewed agreements with Ultra-Tech Laboratories (P) Ltd, Bhilai, and M/s Avanttec Laboratories (P) Ltd., Chennai for Personnel Monitoring Services of Radiation Workers using TLD Badges.

The IPR's Facilitation Center for Industrial Plasma Technology (FCIPT), besides executing its committed projects, signed new projects funded by government organisations, autonomous bodies and private sector companies.

COLLABORATIVE PROGRAMMES

During the year of report, six scientific collaborative MoUs were signed by BARC with various organisations.

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 framework, a structured programme called 'AKRUTI-KRUTIK-FORCE' was formulated and 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. To promote rural techno-preneurs, BARC signed two Akruti Tech-Pack Agreements. This makes a total ten Rural Technopreneurs with two women entrepreneurs.

BARC-Vizag Akruti - SEZ : Akruti Advisory Committee was formed and technology equipment such as foldable solar dryers, direct water purifiers etc., and workshop tools and machines, were procured. Under the infrastructure development work at BARCIT, five Technology Incubation Cells were made ready for operations in phase-1.

INTELLECTUAL PROPERTY RIGHTS

DAE-IPR Cell of DAE works as a nodal agency for all the 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 2011, six regular DAE-IPR Cell meetings were held during which 18 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 9 new patent applications. Patents filed include five in India, two in USA, one each in European Union and Canada. Eight of the previously filed patents were granted to the Department -- all of them are patents granted in foreign countries.

IGCAR licensed a technology titled "A penetration enhancing flux formulation for Tungsten Inert Gas welding of austenetic stainless steel and its application". This was the first time that IGCAR licensed its patented technology.

During the year, 37 patent applications were referred to the Department by the 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.

IP Awareness Programmes were conducted for the trainees and officers of BARC, NPCIL etc.

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.

During the current financial year, the company registered Profit After Tax (provisional) of Rs. 1497 crore up to December 31, 2011. For the year 2010-11, the Profit After Tax was Rs. 1376 crore. The improvement in profit is mainly due to better

EXECUTIVE SUMMARY

capacity utilization of the stations under IAEA safeguards for which imported fuel is available in the required quantity. NPCIL bonds continued to be rated at AAA (Highest Safety) by CRISIL and CARE.

Uranium Corporation of India Ltd.

For the year 2010-11, the total income of the Company increased to Rs.750.26 crore as against Rs.545.38 crore with a 37.56% rise. The profit after tax stood at Rs.101.53 crore against Rs.46.26 crore registering an increase of 119%.

Indian Rare Earths Ltd.

For the financial year 2010-11, the Sales Turnover of IRE was Rs. 388.50 crore and Profit Before Tax (PBT) was Rs.52.44 crore. As against this, for the financial year 2009-10 the Sales Turnover and PBT were Rs. 337.10 crore and Rs.47.81 crore respectively. During the year 2010-11, IRE had earned foreign exchange of Rs. 91.76

crore. It paid 20% dividend on the paid-up capital, amounting to Rs.17.27 crore.

The sales turnover of the company for the financial year 2011-12 is expected to be around Rs. 428 crore.

Electronics Corporation of India Ltd.

During the financial year 2011-12, ECIL achieved a production of Rs 769 crore and a sales (net) of Rs.747 crore upto December 2011 as compared to Rs.846 crore and Rs.774 crore respectively, for the corresponding period during the year 2010-11.

The order book position of ECIL has improved with orders from defence and security segments.

INTERNATIONAL RELATIONS

India has bilateral agreements with a number of countries. For co-operation in the field of peaceful uses of atomic energy, India signed bilateral



Dr. Srikumar Banerjee, Chairman, AEC and other senior officers of DAE in a meeting at DAE with Mr. Gary Locke, Secretary of Commerce, USA along with the US delegation

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agreements with the Government of Republic of Kazakhstan and the Government of Republic of Korea.

India has been a designated member of the Board of Governors of the International Atomic Energy Agency (IAEA) since its inception, and has been taking active part in policy management and programmes of the Agency.

India continued to offer training facilities, fellowships, and scientific visits etc. to various countries, and made available the service of its scientists as experts to various countries under the IAEA Technical Co-operation scheme in the field of peaceful uses of atomic energy.

India is an Observer in the European Organization for Nuclear Research (CERN) and continued to participate in collaborative work in the framework of the developments of computing and computational grid technology for Large Hadron Collider Project (LHC).

India signed a Memorandum of Understanding with the State Atomic Energy Corporation “Rosatom” of Russia, on Cooperation with the Global Centre for Nuclear Energy Partnership (GCNEP) of India.

India also signed a tripartite agreement with the International Atomic Energy Agency (IAEA) and Namibia, for donation of one Bhabhatron Teletherapy unit to Namibia.

The “Civil Liability for Nuclear Damage Act-2010” came into force on 11 November, 2011. A set of rules titled “Civil Liability for Nuclear Damage Rules, 2011” were also notified on 11 November, 2011.

IAEA's OSART programme assists member states in enhancing the operational safety of specific nuclear plants and to promote the continuous development of operational safety within all the member states by dissemination of information on IAEA safety standards and good international practices. During the year 2011, India offered one of its nuclear power plants for OSART review.

CRISIS MANAGEMENT

The Crisis Management Group (CMG) of DAE

coordinates the Department's response to a radiation emergency in the public domain.

Because of the inherent design features and deployment of multiple safety systems, the possibility of any accident in a nuclear facility or during transport is highly remote. However, to handle any unforeseen situation, formal Emergency Response Systems 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 of the DAE in the field of radiation measurement and protection and medical treatment of radiation injuries.

CMG formally meets once in six months to review the crisis management plan at different facilities, to discuss on issues related to radiological incidence occurred, if any, in the country, and provide necessary guidance on matters related to radiological safety in the public domain to avoid recurrence of such incidence.

To ensure that the emergency plans are in high state of readiness, major nuclear facilities such as nuclear power stations and hydrogen sulphide based heavy water plants, periodically carry out a variety of emergency exercises. During the year 2011, the various exercises conducted were:

Communication Exercises - 306 nos; Fire Emergency Exercises - 78 nos; Plant Emergency Exercises - 64 nos; Site Emergency Exercises - 8 nos, and Off-Site Emergency Exercises - 2 nos.

The Off Site Emergency Exercises were conducted in public domain in the vicinity of nuclear power stations at Kaiga in Karnataka and 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 the six Nuclear Power Plant sites.

The Emergency Response System of DAE remained available to respond to a request from any public official in the event of the reported presence

EXECUTIVE SUMMARY

or suspected presence of radioactive material.

The Emergency Communications Rooms in Mumbai, are manned on a round-the-clock-basis throughout the year. These Rooms have multiple modes of communication and remain in constant contact with various nuclear facilities in the country, as well as with IAEA.

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

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 the vigilance administration rests with the Chief Vigilance Officer (CVO) of the Department. A senior officer in each unit has been designated as Vigilance

Officer for vigilance functions. In public sector undertakings, full time Chief Vigilance Officers co-ordinate the vigilance activities.

During the report period, the vigilance functions included timely transmission of various vigilance returns to the Central Bureau of Investigation, Department of Personnel & Training and Central Vigilance Commission, issuance of prosecution sanctions, processing of vigilance and disciplinary cases, monitoring the progress of inquiry proceedings, investigation of complaints etc.

As advised by CVC, the corruption prone areas were continuously identified and corrective measures were taken timely.

A special icon on vigilance was made available on the DAE website incorporating the details of Vigilance Officers of Constituent Units and CVOs of Public Sector Undertakings/Aided Institutions of the Department.

As per the directives of CVC, Vigilance Awareness Week, 2011 was observed from 31 October to 5 November, 2011 in the Department as well as its Constituent Units, Public Sector Undertakings and Aided Institutions.

Uploading of Immovable Property Returns in respect of Group "A" officers of the Department in the official website of the Department continued.

PUBLIC AWARENESS

DAE and its organisations continued with their efforts towards creating mass awareness about the various programmes of the Department, and their societal impact. DAE organised/participated in exhibitions, seminars, workshops and essays and quiz contests, and brought out information literature on various aspects of nuclear energy. As a part of the Founder's Day celebrations, DAE organised the 22nd All India Essay Contest on Nuclear Science & Technology in October 2010. Besides the above activities, DAE also took part in a number of conferences and seminars.

NPCIL carried out various communication activities for dissemination of accurate and authentic information on nuclear power to different



Participants of the 23rd DAE All India Essay Contest with the Officials of the Public Awareness Division, DAE



Visitors at the DAE Pavilion during the Indian Science Congress, Bhubneshwar, Odisha

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Inauguration of the “Hall of Nuclear Power Nehru Science Centre, Mumbai. Kumari Selja, Union Minister for Culture, Housing and Urban Development and Poverty Alleviation lit the traditional lamp in the presence of Shri Prithviraj Chavan, Chief Minister, Maharashtra. From left to right: Dr. Srikumar Banerjee, Chairman, AEC; Shri Prithviraj Chavan, Shri G. S. Rautela, Director General, National Council of Science Museums; Kumari Selja, Dr. Shreyans Kumar Jain, Chairman & Managing Director, NPCIL & BHAVINI, and Shri Anil Manekar, Director, Nehru Science Centre, Mumbai

target groups. The Company's website (www.npcil.nic.in) was updated regularly. News article repository system, an internal communication strategy implemented by NPCIL, was uploaded regularly to the company's intranet. It set up a permanent exhibition on “Hall of Nuclear Power”, at Nehru Science Centre, Mumbai to communicate nuclear science in an interactive way, to the general public.

NPCIL also took up a structured programme on public awareness on nuclear power for engineering college students and faculty members. The

programme was implemented in over 25 colleges across the country including IITs in Mumbai and Guwahati.

The company carried out media interaction on regular basis and organized technical visits of media personnel to stations and projects. Short films and multimedia presentations were used to disseminate information about various aspects of nuclear power.

In order to promote awareness among the public about the peaceful uses of atomic energy, BARC conducted several public awareness programmes for the benefit of students, teachers and farmers

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Students appreciating the Exhibition at BARC

across the country. In all, 32 public awareness programmes were conducted during the period. In addition, media coverage to the various events organized at BARC was also provided. A BARC Media Committee was constituted comprising young scientists to deal with the general public in the event of crisis and emergency.

TMC conducted Information Education and Communication programmes aimed at risk prevention, life style modification and improving health seeking behaviour towards early cancer detection and Tobacco Cessation Programmes at various places.

AWARDS & RECOGNITIONS

NPCIL units received several awards during the year for performance in Occupational Safety and Health, Environment Protection and other areas.

TAPS-1&2, TAPS-3&4, RAPS-1&2, MAPS, KAPS, KGS-1&2 bagged National Safety Council of India's various Safety Awards for the year 2010. AERB's Fire Safety Award & Green Site Award for the year 2010 went to MAPS and NAPS respectively.

NFC was also a recipient of the AERB's Industrial Safety Award (Radioactive Group) and Green Site Award for the year 2010.

Mini-Ratna status was conferred on Indian Rare Earths (IRE) by the Government of India. AERB's green site awards were bagged by OSCOM and Manavalakurichi Unit of IRE. The latter also received National Safety Award for the lowest injury frequency rate. The Chavara unit of IRE received two first prizes and a second prize for Mines Inspection by the Tamilnadu & Kerala Mines Safety Association. Chavara unit also won the first prize for the year 2010, of the Kerala State Pollution Control Board.

ISOMED plant of BRIT received the compliance note from the World Wide Quality Management System of M/s.Johnson & Johnson (Medical) Ethicon-USA.

Tata Memorial Centre bagged the Golden Peacock Innovation Award-2010 by the Institute of Directors for indigenously designed low cost limb salvage prosthesis, Certificate of Excellence "Spirit of Humanity Awards 2011 in Oncology - Research and Services" categories by AmeriCares India, a memento of Fr. Tong Memorial Award for its pioneering role in Cancer Prevention, Treatment, Education & Research, from Voluntary Health Association of India.

CHAPTER : 1

NUCLEAR POWER PROGRAMME : STAGE - I



Kudankulam Nuclear Power Plant





P3A project- Incell process piping work under progress

CHAPTER : 1

NUCLEAR POWER PROGRAMME :

STAGE I

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

The Nuclear Power Corporation of India Limited (NPCIL), a public sector undertaking of DAE has the mandate for the design, construction, commissioning and operation of nuclear power reactors. At present it has 20 operating reactors with an installed capacity of 4780 MW (including RAPS-1 of 100 MW which is owned by the Government) and 6 reactors under construction with capacity of 4800 MW.

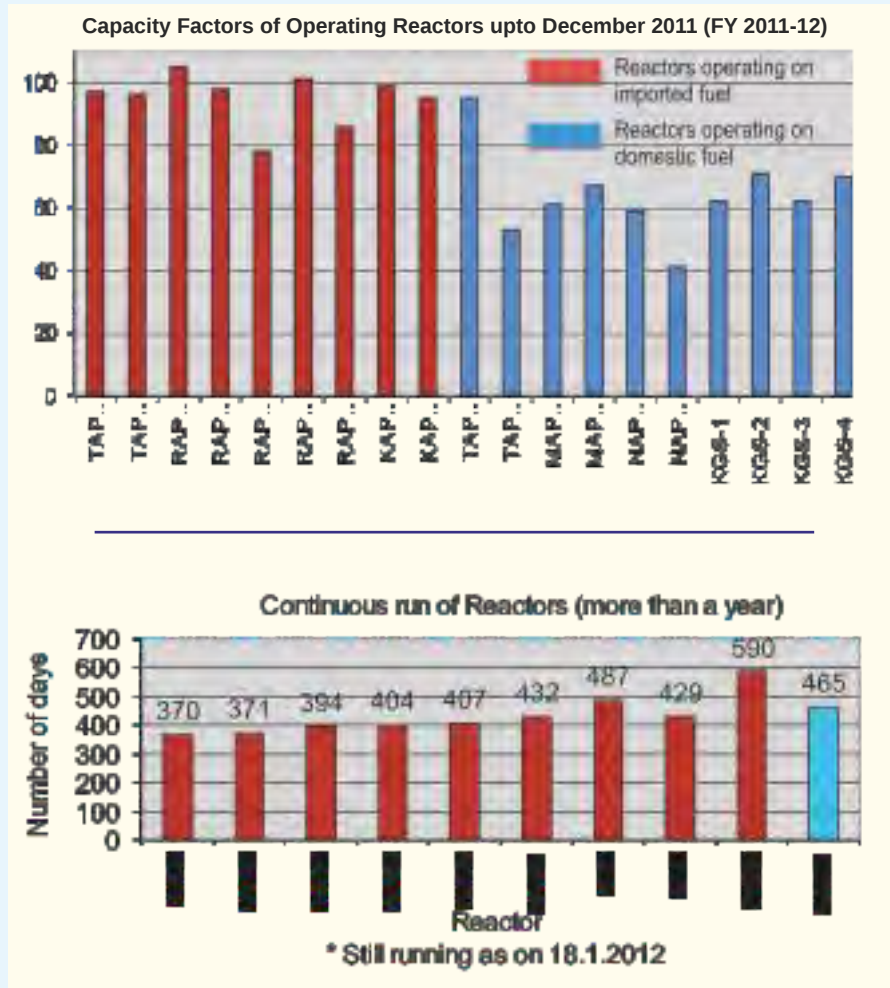
Following is the performance profile of NPCIL during the report period:

Operating Reactors

The total generation in the calendar year 2011 was 32,405 Million Units (MU) as compared to the generation of 23,284 MU in the calendar year 2010, registering about 39% increase.

In the current financial year 2011-12, the generation till December, 31, 2011 was 23,945 MU.

The reactors under the IAEA safeguards recorded capacity factor of about 95% till December 2011, and the reactors operating with domestic fuel supply registered capacity factor of about 67%. The overall capacity factor



up to December 2011 was about 78% which was 12% higher than the capacity factor of 66% of the corresponding period of the last financial year.

The overall availability factor of the reactors up to December 2011 was 90% in the current financial year 2011-12. Ten reactors recorded continuous operation of more than a year. Unit-3 of Tarapur Atomic Power Station logged 465 days of continuous operation as on January 18, 2012.

Ongoing and New Projects

At present, NPCIL has three projects under 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 Tamilnadu, the Kudankulam Nuclear Power

NUCLEAR POWER PROGRAMME : STAGE I



Kudankulam Nuclear Power Project-1&2

Project-1&2 reached an advanced stage of commissioning. The hot run of Unit-1 was completed in August 2011. Afterwards, due to local protest at the site, the work on the project had to be stopped.

Unit-1 achieved physical progress of 99.2% and Unit-2 of 96.4%. Completion of these Units is subject to normalization of situation, remobilization of workforce and completion of balance works. Efforts to resolve the stalemate continued.

Kakarapar Atomic Power Project-3&4 (KAPP-3&4, 2x700 MW PHWRs)

The project, located in Gujarat, is an expansion of KAPS-1&2. This is the first pair of indigenously designed 700 MW PHWRs. The scheduled dates of commercial operation of Units-3&4 are June and December, 2015 respectively.

During the period of report, the main plant civil construction activities continued in full swing

and about 2,00,000 cubic metre of concreting was completed, thus registering a good progress. Raft of Nuclear Building-3 was completed and the raft concreting of Nuclear Building-4 was 75% completed. The entire raft concreting is expected to be completed by March, 2012. All the major EPC Packages were

awarded and their site mobilization work was started.

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

The project at Rawatbhata, Rajasthan, is the expansion of RAPS-2to6.

The construction work on the project commenced with the first pour of concrete on July 18, 2011 after completion of excavation and receipt of clearance from AERB.

Construction of raft for Nuclear Building-7 & Nuclear Building-8 was progressing. Packages for other major works were awarded and they were at various stages of mobilization. Manufacturing of long delivery equipment was in progress.

The scheduled dates of commercial operation of Unit-7&8 are June and December, 2016 respectively.



Internal view of Reactor Building-3, KAPP-3&4

NUCLEAR POWER PROGRAMME : STAGE I



View of the Nuclear Building-7 of the Rajasthan Atomic Power Project-7&8

stage. At the plant site, works on boundary wall, Offices, guest house, etc. made progress.

New Sites

The Government accorded 'in principle' an approval in October 2009 for five new sites, namely Gorakhpur in Haryana and Chutka in Madhya Pradesh, to locate indigenous 700 MW PHWRs, Kovvada in Andhra Pradesh, Chhaya Mithi Viridi in Gujarat and Haripur in West Bengal to locate LWRs based on international technical cooperation. In July 2011, the Government accorded 'in principle' approval for three more inland sites for setting up PHWRs Mahi Banswara in Rajasthan, Bhimpur in Madhya Pradesh and Kaiga expansion in Karnataka.

For the projects in Gujarat, Madhya Pradesh and Andhra Pradesh, approval for Terms of Reference was obtained for Environmental Impact Assessment from MoEF. Studies for EIA of new projects, including preliminary pre-operational radiological survey were largely completed for Haryana, Gujarat, Madhya Pradesh and Andhra Pradesh sites. Pre-project activities were in progress. These were also initiated for new sites at Mahi Banswara and Bhimpur. For setting up 1000 MW or larger capacity LWRs at Kovvada in Andhra Pradesh, Chhaya Mithi Viridi in Gujarat, preliminary discussions with foreign vendors, were in progress.

New Projects

Kudankulam Nuclear Power Project-3&4 (KKNPP-3&4, 2x1000 MW LWRs)

The project, located in Tamil Nadu, is an expansion of the ongoing project KKNPP-1&2. It comprises two light water reactors of 1000 MW each. It is to be implemented with the Russian co-operation.

The environmental clearance from the Ministry of Environment & Forests (MoEF), and the siting consent from AERB, was received for the project. The General Framework Agreement was finalized and Techno-commercial Offer proposal was sent for consideration of the Government. At the plant site, the inner fencing was completed and the other infrastructure works made progress. Excavation

clearance was under consideration of AERB. The Environment Impact Assessment (EIA) report along with marine ecological studies, Coastal Regulation Zone (CRZ) demarcation and thermal dispersion studies were completed for KKNPP-3&4 for obtaining CRZ clearance from MoEF.

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

The project, located at Jaitapur, Maharashtra, comprises two light water reactors of 1650 MW each.

Environmental clearance from MoEF and CRZ clearance for the project were received. Siting consent was under review of AERB. Techno-commercial discussions reached an advanced

FRONT-END

Heavy Water Production

Heavy water, that is used as moderator and coolant in the Indian Pressurized Heavy Water Reactors, is produced by the Heavy Water Board. The Board is also engaged in the development and demonstration of the technological feasibility of various processes for the manufacture of products required for Front and Back End operations of the Nuclear Fuel Cycle.

The Board has initiated technology development campaigns that focus on Specialty Chemicals like organo-phosphorus solvents for application in fuel processing as well as reprocessing of spent fuel, Solvent Extraction Technology including efficient contacting devices for extraction of rare metals and Production of Stable Isotope such as Boron-10.

During the report period, performance of all the Heavy Water Plants was excellent and production of heavy water exceeded the target. The Board continued to focus on reducing the specific energy consumption, a major cost component in heavy water production, through process intensification and optimization. Schemes were also drawn up for life extension of the first generation of heavy water plants.

Following are the highlights of

performance of the Heavy Water Board:

Heavy Water Plant, Manuguru

The plant at Manuguru (Andhra Pradesh) achieved a cumulative percentage target of 113.5%. It was operated with an excellent on-stream factor of 0.995 excluding the annual turn-around period.

As a result of implementation of various energy conservation schemes at this plant, surplus generated power was exported.

Heavy Water Plant, Kota

The plant at Kota (Rajasthan) is expected to meet the targeted production for the year.

As this plant has completed 30 years of its installation, so as to review the effect of ageing of its equipment, a thorough and elaborate maintenance schedule was planned.

At the Kota plant, cooling of the effluent from Exchange Unit was achieved through Mist Cooling System. The cooled effluent was utilized as make up for cooling which resulted in water conservation, and led to significant reduction in the water-cess charges.

For recovery of energy from throttling of steam, installation of auxiliary turbo generator progressed.

Heavy Water Plant, Hazira

Performance of the plant at Hazira (Gujarat) was excellent in spite of the plant taking up shut-down for major turn-around in

May-June 2011 and attending stage pumps in September 2011. The plant had already achieved 99% of the target production.

Heavy Water Plant, Thal

The performance of the plant at Thal (Maharashtra) was very good. It achieved around 95.7% of the targeted production in spite of low deuterium content in the feed gas and interruptions in feed gas supply from the ammonia plants of Rashtriya Chemical Fertilizers Ltd.

In April-May, 2011, the plant had taken annual-turn-around for maintenance work. Various improvement / modification schemes were implemented.

Heavy Water Plant, Baroda

As approved by the Atomic Energy Commission, action was taken for stoppage of production of heavy water at this Plant.

Here, the plants producing tributyl phosphate (TBP) and the potassium metal remained in operation. Laboratory scale development of deuterium-labelled compounds also continued. Two kilogrammes each of d-chloroform and DMSO (NMR solvents) were produced. These solvents were handed over to BRIT for supplying to potential customers.

The quality of effluent water from Baroda Plant met the requirements of the Gujarat Pollution Control Board. As a result it received 25% exemption in water-cess in the fourth consecutive year.

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TBP plant at Heavy Water Plant, Baroda

Organo-Phosphorous solvents

Organo-Phosphorous solvents like Di Ethyl Hexyl Phosphoric Acid (D2EHPA) and Tri Butyle Phosphate (TBP) and various other solvents are produced at HWP, Talcher and Baroda, meeting the international quality standards.

HWB has been developing technology for synthesis of more solvents such as TiAP, DHOA & D2EHPA-II for Nuclear Fuel Cycle. It successfully established the synthesis processes on bench scale. For further development of the technology at the industrial scale level, setting up of a pilot plant at Tuticorin, continued.

Sodium Metal

Development of safe and efficient closed cell for production of sodium metal was taken up by the Heavy Water Board in collaboration with the National Metallurgical Laboratory, Jamshedpur.

Heavy Water Clean-Up Facility

The process of heavy water clean up is based on transfer of activity from reactor heavy water to circulating deuterium gas and its subsequent cryogenic distillation. During the report period, the cryogenic system was developed and mechanical completion of the facility was achieved. Commissioning activities with non-active fluids progressed.

(Manuguru). About two thirds requirement of BHAVINI was already supplied to BARC for conversion to Boron Carbide and pellatization.

HWB is now in a position to meet the international specification for enriched boric acid and can look forward to export opportunities in this area.

Boron Isotope Separation

HWB had earlier taken up development of suitable technology for Boron enrichment for fabrication of control rods and neutron detectors in fast breeder reactors. Country's first industrial scale production facility for enriched Boron based on exchange distillation was commissioned at HWP (Talcher).

A plant for converting the enriched KBF_4 into elemental Boron, based on electrowinning process, was set up at HWP



Boron Exchange Distillation Plant at Heavy Water Plant, Talcher

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Optimisation of operating parameters and design and operation of 50 A & 100 A molten salt electrolytic cell was completed and fabrication of 500A cell was in progress.

MINERAL EXPLORATION

The Atomic Minerals Directorate for Exploration and Research (AMD) established a total of 9,628t Uranium Oxide during the period of its annual programme of work (November 2010 to October 2011). During the XIth Plan the Uranium Oxide reserves established were 65,122 t.

During the report period, AMD continued Uranium investigations in the thrust areas for uranium mineralization. The substantial inputs of various types of surveys and drilling helped in identification of the new areas / blocks and delineation of ore bodies. Exploratory mining continued for detailed assessment of the ore body at Gogi, Yadgir 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.

Highlights of the salient achievements of the Mineral Exploration Programme are summarized below:

Uranium Investigations

Ground radiometric surveys

Reconnaissance (5743 sq km)

and detailed (159 sq km) radiometric surveys resulted in locating new uranium anomalies/extension of known occurrences in the following geological environs:

North Delhi Fold Belt, Rajasthan:

Uranium anomalies associated with banded gneissic complex at Dangarwara near Bichun, Jaipur district; in albitised grey quartzite near Rela, in silicified phyllitic quartzite near Sirsori Ki Dhani and with micaceous quartzite at Barar Ki Dhani, Sikar district, were located.

Aravalli Fold Belt, Rajasthan:

Uranium anomalies associated with argillaceous layered dolomite around Umar, Bundi district and at Gaga Ka Khera, Bhilwara district were located.

Dongargarh Group, Chhattisgarh:

Uraniferous anomalies were located near Duwalgudra and Pandutola associated with fractured rhyolite (Bijli Rhyolite), Rajnandgaon district.

Mahboobnagar Granite, Andhra Pradesh:

Uraniferous anomalies associated with granites and basic dykes were located at Bamanapalli, and Kappagattu along Mannanur-Farahabad sector, Mahboobnagar district.

Geochemical Surveys

Geochemical surveys were carried out over 2765 sq km for delineating the target areas for detailed investigations. The important anomalous areas identified were : Didwana and

Singhi Talab, Nagaur district, Rajasthan; Tadpatri shale, Kadapa district, Andhra Pradesh; Bhima basin, Gulbarga district, Karnataka, and Badami basin, Belgaum district, Karnataka.

Airborne survey and Remote Sensing

Heliborne geophysical survey was carried out over Shillong basin, Cuddapah basin, Kaladagi-Badami block, Sonrai-Bijawar block, Albitite line south extension and North Singhbhum block during this field season.

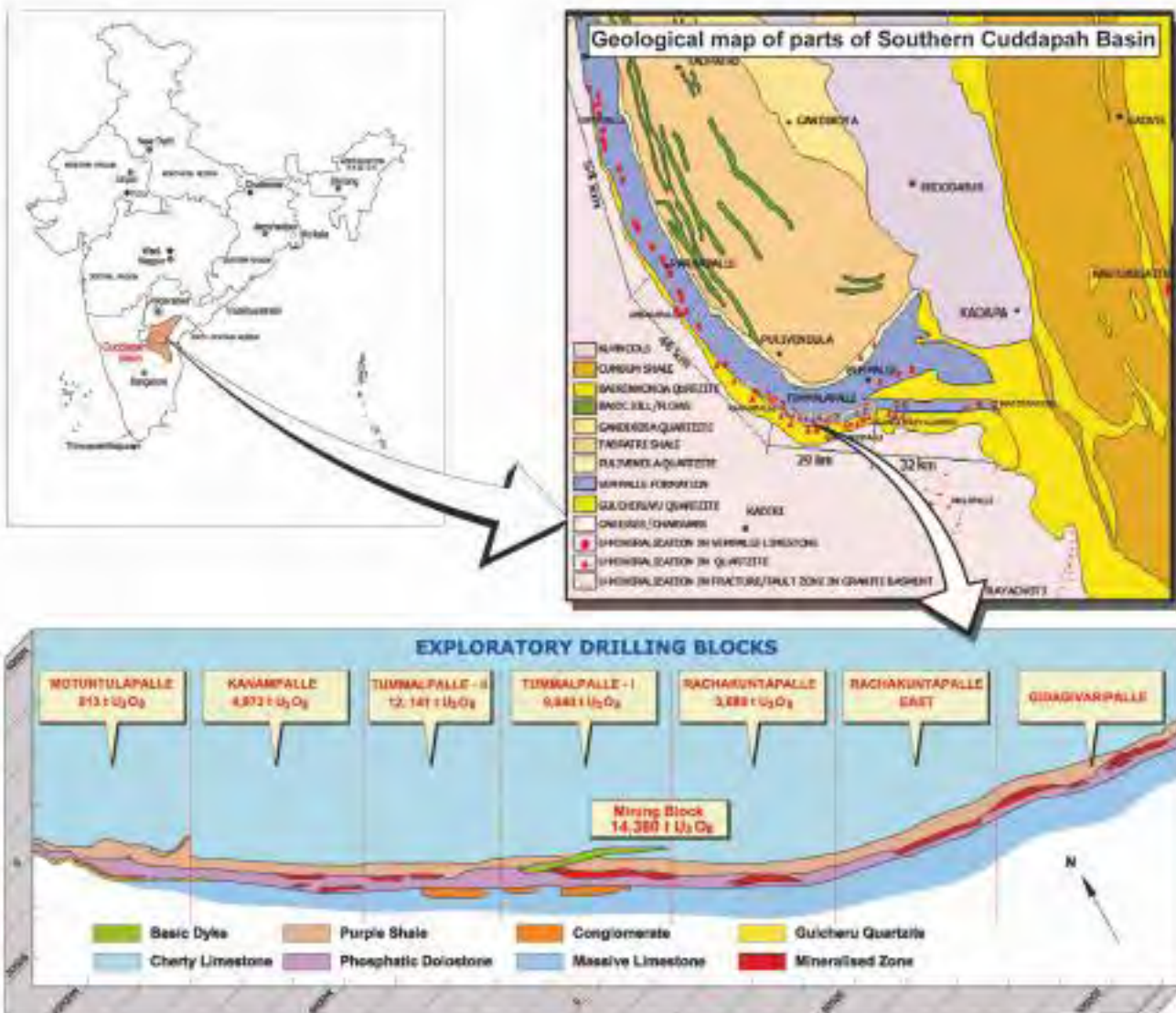
A total of 78,672 line km was achieved. Preliminary interpretation of raw images (radiometric, magnetic and EM) indicated broad geological entities.

Ground Geophysical surveys

Ground geophysical survey was carried out by various methods such as magnetic, IP/resistivity and transient electromagnetic, in parts of Rajasthan, Andhra Pradesh, Chhattisgarh and Karnataka. Following observations were significant:

Guman Singh Ki Dhani Narsingpuri tract, Sikar district, Rajasthan: A well defined linear magnetic anomaly was revealed.

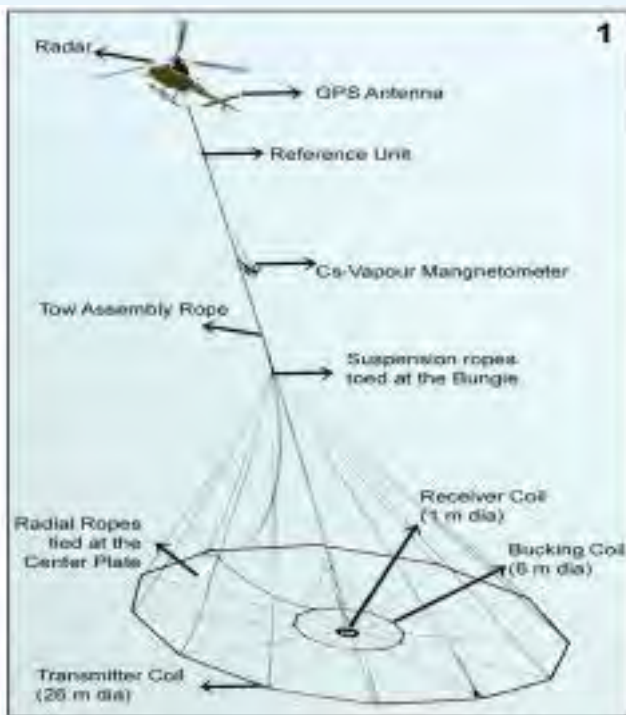
Subbareddypalem area (N. of Koppunuru), Guntur district, Andhra Pradesh: Surveys over 10 sq km in this area indicated two linear magnetic high anomalies.



1. Geological Map of southern part of Cuddapah Basin, Andhra Pradesh showing Uranium Occurrences in Vempalle Dolostone and Gulcheru Quartzite.

2. Map showing exploratory drilling blocks of Tummalapalle U-deposit (strata bound dolostone), Andhra Pradesh.

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Heliborne Geophysical System with VTEM, Radiometric and Magnetometer

Devri area (between Dumhath and Jajawal), Surguja district, Chhattisgarh: Surveys showed a prominent linear zone.

Bodal and Bhandaritola areas, Rajnandgaon district, Chhattisgarh: Surveys were carried out over 25 sq km.

Drilling

A total of 2,03,800 m drilling was carried out during 2010-11 field season to establish additional uranium resources in the known occurrences and sub-surface continuity of mineralisation in the new promising areas. The exploratory / evaluation drilling established an additional ore reserve of 9628 t uranium oxide.

Exploration in the extension/

new areas

Significant mineralised intercepts / bands explored during the field season :

- Extensions of correlatable uranium mineralization was intercepted both in hangwall and footwall at Tummalapalle block-1, Tummalapalle block-2, Kanampalle,

Rachakuntapalle, Motunutalapalle and Madyalabodu blocks, in Kadapa district, Andhra Pradesh.

- Uranium mineralisation was intercepted close to the unconformity between Srisailem quartzite and basement granite in Chitrial Main Block, Chitrial block-2 and block-4 in Nalgonda district, Andhra Pradesh.

Established additional uranium resources

Area	Additional Reserves Established (t U ₃ O ₈)	Cumulative Reserves (t U ₃ O ₈)
Tummalapalle (A.P.)	4396	63269
Chitrial (A.P.)	718	9191
Rohil (Rajasthan)	450	5566
Wahkut (W.Khasi Hills)	588	1161
Umthongkut (W.Khasi Hills)	572	1325
Singhbhum Shear zone (Bangurdih)	1140	
Singhbhum Shear zone Banadungri-Singridungri	1764	

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- Correlatable uranium mineralisation was intercepted close to the unconformity between Banganapalle quartzite and basement granite and within the Banganapalle quartzite. Correlatable mineralisation was intercepted in boreholes of Koppunuru and Chenchu colony, west of Koppunuru exploration block in Guntur district, Andhra Pradesh.
- Correlatable uranium mineralisation related to albitite zone was 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.
- Uranium mineralisation was intercepted in the hangwall and footwall side, associated with brecciated granite in the Gogi uranium deposit, Yadgir district, Karnataka.
- Correlatable uranium mineralization associated to limestone, exactly similar to Gogi uranium deposit, intercepted in boreholes at Kanchankayi (2 km NE of Gogi), 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 Pitepani metabasics (Dongargarh Group) at the unconformity with Bortalao in Rajnandgaon district, Chhattisgarh.
- Correlatable uranium mineralisation intercepted in two boreholes of Narwapahar deeper series associated with quartz-chlorite-sericite schist in East Singhbhum district, Jharkhand.
- Correlatable uranium mineralisation associated quartz-chlorite-sericite schist intercepted in number of boreholes in Banadungri-Singridungri, East Singhbhum district, Jharkhand.
- Correlatable uranium mineralisation associated with zones of secondary silicification and magnetite-apatite vein lets intercepted in number of boreholes in Bangurdih, Seraikella-Kharswan district, Jharkhand.

Exploratory Mining

Exploratory mining at Gogi,

Yadgir district, Karnataka :

During current field season, 31 m shaft sinking was developed and cumulative progress of 212 m in shaft sinking was achieved.

Total Uranium Resources

The country's uranium resources were updated to 1,72,390t of U_3O_8 as on 31.10.2011.

Rare Metal and Rare Earths Investigations

Reconnaissance (450 sq km) and detailed (6.65 sq km) surveys resulted in location of new occurrences of columbite-tantalite and beryl bearing pegmatites at Lendharjhor & Jhikjhiki, Bargarh district, Odisha and Dudawas, Jaipur district, Rajasthan respectively.

Additional reserves of 910 kg of columbite-tantalite were estimated in pegmatites of Sarpanchpara (Dantewada district, Chhattisgarh), Latmetta (Dantewara district, Chhattisgarh) and Sukdapara (Bastar district, Chhattisgarh).

The production of columbite-tantalite and recovery of beryl as by-product continued in the field units at Pandikimal and Jangapara in Jharsuguda district, Odisha and at Bodenar in Bastar district, Chhattisgarh. The columbite-tantalite produced at Pandikimal and Bodenar was a total of 2935 kg.

In addition, a total of 4100 kg of beryl was recovered as by-product at Pandikimal and Bodenar recovery units, respectively.

Beach Sand and Offshore Investigations

For identifying additional beach sand heavy mineral resources, surveys (Reconnaissance - 254 sq km & detailed- 08 sq km) and exploration (drilling, sampling and evaluation) were continued along the coastal tracts of Gujarat, Andhra Pradesh, West Bengal, Orissa, Karnataka and Tamil Nadu.

Survey

1035 boreholes (8225m) were drilled in a grid pattern and 5532 individual and 59 bulk samples were generated. Composite samples were processed for separation of Monazite and Zircon.

A total of 5278 individual samples and 78 composite samples were analyzed for slime, shell and total heavy mineral contents. Grain counting was carried out on 83 composite samples.

The following potential heavy mineral zones were delineated:

- Ghoga-Gopnath area, berm zone of Bhavnagar (Saurashtra) coast (5-20% THM), Bhavnagar and Panchmahal districts, Gujarat.
- Malikipuram coast, East Godavari district (up to 20% THM), Andhra Pradesh.
- Barapahi-Birampur coast (0.13 to 20.18 % THM), Balasore district, Odisha and Midinapore district, West Bengal.

- Inland placer between Deula to Chandanpur (avg. 4.77%), Midinapore district, West Bengal.
- Beach sand bar between Ennore and Pulicate Lake (5-30% THM), Tiruvallur district, Tamil Nadu.
- Mangalore-Mulki-Kaup sector (4-20% THM), Dakshina Kannada district, Karnataka.

Detailed Reports

14 technical reports on beach sand heavy mineral deposits were finalized. Data base was populated on 27 sectors of beach sand deposits during the period.

Mining & Mineral Processing

In India, mining of uranium ore and its processing is done by the Uranium Corporation of India Ltd. (UCIL). The company has five underground mines, one opencast mine and two uranium ore processing plants operating in Jharkhand. One more underground mine and processing plant is under construction in Andhra Pradesh. One underground mine is under construction and a few operating units are undergoing capacity expansion in Jharkhand.

During the year of report, UCIL maintained excellent performance in production.

Jaduguda underground mine, the oldest uranium mine of the country, reached a depth of 880 m, maintaining steady production. Additional ore blocks were added

to the mining limits of the underground mine at Bhatin. The underground mine at Narwapahar, that deploys trackless mining layout, was deepened upto a depth 230 m. Capacity augmentation of this mine was under implementation. The underground uranium mine at Turamdih reached a depth of about 200 m. Sinking of 255 m deep shaft to access deeper levels was completed and shaft equipping was in progress. Production capacity of this mine was under augmentation. The new underground mine at Bagjata achieved its full capacity. The first opencast mine at Banduhurang also achieved its full production capacity.

The third phase of expansion of Plant at Jaduguda was completed. This plant treats the ore of Jaduguda, Bhatin, Narwapahar and Bagjata underground mines. Production of uranium peroxide in place of magnesium di-uranate (MDU) was successfully implemented at Jaduguda. The new processing plant at Turamdih fed by the ore of Turamdih and Banduhurang mines, also achieved its full capacity. Capacity of this plant was under expansion which is expected to be completed after obtaining the environmental clearance. Construction of another underground mine at Mohuldih was in full swing and expected to be commissioned shortly.

The project construction work for a new underground mine and a

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processing plant at Tummalapalle in YSR district (former name Kadapa) of Andhra Pradesh was nearing completion. Its production will start shortly. To augment the uranium production, expansion of the mine and plant at Tummalapalle was planned. During the year, UCIL also undertook exploratory mining in Gogi (Dist Yadgir, Karnataka) on behalf of AMD.

UCIL successfully maintained its ISO 9001:2008, 14001:2004 and IS 18001:2007 certification.

Production and supply of uranium metal of various grades in bulk ingot and powder form for the research reactors, continued at BARC.

The effect of uranium

concentrate source and processing route on the final product microstructure of ammonium diuranate was studied. The upcoming uranium mill at Tummalapalle and the proposed mill at Gogi will be using alkaline leaching technology for the recovery of uranium values. The final product in both the mills would be sodium diuranate.

The process parametric studies carried out at Trombay for effective re-dissolution and re-precipitation followed by calcination of uranium peroxide precipitate, yielded a high purity product. Systematic studies were undertaken on different uranium ore samples from Bichun-

Sakhun-Nayagaon area of Rajasthan to assess leachability of uranium as well as rare earths.

Hydrodynamics of the liquid phase catalytic exchange system of hydrogen-water exchange process was studied. Process modeling of liquid phase catalytic exchange system was carried out and the computer code for the same was developed and the models were validated.

At BARC, a method was developed for determination of plutonium at trace levels in aqueous solutions using high resolution Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES).



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Nuclear Fuel Fabrication

Nuclear Fuel Complex (NFC) is engaged in the production of natural uranium oxide fuel bundles for PHWRs, enriched uranium fuel assemblies for boiling water reactors (BWR), reactor core structurals, reactivity control mechanisms and special materials such as tantalum, niobium etc.

In addition, NFC produces all the core sub-assemblies and other critical components such as 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 applications.

PHWR Fuel

500,000th PHWR fuel bundle, cumulative since inception of

NFC, was manufactured in the fourth week of December 2011. Safeguarded Fuel Plants continued processing of uranium raw material, maintaining sufficient stock of fuel bundles at safeguarded PHWR sites.

As a part of modernization effort, SCADA system with central control was introduced in the Uranium Oxide Plant.

Process parameters were optimized for processing the uranium peroxide supplies of UCIL from Jaduguda. UO₂ Pellets with controlled porosity (40%) were fabricated and supplied to IGCAR for electrochemical conversion to uranium metal.

The throughput was increased by integrating, robot employed for one endplate welding machine, with the second machine.

To meet the demands of higher production, four more integrated spacer pad & bearing pad welding units were fabricated and supplied to assembly plants in a short time.

An automated PHWR UO₂ fuel pellet visual inspection system was developed successfully in collaboration with RRCAT. This system, apart from eliminating operators' subjectivity, minimises their fatigue.

BWR Fuel

To meet the reload requirements of TAPS-2, requisite numbers of boiling water reactor fuel bundles were manufactured at NFC and supplied.

Zirconium activities

At NFC, recovery of free nitric acid from Zirconium Nitrate pure solution and recycling resulted in about 18% reduction in the consumption of nitric acid and 25% reduction in the consumption of ammonia. With the introduction of Zircaloy based off-gas scrubbing system for calcination furnace and with recycling of acidic solid waste, about 5% increase in the recovery



Gamma radiometry analysis software



Robot integrated with two end-plate welding machines

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Automated Pellet Inspection System installed at NFC, Hyderabad



Extrusion press after revamping

of Zirconium Oxide production was achieved.

Towards establishment of production facility for Niobium at NFC for meeting the requirement of ISRO, Safety Report and Design Basis Report were presented to AERB for their consent for siting and construction.

Zircaloy fabrication

3780 T Extrusion Press at NFC is a vital equipment to meet the entire fuel and structural requirements of Indian reactors and to process several strategic materials for other applications. Most of the components of this Press, which was being operated for about 40 years, were worn out, thus significantly bringing down its availability. A massive revamping work was carried out and the Press was brought back to healthy working condition.

Special tubes needed for liquid zone control systems of 700 MWe PHWRs, AHWR critical facility at ATTF-Tarapur and neutron

detectors of TAPS-3&4 were manufactured and supplied. Process for production of double clad tubes needed for metallic fuel of fast reactors was established by using co-pilgering process.

To manufacture pressure tubes for 700 MWe PHWRs, modified process route involving double radial forging, extrusion and single pass pilgering was developed. Special equipment was fabricated for increasing the productivity of seamless calandria tubes for 700 MWe PHWRs.

Commercial activities

The Incoloy-800 Steam Generator tubings for the nuclear power plants were hitherto imported. NFC successfully standardized the manufacturing route for indigenous production of steam generator tubes for the 700 MWe PHWRs.

Titanium half-alloy hydraulic tubes of four different sizes for aerospace application were produced successfully at NFC. A

trial batch of UNS 30432 grade tubes for Advanced Ultra-Super Critical thermal power plants were produced successfully and trial production of Inconel-617 tubes for these plants continued.

HPT 55 pilger mill was revamped completely which significantly increased the productivity.

Projects

Pre-project activities were initiated for setting up PHWR fuel & zircaloy fabrication facilities at Rawatbhata (Rajasthan) to cater to the needs of 700 MWe PHWRs that are under construction at Rawatbhata and Karkrapar (Gujarat). Also, action was taken for the preparation of Environment Impact Assessment Report based on the Terms of Reference issued by the MoEF, and also for appointment of consultants for detailed engineering and construction supervision.

NFC plans to launch 19 nos. of

NUCLEAR POWER PROGRAMME : STAGE I

new projects during the XII plan to meet the fuel and zircaloy requirements of forthcoming 700MWe PHWRs and 300MWe A HWR, in addition to augmenting and modernising the present production facilities at Hyderabad.

Zirconium Complex

AERB issued licence for regular operation of Zirconium Complex, Pazhayakayal after reviewing the data generated during the trial production.

BACK END

Fuel Reprocessing & Waste Management

At BARC, behaviour of Np was evaluated for actinide partitioning under PHWR-SHLW by twelve stage counter-current extraction/stripping runs, using improved TODGA solvent. A novel tripodal diglycolamide (T-DGA) was evaluated as an extractant by batch solvent extraction and supported liquid membrane studies.

Bench scale synthesis was established for strontium specific Dicyclohexano 18Crown6 ligand. A comprehensive data base was generated from this work. It was confirmed that synthesized Dicyclohexano-18Crown6 could be used for selective recovery of strontium from waste streams after separation of actinides.

Fluidized bed thermal de-nitration of synthetic ammonium nitrate solution was carried out at



P3A project - Incell process piping in progress

Trombay. Engineering data generated was used for validation of the design of de-nitration plant of Uranium Oxide Facility at Kalpakkam. PREFRE II commenced production in April 2011. The Plant was in regular operation performing very well with regards to hull losses, waste generation and environmental discharge.

The Spent Fuel Storage Facility (SFSF) at Kalpakkam continued to store spent fuel from Indian PHWRs and its authorized capacity has been fully reached. Regulatory clearance for capacity increase was also obtained. PREFRE-1 plant capacity was utilized for production of Uranium Oxide and other material. Also the new De-mineralized Plant was operated at rated capacity.

Project P3A was designed to increase the capacity of PHWR fuel reprocessing at Kalpakkam.

Mechanical erection of equipment and connecting piping work in various cells and outside areas made significant progress and reached an advanced stage.

Both the reprocessing plants viz. Plutonium Plant, Trombay and KARP, Kalpakkam, were in operation for recovery and purification of Plutonium and Uranium from spent fuels from research reactor and PHWR respectively. The performance of KARP was very good and throughput obtained from it was highest so far.

Waste Management

At BARC, development studies relating to formulation of vitreous matrices for immobilization of futuristic high level waste containing thorium, aluminum and fluoride, were carried out. Issues like solubility of ThO_2 , behavior of fluoride and

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influence of Al_2O_3 on the product characteristics were focused.

A continuous rotary dissolver of capacity 400 t/year was fabricated and installed at site. This dissolver will enhance throughput of the reprocessing plant. Also erection of extraction equipment test facility, required for testing and qualification of high capacity solvent necessary for use in such plants, was completed and execution of process piping and instrumentation works progressed.

A plant adaptable cold crucible induction melter with low level waste feeding capability was developed to study the performance of the melter under liquid feed conditions. The plant was operated to establish the optimum liquid throughput.

An in-house developed oblong shaped Metallic Melter was operated to evaluate its performance with respect to boil up rate, glass melting and pouring. A non-radioactive pilot plant facility was built to demonstrate the remote handling aspects and feasibility of



Plant adaptable cold crucible induction melter for Low Level Waste

production of miniature source pencils using Cs-137 in the form of vitrified product.

Articulated Manipulator having 8 kg payload capacity with gas tight design features was developed for remote handling activities to be carried out for this facility.

A mock-up unit for optimization of tooling for remote operations involved during the remote dismantling of Joule-heated ceramic melter was built and various remote operations were demonstrated. This

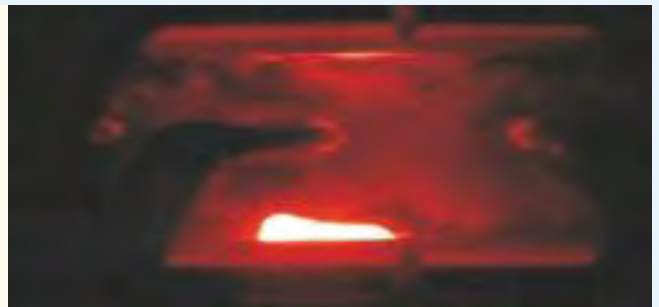
developmental work can be adapted for dismantling and decommissioning of ceramic melters.

The engineering scale actinide separation demonstration facility was set up in the Solid Storage Surveillance Facility, Tarapur. Cold commissioning of the first cycle was successfully carried out. This cycle will ensure removal of residual uranium and plutonium from actual high level waste. Strontium specific ligand, Dicyclo-hexano18 crown6 synthesized, was tested for separation / recovery of Strontium from this waste. Development of glass formulation for fresh high level waste was successfully done including plant scale trial vitrification with simulated waste.

A process developed for catalytic reduction of uranyl nitrate U(VI) by hydrogen as reductant was carried out as an alternative to presently adopted electrolytic process. A process was successfully demonstrated for decontamination of actual alpha contaminated metallic waste. Projects viz. PRTRF &

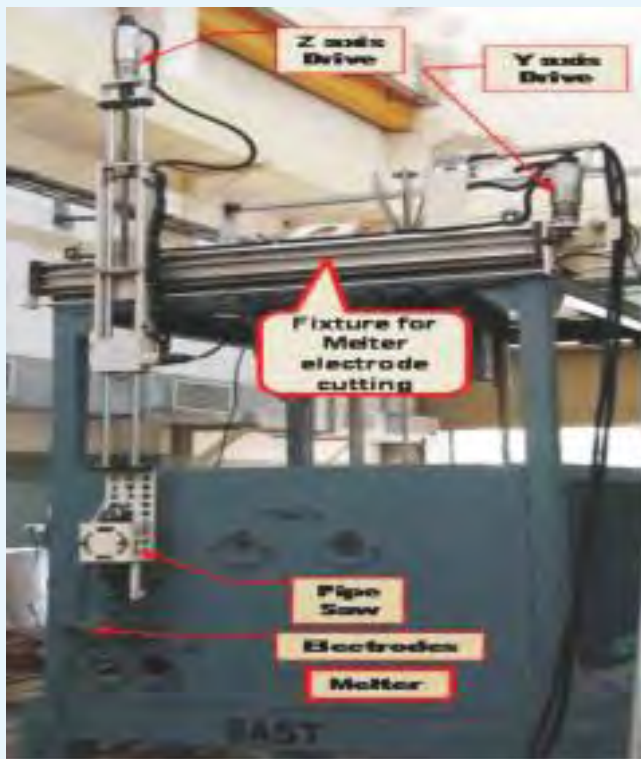


Molten glass pool inside the oblong shaped Metallic melter



Cold cap formed inside the oblong shaped Metallic melter

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Demonstration of Cesium pencil fabrication



Remote cutting of Joule melter side electrodes

AWTF at Trombay, Waste Management Plant at Kalpakkam and Low Level Waste Management Facility at Vizag progressed well. Simultaneous recovery of Strontium and Cesium from actual acidic wastes was carried out.

Tarapur Waste Management Plant continued to provide service in management and safe disposal of radioactive waste materials in solid and liquid form, obtained from BARC and NPCIL units at Tarapur.

Work on the Intermediate Transfer Facility progressed as planned. Uranium Oxide Facility converts uranium nitrate to uranium oxide and also carries out de-nitration. The civil work was progressing satisfactorily.

SAFETY PERFORMANCE OF REACTORS

As on December 31, 2011, NPCIL registered 349 reactor years of safe operation of its power reactors. Following the events at Fukushima, Daichii in Japan owing to a massive earthquake and the ensuing Tsunami, all countries pursuing nuclear power programme, including India, undertook the stress test of the nuclear power reactors in operation and under construction, to verify and validate the safety status of the reactors in their countries. The findings of these stress tests validated that the nuclear power reactor designs and safety features are sufficient to withstand the extreme natural

events that occurred at Fukushima in Japan.

In India, the geographical location and the design parameters of Indian nuclear power plants conclusively brought out that these are safe against the extreme natural events, similar to those at Fukushima, Daichii in Japan.

HEALTH, SAFETY AND ENVIRONMENT

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 collective occupational exposures of employees of NPCIL at the various nuclear power plants were maintained

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within the budget approved by AERB. The process of Quarterly Review of safety status of operating stations was carried out on a regular basis. The environmental releases of radioactive effluents from NPPs were also maintained very low as compared to the limits specified by AERB. The Environmental Management System and Occupational Health and Safety Management System as per ISO-14001: 2004 and IS-18001: 2007 respectively, were maintained at all the stations. Biodiversity studies in the region around the Jaitapur site were initiated to develop Biodiversity Conservation Plan.

NPCIL has voluntarily taken up Environment Stewardship Programme (ESP), besides fulfilling regulatory and statutory requirements. The programme focuses on the scientific study of bio-diversity, particularly avifauna, within and around Exclusion Zones (EZs) of Indian nuclear power plants for the conservation & improvement of habitat in association with the Bombay Natural History Society (BNHS).

A detailed census of peafowl at Narora was conducted for its conservation activities. A booklet on "Narora Bird Marathon 2011" with the details of birds at Narora was published. A study of wetlands and survey of birds in select districts of Tamil Nadu was conducted by the NPCIL volunteers. The information collected on water birds and wetlands during the survey as a

basis for contributing to their conservations was submitted to Asian Waterbird Census an Asia region programme to promote public participation to monitor the distribution and population of water birds and status of wetlands.

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.

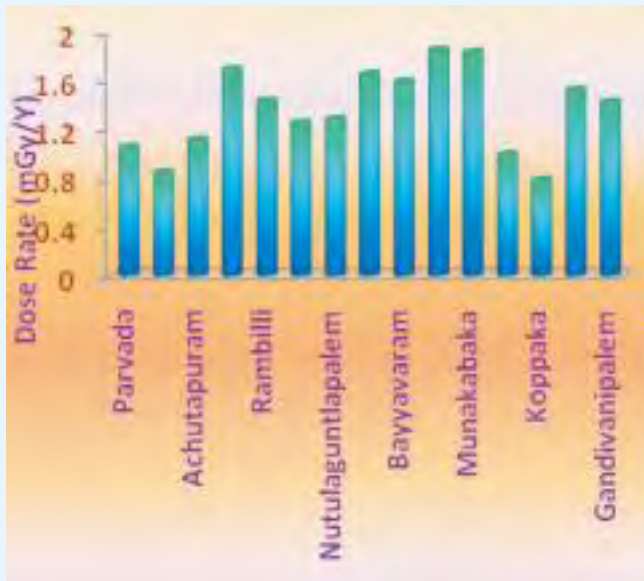
Environmental safety surveillance, radiation protection

and industrial hygiene was provided by BARC to all the operating units of UCIL, IRE, Orissa Sands Complex and Nuclear Fuel Complex. The Centre also provided technical support to UCIL and IRE for environmental impact assessment, public hearing and AERB clearance of uranium mining project at Gogi, Karnataka and monazite processing plant at Chatrapur, Odisha. Baseline Environmental Survey was carried out at BARC Campus, Visakhapatnam, Uranium Mining Project at Tummalpalle and Gogi.

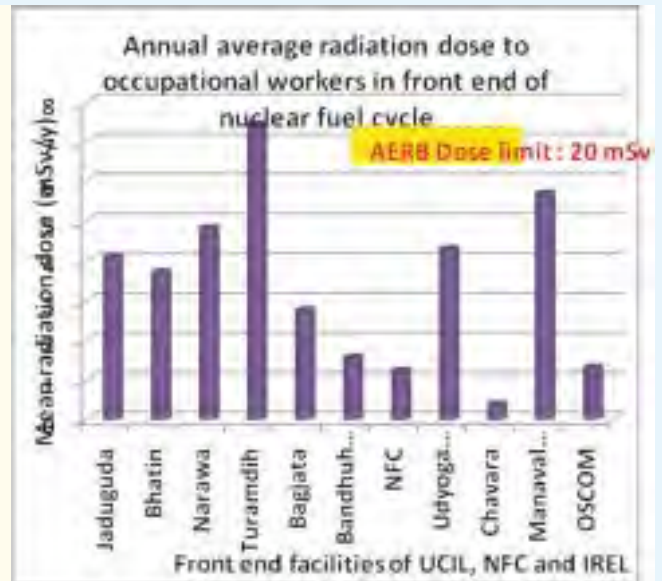


Environmental gamma radiation monitoring sites around DAE installations using TLDs

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Environmental gamma radiation levels around BARC Campus at Visakhapatnam



BARC also extended support for pre-operational radiological and environmental data collection for environmental impact assessment studies, to the new project of NPCIL at Kovada, Andhra Pradesh and INRP at Tarapur.

Environmental gamma radiation monitoring around the nuclear installations in India was carried out by BARC using CaSO_4 : Dy based thermoluminescence detectors (TLDs). The main objective of the monitoring programme was to keep a watch on the prevailing environmental background gamma radiation levels around DAE sites and to assess the environmental impact of the Indian Nuclear Power Programme. Apart from the DAE sites, a programme was also initiated to monitor background level of gamma radiation across the country.

About 4300 occupational workers in uranium mining and ore processing plants, nuclear fuel fabrication facilities and thorium processing facilities were monitored for external and internal exposure. Radiation doses to occupational workers were found to be well within the AERB prescribed limit.

Twenty environmental radiation monitoring systems were installed at different locations in India under the IERMON network of BARC. This was in addition to the existing 90 monitoring systems in this network.

MV Rak, the Panama-flagged cargo ship had sunk off the coast of Mumbai on August 4, 2011. The effect of the oil spill was mapped by measuring concentrations of oil and grease at the CIRUS Jetty as well as a few other locations at the Mumbai Harbour. Juhu Beach sand

samples with oil patches were collected to identify the oil signature pattern. Seawater samples from Juhu were collected on the same day. No major effects of this oil spill were observed in the Mumbai Harbour area.

To simulate dispersion of oil from the sunken ship, a three-dimensional source term model was developed.

A liquid scintillator based beta gamma coincidence counting system was developed to standardize sources decaying by electron capture and emitting X-rays of higher energies.

A Standard Facility was set up at Trombay for beta dose measurement as per the international standard ISO 6980. The main objective of this facility was to test and calibrate the nuclear instruments developed at BARC for measurement of beta radiation fields.

At BARC, a prototype smart

NUCLEAR POWER PROGRAMME : STAGE I



Sampling locations in the Mumbai Harbour

four element Optically Stimulated Luminescence Dosimeter (OSLD) badge was designed and developed to measure X-ray, beta and gamma radiation doses in field conditions, for personnel and environmental monitoring applications. A prototype Personnel Monitoring OSLD badge reader system was also designed and developed for readout of the four element OSLD badge. The OSLD badge was undergoing tests.

The dose estimated using the OSLD badges is in good agreement with the dose values measured by routine TLD badges.

A newly developed, LiMgPO_4 based OSL phosphor was thoroughly characterized and found to be satisfactory for dosimetric applications. This phosphor is now available for OSL Dosimetry in personnel monitoring, environmental

monitoring as well as for food irradiation (high dose range).

Development of a hand and

foot beta-gamma contamination monitoring system using large area thin plastic scintillator detectors was completed at Trombay. Tritium monitors using indigenously developed detector assembly, were developed and installed at various DAE facilities. Laboratory scale prototype units were developed for spectrometry based estimation of alpha and beta gamma activities in the ventilation exhaust.

Direct radon (Thoron) Progeny Sensors were developed for estimating cumulative doses due to decay products. After standardization, about 1500 dosimeters were deployed in thorium plants and uranium mines as personal inhalation dosimeters for workers and in high



Standard Facility for calibration of beta monitors

NUCLEAR POWER PROGRAMME : STAGE I



The four element OSLD dosimeter card badge



Prototype OSLD badge reader system



Various stages of OSLD

background radiation areas.

A clip-on badge, made for personal inhalation dosimetry, was successfully tested in thorium plant environments. The published work on these sensors received international attention resulting in collaborations with several foreign institutes in

Serbia, Italy, Hungary, Netherlands and Czech Republic. About 100 dosimeters were deployed by these institutes in various environments for assessment of radon and thoron progeny concentrations.

Two types of microprocessor based gamma radiation calibration systems, one housing a single Cs-137 source (500 mCi) and the other housing three sources, viz. Cs-137, Co-60 and Am-241 were developed by BARC as a part of the upgradation of Quality Assurance Laboratory. These systems were thoroughly calibrated and accuracy in dose delivery was established.

While the the multi-source calibration system will be useful for the QA laboratory at Mumbai, the second calibrating system will be useful for all the accredited laboratories across the country.

With these automated systems, a highly reproducible calibration set-up is now available which will considerably reduce the exposure to the personnel during the source handling and also improve the accuracy and reproducibility of the personnel monitoring activities.

At BARC, systems, software and impact assessment methodologies were developed for response to any nuclear / radiological emergencies in public domain. These will help in the decision making on implementation of counter measures required to reduce radiological consequences in public domain, if any. Large number of “First Responders”,

“Quick Response Teams” and “Emergency Response Teams” were trained for radiological status assessments as well as response during any radiation.



Hand & foot beta-gamma contamination monitoring system

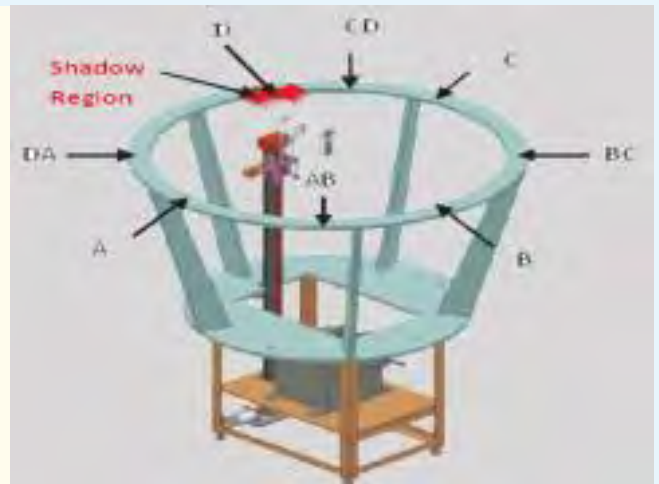


Direct radon (Thoron) Progeny Sensors

NUCLEAR POWER PROGRAMME : STAGE I



Multi-source Calibration System



Single source Calibration System

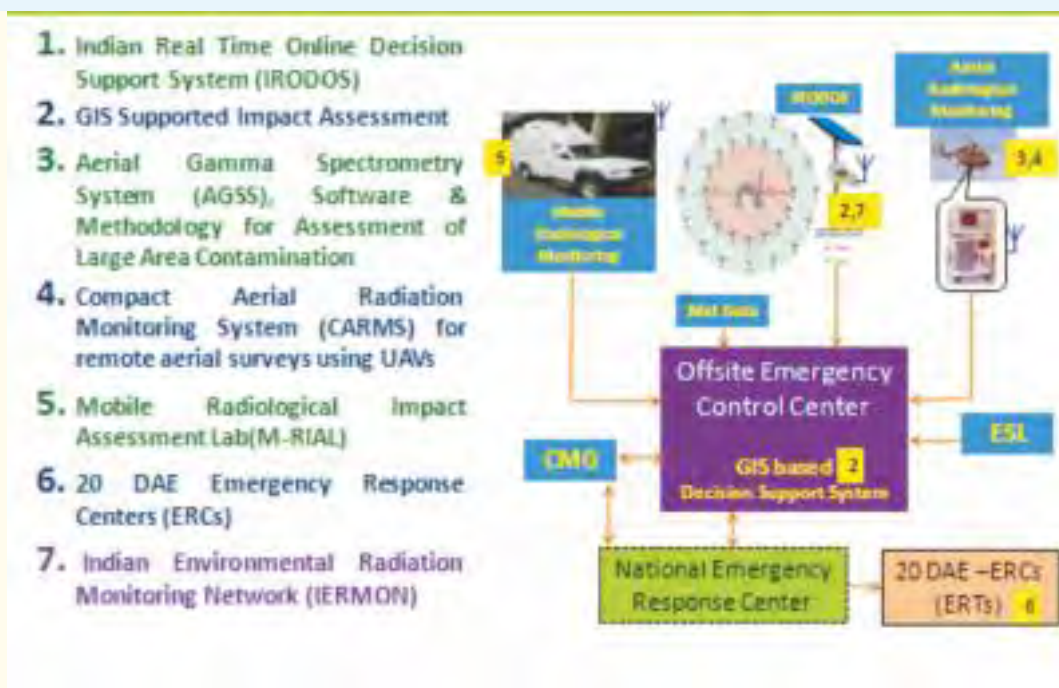
Mobile Radiological Monitoring of Emergency Planning Zone (EPZ) of Kudankulam Nuclear Power Plant, NDRF (National Disaster Response Force) personnel trained by radiological safety experts of DAE, as First Responders, were placed at different parts of the country by

the National Disaster Management Authority (NDMA) for quick response to any nuclear/radiological emergency.

Aerial radiation monitoring exercises over “simulated radioactive contamination / sources” were carried out with the Aerial Gamma Spectrometry System (AGSS) installed in

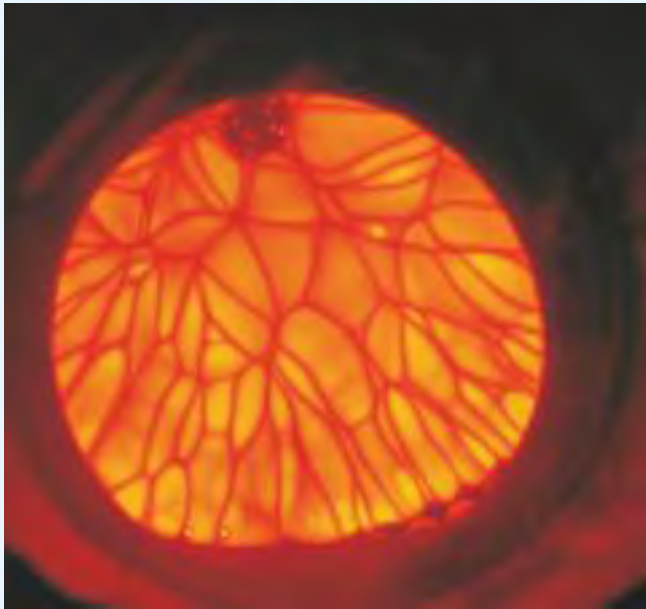
helicopters to train Quick Response Teams. In the current year two Emergency Response Centres (ERC) were added, including 20 ERCs which are operational now.

Manavalamkurchi and Gandhinagar city carried out demonstrating methodology of Environmental Monitoring



Schematic of Offsite Emergency Control Centre's Linkages

NUCLEAR POWER PROGRAMME : STAGE I



Molten glass in furnace Test



Melt Pool Coolability Setup

during radiological emergency as well as for search of orphan sources.

Dose rate mapping and activity measurement of structural components of APSARA was completed. In the field of health, safety and environment various courses and training programmes were conducted. Health and safety regulatory aspects at BARC facilities, such as regulatory inspections of the facilities, licensing of the facilities, and others, were continued.

Personnel monitoring service was provided by BARC to about 90,000 radiation workers in the country - directly to about 30,000 workers from DAE facilities, and to the rest non-DAE workers, through various accredited laboratories. The National Occupational Dose Registry System database was updated and maintained with an addition of about 500 new institutions and

24,000 new radiation workers.

An experimental facility was fabricated and erected at the Waste Immobilization Project to understand coolability of molten corium and to devise effective strategy for cooling of molten corium and to terminate the progression of severe accident.

One experiment on coolability of molten glass in air was carried out to determine whether gap formation takes place between the vessel wall and the solidified glass and to characterize thermocouples for measurement of molten glass.

RESEARCH & DEVELOPMENT

The research and technology development activities at NPCIL were directed towards enhancement of plant safety, improvement in plant performance parameters, development for 700 MW

PHWRs / indigenous LWRs systems & equipment encompassing indigenous products development for import substitution, establishment of experimental facilities for validation of new design / safety studies, establishment of equipment qualification facilities, remote tooling and support to generating stations for in-service inspections and repairs to ensure higher capacity factors and lower man rem, technology development for construction time minimization for NPCIL projects.

Specific technology development activities at NPCIL included Hydrogen Recombiner Test Facility, Integrated Test Facility, LOCA facility, Fuelling Machine Test Facility, Remote Tooling, Indigenization of Self-Powered Neutron Detectors) etc. Electronics systems included development of Hardwired Safety Systems Electronic Modules for

NUCLEAR POWER PROGRAMME : STAGE I



Successfully developed indigenous 3-pitch integral Self-Powered Neutron Detectors (SPNDs) for 700MW Project along with panel for in-pile testing at TAPS-4

700 MW Projects, Hardware Modules for Computer Based Systems for 700 MWe Projects, etc.

R&D relating to PHWR

For developing new methodology for detection of Garter spring by ultrasonic technique, data was acquired in TAPS-4 from I/D measurement ultrasonic probe and time frequency analysis was carried out to ascertain the presence of garter springs. Asymmetric PHWR pressure tube ballooning experiments, simulating stratified coolant channel during severe accident scenario, were conducted at different pressures.

For developing alternate fabrication routes to improve the resistance to reactor dimensional changes of the PHWR pressure tube, laboratory scale deformation studies were carried out at Trombay to generate processing maps on cast Zr-2.5

Nb ingot by compression tests over a wide range of strain rate and temperature. This work was extended to other thin walled nuclear structural components.

In-Service Inspection of coolant channels was carried out using BARCIS (BARC Channel Inspection System).



Fuel pin Simulator

As per the MoU between NPCIL and BARC for the development of BARCIS for 540MWe PHWRs, BARCIS 540 was developed and commissioned at TAPS 3&4 in April 2011. Operator training programme for site O&M personnel was also carried out. The system was deployed for in-service inspection of 20 coolant channels of TAPS-4.

150NB SS 304L pipe loops & 150NB CS(SA106 Gr.B) pipe loops for performing Shake table testing of fabricated piping components, including welds at different levels of seismic excitations, were fabricated

Analysis of sliver samples of pressure tubes received from KAPS-2 and RAPS-3 were carried out and the deuterium contents were found to be within limits, thus ensuring continued safety of the coolant channels of these reactors. To ensure coolant channel safety, detailed metallurgical evaluation of

NUCLEAR POWER PROGRAMME : STAGE I



BARCIS 540 Drive Mechanism



BARCIS 540 Inspection Head with Special Sealing Plug

irradiated garter springs of KAPS-1 PHWR after 8.5 Effective Full Power Years (EFPY) operations, was carried out. All the springs withstood the stretch test under load and crush tests thereby confirming their integrity and good in-reactor performance.

A number of feeders removed from service from RAPS-2 and NAPS-1 were examined.

During a Loss Of Coolant Accident (LOCA), there is a possibility of ballooning of fuel cladding due to internal pressure of fission gases in the fuel element. Towards this high



Ballooning of fuel pin : A fuel pin that was subjected to impulse heating to around 1200 deg Celsius

temperature ballooning and deformation, data were collected by BARC by carrying out experiments on PHWR fuel pins

NUCLEAR POWER PROGRAMME : STAGE I

with different internal pressures. Failure analysis support was given to NPCIL for about 10 components of reactors.

An analytical methodology for quantification of various metals in zirconium matrix by ICP-MS was developed for a precise analysis at ultra trace levels with small sample size. Determination of H/D content in deuterium charged Zr-2.5% Nb-alloy was carried out employing hot vacuum extraction quadrupole mass spectrometer system to assess the life time of pressure tubes along with the feedback on the means of preventing such failures.

R&D relating to LWR

A Boat Sampling System for cutting metal samples from core shroud of TAPS for metallurgical analysis and assessing mechanical properties of the core shroud, was designed and fabricated. This provided the information about integrity of the core shroud with respect to radiation assisted intra-granular stress corrosion cracking.

A novel approach was undertaken to evaluate the extent of radiation-induced segregation in austenitic stainless steels. Electrochemical Potentio-Kinetic Reactivation Test followed by atomic force microscope

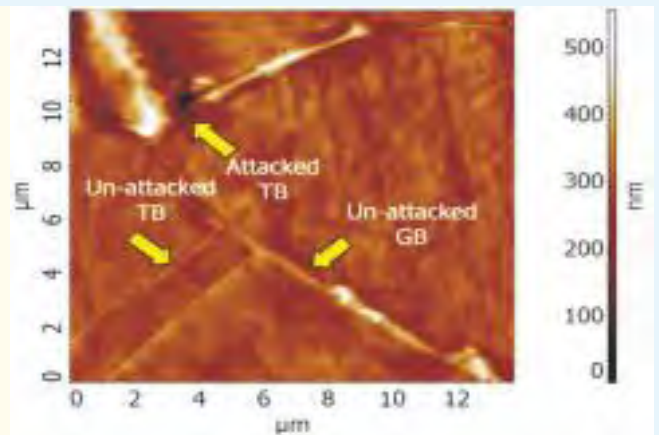
examinations, were used to evaluate the extent of the radiation induced segregation.

Software for analyzing the gamma radiometry data for characterization of fuel for quality control of fuel pins of Light Water Reactor (LWR), was developed.

Indigenously designed Beta Gaseous Activity Monitors along with Interface units, were developed at Trombay, and four such units were delivered for use in LWR. A networked Radiation and Gas Monitoring System for LWR consisting of 28 types of 125 deliverable units was designed and prototyped.



*Hot Vacuum Extraction-Quadrupole
Mass Spectrometer*



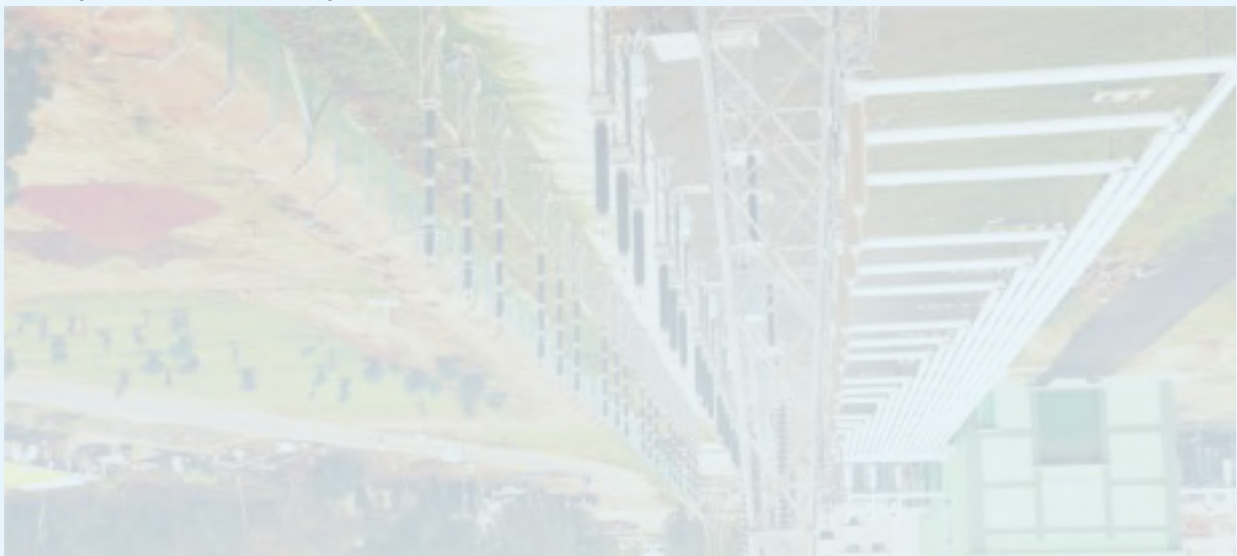
*Radiation Induced Segregation
study on austenitic steel*

CHAPTER : 2

NUCLEAR POWER PROGRAMME : STAGE - II



Switchyard commissioned by BHAVINI





Glove box adapted TG analyser for Pu-fuels

CHAPTER : 2

NUCLEAR POWER PROGRAMME : STAGE II

FAST REACTORS

Fast reactors are the mainstay of the second stage of the Indian Nuclear Power Programme. 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 and instrumentation. BHAVINI, a public sector company of DAE, was incorporated on 22 October, 2003 at Chennai, Tamil Nadu, as a Special Purpose Vehicle, for implementing India's first prototype 500 MW 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

Located 500m south of the existing Madras Atomic Power Station at Kalpakkam, the Prototype Fast Breeder Reactor (PFBR) is a pool type reactor that uses mixed oxide of uranium and plutonium as fuel and liquid sodium as coolant. During the report period, the civil construction of Nuclear Island buildings was completed. The Nuclear Island houses 17 buildings, out of which 8 buildings namely Reactor Containment Building, Steam Generator Buildings (2Nos), Electrical Buildings (2Nos), Control Building, Radioactive Waste Building and Fuel Building are connected together as a single structure on a common raft, and is called Nuclear Island Connected Buildings (NICB). Surrounding the NICB, the other safety related structures were also completed. The Reactor Vault is the critical civil structure in PFBR which houses all the reactor assembly components. The erection of Safety Vessel, main vessel in Reactor Vault & Thermal Baffle, Grid Plate integrated with primary pipe inner vessel inside main vessel was completed earlier. The erection of Roof Slab and integration with main vessel was completed. Roof Slab supports various components and forms as a top cover for the

Reactor Vault. Roof Slab is a box type structure made of carbon steel plates of diameter 12m with a height of 1.5m interconnected by radial stiffeners and cylindrical shells for the various component penetrations. The fabrication of Roof Slab was completed at the site assembly shop and was erected inside the reactor vault after completion of several mock-ups. The welding of the Roof Slab (Top shield of Reactor) with reactor main vessel was also completed.

The roof of reactor containment building was concreted and 280/85 Ton Electric Overhead Traveling (EOT) crane in Reactor Containment Building was commissioned.

The civil structural works of Steam Generator Building-1&2 was completed and 4 Steam Generators were erected in position. The entire quantity of sodium was received at site and transferred to sodium storage tanks.

The entire civil structural works of Electrical Buildings-1&2 were completed and the 6.6kV switchgear panels and Batteries were erected.

Pre-commissioning works for commissioning of 6.6kV switchgear systems were continued. Four Diesel Generator sets were erected in the Diesel Generator Building and pre-commissioning works were in progress.

NUCLEAR POWER PROGRAMME : STAGE II



Roof slab erection & Integration with Main Vessel

Construction of Fuel Building was completed and erection of fuel handling components commenced. Construction of Radioactive Waste Management building and on-site fabrications of effluent treatment tanks was also completed.

Sea water outfall channel was fully completed and the seal pit inlet and outlet were constructed. The 50m deep vertical onshore outlet shaft for sea water intake, horizontal tunnel (length 565m), and the concrete lining works inside the tunnel were also completed.

The caisson for offshore

vertical shaft was lowered into the sea bed and was made stable. The caisson has reached hard rock level.

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 Turbine Building reached its final top elevation and the roof sheet fixing works made progress. Structural completion of Raw-water & Fire-water pump house, DM plant, Auxiliary Boiler plant was completed and equipment erection works were in

progress. Commissioning activities for DM plant was commenced.

Civil construction of the open Raw Water Reservoir was fully completed and water filling in the reservoir was done. In the Sea Water Pump house, the entire raft was completed and erection of large diameter buried piping made progress.

The construction of 220kV Indoor Switchyard GIS Building was completed and commissioned. The entire 13 bays of switchyard and associated Station Transformer, Generator Transformer and SCADA

NUCLEAR POWER PROGRAMME : STAGE II



Steam generator erection

supervisory protection system were fully commissioned through MAPS tie line. 230kV double circuit line from BHAVINI switchyard to Sirucheru was energized.

Manufacture of major components was completed and these were delivered to the site.

The project has achieved an overall physical progress of over 81%.

RESEARCH & DEVELOPMENT FOR FAST REACTORS

Fast Breeder Test Reactor (FBTR)

Seventeenth irradiation campaign of FBTR was completed. The systems intended for detection of failed fuel, performed as expected.

Eighteenth campaign was started for the production of ^{89}Sr from Yttria and test-irradiation of natural U+Zr sodium bonded metal fuel. Both these campaigns marked major milestones for FBTR with the maximum power of 20 MWt and the peak linear heat rating of the Mark-I driver fuel at 400 W/cm. Turbo generator was rolled and synchronized to the grid, developing a power of 3.9 MWe. High temperature fission chamber, developed by BARC for PFBR was tested at various power levels upto a maximum of 10 MWt at a temperature of 673 K.

Periodic safety report was submitted to AERB for relicensing of FBTR. As recommended by safety authorities, leak test of reactor containment building was carried out. Result of the test carried out ensured the integrity of the containment.

Biennial surveillance of internal inspection of reactor vessel using the periscope was completed with reactor vessel in partially drained condition.

Towards understanding the anomaly observed in core monitoring temperature, various thermal hydraulics analyses were performed.

The current power campaign of FBTR was in progress with hybrid core comprising Mark I, Mark II and MOX subassemblies. As a part of this activity, inadvertent withdrawal event of one of the control rods was analyzed and ensured that when this event happens at power level



Switchyard commissioned by BHAVINI

NUCLEAR POWER PROGRAMME : STAGE II



Internal inspection of reactor using periscope

varying from a few kW to maximum power level of 22 MWt, four automatic SCRAM parameters are available to trip the plant safely without exceeding the design safety limits.

A special subassembly was used for irradiation experiments on various structural materials in FBTR. As material irradiation is planned at higher temperatures for high neutron doses, the maximum burnup that the subassembly can withstand under various conditions, were identified.

R&D relating to PFBR

Performance qualification of inflatable seals, seismic qualification of components manufactured by various industries, development of in-service inspection techniques for the reactor assembly components and addressing the safety issues related to sodium were the main

PFBR related R&D activities pursued at IGCAR. Publications on design and technology aspects of PFBR were continued. The feedback of design, manufacturing and erection activities were compiled for taking into account during the design of future 500 MWe FBRs.

Seismic qualifications of various control panels and extended stem frozen seal sodium valve, were carried out.

Based on thermal hydraulics and structural mechanics analysis, the performance of delayed neutron detector in hot pool was ensured without any risk of gas entrainments. The sodium flow rate to source subassemblies and its blockage detection by core monitoring thermocouples were established. The length of the ultrasonic device under sodium scanner attachment to be provided on the shielding subassemblies was finalized. The effects of inter-wrapper flow and secondary

sodium loop capacity during safety grade decay heat removal by natural convection were quantified by developing models.

Compact jet breaker devices for absorber rod drive mechanisms were identified for effective mitigation of free surface sodium velocity within the control plug and for avoiding argon gas entrainment into sodium. Safety analysis of spent fuel storage bay for prolonged duration of station blackout was completed. Operating temperature of bearing for transfer pot of inclined fuel transfer machine was established.

After the successful commissioning of integrated top shield test facility, experiments were carried out at IGCAR and the characteristic thermal behaviour of the assembly was derived.

A dedicated test setup for study of science of sodium fire was built and a test for understanding burning of single sodium particle was carried out. Experimental studies were made to investigate the effect of oxygen depletion on sodium fire.

A benchmark test for understanding the physical, chemical and thermal consequences of sodium spray fire-concrete interactions was carried out.

A facility for experimentally simulating various phenomena involved in molten coolant interactions resulting from a severe accident scenario was commissioned.

NUCLEAR POWER PROGRAMME : STAGE II

Advanced components for PFBR

Electromagnet assembly with eddy current position sensor diverse safety rod drive mechanisms, machining of cushion pad for PFBR CSRDM piston and guide tube and guide roller bracket of transfer pot, were carried out. One fourth Model of PFBR Inner Vessel was manufactured successfully.

Besides, manufacture of additional inclined fuel transfer machine, five steam generators, four intermediate heat exchangers, seven large & small rotatable plugs, seven cold traps, fuel handling equipment and around 2700 metric ton of materials for turbo generator system, were completed and delivered at site. Performance testing of two secondary sodium pumps was completed and the pumps were received at site. High temperature testing of additional inclined fuel transfer machine in

air was also completed successfully.

R&D for Future FBRs

At IGCAR, the reactor assembly components of commercial fast breeder reactor were conceptualized and detailed analytical investigations covering the structural mechanics and thermal hydraulics aspects were completed. Based on the analysis, optimization of the shapes of various components was carried out and optimum thicknesses were arrived at. Further, thermal management including the insulation of top shield component was studied and optimized. This exercise paves the way for beginning the detailed design of commercial fast breeder reactor.

The layout of component handling equipment in fuel building and decontamination

buildings for twin units of commercial fast breeder reactor was arrived based on the experience gained during PFBR design and construction phases.

To enhance the overall reliability of the reactor shutdown system, stroke limiting device was designed and manufacturing of the device was taken up.

Towards total indigenization for future FBRs, development of large diameter bearing (of size 4.6 metre in diameter) was taken up. The challenges faced during the manufacture were overcome successfully.

Boron Enrichment plant had developed the technology for production of 65% enriched ^{10}B required for PFBR. The plant also achieved 91% enrichment in ^{10}B and thus demonstrated the technology for the first time. The technology developed for production of boron enrichment, using fine resin, was transferred to



*Machining of guide roller
bracket of transfer pot*



*1/4th Model of
PFBR inner vessel*

NUCLEAR POWER PROGRAMME : STAGE II



Vacuum hot pressed B₄C disc



Augmentation of Boron Enrichment Plant

Heavy Water Board, Manuguru.

At Trombay, vacuum hot pressed natural B₄C disk of 200mm diameter x 5mm thickness and of near theoretical density was prepared as a first step to fabricate similar type of product to meet the requirement of Joint BARC-ILL France. Several thousand pellets of enriched (65%) ¹⁰B₄C pellets were produced for PFBR applications.

Thermal Hydraulics, Component Testing and Validation

In PFBR, primary pump flow is measured using Eddy Current Flow Meter (ECFM) installed in a bypass line from pump discharge to suction. Eight ECFM probes, indigenously developed were calibrated in sodium at various

temperatures and the relation between Output voltage versus flow rate was established.

Experimental studies were conducted to understand flow through inter wrapper space. Decay heat generation in the core and heat removal by decay heat exchanger was simulated.

The Thermal Shock Test Facility, a test bed to qualify critical components of the PFBR shutdown systems, was commissioned at Kalpakkam and about 750 shock cycles were completed.

A 23.4 metre high and 23 ton in weight transfer arm is the in-vessel Fuel Handling Machine of PFBR. Testing of the machine in air was successfully completed.

As a part of development of oil-less bearings and seals for centrifugal sodium pumps of

future FBRs, design and testing of ferro fluid seal was taken up.

Inclined Fuel Transfer Machine is the ex-vessel fuel handling machine of PFBR to remove spent subassemblies from the reactor vessel and also for loading of fresh subassemblies into the vessel. Air testing of the machine was completed and in-sodium testing was at planning stage.

Steam injection experiments were carried out by IGCAR in sodium water reaction test facility to evaluate the wastage resistance of steam generator tube material in the event of a sodium water reaction.

Steam Generator Test Facility

The Steam Generator Test Facility was operated and tested to demonstrate the endurance and



Eddy Current Flow Meter sensor for PFBR Pump

NUCLEAR POWER PROGRAMME : STAGE II



Transfer arm lifting a subassembly

robust design of the sodium heated once-through steam generator for the Indian fast breeder reactors. The test validated the excellence in manufacturing and quality assurance of the steam generator. Flow induced vibration of steam generator tubes were also measured.

Control systems & sensors

Ten electrochemical hydrogen metres to be installed in PFBR, were fabricated, assembled and tested.

A proton exchange membrane fuel cell based hydrogen management facility was successfully used for safe removal and accounting of hydrogen released during regeneration of model cold trap.

The regeneration campaign demonstrated the safe management and accounting of hydrogen.

The fuel handling operations

of PFBR is carried out offline when reactor is in shutdown state. 3D animation of entire fuel handling operation is of immense help to the operators. For this purpose, 3D modeling, assembly and animation of various subsystems of fresh fuel subassembly handling, spent fuel subassembly handling and in-vessel handling of subassembly, were completed at IGCAR.

As a part of the development of systems related to safety for PFBR, dual VME system with switch over logic based instrumentation & control systems for primary sodium, supervision systems for reactor & fuel handling startup, discordance for control rods & SCRAM signals and alarm generation were developed. The technology was transferred to ECIL for manufacturing and the systems were shipped to BHAVINI.

The control systems developed for control & safety rod and



Hydrogen management system for model cold trap re-generation

NUCLEAR POWER PROGRAMME : STAGE II

diversified safety rod drive mechanisms, transfer arm, inclined fuel transfer, were under advanced stage of testing at IGCAR.

The instrumentation and control systems related to non-nuclear safety for PFBR, were received after fabrication at ECIL. A state-of-the-art distributed digital control system was developed for PFBR to interconnect safety critical, safety related and non safety I&C systems to the plant computers and in turn to operator display stations mounted on control room panels and console, through fiber optic LANs.

The hardware modules for the hardwired and computer based systems were designed.

In the fast reactors, due to high power density and higher operating temperatures, continuous monitoring of the core cooling is essential. As large number of temperature signals are

to be monitored and calculations are to be performed to detect plugging, a real-time computer based system was employed. The required software was qualified by rigorous testing, independent verification and validation.

Indigenous design and development of application specific integrated circuits was undertaken at IGCAR. As a first step, error detection & correction logic for memory and glue logic for VME bus input output card was designed, developed and fabricated.

Process disturbance analyzer, a specialized system for detecting, recording and analyzing disturbances occurring in a nuclear power plant was developed to acquire important plant parameters at a faster rate.

Reactor Safety

Conceptual physics design of a 320 MWt test reactor with U-Pu-

6%Zr metallic fuel, envisaged to provide full-scale testing of fuel sub-assemblies planned for the 1000 MWe commercial power reactor, was completed. Absorber rod withdrawal end of life analysis for Phenix reactor was carried out by IGCAR.

Irradiation test capsule of ferro boron was at an advanced stage of fabrication for introduction in FBTR. Axial shield optimization studies were carried out for Commercial Fast Breeder Reactor (CFBR) with the shield materials Ferro boron & boron carbide combinations to achieve economy and much higher sensitivity for neutron monitoring.

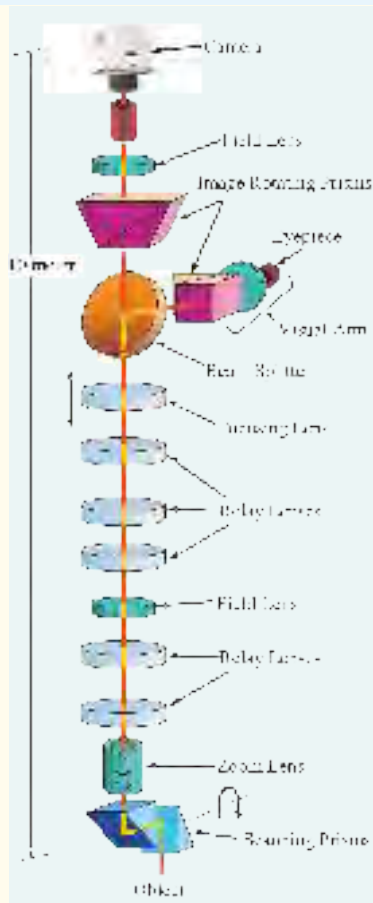
At IGCAR, final Safety Analysis Report was prepared incorporating the comments from various review groups formed by AERB.

A Neutron Flux Monitoring System (NFMS) of PFBR uses five types of neutron detectors that are integrated with mineral



Neutron Flux Monitoring detectors

NUCLEAR POWER PROGRAMME : STAGE II



Periscope for Prototype Fast Breeder Reactor

and developed as an in-service inspection instrument for the visual inspection of PFBR main vessel internals.

Radiological safety

A comprehensive health survey study was completed to assess the health status of the population living in villages within eight kilometers radius of Kalpakkam nuclear site. The survey was conducted in 22 villages within 8 kilometers of the plant and in 3 villages in Marakkanam 54 kilometers from Kalpakkam for comparison.

Continuous monitoring and archiving of background radiation levels in and around the nuclear installation is one of the essential regulatory requirements. A portable Geiger Muller detector based autonomous gamma dose logger for environmental monitoring was indigenously designed and developed.

To understand the aerosol behaviour in the reactor containment building in the event

insulated cables. The System was designed and developed to meet the seismic, environmental and

other qualifications.

At BARC, a 10 meter long optical periscope was designed



Door to door survey in progress in one of the villages



Physical test for height pass

NUCLEAR POWER PROGRAMME : STAGE II

of core disruptive accident condition of fast reactor, parameters of the sodium aerosols are to be determined to predict suspended mass concentration of aerosols, gravitational settling and wall plating. Experiments were conducted in aerosol test facility by generating Sodium and Strontium peroxide aerosols and the aerosol deposition was studied.

Training in industrial & fire safety and first-aid was provided to employees and contractors.

Environmental studies such as periodic monitoring of all coastal waters off Kalpakkam coast and other water resources within IGCAR, monitoring biodiversity & fish diversity, greenery development, sediment characterization, monitoring of air, noise and establishment of baseline data for future impact studies, were carried out.

Nutrients in coastal waters and sediments were monitored for the first time from Kalpakkam. In Kalpakkam complex, 310 species of fauna & 800 species of flora were identified. As a part of greenery development, about 30,000 trees were planted. Two monographs on Faunal Biodiversity in IGCAR and Phytoplankton in Kalpakkam coast were published.

Studies on materials for FBRs

At IGCAR, following major studies were conducted on various aspects of materials for fast breeder reactors :

- Creep properties of 316LN stainless steel structural material for PFBR in flowing sodium,
- Creep crack growth characterisation of 316(N) stainless steel weld,
- Corrosion studies in bimetallic loop,
- End plug welding of IFAC-1 (Indian Fast Reactor Advanced Cladding-1) stainless steel cladding tube,
- Improvement in type IV cracking resistance of modified 9Cr-1Mo steel weldment by boron addition and heat treatment,
- Establishment of a new relationship for constitutive analysis in hot working of modified 9Cr1Mo steel,
- Thermo-mechanical fatigue behaviour of modified 9Cr-1Mo steel, and
- Effect of loading rate on ductile-brittle transition temperature by reference temperature and master curve approach for modified 9Cr-1Mo steel.

Instrumented irradiation capsule for experiments in FBTR

An instrumented irradiation capsule was developed to enable raising the temperature of structural material specimens kept in it, to a temperature above the reactor sodium temperature and to maintain this temperature as constant during the period of irradiation, irrespective of reactor power level.



Out of pile instrumented irradiation capsule

FBR - Front End Fuel Cycle

For the first core of PFBR, manufacture of MOX fuel pins at BARC, made progress.

Laser decontamination of MOX fuel pins for PFBR was successfully demonstrated and was in use. This decontamination system reduced the exposure to the operating personnel.

Fuel pin bird cages for transporting MOX fuel pins to Kalpakkam were fabricated as per

NUCLEAR POWER PROGRAMME : STAGE II



Bird cage for transport of MOX fuel pins is tested



Reduced uranium metal

IAEA standards.

Towards fabrication of sodium bonded metallic test fuel pin, an inert atmosphere glove box train facility was constructed and commissioned. Using this facility, six sodium bonded metallic test fuel pins were fabricated and qualified. The qualified fuel pins were loaded in FBTR core for irradiation studies.

Fine UO_2 microspheres for the fabrication of sphere-pac fuel pin were analyzed and found to meet the specifications required for the

fabrication of a sphere-pac fuel pin for test irradiation in FBTR. A mock sphere-pac fuel pin was fabricated and subjected to thermal cycling. The fabrication procedure was qualified by carrying out gamma absorptiometry.

The solidus and liquidus were experimentally measured in the U-Zr binary system over the entire range of compositions using the spot technique. An experimental set-up was developed in-house for measuring the phase transition temperatures.

In the studies on coolant, partial phase diagram of Pb-Fe-O systems was established by phase equilibration studies over a wide temperature range coupled with high temperature EMF studies.

Studies were carried out to synthesize boron from boron carbide using molten salt electrolysis. Results showed the presence of nanocrystallites embedded in an amorphous mass of boron.

A parametric study was undertaken by IGCAR that

resulted in enhanced production of the fuel pellets. In PFBR, dummy fuel and blanket subassemblies were loaded to facilitate various commissioning tests initially. A scheme was evolved for core loading.

At BARC, the total gas contents of $(\text{U}, \text{Pu})\text{O}_2$ microspheres prepared through sol-gel route were analysed successfully.

A new high temperature furnace was commissioned for the simultaneous determination of plutonium and alloying elements in Pu-alloy samples.

A comprehensive characterization programme was carried out that will be used to optimize the design and to predict the in-reactor fuel behaviour. Studies on ternary U-Pu-Zr fuel were in progress.

The candidate Cermet fuel for fast reactor is PuO_2 dispersed in U metal matrix. Cermet fuels comprising 15% and 30 volume % UO_2 (in lieu of PuO_2) dispersed in U metal powder, were fabricated and characterized.



Experimental assembly for spot-technique developed in-house

NUCLEAR POWER PROGRAMME : STAGE II



Glove box adapted TG analyser for Pu-fuels

Twelve natural U-6wt% Zr alloy slugs, meeting required specifications, were produced at Trombay and supplied to IGCAR for fabrication of test pins for evaluation of irradiation performance in FBTR, pyrochemical reprocessing studies and for molten metallic fuel-coolant interaction studies.

Uranium rod of 12mm diameter x 1200mm length was cast using continuous casting set up. Necessary modifications were progressing to get higher length and lower diameter to suit requirement of FBR. Glove box for duplex swaging machine was commissioned and trials were carried out.

FBR- Back End Fuel Cycle

Fuel reprocessing is an important link for the success of fast reactors. The FBTR spent fuel reprocessing in the CORAL facility provided the much needed

experience in the design and operation of hot cell facilities in fast reactor fuel reprocessing.

During the report period, the design concepts of vital equipment such as chopper, dissolver, centrifugal extractors etc., were validated at IGCAR. Many campaigns were carried out

successfully and the product was re-fabricated into fuel.

As a part of the comprehensive in-service inspection of fast reactor fuel reprocessing plants, a tethered remote controlled vehicle with an on-board camera was designed and deployed for inspection of the CORAL waste vault for assessing the integrity of the vault, waste farm tanks, drip trays and the sump by visual examination.

The Demonstration Fast Reactor Fuel Reprocessing Plant (DFRP), represents the vital link between the pilot stage, CORAL and commercial fast reactor fuel reprocessing plants.

DFRP reached an advanced stage of construction. Safety review of the plant by AERB was in progress.

A remote sampling system was successfully developed. The system was augmented with modular features for remote

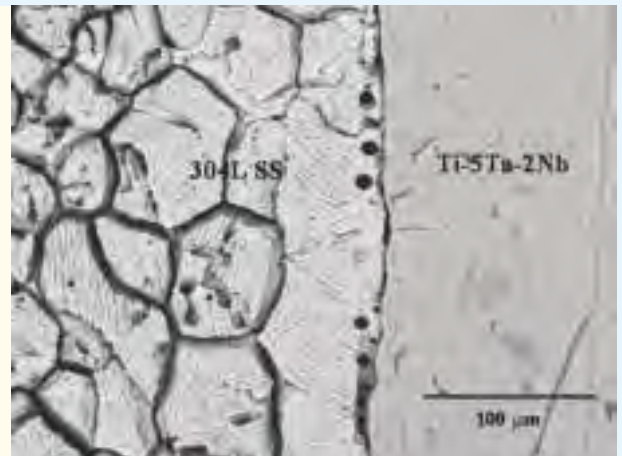


Sampling handling robot

NUCLEAR POWER PROGRAMME : STAGE II



Mixer-settler facility used for flow sheet development studies with TiAP for fast reactor fuel reprocessing



Microstructure of explosive clad exposed to liquid phase of nitric acid

maintenance using in-cell crane and master-slave manipulator of the sampling cell. Dedicated application-specific software was also developed with complete security features. The system was installed in a mock-up cell for training of operators.

A 16-stage ejector mixer-settler housed in a double-module glove box for flow sheet development studies, was commissioned to demonstrate the feasibility of using tri-iso-amyl

phosphate (TiAP) as an alternate extractant to TBP in fast reactor fuel reprocessing, with conditions simulating the PUREX process.

High performance separation technique was demonstrated for the rapid separation of lanthanide fission products and actinides, using a monolith based support. Supercritical fluid extraction technique was demonstrated for the recovery of plutonium from polymeric waste matrix.

Corrosion studies carried out at

IGCAR included corrosion studies in dynamic nitric acid loop; Corrosion studies on materials for pyrochemical reprocessing, Mechanical property evaluation and corrosion assessment of explosive clad 304L stainless steel and titanium-5% tantalum-2% niobium alloy.

Pyrochemical method based on molten salt electrorefining process is considered ideally suited for reprocessing spent metallic fuels. Studies of the



Uranium metal ingot



Strontium-89 produced by irradiation of yttrium pellets in FBTR

NUCLEAR POWER PROGRAMME : STAGE II

different important process steps in the flow sheet for the uranium based fuels were carried out in the engineering scale demonstration facility.

Studies were being carried out to understand the underlying mechanism of reduction of UO_2 to uranium by direct oxide electro-reduction method in molten LiCl (923K) and CaCl_2 (1173K) media.

Two irradiation capsules were fabricated with yttrium oxide pellets loaded in quartz tube for irradiation and production of ^{89}Sr isotope in FBTR.

^{89}Sr is used as a palliative medicine for the treatment of terminal cancer patients.

Waste Management

Iron phosphate glass is a promising matrix for the fixation of radioactive elements. A systematic study was carried out

on the crystallization of Iron phosphate glass and cesium loaded Iron phosphate glass on heating under inert atmosphere.

Apatites are considered to be suitable solid host matrices for immobilizing metal chloride wastes generated from pyrochemical reprocessing of metallic nuclear fuel.

R&D for Reprocessing

To improve the reliability of the drive motors of centrifugal extractors, the existing motors were modified with improved power and corrosion resistance, and were installed in CORAL facility at Kalpakkam.

A semi-continuous dissolver system was designed for plant scale reprocessing of fast reactor fuels.

To ensure safe operation, red-

oil formation has to be avoided in the fuel cycle facilities by a careful combination of several independent measures. TiAPred-oil was synthesized and characterized by instrumental analysis.

To protect the aluminium components from the attack by nitric acid vapour in the manipulators of CORAL facility, PEEK-alumina composite coating based on liquid dispersion was developed and the properties were measured.

Fast Reactor Fuel Cycle Facility

Detailed design of the Fast Reactor Fuel Cycle Facility (FRFCF) to close the fuel cycle of PFBR, continued. The work was piloted by IGCAR with technical support by BARC and NFC. A preparatory project for development of site infrastructure and



Fast Reactor Fuel Cycle Facility Project

engineering of FRFCF was nearing completion. Approval of AERB for the site of FRFCF was obtained. Basic infrastructure was created at the site to reduce the lead time required to commence the construction work once the financial sanction for FRFCF Project is issued. Review of the preliminary safety analysis report by the Project Design Safety Committee for FRFCF and specialist working groups was in progress. Detailed Project Report for FRFCF was prepared and project proposal is in process for obtaining financial sanction.

Inspection Technologies

Following innovative developments were achieved in

the field of Inspection technologies:

- A new method for determination of orientation of under sodium ultrasonic scanner.
- Eddy current technique for detection of Helium bubbles in sodium bonded metallic fuel pins.
- New methodology for accurate sizing of small surface opening defects.
- Acoustic emission and thermography studies during hydro-testing of stainless steel pressure vessels.
- Development of magnetic flux leakage technique for condition monitoring of steel

ropes

- Post-irradiation examination of FBTR nickel reflector subassembly.
- Fractographic examination of mechanically tested irradiated clad specimens, and
- Development of compact special purpose Computer-Numerical-Control (CNC) tensile testing specimen preparation machine for hot cells

CHAPTER : 3

NUCLEAR POWER PROGRAMME : STAGE - III



A test bench used to characterize Low Energy Beam Transport System.





Advanced Heavy Water Reactor Type (Th-Pu) MOX Fuel Pins

CHAPTER : 3

NUCLEAR POWER PROGRAMME : STAGE III

THORIUM BASED REACTORS

The Stage-3 of the Indian Nuclear Power Programme 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.

ADVANCED HEAVY WATER REACTOR

The AHWR design involving compartmentalized Inlet Header and Emergency Core Cooling System header and connecting compartments of both in interleaving manner was evolved. Large safety margins were achieved so as to avoid fuel failures using inherent and passive features of the reactor.

Creation of a new infrastructure called “Integrated Test Facilities, Tarapur (ITFT)” continued at Tarapur jointly by BARC and NPCIL. A 45m tall building will house Fuelling Machine Test Facility and Integral Thermal Facility for performance testing of fuelling machine in



AHWR Thermal Hydraulic Test Facility

reactor simulated condition. Fuelling Machine will be supported on a Test Carriage assembly during its testing. The test carriage was manufactured, assembled, load tested and delivered.

An experimental cluster having six AHWR type (Th-LEU) MOX fuel pins was designed and fabricated for carrying out reactor physics experiments in AHWR-

Critical Facility and for irradiation studies in Dhruva. The fuel pin has (Th-LEU) MOX pellets encapsulated in zircaloy clad tube.

The contract for Engineering Services Consultancy for AHWR was awarded. The 3-D layout was generated, and the Structural Design will be taken up after the review of these layouts.

An Air-Water Loop was

NUCLEAR POWER PROGRAMME : STAGE III



Fuel cluster

designed, fabricated and installed to study the thermal-hydraulic

reactivity feedback was used for analysis of rod withdrawal

(Th-8%Pu)O₂ fuel pins were used for reconstitution of AC-6



Isometric view of AWL



Steam drum



Tail pipes with Instrumentation

phenomena relevant to AHWR steam drum.

The coupled code system ARCH-RELAP with void

transient for AHWR. The code was modified to include the Doppler reactivity feedback.

An experimental cluster with central pin, 6-pins in first ring made of thorium (ThO₂) and 12-pins in outermost ring made of natural uranium, was irradiated in the central E5 lattice position in AHWR Critical Facility.

The AHWR-LEU equilibrium core cluster (discharge burnup of 60 Gwd/Te) was re-optimised to facilitate on power fueling. The cluster was designed to have radial as well as axial gradation of fissile content for better thermal hydraulics.

cluster and subsequent irradiation in CIRUS. (Th-1%U²³⁵)O₂ cluster for irradiation in DHRUVA was also fabricated. A number of

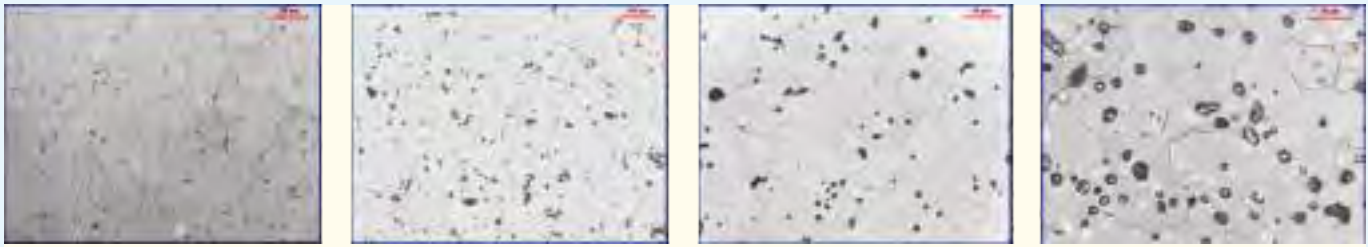


Mixed Pin (Nat. U-ThO₂) experimental cluster



(ThO₂-1%PuO₂) MOX cluster for experimental irradiation

NUCLEAR POWER PROGRAMME : STAGE III



ThO_2

ThO_2 - 4% UO_2

ThO_2 - 8% UO_2

ThO_2 - 20% UO_2

Microstructure of thoria-urania mixed oxide fuel (by cathodic vacuum etching)

AHWR type (Th-Pu) O_2 fuel pins containing varying Pu content were fabricated for experimental irradiation in DHRUVA and AHWR Critical Facility. Resistance Spot Welding process was developed for welding of AHWR spacer assembly to the central rod in the fuel assembly.

Impregnated Agglomerate Pelletisation process (IAP) for fabrication of Th-based mixed oxide fuel pellets using ThO_2 spheroids and uranium nitrate solution as the starting materials, was developed. Fuel pellets made

were characterized by optical microscopy. As a part of development of fuel for AHWR-LEU 300, trials for fabrication of ThO_2UO_2 pellets with different UO_2 contents were carried out.

Post Irradiation Examination of experimental fuel cluster BC-8 with a variety of fuels, irradiated to a nominal burn up of 10.400 RMWd/t, was carried out. The pins were subjected to various tests.

During the report period, the Critical Facility for AHWR and 540 MWe PHWR was operated for various experiments. The experiments for measurement of moderator temperature coefficient of reactivity were completed.

Fine structure neutron spectrum measurement was carried out inside and around (U-Th) cluster loaded at core centre.

An integral experiment was carried out with one (Th-1%Pu) mixed pin cluster at centre & other five core locations towards validating the theoretical evaluations.

The On-line flux mapping system was calibrated. Use of the Critical Facility continued for testing of nuclear detectors and

irradiations of large volume samples for neutron activation analysis.

At Kalpakkam, KAMINI reactor remained in regular operation up to a maximum power of 25 kW for neutron radiography of pyro-devices, control rods, PFBR-MOX fuel pins and activation analysis of samples from users. Calibration of self-powered neutron detectors was also carried out.

At BARC, a new computer-based Integrated Control & Information System (ICIS) was

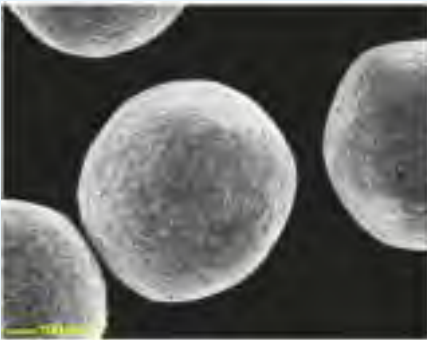


Installation of flux mapping assembly around central core location

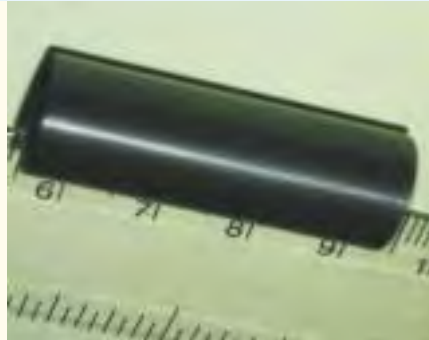


Prototype of Integrated Control & Information System for Kamini

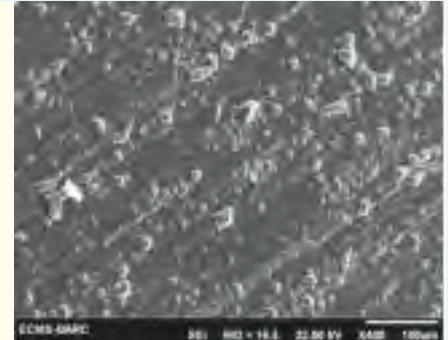
NUCLEAR POWER PROGRAMME : STAGE III



SEM image of SiC coating zirconia particles using halogen-free vapour source



SiC coating on Zircaloy-4 tube



Morphology of SiC coating on Zircaloy-4 tube

developed as a part of control and inspection up-gradation for Kamini reactor.

Thorium Fuel Cycle

Counter-current mixer settler studies on simulated AHWR feed carried out to validate batch extraction data and to compare the performance of N,N-dihexyl octanamide (DHOA) vis-à-vis tri-n-butyl phosphate (TBP) in

n-dodecane as extractants demonstrated that DHOA was a promising alternative to TBP for AHWR spent fuel reprocessing.

Based on the automation scheme developed for the fabrication of fuel clusters for AHWR, automated systems were under fabrication.

Lanthanum and cerium metal were prepared in 250 g batch by fused salt electrolysis method. Process parameters were

optimized to scale up the product to produce 1 kg metal.

The technology for coating the fuel tubes with a protective silicon carbide coating using non-toxic precursors was successfully developed and design scale-up was taken up. Halogen-free precursors were also successfully used to deposit nano-crystalline silicon carbide thin films on Zircaloy tubes to improve its oxidation resistance and on zirconia particles (as TRISO layer).

Beryllium pebbles of size 0.2-2 mm are expected to be used as neutron multiplying material in the solid breeder concept of Test Blanket Module of the fusion reactor. Beryllium pebbles produced using Rotating Electrode Process (REP) possess high purity and sphericity.

Work was in progress for installation and commissioning of a completely automated pilot scale production facility at Trombay. To meet the requirements of the Plutonium Recycle Project (PRP) at Kalpakkam, a process flow sheet for preparation of low density gadolinium aluminate material



Pilot scale Be pebble production facility

NUCLEAR POWER PROGRAMME : STAGE III

for Burnable-Poison-Rod (BPR) application was developed. The materials were characterized and found to conform to specifications. To scale up the production of low density BPR material, necessary equipment were procured and commissioned. Regular production of high density BPR material was continued to meet the ongoing PRP programme.

Other Reactor Systems

A Compact High Temperature Reactor (CHTR) uses graphite pellets containing a uniform distribution of TRISO coated particle fuels. For achieving the uniform distribution, an innovative scheme for picking up of steel balls, layering them in graphite powder precursor and pelletisation was developed. Parameters were optimised for making fuel pellets of 30%

packing density. Uniform distribution of balls inside pellet was verified by tomography. A scheme for automation for large scale production of pellets was made. CHTR fuel tubes are made of graphite. Efforts were on for fabrication of fuel tubes in single piece.

For the CHTR critical facility, design of shielding system was worked out. In order to improve safety behaviour of the reactor, the design of the down-comer system of CHTR was modified.

A reaction-bonding based joining technique was conceptualized and implemented for joining carbon based materials.

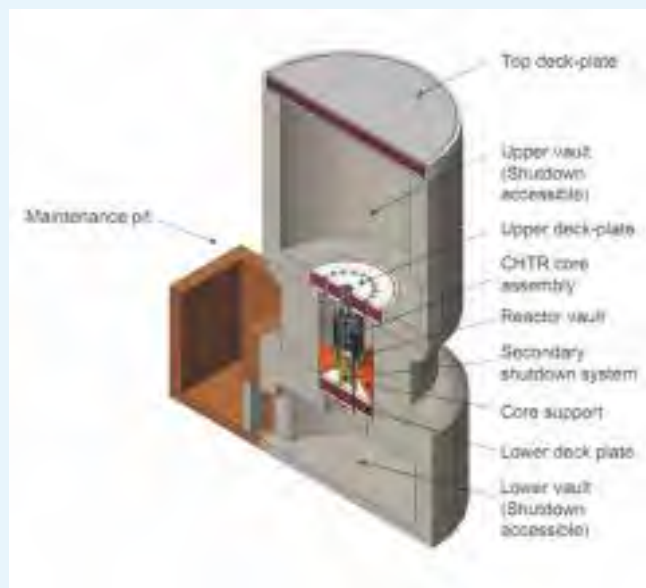
Monte Carlo simulations were done for the subcritical facility which will use Natural uranium as fuel, high density polyethylene as moderator and 14 MeV neutron accelerator as the fast neutron source. This assembly will be used for the ADS related

subcritical reactor physics experiments.

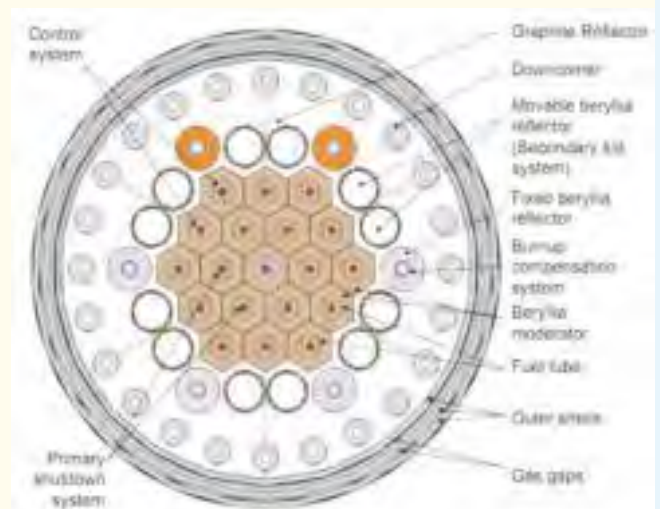
Hydrogen Energy

A Compact Prototype Electrolyser Plant was developed for demonstration of a large scale hydrogen generation ($10 \text{ NM}^3/\text{hr}$) unit for hydrogen energy programme. The system was designed, fabricated, installed and tested for its performance. The plant was successfully commissioned. Product purity better than 99.99% was achieved during the operation.

Sulphuric acid decomposition is the highest temperature operation in the I-S process of hydrogen production. In order to enhance conversion efficiency and reduce plant costs, the doped iron oxide catalysts were developed by wet-chemical process to produce high purity chromium doped iron oxide



3-D layout of Compact High Temperature Reactor critical facility



Core cross-sectional layout of Compact High Temperature Reactor

NUCLEAR POWER PROGRAMME : STAGE III



Compact Water Electrolyser Plant

($\text{Fe}_{1.8}\text{Cr}_{0.2}\text{O}_3$) ultrafine powder in bulk (1 kg).

FUSION ENERGY

A reduced size prototype of the Indian liquid lead lithium cooled Test Blanket Module was fabricated in P91 steel. A buoyancy driven loop for lead-lithium (Pb-17Li) eutectic was setup for corrosion test of 9Cr-1Mo steel.

Forced circulation liquid metal loop were developed for

conducting corrosion studies of P91 material under liquid metals such as lead-bismuth and lead lithium. A forced circulation liquid metal loop was designed and fabricated to carry out corrosion experiment of 9Cr-1Mo steel in the presence of magnetic field.

CHAPTER : 4 | ADVANCED TECHNOLOGIES AND RADIATION TECHNOLOGIES AND THEIR APPLICATIONS



K-500 Superconducting Cyclotron with one of its external beam lines, at VECC, Kolkata





Tunable UV generation from copper vapour laser pumped dye laser beam developed at RRCAT



Helium liquefier under commissioning at Trombay



Groundnut seeds irradiated with 8.5 MeV Linac for mutation breeding experiments

An assembly of remote analytical robotic gadgets developed at IGCAR



CHAPTER : 4

ADVANCED TECHNOLOGIES AND RADIATION TECHNOLOGIES AND THEIR APPLICATIONS

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

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

In the field of radioisotope production and applications of radiation technologies these organizations have made remarkable contributions which are immensely benefiting the domains of healthcare, nuclear agriculture, food preservation and industry.

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.

During the report period, following were the major activities and achievements of DAE organizations.

RESEARCH REACTORS

APSARA

At Trombay, work on upgradation of APSARA reactor to a 2 MW reactor was in progress. Preparations for decommissioning of the existing pool continued. Design of various reactor systems of the upgraded reactor was carried out. Design basis reports were prepared and were under safety review. Procurement of various equipments & components progressed. Prequalification of vendors for the construction of civil structures, mechanical, electrical and AC ventilation systems was carried out and preparation of detailed tender and specifications continued.

CIRUS

CIRUS reactor remained in permanently shut down state and the reactor auxiliary systems were maintained in preservation mode. The reactor was completely defueled and fuel assemblies were stored under cooling. All the in-pile assemblies including shut off

rods, were removed and stored at safe storage locations as part of complete core unloading. Periodic recirculation of primary coolant and auxiliary systems was continued to preserve the systems till decommissioning is taken. A new manual "Technical Specifications for Permanently Shut down Cirus" was prepared and the same was implemented after getting required regulatory approval. Preparations for transfer of the entire quantity of heavy water in storage tanks at CIRUS to Dhruva and transfer of spent fuel from CIRUS, were progressing.

DHRUVA

Research reactor Dhruva continued to operate with a high level of safety and an availability factor of over 70%. Over 940 samples were irradiated for radioisotope production during the year. Over 200 samples were irradiated in Pneumatic Carrier Facility as per the requirements of the users for neutron activation analysis.

Dhruva continued to serve as 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 a part of reactor utilization, the following

works were carried out:

Feasibility checks were continued for production of Neutron Transmutation Doped (NTD) Silicon at Dhruva.

- A prototype fuel assembly consisting of Advanced Heavy Water Reactor (AHWR) fuel pins was installed in F-15 pile position for test irradiation. This test irradiation will be helpful in studying thorium based fuel behavior in terms of fission gas release, fuel centerline temperature, fuel pellet swelling, fuel grain growth etc. It will also provide feed material for carrying out reprocessing studies on the thorium based MOX fuel
- For fission products release kinetic studies, irradiation of Uranium-Zirconium alloy samples was carried out in Pneumatic Carrier Facility (PCF)
- New control panel of Controlled Temperature Irradiation Facility (CTIF) was made functional as a part of commissioning trials of this facility in beam hole R-3002
- For augmenting isotope production capacity to meet the increased requirements, additional tray rod for irradiation of miscellaneous samples was installed

Up-gradation of Control & Instrumentation (C&I) for Fuelling Machine-A was completed. The existing hardwired systems were in the process of upgradation to

computer based systems. A New Trombay Programmable Logic Control based Reactor Trip Logic System and an Alarm Annunciation System were developed and tested.

Replacement of the existing hardwired Fire Alarm System for Local Indication Panel-10 was carried out with new PC based system (FADAS). The heavy water leak detection system (Beetle Monitoring System) was replaced with new beetle system with additional features. Upgradation of the control and instrumentation related to Coolant Flow Monitoring System and Emergency Core Cooling System made progress.

An Iodine Monitor developed by BARC was installed at Dhruva. The monitor designed to compute integral releases as well as release rates, was provided with user interface to display energy spectrum, to plot integral releases and release rate trends, and to identify alarm conditions. A relief valve test facility was also installed and commissioned at Dhruva.

A solar water heating system (2 x 3000 litres per day) for Dhruva change room was installed and commissioned as part of a programme for energy saving and tapping non-conventional energy resources.

Fabrication of 130 fuel assemblies was completed at Trombay, and 128 Al shields and 124 SS plugs were assembled and delivered to Dhruva. For Accelerator Driven System (ADS), 162 Uranium Fuel

assemblies were fabricated and delivered. As Uranium-Molybdenum alloy can be used in manufacture of research reactor fuels for high burn up, parameters were therefore optimised for producing U and U-Mo powder. About 1kg of U metal powder and 200gm of U-Mo powder was produced and given to different users.

High Flux Research Reactor

Conceptual design of the proposed High Flux Research Reactor was carried out. The Physics design of the reactor fuelled with low enriched uranium dispersion type silicide fuel, light water coolant & moderator and a square inner shell of heavy water reflector was optimized. In addition to meeting the requirements of high specific activity radioisotopes, the reactor will also have enhanced facilities for neutron beam research, applied research related to development and testing of nuclear fuel and reactor materials, production of NTD Silicon, etc.

Fuel for modified APSARA reactor

An innovative powder processing technique was developed for the synthesis of uranium silicide with excellent homogeneity, low impurity content and intra-granular porosity to enhance in-reactor performance of the modified APSARA reactor core. A technological demonstration of



Renovated Fuelling Machine control panel



*Operator Console for Trombay-PLC-based Reactor
Trip Logic System & Alarm Annunciator*



Refurbished Panel-C of control room



Iodine Monitor



Neutron REM Monitor (NRM200)



Solar water-heating system

ADVANCED TECHNOLOGIES AND RADIATION TECHNOLOGIES AND THEIR APPLICATIONS



Uranium silicide pellets after synthesis



APSARA fuel assembly with natural uranium

the process was carried out with natural uranium for the fabrication of fuel assemblies. Two standard fuel assemblies with natural uranium were fabricated and characterized for upgraded APSARA reactor.

ACCELERATORS

In an experiment conducted by

BARC at Pelletron-linac TIFR, a thick Al target was bombarded with 115 MeV Carbon-12. The determination of neutron ambient dose equivalent was also done using the weighted average dose conversion coefficient for heavy ions ($^{12,13}\text{C}$, $^{10,11}\text{B}$ and $^{16,18}\text{O}$) interaction with thick Al target at the Pelletron accelerator at TIFR. The data generated in these

studies will be useful for radiological safety.

An experiment was conducted by BARC at Indus facility of CAT, to determine the Bremsstrahlung source term at 450 MeV using water phantoms with thermoluminescence (TLD) detectors placed inside. The data will be useful for high energy photon dosimetry in electron accelerators.

A 14 MeV Neutron Generator based on 400 keV, 1 mA (deuterium ion), radio frequency quadrupole (RFQ) accelerator was under development in BARC for various applications such as study of physics of coupled neutron sources, subcritical assembly and radio frequency coupling to accelerator.

As a prototype of the 3 MeV RFQ for the 20 MeV, 30 mA LEHIPA for ADS Programme, and a 400 keV deuteron RFQ, were under development. The 400 keV RFQ will be integrated with the test bench shortly. In order to



Experimental arrangement at Pelletron-Linac

ADVANCED TECHNOLOGIES AND RADIATION TECHNOLOGIES AND THEIR APPLICATIONS



RFQ Test Bench



RFQ Test Bench

feed RF power to the RFQ, two 50 kW power couplers were developed. Design of the 250 kW RF couplers was completed and their fabrication was in progress.

The 10 MeV, 10 kW RF Linac at Electron Beam Centre (EBC) remained in regular operation at an electron beam energy of 10 MeV and beam power 3kW. The facility was utilized for study of photo-fission, BHEL semiconductor diode irradiation

which has led to reduction in the reverse recovery time from 15 micro sec to 6 micro sec polymerization of vinyl acetate monomer into a solid polymer with 50 kilo gray radiation as well as food irradiation. A modified pierce type electron gun was developed and used, resulting in higher transmission of beam current.

The performance of indigenously developed 6 MV

Folded Tandem Ion Accelerator (FOTIA) continued to improve. Proton beam currents of upto 2 micro amp. were available for experiments. The operation of the Low Energy Accelerator Facility (LEAF) was made automated.

At BARC, a modular



RF Linac assembly at EBC First + Ground Floor View

Radiofrequency Linac assembly at EBC

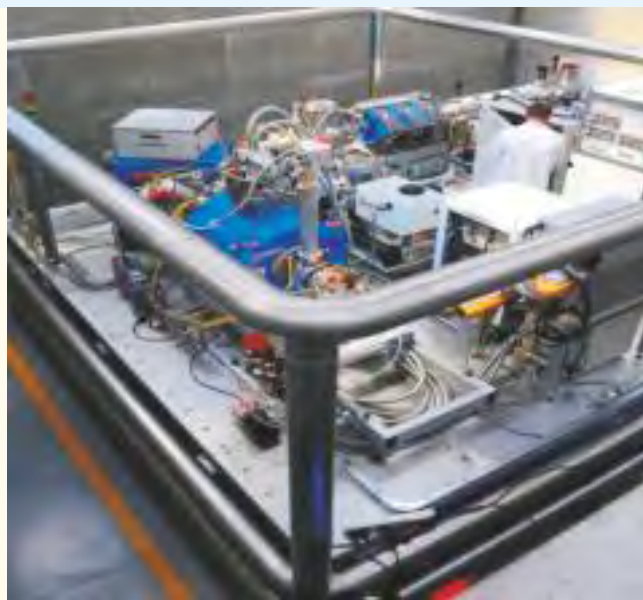


Compact RF Linac Assembly

ADVANCED TECHNOLOGIES AND RADIATION TECHNOLOGIES AND THEIR APPLICATIONS



Electron Gun Assembly



ECR Ion source under installation

Subcritical Assembly was designed for experiments related to ADS. The new design of subcritical assembly is based on metallic natural uranium as fuel, polyethylene as moderator and beryllium oxide as reflector. The proposed system is modular in design and can be scaled up easily. The subcritical assembly will be coupled to the 14 MeV Purnima Neutron Generator for experiments to study the physics of subcritical system.

An ECR ion source capable of delivering ions from H^+ to U^{34+} was under installation at BARC. It has an operating frequency of 18 GHz and RF power upto 1.7 kW and maximum extraction voltage of 30 kV. A Self Excited Loop based digital RF control system was successfully developed and tested with the super-conducting resonators of BARC-TIFR Linac. It is planned to upgrade the existing analog based RF control of cryostat

having four resonators with this SEL based RF control.

Solid State RF Amplifiers at 505.8 Mhz

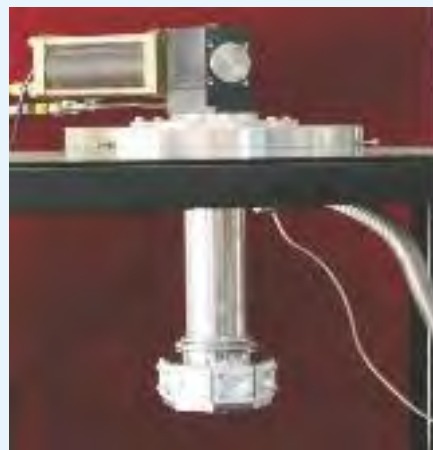
At RRCAT, under a programme to build solid state amplifiers at 505.8 MHz as a substitute for the high power klystrons of the Indus-2 Synchrotron Radiation Source, solid state RF amplifiers capable of delivering 20 kW and 30 kW RF power were designed, developed and successfully integrated with RF cavities of Indus-2. With the addition of these amplifiers and optimization of RF system operating parameters, beam energy could be increased upto 2.5 GeV at 100mA.

Cryo-technology

Performance of the indigenous helium liquefier, commissioned last year at RRCAT, was further improved to give a liquefaction rate of 10 lit/hr. About 1,000 liters

of helium was liquefied in this system.

A indigenously designed and developed Cryocooler producing a lowest temperature of 7K (-266 deg C), was installed in Photophysics Beamline at Indus-1 for Matrix Isolation Spectroscopy setup being developed by BARC and IGCAR. Six 30K cryocoolers provided to different labs in RRCAT earlier,



Indigenously designed and developed cryo-cooler with lowest temperature of 7K



*20 kW solid state
RF amplifier*



*30 kW solid state
RF amplifier*



*Two units of solid state RF amplifiers
coupled to RF station-1 of Indus-2*

ADVANCED TECHNOLOGIES AND RADIATION TECHNOLOGIES AND THEIR APPLICATIONS



*650 MHz superconducting
RF cavity forming Dies*



*Formed half cell-inside view with
inspection template also in view*

performed for more than 1000 hours each without any failure.

Forming of 650 MHz SRF cavity half-cells

Half-cell cavity forming tools for the 650 MHz, $\beta = 0.9$ superconducting RF cavities were developed. Such cavities are

required for high intensity proton accelerators.

Automation of Multilayer mirror deposition facility based on Ion Beam Sputtering

An Ion-beam sputtering (IBS) system was developed for preparing thin films and multi-

layers of various elements, alloys and compounds. Software developed in Labview automates the deposition process and checks for interlocks on vacuum and flow and then proceeds for multilayer deposition. This development achieves rapid growth, achieves high repeatability of the process and saves time.

H-ion Injector Linac Sub-systems

Ion Source Development

A prototype filament based multi-cusp H- ion source with three electrode ion extraction system was designed, fabricated and tested. It qualified trial runs of operation at 5 keV energy, generating hydrogen ions beam current of 0.78 mA.

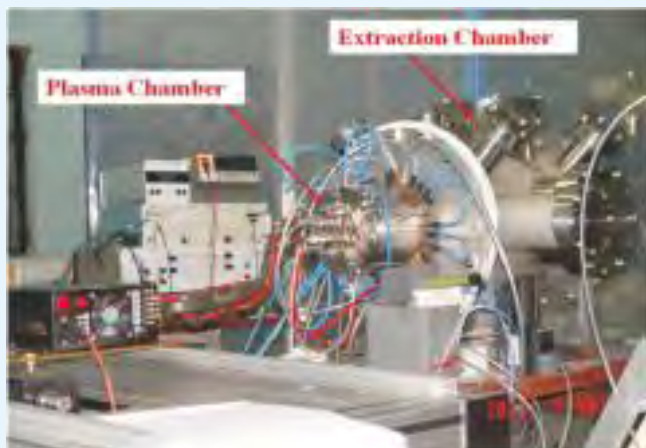
Radio Frequency Quadrupole Development

A prototype 352.2 MHz Radio Frequency Quadrupole (RFQ)



Ion-beam sputtering system

ADVANCED TECHNOLOGIES AND RADIATION TECHNOLOGIES AND THEIR APPLICATIONS



Prototype multi-cusp filament based pulsed H⁻ ion source



Hydrogen plasma formation and recorded optical emission spectra

structure was designed and fabricated to study the physics and RF design parameters. Prototype fabrication of 1st segment of RFQ structure (unmodulated) was carried out.

LASER TECHNOLOGY

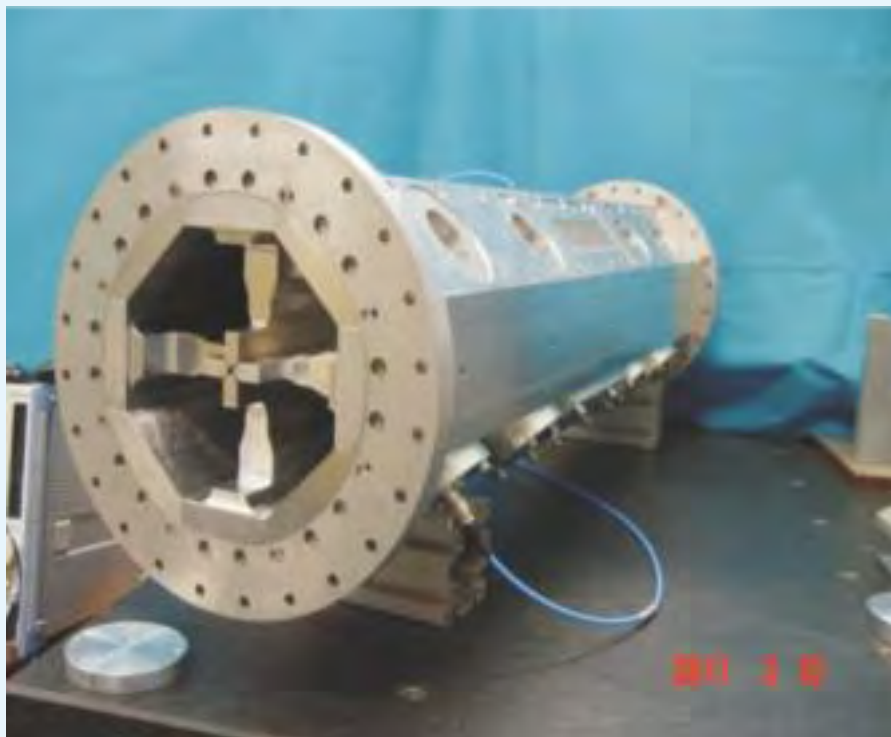
Development of tunable UV coherent radiation source based on second harmonic of copper vapour laser pumped dye laser

A tunable UV coherent

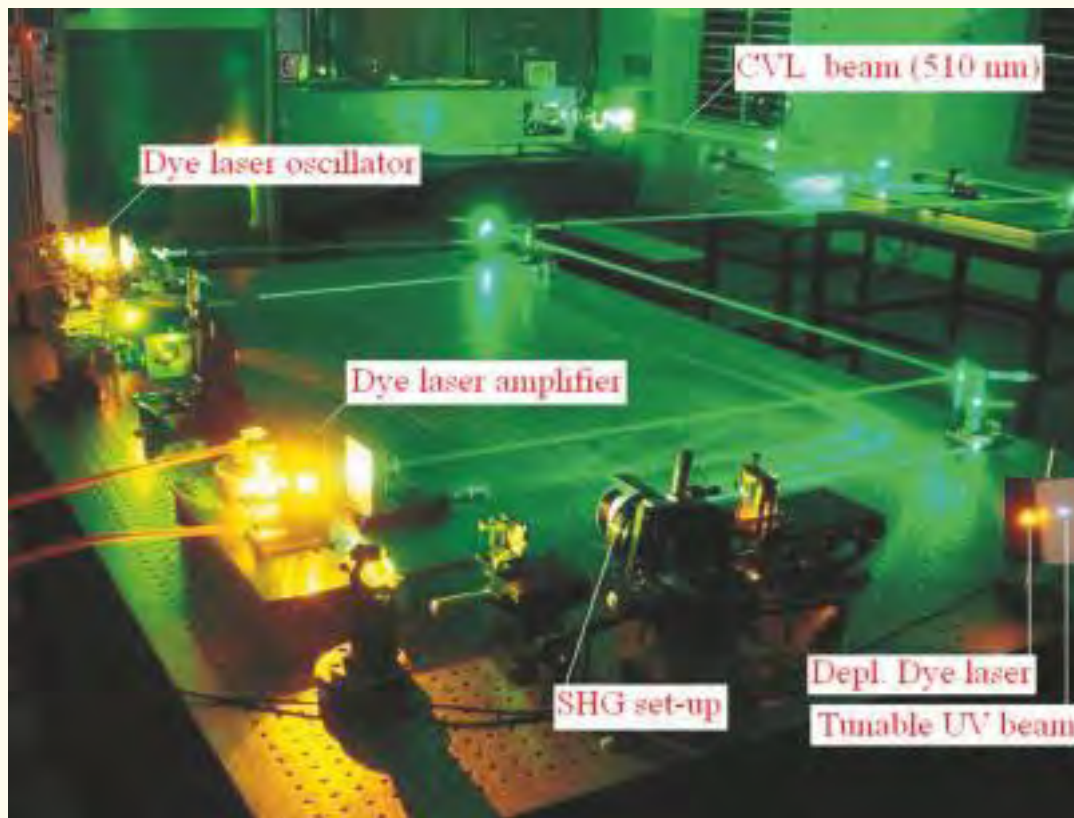
radiation source of average power ~125 mW at 5.5 kHz repetition rate was developed. By simultaneously tuning dye laser wavelength and phase matching angle of crystal, UV radiation tunable from 290 nm to 300 nm is generated. Average UV power of 125 mW in wavelength range 290 to 300 nm is obtained at a conversion efficiency of 9.6%.

Development of underwater laser cutting technique for nuclear applications

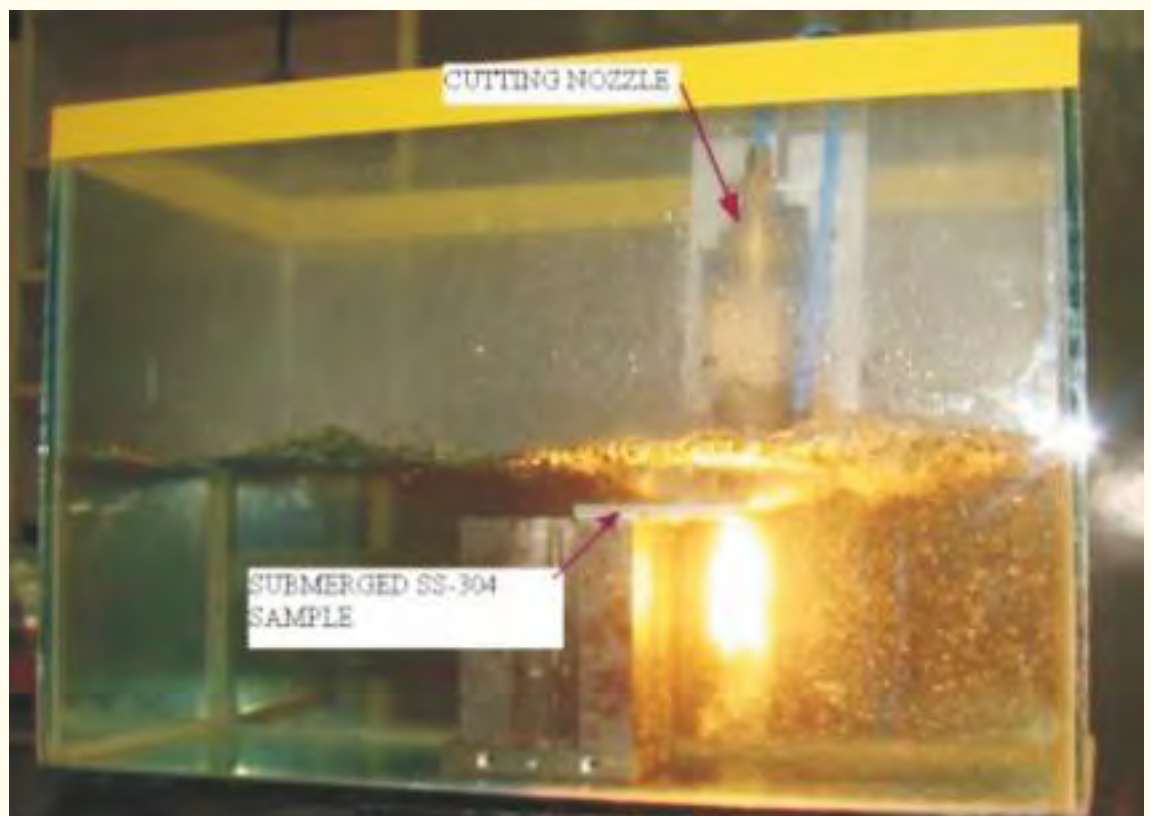
Technology and tools for underwater laser cutting of components was developed based on the 250W average power industrial Nd:YAG laser. Underwater cutting of 12 mm thick SS304 and 4 mm thick zircaloy using air and oxygen as assist gases showed 50% reduction in heat affected zone and considerable reduction in adhesion of dross to surface compared to cutting in dry air. Design of manipulators for underwater laser cutting of zircaloy pressure tubes for NPCIL



Assembled prototype first segment of Radio Frequency Quadrupole structure



*Tunable UV generation
from copper vapour laser
pumped dye laser
MOPA beam*

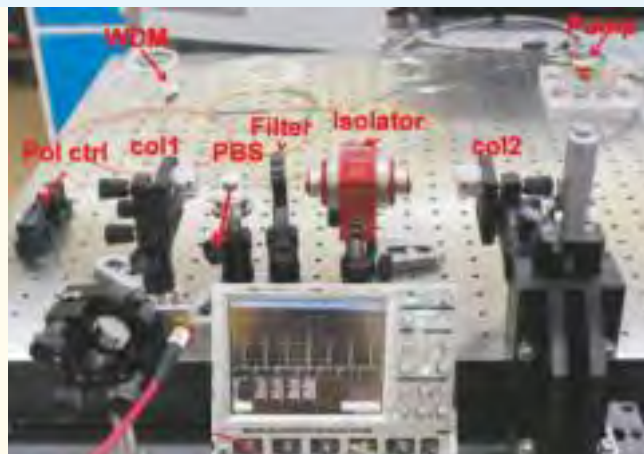


*Underwater
Laser Cutting*

ADVANCED TECHNOLOGIES AND RADIATION TECHNOLOGIES AND THEIR APPLICATIONS



*In-house developed 100 W
single transverse mode CW fibre laser*



The mode locked fibre laser

and BARC, for aluminium fuel racks in Dhruva reactor, and for cutting of irradiated Cobalt bundles for RAPP COF (RAPP Cobalt facility) is underway.

Development of 120 W CW Fibre Laser and demonstration of mode-locking operation in Yb-doped fibre laser

A 120 W single transverse mode continuous wave (CW) fibre laser based on Yb-doped gain fibre at 1070 nm wavelength

with a very high optical-to-optical slope efficiency of 64%, was developed at RRCAT. In another setup stable mode-locking operation in Yb-doped fibre oscillator in all-normal dispersion configuration was demonstrated for the first time in India. Stable mode-locked pulse train at 37 MHz was observed near threshold. At a pump power of ~300 mW about 50 mW of average power with 1.3 nJ of energy per pulse was obtained.

Development of water-cooled laser marker and Laser Radiator Unit

A compact water-cooled laser marker system was designed, tested and successfully installed by RRCAT at NFC, Hyderabad for serial number marking on the fuel elements. A trial version of an arc-lamp pumped laser radiator unit was developed for the Opto Electronics Factory, Ministry of Defence, Dehradun for missile firing block of tanks.



*Laser Marker system installed at NFC, Hyderabad
for serial number marking on the fuel elements*



*Laser Radiator Unit developed for
the Opto-Electronics Factory, Dehradun*

ADVANCED TECHNOLOGIES AND RADIATION TECHNOLOGIES AND THEIR APPLICATIONS



Dye laser Pumped by DPSS green laser beam



White light beam generation by combining of RGYB laser

Diode pumped solid state green laser and white light laser beam generation

A compact high power Diode Pumped Solid State (DPSS) green laser that uses a novel coupled cavity configuration, was developed at RRCAT. This laser, which delivers 50W of average power with less than 50ns pulse duration, was successfully used for pumping a narrow line width tunable dye laser. This laser can be an alternative to copper vapour lasers for pumping of dye lasers.

Red, Green, Blue and Yellow

(RGYB) laser was demonstrated by intra-cavity frequency doubling and frequency mixing of different laser transitions from an array of four Nd:YVO₄ lasers. The individual colours are then combined to a single beam using fibre based multiple pump combiner. By adjusting the power of the individual lasers intense continuous white light beam of ~300mW of power was obtained.

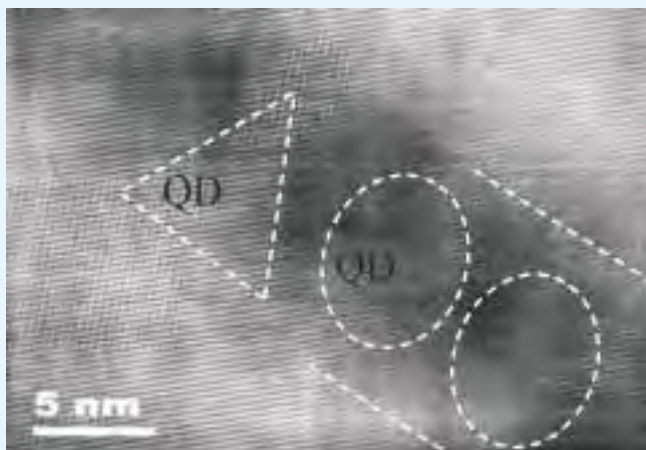
Semiconductor Laser

Two dimensional optical modeling of symmetric and

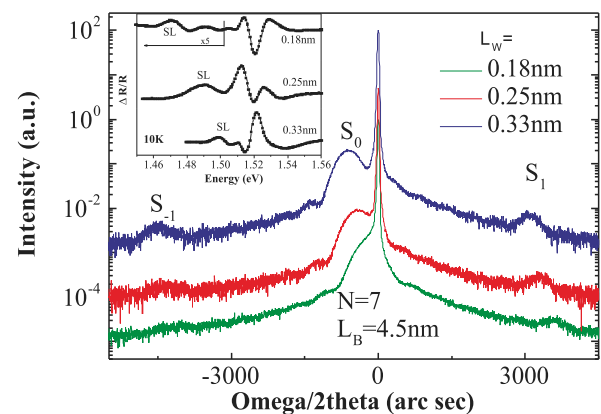
asymmetric waveguide structures at 980 nm and 808 nm wavelengths, were studied at RRCAT. Process of further optimization of photolithography, high reflection coating on laser diode facet and bonding steps were in progress to achieve high power operation under CW mode.

Quantum Dot-in-Well and Type II Structures for Infrared Detectors

New structures of Quantum Wells and Quantum Dot in Well (DWELL) that have the



TEM image of quantum dot-in-well



HRXRD and Photoreflectance of InP/GaAs Type II superlattice structures

advantage of normal incidence absorption and reduced nonradioactive losses, were investigated by RRCAT, including dot in well and type II structures.

High Resolution X-ray Diffraction (HRXRD) measurements of InP / GaAs Super Lattice (SL) structures were carried out to assess their strain status. Surface morphology of these SL structures was also analyzed by atomic force microscopy measurements.

Pulsed compressor vacuum chamber for 150 TW Ti : Sapphire laser

A vacuum chamber to house large size gratings and other optical components to set up a pulse compressor chamber for 150 TW Ti: Sapphire laser system was designed, fabricated and leak tested for an ultimate vacuum of 5×10^{-9} mbar.

For investigation of pulse laser induced photo-physics phenomena in thin films, multilayers and precision optics, an experimental setup, as shown, was established at Trombay. The system consists of a multi-harmonic Nd-Yag pulse laser and a fibre optics based pump-probe detection scheme. The setup was put into regular use to probe various optical materials, crystals, surfaces and multilayer thin film coatings, for their laser induced damage threshold factors.

An experimental set-up for coherent population trapping in Rubidium atomic gas was created. The phase coherent bi-chromatic laser field for inducing quantum interference in the excitation path was generated by high frequency modulation of the injection current of a diode laser.

A round-the-clock performance test of a high power copper vapour laser pumped dye laser

system was carried out for 60 hrs. The critical output parameters of the system such as wavelength, spectrum, and beam pointing showed excellent stability.

A programme was initiated for generation of coherent optical source in mid infra-red radiation range.

A thermal plasma process was implemented and plasma chemical reactor commissioned for UF₄ production from depleted UF₆. The first experimental run saw about 200 grams of UF₆ processed to get UF₄. The purity of the product was high.

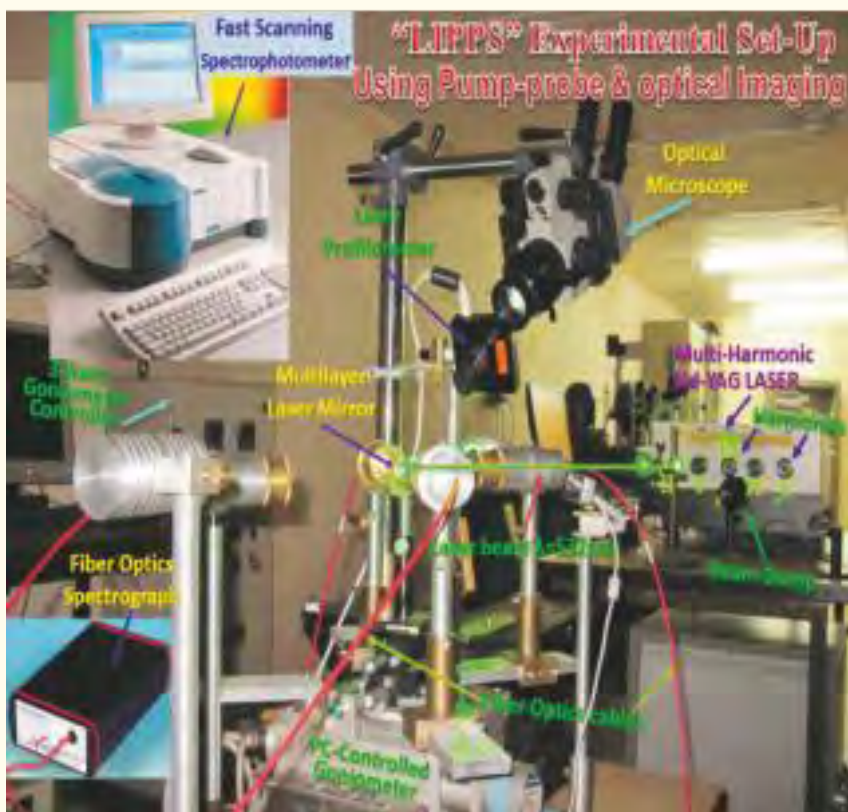
Nano-sized high purity Al₂O₃ (Aluminum oxide) is an important and critical constituent of ceramics like YAG (Yttrium Aluminum Garnet). High purity requirement, necessary for laser grade ceramics, demands electrodeless discharge to avoid electrode contamination. A system was developed for synthesis of oxide nano-powders (Al₂O₃, Y₂O₃, Nd₂O₃ etc) based on an existing RF (3MHz) plasma source. Process parameters were optimized and discharge was made stable at atmospheric pressure.

BARC successfully developed and tested hafnium based air plasma torches operating up to 40kW. A 20kV, 40kJ electromagnetic forming and welding machine was designed, fabricated, assembled and tested. The system will be used for joining of FBR clad tubes of D9 alloy with SS end plugs, and for other future applications.

A compact pulse power system



Assembled view of pulsed compressor vacuum chamber



Experimental station established for laser induced photo-physics study



Copper vapour lasers pumped dye laser system

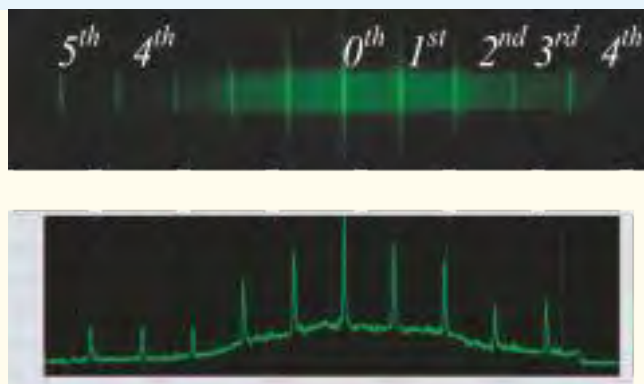


Plasma chemical reactor and the UF_4 powder collected from the bottom of the reactor



Inductive Energy Storage Pulsed Power System Machine

ADVANCED TECHNOLOGIES AND RADIATION TECHNOLOGIES AND THEIR APPLICATIONS



Capillary discharge X-ray laser system and right the spectrum of the emitted laser radiation

based on inductive energy storage and exploding wire switch was designed, and developed to generate 250kV, 300ns pulse into a matched load of 40 ohms. A maximum voltage gain of 8.5 was achieved.

Laser Applications

Demonstration of X-ray lasing

At RRCAT, X-ray lasing at 46.9 nm, in Ar^{8+} ions, in a capillary discharge plasma was demonstrated for the first time in India. A spectrum dominated by

the intense laser line and its higher orders upto 5th order, was recorded. The spatial profile of the laser beam was recorded with a micro-channel plate detector kept at a distance of 1.5 m.

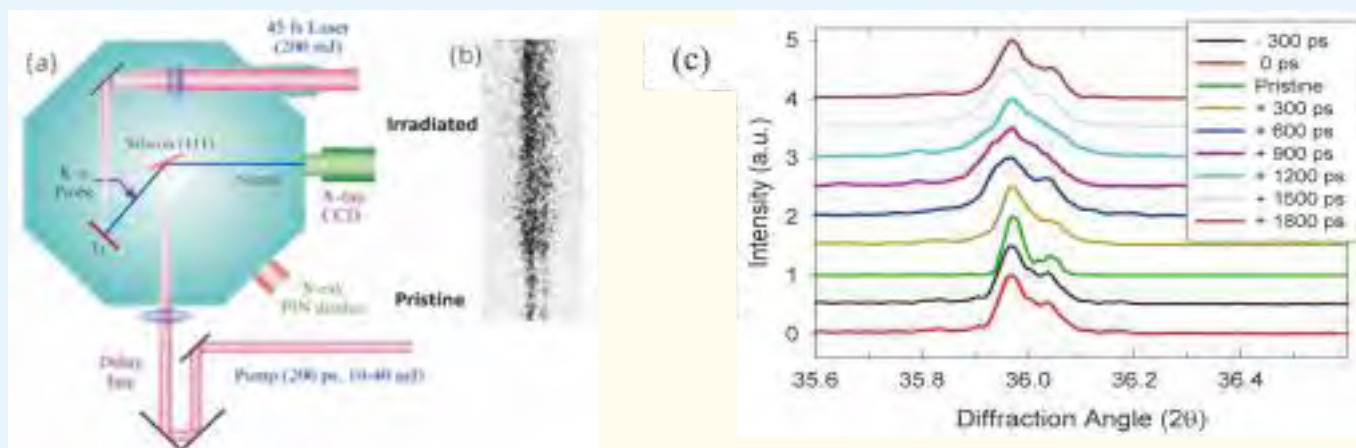
Neutron generation in interaction of ultra-high intensity laser matter interaction

Neutrons produced by D-D fusion reaction in the interaction of ultra-high intensity laser pulses focused to an intensity $\sim 3 \times 10^{18} \text{ W/cm}^2$ on deuterated polythene target, were observed. The energy

of the neutrons was measured, confirming these to be fusion neutrons. Neutrons were also generated in gamma-neutron reactions by the high energy X-rays produced in copper target impinging on Be target.

Ultrafast time resolved X-ray diffraction studies

Initial experiments on ultrafast (picoseconds time scale) time resolved X-ray diffraction study of strain propagation in laser shocked crystal were carried out at RRCAT using the Ti: Sapphire



(a) Experimental setup for time resolved X-ray diffraction studies, (b) A typical spectrum recorded, (c) Variation of the spectral profile as a function of the time delay

laser system. The dynamics of the strain propagation was inferred.

Coherence measurement of High Order Harmonics from plasmaplumes

The spatial coherence of the high order harmonics was studied using Young's double slit interference. The fringe visibility, related to coherence radius, was measured for different slit separations. It was found to decrease with increase in the harmonic order.

Development of femtosecond pulse shaping setup

As femtosecond pulses cannot be shaped in the time domain due to limited speed of electronics, the pulses are shaped in the frequency domain using a standard $4-f$ optical geometry, where f is focal length of the lens. Amplitude and phase modulation by user defined functions were demonstrated. The setup will be used to control molecular processes such as photo-emission and excited state absorption.

Biomedical applications

A near real time single mode fibre-optic based Polarization Sensitive Optical Coherence Tomography (PSOCT) setup utilizing a swept source was developed at RRCAT. The setup was used for imaging birefringence of mice tail tendon, thigh muscle ex-vivo and human nail fold in-vivo, the measurement of the refractive index of cells undergoing photodynamic



Laser cutting demonstration of thick steel

action, study the effect of low power red laser light pre-exposure on Zebrafish embryos exposed to ethanol and in vivo study of healing of wounds in mice skin.

The fluorescence and Raman spectra acquired earlier at the Tata Memorial Hospital (TMH), were used to make a comparative evaluation of the efficacy of these two approaches for screening neoplasms of oral cavity and also check the influence of tobacco consumption in the spectra of healthy volunteers.

Studies were carried out on the effect of PhotoDynamic Treatment (PDT) on infected wounds. The results obtained showed that apart from killing the bacteria, PDT also led to inactivation of virulent factors of *Paeruginosa*. It was also shown that the PDT treatment led to faster re-epithelization and ordering of collagen in

the wounds.

Development of 1 kW average power long pulse Nd:YAG laser and laser cutting technique for 23 mm thick steel

A pulsed Nd:YAG laser of 1kW average power with variable pulse duration (from 2-40 ms) and rep. rate (1-100 Hz) was developed at RRCAT for deep penetration welding of materials like Copper, Aluminium, Titanium and Stainless Steel and for cutting of thick SS components for nuclear decommissioning and in reactor maintenance operations. Laser cutting of 23 mm thick stainless steel was demonstrated.

TEA carbon dioxide Laser based Paint Stripping System

A TEA carbon dioxide laser based Paint Stripping System, providing 1.5 J pulse energy at

ADVANCED TECHNOLOGIES AND RADIATION TECHNOLOGIES AND THEIR APPLICATIONS



TEA CO₂ laser-based paint stripping system and paint stripping in progress

200 Hz repetition rate and having a robot maneuvered articulated arm with control panel was developed. Laser-assisted stripping of enamel and epoxy based paints of thickness of about 50 micrometre was demonstrated.

Machine vision system for PHWR fuel pellet inspection

A prototype machine vision based automated inspection system, was designed and developed by RRCAT in collaboration with NFC, for quality assurance of the

cylindrical fuel pellets used in PHWR. The inspection system was installed and commissioned at NFC on 1 November 2011. NFC successfully carried out inspection of about 6 lakh pellets (1000 tray).

Micro-fluidic chip for uranium sensing

A micro-fluidic chip for uranium sensing application, was designed and fabricated. The designed micro-fluidic chip was integrated with the flow tubes, excitation source and

fluorescence detection system. Testing and validation of the system was in progress.

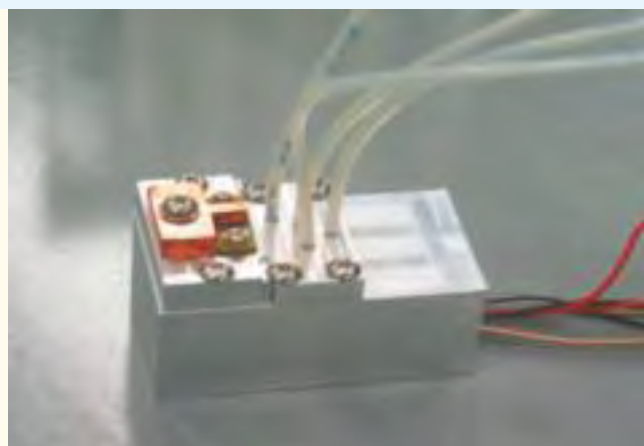
SPECIAL MATERIALS

Synthesis of lithium titanate

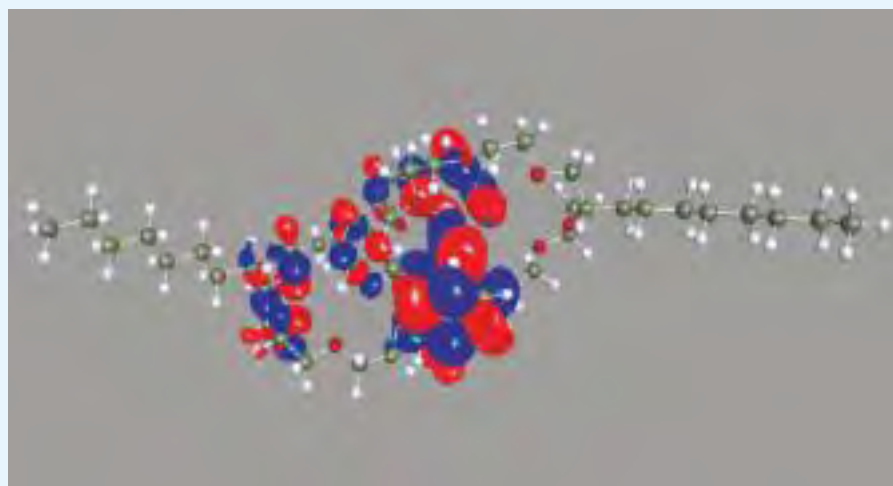
At BARC, experiments were conducted to study the effect of process parameters for the synthesis of lithium titanate by Solid State Reaction Process (SSRP). The synthesized lithium titanate was evaluated and process parameters were optimized to get the desired



Machine vision based automated pellet inspection system installed at NFC, Hyderabad



Uranium sensing chip bonded to fused silica



Highest occupied molecular orbital and lowest unoccupied molecular orbital of Calix[4]arene-bis(octyl-crown-6)-Cs⁺ complex

properties of pebbles. About 50kg lithium titanate pebbles of specific size were fabricated from the synthesized lithium titanate powder.

Hydro-dynamic properties of lithium titanate pebbles in gas-solid fluidized and packed fluidized bed were determined and a general correlation was developed to estimate the effective thermal conductivity of lithium titanate pebble bed.

Separation of cesium metal ions

Studies using density functional theoretical molecular orbital calculations at BP-86/TZVP level of theory were performed to predict suitable ligand architecture for the effective separation of cesium metal ions. The optimized structures of Calix[4]arene-bis(octyl-crown-6)-Cs⁺ complexes were compared with the crystallographic data and found to be in good agreement

with respect to various structural parameters. The present study will help to screen and design a suitably modified calix-crown scaffold for effective removal of Cs metal ion from nuclear waste by elucidating the underlying mechanism of ion-ligand interaction at molecular level.

Flow patterns in serpentine micro-channel

Liquid-liquid extraction in three different types of microchannels like T-junction channel, split and recombine channel were studied using water succinic acid n-butanol system. Using the same phase system, performance of two conventional stage-wise contactors mixer-settler and annular centrifugal extractor was also studied.

A numerical approach based on phase field method was used to simulate liquid-liquid two-phase flow for different kinds of microfluidic junctions.

Aluminium - Beryllium composites

Indigenous production of Al-Be composites for inertial systems and satellite applications of ISRO was initiated at Trombay. A process for making Al-Be composite through powder metallurgy route starting from elemental constituents, was developed.

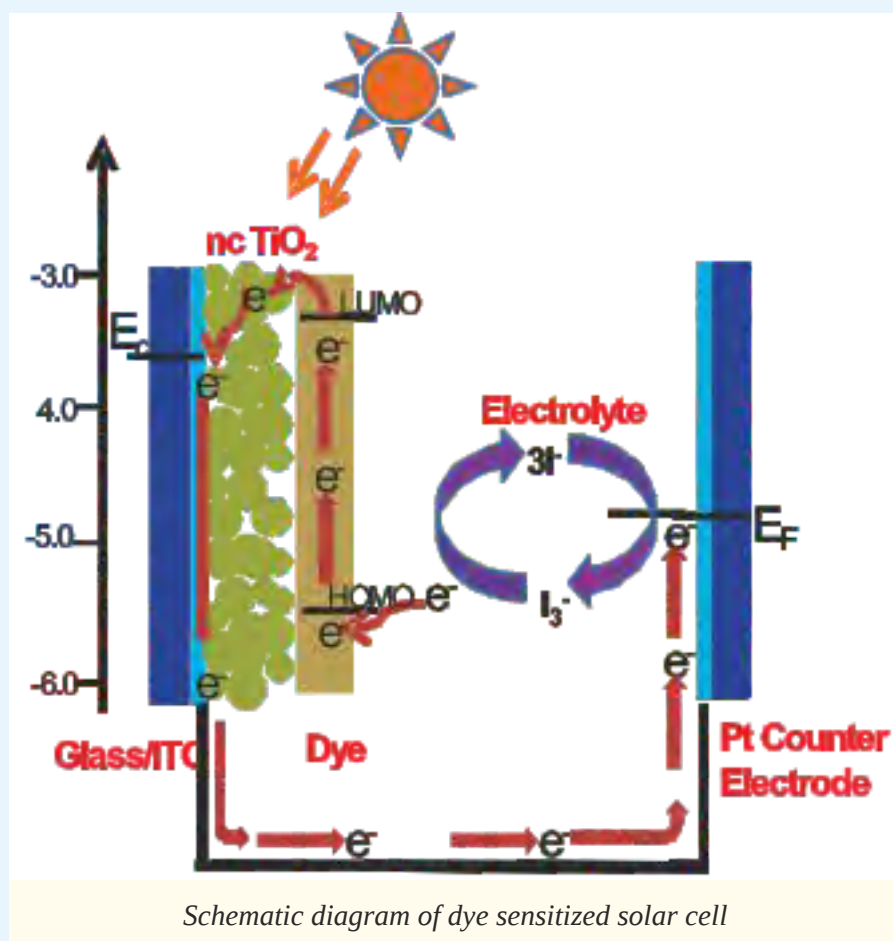
Homogeneity study on the proposed U-6% Zr fuel was carried out by composition analysis of U and Zr. A method based on gravimetry which involves the precipitation of Zr as Zr-mandelate followed by its ignition at 110°C to get the stoichiometric ZrO₂ was developed.

Determination of Lithium in Li-Al Alloy

For ascertaining the homogeneity of the alloy, a method using ion-chromatography was developed for the determination of Li in Li-Al alloys.

Dye-Sensitized Solar Cells

BARC has undertaken development of dye-sensitized solar cells as they are relatively easy to fabricate at low cost as compared to conventional silicon solar cells. In order to improve the efficiency of these solar cells, a simple and novel method was adopted. By using bilayer consisting of rhodamine (RhCl) and a ruthenium based (N3) dyes Solar cells were demonstrated to have 8% efficiency.



Optically Transparent Ceramics

A new process to prepare optically transparent ceramics of the $\text{CaF}_2\text{:Mn}$ and $\text{CaF}_2\text{:Mn+Ce}$ materials, was developed at BARC. The process is based on

vacuum hot-pressing of nano-particles at 1000 deg C. These ceramics showed good sensitivity and linearity as thermo-luminescent dosimeters.



Elements fabricated from 0.3 atom % Nd:YVO_4 crystals

Magnetic materials

At RRCAT, magnetocaloric effect of the $\text{Fe}_{0.975}\text{Ni}_{0.025}\text{Rh}$ alloy was measured using both the isothermal field dependence of magnetization and the temperature dependence of constant-field magnetization results. Magnetization studies were performed on bulk niobium (Nb) samples to study the magnetic flux dynamics in the material as functions of various practical operations like heat treatment, chemical polishing, and welding techniques.

Characterization of Nd doped YVO_4 single crystals

Elements fabricated from 0.3 atom % (Nd:YVO_4) crystals were characterized for lasing performance. About 2.0 W of CW power at 1064 nm was obtained in a plane-plane cavity configuration.

Growth of type-I oriented Potassium Dihydrogen Phosphate (KDP) and Zinc Cadmium Thiocyanate (ZCTC) crystals

Type-I oriented potassium dihydrogen phosphate (KDP) crystal was grown by platform method such that the plate parallel to the platform is suitable for type-I SHG element of Nd:YAG/Glass lasers.

Zinc cadmium thiocyanate (ZCTC) crystals, with dimensions as large as 3x3x15 cu.mm, were grown by solvent evaporation technique on the platform at 40deg C. Experimental set up for



Type-I SHG oriented
KDP crystal



Top to bottom : Pictures of Nd:YAG,
Yb:YAG and Yb:Y₂O₃ ceramics

holographic imaging of the crystal growth process was made and imaging experiments were performed on ZTS crystal.

Synthesis of polycrystalline transparent ceramic

A vacuum sintering facility was developed at RRCAT for polycrystalline transparent ceramic. Co-precipitation route with various co-precipitating agents was in use to synthesize powder having soft agglomeration with particle size distribution in 70-100 nm. Optimization of sintering parameters obtained polycrystalline transparent ceramics with 99.9% density or better.

ADVANCED TECHNOLOGIES

Cryogenics

The complete Process Compression System for Helium liquefier for cryogenic studies, consisting of compressor, buffer vessel and oil removal system, was installed and commissioned at Trombay. Helium liquefier cold box, complete with instrumentation, was installed and connected to the process compressor and helium recovery system. Cold box and piping system integrity were performed with liquid nitrogen.

A cryogenic turbine impeller, size 16 mm and capable of handling 50 g/s of flow was designed and developed. The same was field tested.

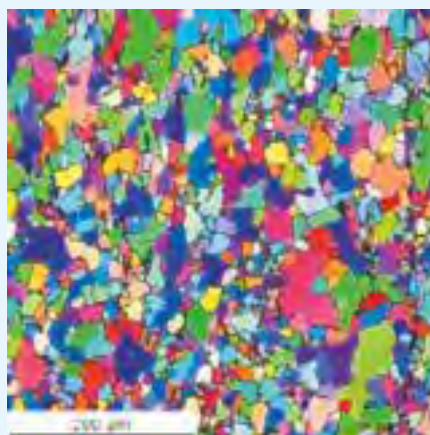
Helium Evaporator

Towards developing a dilution refrigerator, a pre-cooling stage at 0.97K was built and tested at VECC.

A non-cryogenic helium purification system was developed and successfully commissioned. This helium purification system is a cost effective and energy efficient solution to the existing expensive cryogenic counterpart. A cryogenic Penning trap system was under development.

Alloys for structural components

The Nb-1Zr-0.1C (wt%) alloy was developed by BARC for structural components in the proposed Compact High-Temperature-Reactors (CHTR). In a parallel work this alloy was produced by melting using electron beam melting facility.



Recrystallized microstructure of
the Nb-1Zr-0.1C alloy showing
uniform grain size

Gimbal and Connect bars for Scan Mirror Mechanism

For Scan Mirror Mechanism of



Helium liquefier under commissioning



20K Helium refrigerator



Helium Evaporator in operation

ADVANCED TECHNOLOGIES AND RADIATION TECHNOLOGIES AND THEIR APPLICATIONS



Connect and Gimbal Bars

advanced meteorological payloads Sounder and Imager for INSAT-3D/3DR, two sets of EN plated Gimbal bar and Connect bar made out of Al-Be alloy, were delivered to IISU/ISRO.

Robots

Force Reflecting Tele-robot

A Force Reflecting Tele-robot represents a new generation of remote handling technology with advanced features like scaling of slave motion, constrained motion, teach and playback mode, autonomous mode etc. A Force Reflecting Tele-robot was designed and fabricated. A 'Spot picker' which is a state-of-the-art technology for precise protein spot excision, was developed. Liquid Handling Robots were developed. It will carry out the function of separating biological molecules, DNA molecules by magnetic bead separation method.

All Terrain Robot

An all terrain robot was designed and developed. It offers

a variety of effective and practical unmanned operations to the operator. The robot transverses trenches of 400 mm, operates in loose gravel, sand, bricks, pipes, staircases, grass, mud, muddy water, water up to 50 mm, and is water resistant. It can be operated in the rains also. It can climb staircases up to an angle of 45 deg,

maximum speed of 1 mts/sec on flat surfaces. Work was in progress to add a manipulator to carry radiation sensors.

Micro Surveillance Robot

The Micro Surveillance Robot is a small size compact palm held robot that can be sent for surveillance into small-restricted spaces. It has a swing arm but there is no belt drive. The swing arm serves the purpose of a lever to help it maneuver obstacles such as large stones, pipes, tracks etc. This Robot has a limited operating range of 100 mts. and carries a fixed lens camera with a RF video transmitter. Applications include, first surveillance response to fire, nuclear industry inspection, remote surveillance for counter terrorism operations etc.



Force Reflecting Tele-robot

All terrain portable robot



Micro Surveillance Robot



Hot Cell Visual Metric System Tele-robot



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Tele-control Mobile Work Agent



Reflector Cleaning Mechanism

Tele-Robot Operated Periscope

Hot cell Visual Metrics System Tele-Robot Operated Periscope was developed for post-irradiation examination of irradiated hot components and structural materials. The 'Periscope Operator Robot' emulates a human operator arm. It consists of multi axis servo control system, high resolution imaging system, on line visual metrics support for inspection and result logging and hands free "voice actuated" lighting robot as assistant for specimen lighting inside the cell.

Tele-control Mobile Work Agent

Tele-control Mobile Work Agent for Hazardous Areas was developed for Campaign mode visual inspection in remote hazardous areas and Surveillance of plants and perimeter, Radiation mapping and swab collection etc. It is an intelligent Tele-controlled mobile robotic agent with versatile navigation. It has Power efficient traction with Brushless DC motors for maintenance free

operation, all time all wheel contact with ground for vehicle stability, versatile Motion Modes, single remote control environment for vehicle control as well as robot arm with kinematics model support etc.

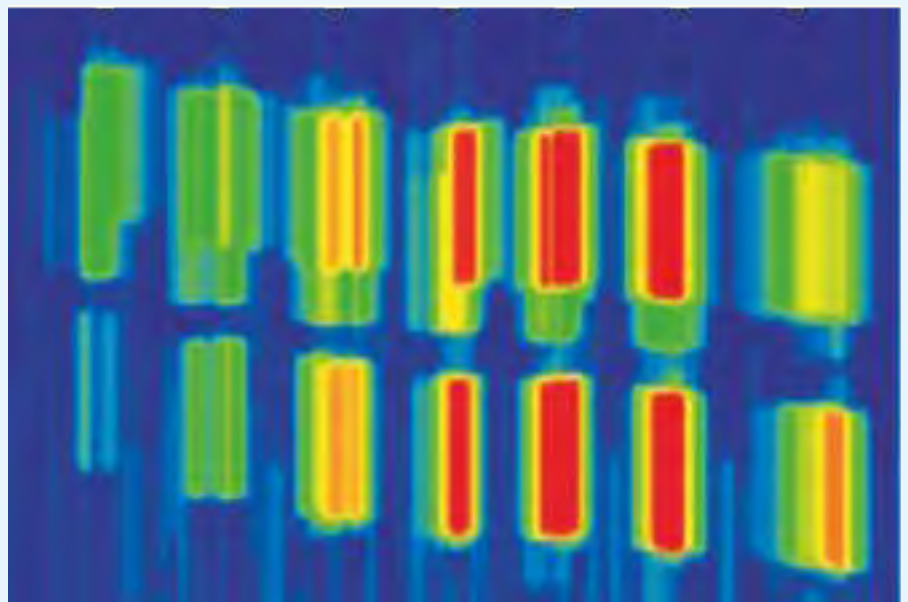
Automated Solar Reflector Cleaning Device

A gadget for automated cleaning of parabolic solar

reflectors being used in the DST sponsored solar thermal demonstration plant of 250 kW rating, located at Shive village near Pune, was developed.

Ultrasonic Phased Array for Inspection of Pressure Tubes

The ultrasonic phased array comprise an array of elements (linear, circular, encircling, matrix) that can be used as pulsers



C-scan image showing flaws in the pipe

ADVANCED TECHNOLOGIES AND RADIATION TECHNOLOGIES AND THEIR APPLICATIONS



Mass spectrometer for boron analysis

and receivers to achieve high reliability in flaw detection, good accuracy in flaw characterization, high sensitivity, good signal to noise ratio and faster inspection. This technique was applied at BARC for the inspection of the Roll joint in PHWR pressure tube, Reactor Pressure Vessel weld of BWR and Primary pipeline welds of BWR.

Thermal Ionization Mass Spectrometer

A thermal ionization mass spectrometer for boron isotope ratio analysis for use in boron enrichment plant at Heavy Water Plant, Manuguru was developed and will be installed soon. Isotope ratios with a precision of $< 0.1\%$ are routinely obtained in samples of different enrichment levels up to 65% for Boron-10 isotope.

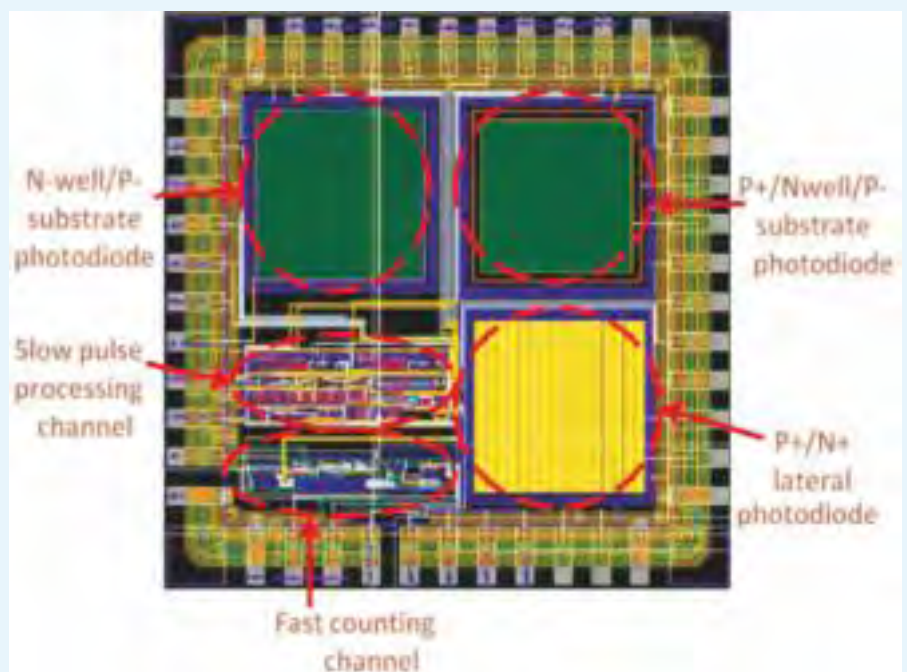
Application Specific Integrated Circuits

At BARC, three ASICs (Application Specific Integrated Circuits) - ANUSPARSH, ANUDRISHTI and

ANUSUCHAK were designed, developed and tested successfully. The ANUSPARSH is front-end readout for Resistive Plate Chamber detectors of INO (India based Neutrino Observatory), the ANUDRISHTI is a monolithic photodiode and readout electronics for compact gamma detection probes, and the ANUSUCHAK is low power front-end readout for silicon PIN detectors.

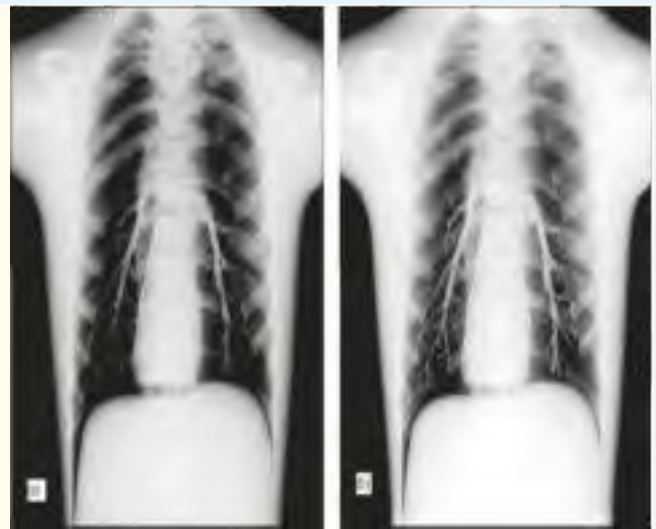
Digital Medical Imaging System

A new flat panel based Digital Medical Imaging System was developed. This system is capable of doing both radiography and fluoro mode operation using same detector. This makes this detector truly digital in nature as the need for film is completely avoided.



ANUDRISHTI ASIC

ADVANCED TECHNOLOGIES AND RADIATION TECHNOLOGIES AND THEIR APPLICATIONS



Flat panel detector and (Right) X-ray images of chest-lung anthropomorphic phantom in case of (a) fluoroscopy and (b) radiography

Sensors for Nuclear Reactor Applications

Indigenous and highly customized sensors for nuclear reactor applications were developed at BARC. They were designed considering stringent reactor environmental conditions. Various sensors developed are Multipoint Ultrasonic Level sensor, LOCA qualified Absolute Pressure sensor, Capacitance type flexible Level sensor, Thermocouple Assembly for reactor coolant temperature measurement, Single point ultrasonic level signalizer, Three channel ultrasonic flow meter and Salinity meter.

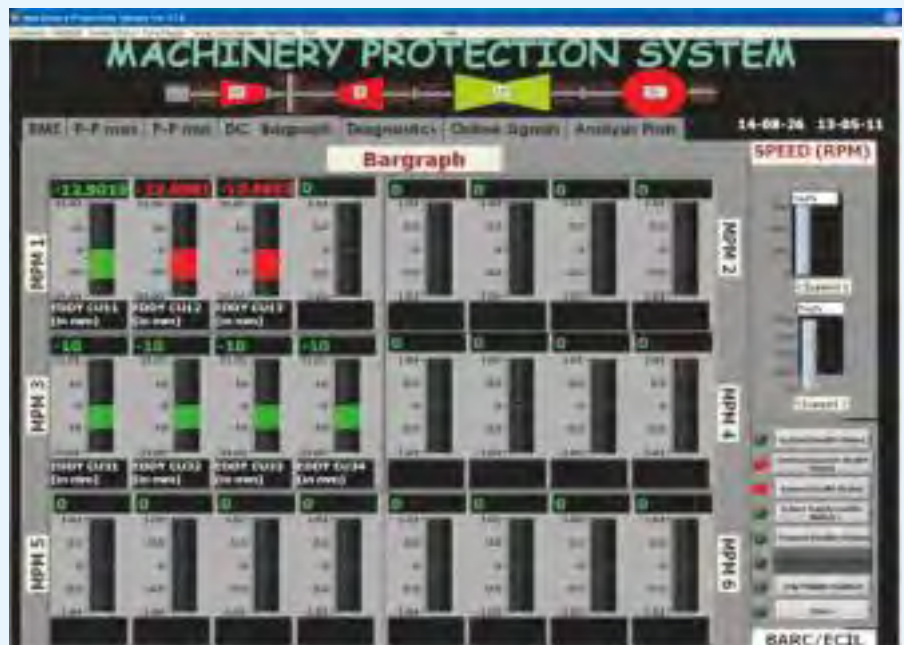
Calorimeter for Assay of Nuclear Material

At BARC, a Calorimeter for assay of nuclear material was developed. The Calorimeter was integrated, calibrated, tested and measurements were carried out.

Machine Protection System

For monitoring and protection of large rotating machines (like turbines, large motors, etc) a digital signal processors (DSP) based Machine Protection System was developed at BARC. The system can monitor absolute

bearing vibration, shaft vibration and eccentricity, absolute and differential casing expansion and tachometer speed signals. It generates digital alarm output on alarm conditions and trip signal for critical alarms by relay actuation.



Graphical User Interface of Machinery Protection System on Engineering Console

*Three Channel Ultrasonic
Flow Meter for Feed Water
Flow Measurement
Full Assembly (top) and
Internal View (bottom)*



Salinity meter

*Single point Ultrasonic
Level Signalizers*



*LOCA qualified
Absolute Pressure Sensor*

ADVANCED TECHNOLOGIES AND RADIATION TECHNOLOGIES AND THEIR APPLICATIONS

Radioactive Ion Beam Facility

The Radioactive Ion Beam Project at VECC aims at developing a state-of-the-art accelerator facility for studying nucleo-synthesis in explosive and normal stellar environments, properties of exotic nuclei, material properties, and biology.

During the report period, one IH Linac was built and added to the facility taking the energy of ion beams to 400 keV/u. Also a dedicated facility for condensed matter physics, that comprises a beam line, was installed.

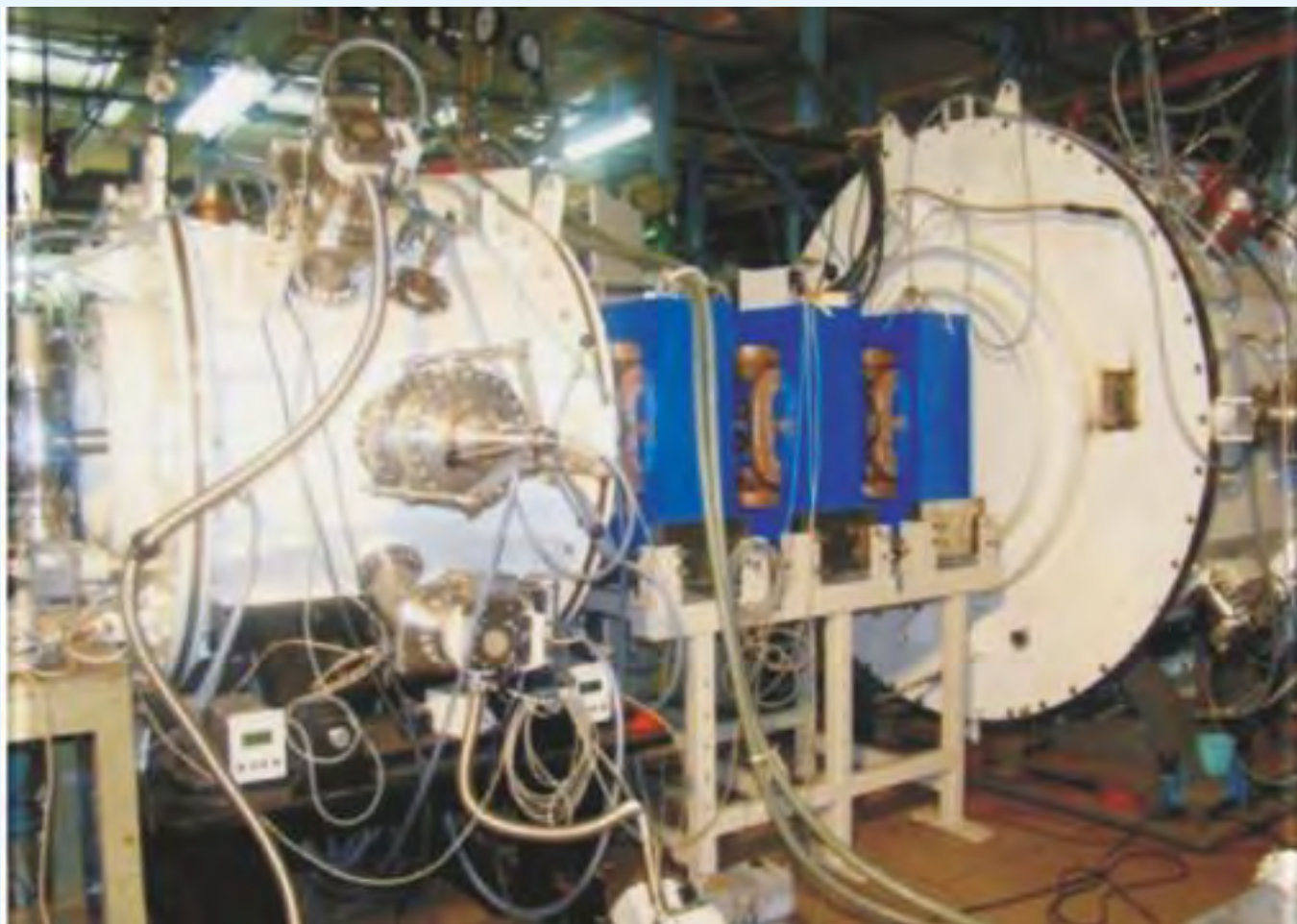
Superconducting Magnetic Energy Storage System Technology Development

Significant developments achieved in the Superconducting Magnetic Energy Storage (SMES) project included : Field testing of SMES coil and development of a 12T hybrid magnet; development and integration of the quench protection system, and development of a bipolar power converter with embedded supervisory controller for superconducting magnets.

SPECIAL PROGRAMMES

In order to estimate the amount of radioactivity released from Fukushima Daiichi Nuclear Power plant into the atmosphere, a Gaussian puff based atmospheric dispersion model was developed at BARC. The estimated and measured deposited activity values were used to estimate the source term. The estimated release rates were found to be comparable with the reported values.

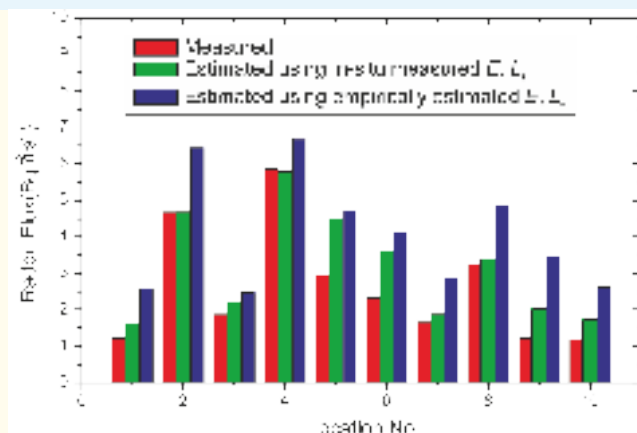
The release rates of different radionuclides into the Pacific



Beam line



Emission flux measurement set up



Comparison of measured and model predicted radon fluxes from Jaduguda Tailings Pond

Ocean from the Fukushima Daiichi Nuclear Power Station were reconstructed from the measured concentrations of radionuclides at different distances.

Several new techniques were established by BARC for characterising the radon releases from Residues of Naturally Occurring Radioactive Materials (NORMs) such as Uranium Tailings Pond. These included diffusion theory based accumulator technique for flux and mass exhalation rate measurements, techniques for the measurement of radon diffusion coefficient, porosity and radon emanation coefficient in the residue matrix. Using these techniques, the radon emission model was validated through extensive field studies at Jaduguda Tailings Pond. These studies received the attention of IAEA. A forthcoming IAEA document (TRS-333) on "Measurement and Calculation of Radon Releases from NORM Residues", authored by an

International team of experts from Australia, Japan, Canada, India and the IAEA, is extensively based on the experimental and modelling contributions from BARC.

ISOTOPE PROCESSING

In India, radioisotopes 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 are 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.

Production of medically important radioisotopes such as I-131, Mo-99, Sm-153 etc. continued at Trombay. Radioisotopes of about 1,00,000

GBq of activity were processed and supplied to users. About 325 numbers of Cobalt-60 polymer film sources were prepared and supplied for use in oil and gas exploration. Three Nickel-63 annular copper-ring deposited sources (2.77MBq), were supplied for use in TLD readers. One Nickel-63 annular copper ring deposited source (555MBq), was prepared for use in electron capture detectors in gas chromatography applications. About 750 numbers of reference sources of activity up to 1MBq, were supplied to various users through BRIT.

At BARC, a nano-zirconia based Germanium-68/Gallium-68 generator was developed to avail Gallium-68 for preparation of Gallium-68-labeled radiopharmaceuticals. Low active sealed radioactive sources Iron-55, Cobalt-57, Cobalt-60, Barium-133 and Cesium-137 were prepared and supplied to various agencies.

A multi-cavity powder compaction facility for the

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production of sintered cobalt pellets of 1 mm diameter and 1 mm thickness was installed. The facility is capable of producing 500 pellets per hour and has already produced over 25,000 pellets.

At the Regional Centre, Kota (RAPPCOF), a total activity 38.80 PBq (1048 kCi) of Cobalt-60 was processed of which 30.48 PBq (824 kCi) was transported in 9 shipments.

The high intensity proton beam from the DAE-Medical Cyclotron coming up at Kolkata, will be used for production of radioisotopes for medical use and materials science research. There will be two different beamlines : Beamline-1 for high dose irradiation and Beamline-2 for short time and low dose experiments. A general purpose target chamber was designed for

use in Beamline-1 consisting of specialized features.

Identification of Gamma Chamber pencils was carried out by BRIT at SWRI, San Antonio, USA. This unit was supplied to Uruguay in April 1972.

Two numbers of cobalt-60 teletherapy sources were supplied by BRIT to different hospitals. Another 13 numbers of sources were ready for supply. Eight numbers of decayed sources were unloaded from the teletherapy units and stored for fabrication of irradiator sources.

AGRICULTURE

Crop Improvement

A confectionary large seed Trombay groundnut variety TG-47 (Bheema), was released for commercial cultivation for early

Kharif and Rabi under irrigated conditions in all agro-climatic zones of Andhra Pradesh. Trombay Urd bean (Blackgram) variety TU-40 was identified for release in south zone by the Central Varietal Release Committee of Indian Council of Agricultural Research (ICAR). A Bruchid resistant Trombay wild Urd bean was registered with the National Bureau of Plant Genetic Resources, New Delhi. Two high yielding Urd bean cultures TU-136 (Kharif) and TU10-13 (Rabi) and three high yielding Mung bean cultures TLM-24 (Kharif) and TMB-71 and TRM-24 (Rabi) were entered in the initial varietal trial of ICAR.

Large scale breeder seed production was undertaken at BARC, Gauribidanur and under contract farming at Kehal, Parbhani and Pattanakodoli,



Trombay Groundnut variety TG 51



Breeder seed plot of Trombay groundnut variety TG 38 near Kolhapur, Maharashtra

Kolhapur. In total of 466 quintals 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. Nucleus seed of several other Trombay varieties of oilseeds and pulses were multiplied for use as test entries in different trials. Multiplication of a few high yielding cowpea cultures was taken up for giving as new entries in the ICAR Coordinated Trials. Genetic stocks in bread wheat with certain traits were developed.

For the development of large seed size varieties through recombination breeding, 1200 lines in F3 generation of crosses between large seed (SML-668, Rsel-246 & JL-781), medium seed (Kopergaon) and yellow mosaic virus resistant variety (Samrat) were raised in the field and eight transgressive segregants were identified. Towards development of large seed size and earliness in variety TARM-1 through mutation breeding, seeds of variety TARM-1 were irradiated. M1 generation was grown and 2000 individual plants were harvested separately. For the development of multiple disease resistance for yellow mosaic virus and powdery mildew diseases, nine crosses were made using TARM-1, TMB-37 and TM 98-50 as donor parents and JL-781 and SML-668 as susceptible large seed size parents. 1500 lines were screened in F3 generation for

yellow mosaic virus disease in the field and for powdery mildew disease in laboratory.

Multiplication of nucleus seed of TAU-1, TAU-2, TPU-4 and TU94-2A, was undertaken for the production of breeder seed and multiplication of advanced selections (TU-26, TU-17-4, TU-80 and TU-40). Development of yellow mosaic virus and powdery mildew disease resistant black gram variety was undertaken

M2 population of Soybean varieties JS-335 and NRC-37 was screened for phytic acid content and identification of low phytic acid mutants were carried out. Low phytic acid mutants were raised in M3 generation for studying breeding behavior and its correlation with other quantitative characters. Multiplication of high yielding advanced selections TS- 46, 48, 69 and TS-72 from the cross between mutant TS 98-91 and exotic germplasm lines were also carried out.

Cowpea mutants of GC-3 identified in M2 generation were advanced to M3 and three mutants with respect to seed size and one mutant with respect to testa colour (full white against mottled fawn of parent GC-3) were found to be true breeding. Seven cowpea lines and thirteen lines in the F7 generation of the cross EC394763 x EC394745 were found to be highly resistant against leaf crinkle disease under high field incidence. Twenty eight true breeding lines having more pods, semi-determinate growth habit and more yield in F7

generation of 5 different crosses genotypes were developed.

Canopy temperature depression and translocation from vegetative parts to grain were studied in wheat grown in heat stress environment.

BC5F2 generation grains were harvested from plants with HD2189 as recurrent parent. Back crossing was carried out to introduce high molecular weight subunits 5+10 and rust resistance genes Sr24/Lr24. Selection was carried out using markers. A genetic stock was developed by transferring the Sphaerococcum locus to background of wheat variety Kalyan Sona. A genetic stock with dwarfing gene Rht3 and ADH variant trait was also developed. In rice, CSR 30 derived salt tolerant semi dwarf mutants were tested in a station trials; three were found to be promising.

Marker assisted selection was carried out in wheat, groundnut and cowpea. Simple sequence repeat marker genotyping of 164 RILs (VG 9514 X TAG 24) generated a genetic linkage map with 24 linkage groups. The significant association of certain two markers with the rust resistance, was also confirmed by discriminant analysis and validation in other 20 groundnut genotypes differing in rust reactions.

The genetic diversity of 38 cowpea germplasm lines was studied. 22 % polymorphism could be discerned using these primers. Thirteen cowpea germplasm lines were sown in

field for attempting crosses to study inheritance of leaf crinkle disease, determinate growth habit, seed testa color and to develop RIL population for tagging various quantitative traits.

Micropropagation of banana was successfully carried out by BARC in the collaborating institutions. More than 26,000 plants were produced in Tissue Culture Lab at KVK Pondicherry and over 30,000 banana plants were produced in AKRUTI-CARD Tissue Culture Lab at Anjangaon-Surji, Amaravati established as a part of AKRUTI programme. About 3000 tissue culture derived banana produced are being grown in a demonstration plot at Anjangaon-Surji. Studies on biotic and abiotic stress responses of banana were conducted. Two *ihp*-RNAi Constructs derived from replicase gene from banana bunchy top virus (BBTV) were used to develop BBTV resistance. Several abiotic stress related gene homologs from banana and grapes were identified.

Multiple shoot cultures were established from seedlings of *Nothapodytes foetida* and transferred to different combination of hormones, or different sugars for further multiplication and growth. A protocol was standardized for the storage of pollen grains of pearl millet. Using this method pollen grains were stored for over one year, which is useful for pearl millet breeding programmes. NDP kinase gene was identified



Soybean seed irradiation using 700keV DC accelerator

using *in silico* approaches from banana EST database.

Transformation of *Brassica juncea* (mustard) with 'ech42' gene was carried out.

Electron Beam Irradiation for mutation breeding experiments

At RRCAT, electron beam irradiation of five varieties of fresh groundnut seeds was done to standardize the LD50 dose for mutation breeding experiments. Accelerators namely DC accelerator (continuous) and Linear accelerator (pulsed) were used for the purpose. Two varieties of soybean seeds from the National Research Centre for Soybean, Indore, were also irradiated to study mutations in growth phases of soybean.

Fertilizer & Plant Growth

About 500 tons of radiation hygienised sewage sludge was

supplied to farmers for agricultural use.

Bioregulatory molecule such as thiourea (TU) was demonstrated to be associated with the improvement of cellular energetics and redox state homeostasis during salt tolerance in brassica. The Carbon-14-labelled thiourea uptake was studied in root and shoot of Indian mustard. Studies were also initiated to reveal the potential of thiourea for increasing the arsenic stress tolerance in Indian mustard. The sugar to oil conversion pathway was also studied in pods.

In order to identify the suitable marker of the salinity stress tolerance, ERD-4 (early responsive to dehydration) gene was identified. The RNAi mediated silencing on ERD-4 was performed in *Arabidopsis* and six independent knockdown lines.

In an ongoing attempt to

unravel arsenic tolerance and detoxification mechanisms, As-responsive microRNAs were identified in *Brassica juncea* through microarray profiling.

Bacillus sphaericus ISPC-8 strain was mass multiplied in nutrient broth medium (NBM) supplemented with 0.3% sugar cane molasses and used for formulation development.

Pest control

Cowpea weevils, *Callosobruchus maculatus* and *C. chinensis* (are the primary pest of Cowpea, Mungbean and other legumes worldwide, both in fields as well as in stored seeds. Effects of gamma radiation on various stages: eggs, larvae and adults of both bruchids were investigated at different doses on *C. maculatus*

FOOD PROCESSING

At BARC, various traditional Indian meat products were selected for development of radappertized (radiation sterilized) products. The radappertized samples were found to be microbiologically sterile and had high sensory acceptability. Ability of chitosan coating in reducing the load of Gram positive in chicken and mutton seekh kebab over a period of 12 days was demonstrated. Use of active edible CMC-PVA (polyvinyl alcohol) composite films containing clove oil as a packaging film, increased the shelf life of minced chicken meat by 8 days when stored at 0-3°C.

Radiation processing of

intermediate moisture prawns reduced bacterial and mold count to acceptable levels. Sensory analysis showed that even after two months storage at room temperature irradiated samples were acceptable. Large scale studies in collaboration with Central Institute for Fisheries Education, Versova, Mumbai showed that radiation processed samples were acceptable beyond 4 months of storage at room temperature while control samples were unacceptable in 2 months.

Thermoluminescence technique was employed for identification of irradiated (80 and 120 Gy) ginger and fresh turmeric. The irradiated samples could be readily identified even after a storage period of one month. Feasibility of using EPR method for detection of irradiated herbs such as *Aswagandha*, herbal formulations such as *Amirtamehari churnam* and apricot based on distinct changes in EPR line in the irradiated samples was demonstrated. Ferulic, o-coumaric and vanillic acid were found to be the major antioxidant phenolic acids of apricot. Radiation processing (3kGy) had no effect on the qualitative composition of these phenolics. A higher extractability (5.5%) of these compounds was, however, noted in the irradiated apricots. Mechanism of protection against UV (254 nm) induced mutagenesis by honey was investigated. Honey was found to inhibit the SOS mutagenesis. The methanol

extract of honey also displayed high antioxidant activity. Honey samples also showed a significant DNA protective ability. Aqueous extracts of rose and guggul were also found to have high level of radioprotective activity. Potential of star anise extracts as antioxidant with comparable activities to synthetic antioxidants such as BHT was demonstrated. Vitexin, isovitexin, two apigenin glycosides and biochanin A were identified as the major flavonoids in fenugreek seeds. Gallic acid, epicatechin gallate, quercetin 3-O-glycoside, quercetin-3 malonyl glucoside and kaempferol glucuronide were identified as the major phenolic compounds of *Phyllanthus fraternus*, a medicinally important plant used as a traditional remedy for the treatment of various liver diseases.

Studies on the effect of radiation processing on the nutritional quality of RTC vegetables such as ash gourd and French beans demonstrated that the process does not affect the vitamin C, total phenolic and flavonoid content as well as the antioxidant status of the products. A combination treatment was developed that helped in inhibiting browning by 90% and in extending shelf life of ready-to-cook brinjal for 20 days when stored at 4 °C. A combination of radiation with other processing methods including a chemical dip treatment was employed for shelf life extension of litchi. Radiation dose in the range of 10-25 kGy could control the growth of

bacteria as well as yeast and mold within the safe limits and extend shelf life of vegetable pulao up to 20 days at ambient temperature without affecting its sensory quality. Radiation processing (0-2 kGy) was found to enhance isothiocyanate content in the essential oil of cabbage in a dose dependent manner. An enhanced antimicrobial activity of the oil towards *Salmonella typhi* was also noted suggesting an improved antimicrobial status of irradiated cabbage.

Use of GC/MS as an electronic nose in combination with chemometrics was proposed as a method for identifying gamma irradiated grapes for the first time. Flavor precursors in fruits such as grapes, jackfruit, and pomegranate were identified. The role of these precursors during ripening or processing in modifying odor characteristics of the fruits was established. Among the aqueous extract of 32 raw vegetables tested for their protective efficacy against UV induced mutagenesis *E. coli*, seven vegetables namely bean, eggplant, Indian gooseberry, pea, hot-red pepper, zucchini, and drumstick, were found to confer the greatest protection and lowered the mutation frequency to within 10-50% of that of control.

Four different culturable bacterial species were isolated from Mung sprouts. *Pantoea stewartii* was the most dominant population in both control and irradiated (2 kGy) samples. *Pantoea agglomerans*, an

opportunistic human pathogen, was eliminated after irradiation. Radiation processing (5-10 kGy) of ready-to-eat Mung sprouts resulted in reduction in aerobic plate count (APC) by 6 log cycles in 5 kGy irradiated samples, while no microflora was observed in the 10 kGy treated samples when stored for 15 days at 4 °C. No aerobic and anaerobic spores were detectable in radiation processed samples during storage. Irradiated samples were found to be organoleptically acceptable during first week of storage. Radiation processing (1 and 2 kGy) was found to increase the shelf life of dew gram and chick pea sprouts by 4 and 2 days, respectively. Gamma irradiation was found to reduce the phytate content of soybean, while that of ragi was found to be unaltered. Hull extracts of common pulses were found to possess strong antioxidant activity and their potential to replace synthetic chemical antioxidants in food industry was demonstrated. Scale up experiments of radiation processing of commercially available Rawa packets were carried out in 10 MeV, LINAC facility, EB Centre, Kharghar. The absorbed doses measured by Alanine-EPR dosimetry were found to be satisfactory.

Irradiation (2 kGy) resulted in an increase in tensile strength of cling wrap packaging films by 15 % without affecting its puncture strength and water vapor transmission rate. Tensile strength of biodegradable films prepared from irradiated (0.5 kGy) guar

gum increased from 60 MPa to 80 MPa while no significant changes were observed in its puncture strength. Addition of nano clay (7.5 %) improved tensile strength (120 MPa) and resulted in better mechanical properties of films. Gamma depolymerized guar gum was successfully employed for encapsulating flavor compounds and had a higher entrapment efficiency (63%, 60 days) compared to other commercial wall materials such as Gum Arabic (50%, 60 days).

Under a joint IAEA-RCA project undertaken to develop irradiated foods for immunocompromised patients, blenderized food obtained from Tata Memorial Hospital was treated with different doses of gamma radiation (2.5 to 10 kGy) and stored at 4 °C. A 5 kGy dose was found to reduce the microbial load significantly while a dose of 10 kGy could completely eliminate the microbial load without affecting its sensory quality. Nutritional quality in terms of protein content, total carbohydrate, dietary fibre, energy value, vitamin A and C, and different macro/ micro elements including calcium, iron and zinc, were also unaffected.

Gamma irradiation was successfully employed to inactivate ochratoxin A (OTA), a toxin produced by a contaminating fungus in green coffee beans. Protocols were standardized for quantitative extraction of ferulic acid from rice bran and its biotransformation to vanillic acid (molar yield, 33 %)

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using *Fusarium solani*. Using the above fungus procedures were also standardized for the biotransformation of verbinol to commercially important aroma chemicals such as verbinone, p-mentha-1,5-diene-8-ol and cineole.

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 150 customers from all over the country.

During the current financial year, about 2438 MT of spices and other products were processed till November 2011, which was about a 30% increase in quantity over the corresponding period last year. This year the plant is expected to process around 3000 MT spices and allied products yielding revenue of about 1.90 crore. Since its inception, this facility has processed about 18,500 tonnes of products realizing revenue of about Rs. 10crore.

To meet with the increased demand for radiation processing, Source replenishment was carried out to enhance source strength from 350 kCi to 500 kCi. Product scanning machine was installed and commissioned to screen incoming products for detection of security threatening materials inside packaging.

Approval was obtained from FDA, Maharashtra for sterilization of health care products in the facility. Surveillance Audits for ISO-9001:2008 (Quality Management Systems) and ISO-22000:2005 (Food Safety Management Systems) were carried out and found to be in full compliance with the requirements of the standards.

Radiation Processing Plants in Private Sector

BRIT is involved in setting up Radiation Processing Plants in private sector. Till now a number of plants have been set up with the assistance of the Board.

During the year of report, the Radiation Processing Plant of Innova Agri BioPark, Malur was commissioned; A radiation

processing plant at Hindustan Agrotech Rahuri was inaugurated, and two new MoU for setting up of Radiation Processing Plants -- at Pune with Maharashtra State Agricultural Marketing Board, Maharashtra, and at Medinipur, West Bengal with MSV Laboratories Pvt. Ltd., Purab Medinipur -- were signed.

Electron Beam Irradiation for mutation breeding experiments

Electron beam irradiation of five varieties of fresh groundnut seeds (TAG 24, TG 26, TG 51, TG 69 and TG 68) was done by RRCAT with the Bio-Medical Group, BARC, to standardize the LD50 dose for mutation breeding experiments. Two varieties of soybean seeds (Hardee and JS 97-52) from the National Research Centre for Soybean,



*Groundnut seeds irradiated with 8.5 MeV linac
for mutation breeding experiments*

*Radiation Processing Plant at
Innova Agri Bio-Park, Malur, Karnataka*



*Radiation processing plant at
Hindustan Agrotech Rahuri, Maharashtra*



*MoU signed with Maharashtra State
Agricultural Marketing Board,
Pune, Maharashtra*



Indore, were irradiated at beam energy of 700 keV from DC accelerator, in the dose range 75 to 225 Gy to study mutations in growth phases of soybean.

HEALTH

Radioisotope based formulations, techniques and equipment are widely used in the diagnosis and treatment of various diseases. BARC, BRIT, RRCAT and VECC are a 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 radioprocessing 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.

RADIO-PHARMACEUTICALS

More than 65,000 cold kits for formulation of Tc-99m radiopharmaceuticals were supplied by BRIT to various Nuclear Medicine Centres. 300 Ci of Mo-99 for solvent extraction and around 200Ci of Mo-99 for Gel Generators, were supplied to hospitals for separation of Tc-99m. Various accessories of Tc-99m solvent extraction generator system and other products were also supplied. Nearly 15,000 consignments of ready to use radiopharmaceuticals of I-131, P-32, Cr-51 and Sm-153 were supplied to various nuclear medicine centres in India. The supply of the injectable products Sm-153-EDTMP and I-131MIBG to various nuclear medicine centres in India, was increased.

The ongoing contract work, of certain monoclonal antibody labeling with I-131, for Peregrine Pharmaceuticals Inc., USA, was concluded at BRIT.

At Trombay, procedure for preparation of $^{177}\text{LuCl}_3$ suitable for Lutetium-177 based pharmaceutical, and large scale preparation of ^{177}Lu -EDTMP radiopharmaceutical for use in bone pain palliation, were optimized. The preparation of a single patient dose of ^{177}Lu -EDTMP as a ready-to-use

injectable formulation was also developed.

During the report period, nine batches consisting of Iodine-125 brachytherapy sources (127 nos.) were supplied for treatment of ocular cancers in various hospitals. Efforts for development of Iodine-125 brachytherapy sources for prostate cancer treatment, were continued. The first implant of 'BARC Iodine-125 Ocu-Prosta seeds' in a patient with prostate cancer, was carried out at P.D. Hinduja Hospital, Mumbai, and one batch consisting of 50 Iodine-125 seeds was supplied.

There is good utility of nano-alumina as a column matrix in the preparation of a clinical-scale Molybdenum-99/Technetium-99m generator. An 18.5 GBq (500 mCi) Molybdenum-99/Technetium-99m generator system was developed by BRIT. The quality of the Technetium-99m obtained from the generator was found to be suitable for preparation of Technetium-99m based diagnostic radio-pharmaceuticals. An electrochemical Strontium-90 / Yttrium-90 generator system was put into regular use for elution of Yttrium-90 (in the activity range of 1.85 GBq) for the development of Yttrium-90 radio-pharmaceuticals. A Monoclonal antibody, Rituximab, was radiolabeled with Iodine-131 as well as Yttrium-90, for therapy of cancer patients suffering from non-Hodgkins lymphoma. EDTMP cold kits were sent to 'Frederic Joliet-Curie Research

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Institute for Radiobiology and Radiohygiene', Budapest, Hungary along with a consignment of Thulium-170 for carrying out advanced biological evaluation of ^{170}Tm -EDTMP -- another potential agent for bone pain palliation.

Tc-99m Column Generator

Production and supply of Geltech generators were continued at BRIT and supplies to hospitals were maintained. Over 620 consignments of Geltech generators and activity over 160Ci Mo-99 were supplied to Nuclear Medicine Centres in India.

The work on the Project for the production of Mo-99/Tc-99m Column generator, using high specific activity Mo-99, made progress. The trial production at this facility and supply of product generators to Radiation Medicine Centre of BARC had commenced.

RADIATION TECHNOLOGY EQUIPMENT

Bhabhatron Teletherapy Machine

BARC has so far commissioned 19 units of indigenously developed Bhabhatron Teletherapy Machine. The first unit of Digital Radiotherapy Simulator, also indigenously developed, was commissioned at the Indian Red Cross Society Hospital, Nellore, Andhra Pradesh. Another such unit was under installation at the Tata Memorial Centre. To meet the fire test requirement of the Bhabhatron-II Transportation Flask, a thermal shield of ceramic wool was provided just outside the flask's outer surface.

India is going to donate one unit each of Bhabhatron and Radiotherapy Simulator to Sri Lanka, through the PACT initiative of the IAEA. These units

will soon be shipped.

Research Irradiators

During the current financial year BRIT supplied and installed a Gamma Chamber GC-5000 at Mangalore University, and a Gamma Chamber GC-1200 at the Inter-University Accelerator Centre, New Delhi. A Gamma Chamber GC-5000 was made ready for dispatch to Berhampur

BRIT exported a Laboratory Research Irradiator, Gamma Chamber 5000 to the National Institute for Physics & Nuclear Engineering, Bucharest, Romania, for US\$ 140,000 FOB. The order was received through IAEA.

BRIT strengthened its presence in the North-East India by supplying a Low dose Irradiator for research purposes to North Eastern Hill University (NEHU) Shillong.

Install & Operate Irradiator

BRIT completed cold commissioning of an Install and Operate Irradiator was completed. The Irradiator will be used for radiation processing of frozen marine products, spices, flour and medical products. It has 200 litres of irradiation capacity and can be loaded with 400 kCi of Co-60 source. The Irradiator is innovatively designed such that its main cask can be used as irradiator as well as transportation cask.

Blood Irradiator

The production and supply of Blood Irradiator BI 2000 was



Technetium-99m Column Generator plant at Vashi



Bhabhatron



Radiotherapy Simulator

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Low dose irradiator for NEhu, Shillong



Single bag blood irradiator

pursued further at BRIT. The Board supplied and installed Blood Irradiators / LDI for Tata Memorial Centre, Kolkata, and 2 nos of BI 2000 were made ready for dispatch to CMC, Vellore. Two more Blood Irradiators are expected to be supplied shortly.

At BRIT, a compact single bag Blood Irradiator was designed and fabricated. It has hybrid shielding of Tungsten-Lead and can be loaded with 275 Ci of Co-60.

Radiodiagnostic & Treatment Services

A total of about 9000 radioimmunoassay (RIA) and immunoradiometric assay (IRMA) kits were produced and supplied to various hospitals, research centres and immunoassay laboratories throughout India.

Regulatory approval for the regular production and supply of

newly developed IRMA kit for human thyroid stimulating hormone (hTSH) was obtained from the Radiopharmaceutical Committee. This user-friendly kit was included in the BRIT product list. A similar IRMA kit was also developed for human follicle stimulating hormone (hFSH).

Development of IRMA procedure for human C-peptide was initiated and optimization of the assay procedure was completed. The work on the kit formulation for the large scale production and supply continued.

Regional Centre, Delhi carried out production and supply of around 57,000 mCi of various ready-to-use Tc-99m Radiopharmaceuticals injections for diagnostic nuclear medicine studies in 21 hospitals in Delhi and the NCR region. An alternate column based solid-phase extraction method is developed for production of Tc-99m for clinical applications. Retail outlet

for supply of cold kits for preparation of various Tc-99m-radiopharmaceuticals, supplied 1100 kits.

The Regional Centre, Bangalore supplied over 63,700 mCi of ready-to-use Tc-99m formulations and carried out about 240 RIA investigations. Over 770 TCK cold kits were sold through retail outlets. Blood bags were irradiated at the centre.

BRIT's Regional Centre at Kolkata was partially successful in radiolabelling different porphyrin derivatives with Ga-67 and In-111 in collaboration with BARC and VECC. Ge-68 produced by internal alpha irradiation of electroplated Zn target for Ge-68-Ga-68 radioisotope generator, was carried out for the first time in India using indigenously produced Ge-68. The direct use of Ga-68 for radiolabelling of peptides was limited for clinical PET applications.

Ga-68-EDTMP used for PET Bone imaging agent was prepared with Ga-68 adsorbed on the cation exchange column by eluting with EDTMP (50mg). The chemical yield of Ga-68 in EDTMP was 75-80% and radiochemical purity of Ga-68-EDTMP was 100%.

A new target holder for external irradiation with high beam current was fabricated with VECC. An electroplated Zn target was irradiated with 40 MeV alpha particles. The irradiation was successful and no damage of the irradiated target was observed.

A modification of the solvent extraction system in Mo-99-Tc-99m-SOLKOL (Solvent and Column) Generator was introduced. A PC-controlled SOLKOL generator was installed at BRIT, Mumbai. A new infection imaging agent using a cephalosporin antibiotic (Tc-99m-Cefuroxime) is developed and being evaluated for potential use as bacteria specific infection imaging agent. Animal imaging studies were done in collaboration with Department of Nuclear Medicine, IICB, Jadavpur and RRMCC, VECC. Bio-distribution studies were done in collaboration with Department of Nuclear Medicine, IICB, Jadavpur.

A new tumour imaging agent Tc-99m-HYNIC-OCT was developed at BRIT. This was radiolabelled with Tc-99m. A few freeze dried kits were prepared with HYNIC-OCT. A new derivative of octreotide analog HYNIC-HIS3-TATE and its Tc-99m complex were developed. HYNIC-HIS3-TATE was

synthesized by using semi-automated peptide synthesizer at IICB, Jadavpur.

Regional Centre of BRIT at Dibrugarh continued rendering its RIA and IRMA diagnostic services for the benefit of North-Eastern region. These services offered to the hospitals in the region, benefitted more than 10,000 patients in 2011.

Labelled Compounds and Diagnostic Kits

The Labelled Compounds Programme of BRIT is focused on the synthesis and supply of a variety of C-14, H-3 and S-35 labelled products, oligonucleotides (DNA primers) and ready-to-use non-radioactive (cold) kits for nucleic acid labelling. These products are used as radiotracers in diverse investigations in the fields of biology, agriculture, medicine and chemistry.

Labelled Compounds Programme is also involved in the production and supply of tritium filled sources of various types for defence applications. These sources are used for the illumination of military gadgets and instruments.

Custom-synthesis of various radiolabelled compounds using Carbon-14 and tritium radioisotopes was also carried out to meet the specific requirements from researchers.

A method development was carried out for the preparation of some deuterated NMR solvents having deuterium abundance more than 99%, as part of the

MoU signed by BRIT with Heavy Water Board. Five such solvents, prepared both by BRIT and HWB, were launched for commercial supply.

Real time PCR kit for detection of M. tuberculosis based on the BRIT's patented Real time PCR chemistry developed at Jonaki laboratory, was in progress. The RTPCR kits will make an impact in the diagnostic area.

Jonaki produced and supplied Phosphorus-32 labelled nucleotides, Molecular diagnostic kit for MTB Detection, Taq DNA polymerase enzyme, Nucleic acid Isolation kits and others, required for molecular biology, biotechnology, biomedical and drug discovery research. Jonaki also marketed S-35 labelled amino acids. Retail outlet for TCK Cold kits at Jonaki catered to the requirements of nuclear medicine centres in the region.

Radio Analysis

The measurement and certification of man-made 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 Radio-Analytical Laboratory of BRIT at Vashi. Food items were monitored for the presence of Cs-137 and Cs-134. Presence of I-131 was also monitored in food items imported from Japan. Water samples were routinely analysed for gross alpha/gross beta, Uranium, Ra-226 and Ra-228 content, depending upon the

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requirement.

Radiation Sterilization Services for Medical Products :ISOMED

The Facility had been operating in full compliance with the statutory guidelines with an average load availability factor 99% and average utilization factor of 95%. About 4660 cubic metres of healthcare products were processed for terminal sterilization between April 2011 to November 2011. Different suppliers to the nuclear industry for thermal insulations/power cables/ paints/ instrumentation devices etc. availed of the gamma radiation processing.

As part of the regulatory approval procedures, the operating license of the facility was renewed by AERB from July 2011, up to June 2014. GMP plan of the facility was accorded

formal approval by the Food and Drug Administration (FDA) Bandra, Maharashtra.

New Projects

Integrated Facility for Radiation Technology

Under this project, a Hot Cell for handling, storage and fabrication of sealed sources up to 300 kCi of Co-60 will be set up at Vashi. This project was in progress as per schedule and reached an advanced stage of execution as the civil construction for administrative building, water pool, radiometry room and Hot Cell was completed.

Integrator Irradiator Development Project

The objective of the Project is to upgrade safety and security features in the Radiation

Processing Plant and Vashi and ISOMED facilities, and to set up an Irradiator Training Facility for training of personnel for operation of irradiator.

The work carried out during the current fiscal included : Installation of the Systems for Access control and vehicle tracking; Procurement of Early fire warning system for ISOMED, and Design and fabrication of Aerosol Generator. Fabrication of Single bag blood irradiator and Scale down model of medical sterilizer was completed, and the irradiator and sterilizer were supplied.

Production Facility for Mo-99/ Tc-99m Column Generators

The project aims at setting up of a new automated facility for production of Mo-99 Tc-99m Column generators using high specific activity Mo-99.

The installation of the facility and cold runs were completed. During December, 2011, trial production and supply of product generators to the Radiation Medicine Centre was started. This project was completed as per schedule.

State-of-the-Art Immunoassay Facility

The facility has the objective to create an infrastructure for coated tube technology, development and building up of infrastructure for immunoassay based on non-isotopic labels, and development of diagnostic kits for infectious diseases.

Procurement of necessary



*Inside view of Integrated Facility
for Radiation Technology*

equipments needed for development of isotopic/non-isotopic assays was over.

Indigenous HDR Brachytherapy Equipment (IHDR)

BRIT aims at establishing the complete process and facilities for fabrication of Ir-192 HDR sources for regular production, and development of indigenous, remote operated high dose rate HDR brachytherapy equipment including necessary treatment.

First prototype of IHDR was successfully developed, and cold trials continued. A miniature Ir-192 source assembly for IHDR was developed and AERB approval obtained.

Facility for production of medical grade Fission Molybdenum

The project aims at setting up facility for production of Mo-99 for medical use. It will supply indigenous column generators to various diagnostic centres and hospitals in the country. The project was sanctioned by AEC. It is scheduled for completion by the year 2014.

The site clearance for the project was obtained from AERB and the designs for the building were finalized. Further works are in progress.

Biomedical Applications - Polarization Sensitive Optical Coherence Tomography

A near real time single mode fibre-optic based Polarization Sensitive Optical Coherence Tomography (PSOCT) setup

utilizing a swept source was developed at RRCAT. The setup was used for imaging birefringence of mice tail tendon, thigh muscle ex-vivo and human nail fold in-vivo, the measurement of the refractive index of cells undergoing photodynamic action, study the effect of low power red laser light pre-exposure on Zebrafish embryos exposed to ethanol and in vivo study of healing of wounds in mice skin.

The fluorescence and Raman spectra acquired earlier at Tata Memorial Hospital (TMH) at Mumbai, were used to make a comparative evaluation of the efficacy of these two approaches for screening neoplasms of oral cavity and also check the influence of tobacco consumption in the spectra of healthy volunteers.

Studies were carried out on the effect of Photodynamic Treatment (PDT) on infected wounds. The results obtained show that apart from killing the bacteria, PDT also led to inactivation of virulent factors of *P. aeruginosa*. Non-invasive imaging of wounds subjected to PDT treatment was also carried out using polarization sensitive optical coherence tomography. Results obtained show that the PDT treatment led to faster re-epithelization and ordering of collagen in the wounds.

Production of Oxygen-18 enriched water

Oxygen-18 is one of the isotopes of oxygen that has varied

applications in nuclear medicine and biochemical research. The Heavy Water Board, that is entrusted with the production of Oxygen-18 enriched water, 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 Oxygen-18 from natural / heavy water. The experimental set up at Talcher was shifted to Heavy Water Plant, Tuticorin, and experiments continued. First set of experiments were completed.

Engineering was carried out for the Small Scale Prototype Facility for upgrading off-grade $H_2^{18}O$ water available at the 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 and the facility is expected to be available shortly.

Basic cascade design was carried out for industrial scale facility. Procurement of equipments/systems for Oxygen-18 enriched 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.

TMC, that comprises the Tata Memorial Hospital (TMH) and

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Advanced Centre for Treatment, Research and Education in Cancer (ACTREC), continued to provide service in the diagnosis and treatment of cancer, and carryout cancer research. The Centre also enhanced training and education in the field of cancer.

During the report period, about 62,000 cases under conventional radiography, over 19,000 cancer surgeries and over 8500 cases of mammography were handled at the Tata Memorial Hospital.

The Clinical Research Secretariat initiated the process of registering clinical trials in a central registry. The Hospital Scientific Review Committee (HSRC) and Hospital Ethics Committee of Tata Memorial Hospital (TMH) reviewed and approved 102 projects.

Cancer Awareness & Prevention

As a part of its societal initiative, TMC continued its outreach programmes such as 'TMC- Urban Outreach Programme' in the slums of Mumbai and the 'TMC-Rural Outreach Programme' in the districts of Ratnagiri and Sindhudurg, of Maharashtra.

In addition, TMH-Outreach Programme aims to reach the slums and underserved areas of Mumbai, for early detection of oral, breast and uterine cervix cancers among women. Women detected with cancers or pre-cancers are offered appropriate treatment free of cost at the Tata Memorial Hospital thereby improving their survival. The project will cover 1,50,000 low

socio-economic population residing in Mumbai.

As part of cancer prevention programme, TMC provided cancer screening services for common cancers and created a model for cancer control programmes for the country and conducted Information Education and Communication programmes aimed at risk prevention, life style modification and improving health seeking behaviour towards early cancer detection and Tobacco Cessation Programmes at various places.

WATER

DESALINATION OF WATER

BARC's Nuclear Desalination Demonstration Plant (NDDP) consisting of Multi-Stage Flash and Reverse Osmosis sections of 4.5 million litres/day and 1.8 million litres/day capacities respectively were operated round

the clock at Kalpakkam producing water at a quality of about 5 ppm total dissolved solids from sea water having 35,000 ppm total dissolved solids, as well as potable water.

Design of 240 cu.m/hr Multiple Effect Distillation-Thermal Vapour Compression (MED-TVC) system was finalized and cleared for fabrication. Also site preparation work for this continued. A Multi-Effect Humidification (MEH) experimental facility was installed and operated at Trombay. A 1000 LPD capacity MEH based desalination unit, powered by solar energy through solar thermal collectors, was installed at Kalpakkam and the performance was under evaluation.

A Brackish Water Reverse Osmosis (BWRO) demonstration plant integrated with a wind-based power unit was designed, installed and commissioned at



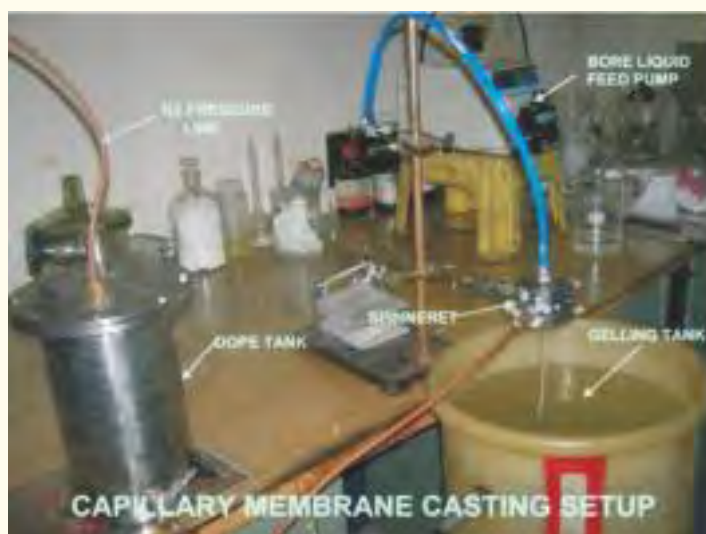
*Solar driven 1000 litres/day
Multi-Effect Humidification facility at Kalpakkam*



Brackish Water Reverse Osmosis Unit powered by wind energy at Trombay



Brackish Water Reverse Osmosis Plant at Chiplun (Maharashtra)



In-house developed capillary membranes

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*Delayed coincidence counter for
measurement of Radon-223 and Radon-224*

Trombay. The power unit can work as a stand-alone system or as complementary to the existing solar photo-voltaic unit, to drive the RO plant. As a part of field trial of BWRO technology through AKRUTI programme, a 7 cu.m/day BWRO unit was integrated with a community well at Chiplun.

A beginning was made for making support-less capillary membrane based systems for various applications in nuclear streams, besides water treatment. Capillary membranes of various lumen diameters were developed.

The drinking water sources in several villages of Punjab were found to be contaminated with uranium up to about 700 ppb compared to the AERB permissible limit of 60 ppb. BARC developed a water purification system comprising of 10 and 5 micron cartridges followed by Ultra Filtration and Reverse Osmosis membrane

modules. The field test was carried out in twenty four village sources.

A beginning was made towards development of commercial size indigenous seawater membrane and elements. The first batch of indigenously developed thin film composite reverse osmosis (TFC-RO) membranes was prepared and spirally rolled to commercial sizes. Six of these elements were made ready for replacing the membrane elements with in-house developed membranes in reverse osmosis plant at

Kalpakkam.

An isotope hydrological investigation was carried out to identify groundwater sanctuaries in and around the Anjangaon village and a huge groundwater sanctuary was identified about 10 km south of Chinchona hill range.

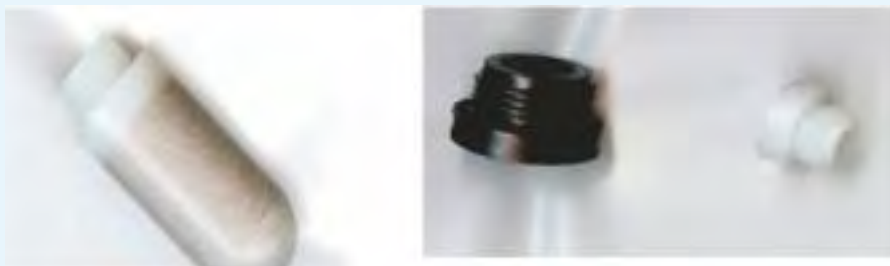
Borehole drilled at the site is yielding ~30,000 litres/hr and is a perennial source of good quality water. This water can be supplied to 5-6 villages for drinking and for irrigation.

A radium delayed coincidence counter was installed for the measurement of Radon-223 and Radon-224 in seawater to identify and quantify the submarine groundwater discharge from multi-aquifers in the coastal regions for various water needs in water scarce regions.

INDUSTRIAL APPLICATIONS

Electron Beam Cross linked Polymers

During the current financial year, BARC's research and development support to industry, for the development of polymer nano-composites, nylon based



*Electron Beam Cross linked Polymer bushes and adaptors for
automobile silencers (more than 1 lakh pieces were
irradiated on commercial basis at IIU-6 EB facility)*

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cross-linked railway liners, polyethylene-O rings, battery separators, polymer bushes and adaptors etc. continued.

New methodologies and materials were developed using radiation engineering of nano-materials for detections of biomolecules and advanced grafted materials for dyes and pesticides remediation of polluted water.

Radiation processed advanced conducting polymer composites were developed for various applications.

A radioactive particle (Sc-46) tracking technique was developed at Trombay and applied to track the motion of the packing elements in a Rotary Fluidized Bioreactor at a private industry, for visualizing flow and evaluate design of the reactor. The radioactive particle tracking experiments were implemented in a pilot-scale reactor.

Gamma-ray transmission technique was explored to study the quality of fluidization in conventional fluidized bed and packed fluidized bed for understanding efficient heat and mass transfer in gas-solid fluidized bed. Experiments were conducted in packed-fluidized bed of silica particles in the interstices of large size alumina pebbles and lithium-titanate particles in the interstitial void space of large size lithium titanate pebbles. It was observed that packed fluidized bed provides better quality of fluidization or more homogeneous fluidization as compared to when in a



Gamma Scanning of a Process column



Field Isotope tracer studies in progress

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conventional fluidized bed.

Under an MoU between the Indian Oil Corporation (R&D Centre), Faridabad and BARC, development work was carried out on a Cesium-137 based multi-detector Gamma Process Tomography System for their 600 mm cold solid catalytic bed column, to characterize liquid and gas flow distribution through the column under specified operating conditions, and to map approximate planar and volume density distribution. The developed system is one of its first kinds in the country for fixed bed operation for use in research and development studies.

Cobalt Sources for industrial use

During the year of report, 2 Cobalt Teletherapy Sources were prepared using indigenous pellets, 32 Tungsten (W-91) pencils containing about 600 kCi, were welded and tested as per AERB guidelines for sealed source fabrication. The

radiosources supplied by BRIT for various industrial uses, were as per the following Table.

Radiosources supplied by BRIT

Following Radiation Sources for Nucleonic Gauges and other uses were custom made :

- 13 sources of Cobalt-60 with activity of 1978 mCi
- 5 sources of Cesium-137 with activity of 4705 mCi 1 source of Europium-152 with 33 mCi of activity

Radiation Technology Equipment

Radiography Camera ROLI-1 & II

During the financial year (Upto December, 2011), BRIT supplied 72 Radiography Exposure Devices. Supplies of another 15 cameras are expected to be completed by March 2012.

One more model of Radiography Camera : ROLI-II was launched. It is remotely

operated hybrid shield camera with a capacity of 65Ci of Ir-192 source. The camera was approved as Type B(U) by AERB.

Over 380 ROLI cameras were serviced up to December 2011 and another 130 cameras will be serviced before March 2011. About 720 decayed sources were removed between April-December 2011 and another 270 sources will be disposed off by March 2011. BRIT carried out inspection of over 690 imported cameras by December 2011 and another 250 imported cameras will be inspected before the end March, 2012.

Transportation Cask

BRIT modified and enhanced capacity of its main transportation cask BLC from 100kCi to 125 kCi Co-60. The new cask was subjected to various tests as per the national and international standards of safety for transportation and was approved by AERB. The New cask (BLC-125) will be used for the supply of Irradiator sources.

User	No. of Sources	Total Activity
Industrial Irradiator Cobalt-60 sources supplied to the Irradiators in Delhi, Bangalore, and Vadodara	36	600 kCi
Ir-192 Radiography Sources supplied to various users	814	31 kCi
Cobalt-60 Radiography Sources supplied to various users	8	388 Ci
Tm-170 Radiography source supplied to user	1	5Ci
Equipment	Source loaded	Total Activity Loaded
Gamma Chambers (GC 5000) - 2 nos	Cobalt-60	28,000 Ci
Blood irradiator (BI-2000) – 2	Cobalt-60	1600 Ci
Cesium-137 Kit (CSA)	Cesium-137	579 mCi
Ir-192 + Pt Wire - 100 cm long	Ir-192	643 mCi



*ROLI I Radiography Camera
with Stainless Steel body*



*Irradiator source
transportation cask*

CHAPTER : 5

BASIC RESEARCH

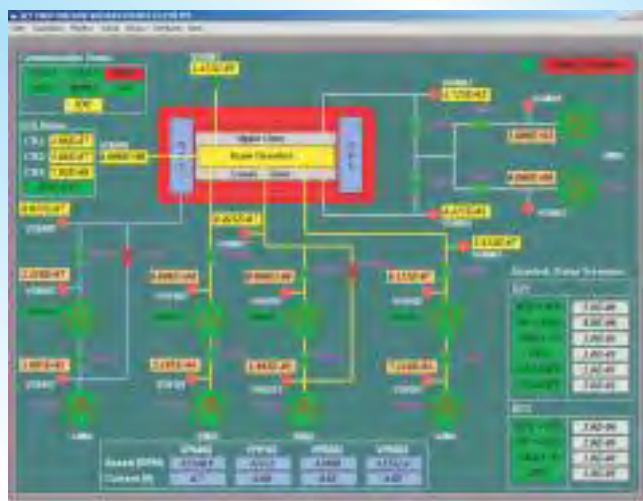


X-ray lithography beamline on Indus-2





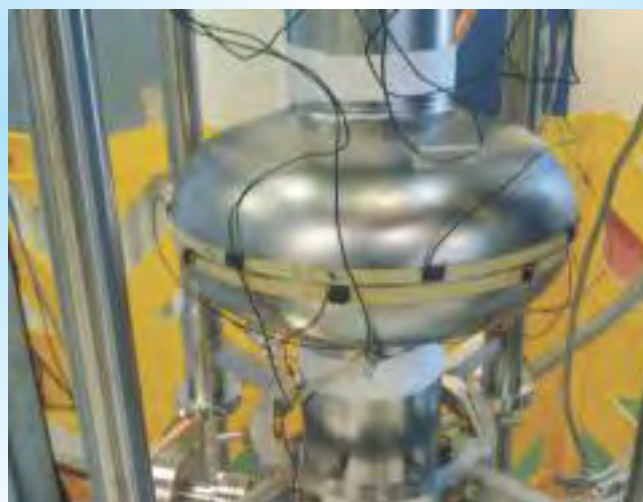
One read-out controller board built in India for CBM research and development



Graphic User Interface of vacuum control system for Superconducting Cyclotron



Magnet assembly with inflector



1.3 GHz Single cell Superconducting Radio Frequency Cavities for Fermi Lab

CHAPTER : 5

BASIC RESEARCH

The Department of Atomic Energy has a strong commitment to basic research and 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.

In the field of basic research, following were the major activities and achievements of DAE during the period of report.

MATHEMATICS & COMPUTATIONAL SCIENCES

Theoretical investigations of heavy metal based hydrogen isotope storage materials were carried out at Trombay. The structural, electronic and thermodynamic properties of U, Ti and U_2Ti were calculated. The effect of the relativistic spin orbit interaction on these properties was investigated.

Experimental measurements of enthalpy increment and specific heats of U_2Ti were carried out to supplement the theoretical data. Potential oxoacidity diagrams of An (An=Am, Cm, and Np) in LiCl-KCl eutectic at 743K were constructed.

A Profibus based communication system for nuclear



Profibus Master Card

plants was developed which helped in eliminating large amount of signal cabling.

Deterministic Fault Tolerant Communication Protocol Board was also developed to meet the requirement of hard-real-time distributed / networked control systems. It provided reliable, deterministic and fault tolerant data communication. A five node prototype system was setup by BARC using these boards.

The data acquisition software for the system in operation at VECC was upgraded to easily configure multiple crates and perform high speed block data transfer from each crate. One synchronizer module was developed in-house to properly synchronize the hardware

modules distributed over multiple crates. A framework for semi-automatic parallelization of sequential codes for SMP machines was implemented. A monitoring system for the IT infrastructure was developed using Nagios. This monitoring framework will identify and resolve IT infrastructure related service issues.

Other developments at VECC were : a Trouble Ticketing System - a ticket initiation, monitoring and tracking system, for solving users' request / problems related to services provided; a handheld RFID reader system and an online TLD badge identification system.

A Readout Controller Board is one of the most important components in DAQ chain.

Thirteen such boards were successfully completed and tested. This is a major contribution of VECC in the field of development of electronics for CBM (Compressed Baryonic Matter Experiment) Collaboration (GSI, Darmstadt).

TIFR remained actively involved in research in several areas of pure mathematics, and also in several instructional and training programmes. New methods were developed to estimate the size of L-functions of degree 2 and 3, and various strong sub-convex bounds were established for these L-functions. A conjecture of Shafarevich that, universal cover of a surface is holomorphically convex, was proved for a class of surfaces. The intersection complex on the canonical smooth compactification of the Siegel modular variety of dimension three with coefficients in the direct image sheaf from the universal family was realized in a suitable category of Chow motives. Strong multiplicity one was proved about the spectrum of locally symmetric spaces.

At TIFR, conditions were obtained for the entropy power inequality to hold for a class of discrete distributions. A characterisation of popular matchings in bipartite graphs was obtained, from which the first polynomial-time algorithm for computing a maximum cardinality popular matching in a bipartite graph was derived.

At SINP, successful

application of the integrable perturbation was achieved for a wide range of nonlinear systems generating new nonlinear models, including N-wave deformation and hidden possibilities in the integrable structure of the deformed nonlinear Schrödinger equation in controlling the optical soliton in fibre optic communication.

Non-commutative black holes and the behaviour of scalar fields in such backgrounds were investigated. Effect of topological defects of the quantum dynamics of lower dimensional systems such as grapheme, were explored.

With the Cray Supercomputer at SINP, the lattice QCD (Quantum Chromodynamics) investigations with 2-degenerate light dynamical flavours of Wilson quarks and plaquette gauge action got a boost. Gauge configurations were generated for two different lattice spacings, three different volumes and a host of quark masses corresponding to pion masses in the range below 300 MeV to about 700 MeV.

In the field of Mathematics, the research at HRI spanned the domains of algebraic geometry, arithmetic geometry, analytic and combinatorial number theory, group theory, harmonic analysis, mathematical physics and geometry.

Several mass formulae were found for a local field with finite residue field. Some progress was made towards some questions in Euclidean Ramsey Theory and

results were obtained in the area of weighted zero-sum problems.

At HRI, the research in Harmonic Analysis was centered around Schrodinger equations and related problems. One of the problems studied concerned the wellposedness of a class of nonlinear Schrodinger equations associated with the special Hermite operator.

The IMSc continued its work relating to the projects: Mathematics Education : Mathematical Sciences without Walls; Interplay of Non-linearity with Quantum Effects and Curved Geometry, and Physical Principles relevant to Nanoscale Devices and Biological Motors in the Brownian regime. It carried out development of tools for dynamical modelling of C elegans neuronal network activity, and Computational study of Functionalized Nanoparticles.

In the field of mathematics, NISER has academic expertise in harmonic analysis, operator theory, representations of geometries, theoretical computer science (cryptography), algebraic graph theory and probability theory. Recently 18 research papers were published by the School of Mathematical Sciences of NISER.

Also, using the Konark facility, the researchers at NISER calculated the electronic structure of materials from the first principles using parallel implementation of methodologies based on density functional theory, time dependence density

functional theory, many-body perturbation theory and non-equilibrium greens function.

PHYSICS

At BARC, several new results were obtained in the field of laser spectroscopy with supersonic beams. Radiative lifetimes of 45 odd parity excited levels of Lanthanum atom were measured. Extensive work was carried to form and study the spectroscopy of transition metal containing diatomic molecules.

Experimental and theoretical work in nano-photonics resulted in several new and interesting results having important

technological implications. Excellent quality self-assembled photonic crystals with 40 well-ordered layers were synthesized using micro-particles of sub-micron dimensions. Optical response of these crystals was investigated. Light propagation studies were conducted on the photonic crystals generated using dye doped polymer microspheres.

Experimental and theoretical investigations were carried out on ion clouds in Paul and Penning traps. Europium ions were trapped in a Paul trap and optically detected using laser induced fluorescence to obtain the shape and size of the ion clouds.

Neutron diffraction studies

were performed on multiferroic core-shell nanoparticles of Bi-Fe-Mn-O. The effect of particle size on the nature of spin, orbital and charge ordering were investigated in nanoparticles of the half doped manganite, Nd-Sr-Mn-O.

Small-angle neutron scattering experiments were carried out to study the adsorption of proteins Lysozyme and BSA on gold and silica nanoparticles. Neutron scattering measurements reveal the evolution of mesoscopic structure of cement paste which exhibited temporal oscillations, strongly dependent on the scale of observation and on the medium of hydration (light or heavy water).

Nano-composite micro-



Laser heated diamond cell facility at Trombay

capsules of silica and surfactants were synthesized. Raman spectroscopy was used for characterization of a variety of materials - in particular for nondestructive composition analyses of nuclear materials like ThO_2 - UO_2 mixture. A study revealed the finer details of influence of chemical bonding on electron density.

To carry out high pressure studies at very high temperatures (a few thousands K), a laser heated diamond cell facility employing a 100 W air cooled Ytterbium fibre was set up at Purnima Laboratories at Trombay. The studies on new materials were initiated using this facility.

X-ray Absorption Fine Structure (XAFS) studies on manganite nano-particles helped to establish the role of disorder on the magneto-transport properties of these materials. Besides, high pressure X-ray diffraction and Raman scattering studies on amorphous Silicon high pressure, X-ray diffraction investigations of intermetallics, Heusler alloys,

and rare earth garnet were completed. High pressure Raman, infrared spectroscopic and X-ray diffraction studies of Bis(glycinium) oxalate, an organic complex of glycine, revealed a structural transformation. High pressure Raman behavior of zircon structured rare earth ortho vanadates (DyVO_4 and EuVO_4) indicated an irreversible structural phase transition.

A Charged Particle Detector Array was fabricated at Trombay for BARC-TIFR Pelletron-LINAC Facility. This array will be used for investigations in fusion-fission dynamics, nuclear structure at elevated temperatures, angular momenta, exotic nuclear clusters and related domains.

BARC's TACTIC Gamma Ray Telescope at Mt. Abu was deployed for observation of a number of active galactic nuclei and to monitor their flaring activity in the TeV (1TeV=One thousand billion electron volt) energy range. Detailed analysis of data collected from the Mrk 421

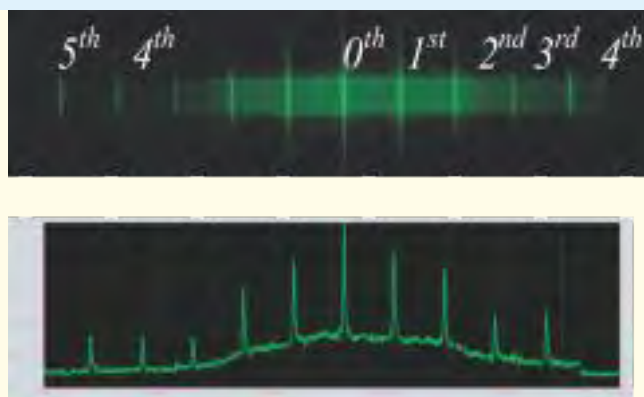
direction revealed the presence of gamma-rays. The source parameters determined from the TACTIC data were in close agreement with those reported by other telescopes around the world.

The manufacturing activities related to the 21m diameter MACE Gamma Ray Telescope progressed well and the trial assembly of its mechanical structure was started at Hyderabad in December 2011.

The Gulmarg Neutron Monitor was operated on a continuous basis for recording neutrons of cosmic-ray origin and also neutrons generated in the atmosphere by lightning discharges.

The studies carried out at RRCAT during the report period resulted in achieving X-ray lasing at a wavelength of 46.9 nm in Argon capillary discharge plasma for the first time in the country, and neutron generation was observed in ultra-high intensity laser matter interaction.

At VECC, salient research activities were the following :



The capillary discharge X-ray laser system and (right) the spectrum of the emitted laser radiation

An extensive experiment was carried out to investigate the temperature dependence of the GDR width using alpha induced fusion reaction.

The excited levels of Pm-150 were investigated using proton beams of 8-11 MeV energy range and the 97% enriched Nd-150 target.

Investigation of high spin structure of heavy thallium isotopes Tl-197 and Tl-200,201 were carried out using alpha beam from K-130 cyclotron at VECC and Li-7 induced reaction at Pelletron-LINAC facility at TIFR. The high spin band structures based on intruder shell model orbital with oblate deformation were observed in these nuclei.

Offline decay spectroscopic studies of Eu-146 and Os-186-189 were carried out using Low Energy Photon Spectrometer.

An exclusive experiment was performed to study the Hoyle state that plays an important role in the production of the elements in the universe.

Nuclear Level Density (NLD) parameter is an important ingredient in all statistical model codes that are used for certain reaction modeling. In a recent experiment at VECC, angular momentum dependence of the NLD parameter was studied using the alpha induced reactions on In-115 and Nb-93 target.

Alpha-induced reaction cross-sections measurements as a function of alpha beam energy were carried out.

Using alpha beams from K-

130 cyclotron, different radio-tracers for various applications were synthesized at VECC.

An analytical model was developed from nuclear reaction theory to calculate neutron-nucleus total, reaction and scattering cross-sections.

For the Indian Neutrino Observatory and other areas of applications such as medical imaging detector developments continued at VECC.

The INO-laboratory at VECC, in which a 30-ton Iron Calorimeter (ICAL) was installed for cosmic ray detection, continued to take data. A major programme was launched where INO collaborators from all over the country were engaged in the analysis of this data set consisting of several million cosmic-ray events.

As a part of the applications of Gas Electron Multipliers (GEMs) and Multigap Resistive Plate Chambers (MRPCs) in the area of medical imaging, a laboratory was setup at VECC. MRPCs, due to their excellent time resolutions, have the capability to be used as an inexpensive PET imaging detector-system. A setup was made where 511-keV photon pairs from the Sodium-22 source will be detected for feasibility study of PET imaging.

At TIFR, dissipative superfluid dynamics was inferred from gravity and a theory of first order dissipative superfluid dynamics was elucidated. Initial-state fluctuations were determined from flow measurements in heavy-ion

collisions and anisotropy generated by fluctuations was understood. The interplay between the diphoton events from Higgs decay and squark gluino production at the Large Hadron Collider experiments at 7 TeV and 14 TeV was studied. Neutrino-neutrino interactions in a supernova and their effect on neutrino flavor conversions were studied. A multi-species model with interconversion, chipping and injection was solved by researchers of TIFR.

Other activities were : The bulk viscosity of anisotropically expanding hot QCD plasma was studied; A novel Higgs mechanism in (2+1)d Chern-Simons theories was unraveled; Tetraquark states from lattice QCD were studied, and the scale for the Phase Diagram of Quantum Chromodynamics was determined.

A Near-Infrared Spectrometer and Imager for Large Aperture Indian Telescopes (TIRSPEC-1) reached completion stage. TIFR will be integrating TIRSPEC-1 with the 2-metre Himalayan Chandra Telescope at Hanle (Ladakh) and the engineering run of TIRSPEC-1 will be carried out in March 2012.

At the National Balloon Facility, Hyderabad, the Aethelometer payload of Space Physics Laboratory, Trivandrum along with Optical Particle Spectrometer & Ozonesonde payload of TIFR weighing 168 kg was successfully launched and in-situ measurement of the altitude profiles of Black Carbon (BC)

and Composite Aerosols in the troposphere was successfully carried out.

Research was also carried out in the areas of large scale structure of cosmology, general relativity, helioseismology, black holes, neutron stars, accretion-powered pulsars, supernovae, gravitational lensing, quantum gravity and gravitational waves.

At the TIFR's National Centre for Radio Astrophysics (NCRA), Pune, Phase-1 of the development of a new technology receiver system for the Ooty Radio Telescope was completed. Prototype versions of multi-antenna were developed, and prototype version of wide-band RF (550 to 900 MHz) feed and related low-noise amplifiers had undergone successful testing on GMRT antennas and cleared for mass commissioning. The mechanical erection of the new technology 15-metre antenna was completed. A modern, authenticated data archival and retrieval tool for GMRT data was developed in collaboration with the Virtual Observatory India project.

In the field of high energy physics, at TIFR, a cold atoms experiment with three isotopes of Potassium and two isotopes of Rubidium, was fully operational.

The HAGAR array at Hanle was in regular operation. Sources of gamma-rays, viz., pulsars, supernova remnants and active galactic nuclei (AGNs) were observed.

In nuclear physics, the clover detectors were used in the Indian

National Gamma Array for the investigation of nuclear structure and reaction studies. An ideal magnetic rotational band in In-112 isotope was established through lifetime measurement.

One major experiment was carried out by TIFR where a combined assembly of a high energy gamma ray spectrometer and the sum-spin spectrometer for exclusive measurement of GDR gamma rays spectra from hot-rotating Hg-196 was used. Absolute cross section measurements were made of electron impact ionization of organic and inorganic molecules in gas phase.

Frequency control of coherent random lasers was achieved using an aperiodic array of monodisperse dye-doped microspheres. The frequency fluctuations were narrowed down to 1.2 nm.

In Condensed Matter Physics, the X-ray, EDAX characterization facility continued to meet the needs of TIFR researchers and other users from Mumbai. A 16 Tesla VSM was added to the magnetometer facility.

Mapping was done of the entire phase diagram of a strongly disordered conventional superconductor. For the preparation of high quality single crystals for research, an induction furnace for melting intermetallic samples and a 14 T magnet platform, were successfully commissioned.

The spin resolved photoemission spectrometer and the high resolution electron

energy loss spectrometer were installed. An energy resolution of 2 MeV in the high resolution electron energy loss spectrometer was achieved.

An indigenously designed and developed THz source was successfully fabricated and tested.

During the report period, the experimental activities at SINP were centred around the Tokamak, the linear Magnetized PLasma machine (MaPLE), the Deep space plasma propulsion experiment, Diamond Nanotechnology for Biological Applications Facility and nonlinear dynamics experiments. Some of the interesting results from the tokamak were related to the behaviour of runaway electrons in a Tokamak plasma.

SINP carried out research on a variety of topics in Astro Particle Physics. Some of these related to the experimental search for WIMP Dark Matter Candidates using superheated drop detectors; Work on various particle physics models of dark matter; Phase transitions in Neutron Star interiors; Neutrino mass and leptogenesis, and Black Hole spacetimes.

A theory developed at SINP within the effective Lagrangian framework, predicted that the dilepton production in proton-neutron collisions was three to four times larger than the corresponding rate in the proton-proton collisions.

At the Harish-Chandra Research Institute, studies continued on string theory,

quantum information and computation, condensed matter, and astrophysics. The members of the string group carried out research in various areas of string theory, quantum field theory and its applications to other disciplines. Research also spanned quantum information, quantum communication, and the interface of quantum information with condensed matter physics. There was ongoing work on studying the role of geometric frustration on magnetic order and the Mott transition. A working scheme was set up to study superconductivity in disordered systems as well as trapped cold atomic systems.

Other areas of research covered relativistic and high energy astrophysics, compact objects, reionization and the intergalactic medium, and inflationary cosmology. In the field of compact objects, the magnetic field evolution of neutron stars in ultra-compact binaries was investigated.

The Institute of Physics continued to pursue research in String Theory, Cosmology and Particle Physics. Some of the topics in focus were Gauge / Gravity duality, 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 system such as liquid crystal is being investigated.

Research at IoP was also

focused on nuclear structure and nuclear reaction. The mechanism for the formation of superheavy elements in astrophysical objects, nucleon-nucleus and nucleus-nucleus reaction and study of cluster decay properties was pursued. Recently discovered superheavy nuclei and a new mode of fission decay for neutron-rich heavy nuclei were studied.

On the experimental side, activities covered the studies related to accelerator based material science, surface and interface physics and nano systems. Different ion beams from the 3 MV Pelletron were used at IoP for modification and preparation of many of the nanomaterials.

The research programme of the School of Physical Sciences of NISER remained focused on a wide range of areas such as high energy theory, high energy experiment, condensed matter theory, condensed matter experiments covering nano materials, magnetism and superconductivity, ultracold atom and Bose-Einstein condensation, and non-linear optics.

CHEMISTRY

In the round robin exercise for comparison of methodology on measurement of distribution coefficient, values for different radionuclides using synthetic ground water samples, were computed at Trombay. Results reported in this study will be used as a basis for further inves-

tigations regarding the detailed nature of nuclide transport at the mining site.

Gamma irradiation studies of polyaniline showed that its capacity decreased gradually with increased dose and reduced to nearly half of the initial capacity on exposure to 3.6 MGy dose. Charge particle activation analysis of trace impurities in high purity graphite and alumina was carried out by optimizing the current and irradiation time.

Magnesium silicate hollow spheres were synthesized at Trombay. Studies conducted suggested that hollow spheres can be used for the removal of uranium from groundwater and other fresh water streams. A new adsorbent was prepared that was used to remove fluoride from the synthetic solutions with an efficiency of 87% within 15 minutes.

A new and efficient method for the synthesis of a cationic resin, suitable for Pu(IV) ion sequestration was developed by BARC. Synthesis of a Cs^+ ion-selective calix-crown ether was formulated. A series of bis-triazinylphenanthrolines (BTPhen) and triazinylphenanthrolines (Tphen) were synthesized. The TPhen compounds showed excellent selectivity in extracting the An(III) ions in presence of the Ln(III) ions.

The diarylnonanoid and malabaricone C, isolated from the Indian spice, rampatri (false nutmeg) showed better potency than resveratrol in inducing

apoptosis to human breast cancer MCF-7 cells. The cytotoxicity of the compound was due to its ability to cause both mitochondrial and DNA damages.

The Piper betel leaves (pan) - derived phenol, allyl-pyrrocatechol, was found to reduce blood pressure, and induce positive cardio-vascular remodeling in a steroid (DOCA)-salt induced acute cardiac rat model.

A Vibrational Sum Frequency Generation (VSFG) set up was developed at Trombay to investigate molecular structure and dynamics at surfaces and interfaces especially in catalysis, biology, environmental chemistry etc.

Various novel organocatalytic, biocatalytic and substrate, as well as reagent-controlled asymmetric

routes, were formulated using indigenous reagents. The methods were used for the syntheses of a diverse array of anti-cancer, anti-viral and immuno-modulatory compounds. A facile approach to functionalize pyrromethene (PM) compounds at the meso-position was formulated. This would be very useful in developing various PM-based functional materials. A silicon-porphyrin hybrid system was designed and prepared by electro-grafting. The material showed impressive electrical rectification property.

Melanins, high molecular weight pigments were explored as potent radioprotector.

A facile supramolecular approach was adopted to prepare cucurbit[7]uril (CB7) based surface functionalized silver nanoparticle (AgNP) conjugates.

These conjugates were investigated in relation to their molecular recognition capabilities for photo-therapeutically important chromophoric dye TMPyP.

A novel solvent system was developed for recovery of palladium from high level liquid waste (HLW) solutions. Its radiolytic and hydrolytic stability were investigated.

Interfacial modifications of materials for diverse applications such as drug delivery, sensors and energy conversion were carried out at BARC. Stimuli sensitive assemblies for encapsulation of proteins or drug molecules were developed using self assembly route. Polyaniline-prussian blue based electrochemical biosensor was developed for detection of uric acid, in the presence of interfering species such as ascorbic acid, urea and glucose.

Thin films comprising Ru-bipyridyl complexes containing different hydrophobic chain lengths were prepared via Langmuir-Blodgett technique.

The nature of structure and bonding of Ag-Pd bimetallic clusters on the Al_2O_3 surface using the plane wave pseudo-potential method was investigated to identify preferred adsorption sites and structure of deposited clusters and explore the nature of bonding in comparison to homoatomic adsorption.

The adsorption behavior of oxygen with transition metal atoms deposited on the Au(111) surface was investigated using plane wave based pseudo-



Sum Frequency Generation Spectrometer

Vibrational Sum Frequency Generation



Diamond film based Alpha particle detectors

Diamond films for the above detectors were grown in-house using MPCVD (Microwave plasma chemical vapour deposition) technique and were characterized. Extensive research carried out in this direction enabled in optimum control of growth conditions so as to grow very high quality diamond films.

Research work was carried out to generate an indigenous database on thermophysical properties of thorium based metallic alloy fuels for future advanced reactors.

A new inorganic-organic hybrid assay of Ag nanorod (AgNR) - Rhodamine 6G (R6G) was developed for the sensitive and selective determination of Pb^{2+} ions in aqueous solutions.

BARC carried out extensive

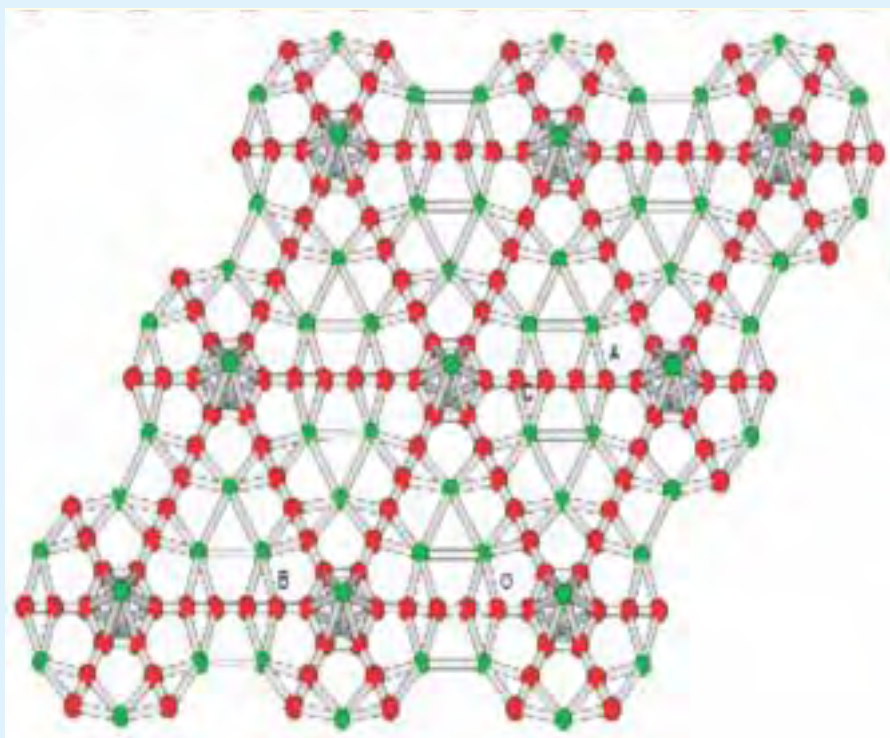
potential approach.

Interaction of clusters (aggregate of atoms and molecules held together by weak forces of interaction) with low intensity laser pulses generated was studied. Studies were carried out to probe possibility for generation of X-rays upon interaction of nanosecond laser pulses with xenon cluster using Optically Stimulated Luminescence (OSL) technique.

Significant work was done on the syntheses and developments of non-lanthanide based host, for doping Lanthanide ions for making efficient luminescent materials. Nanomaterials such as $GaOOH$ and Ga_2O_3 were extensively investigated for their structural aspects and luminescence properties.

In a significant achievement towards development of diamond based alpha particle sensors for use in highly corrosive and radioactive liquid medium

(mimicking the tail streams of fuel reprocessing cycles), a few detectors were fabricated indigenously using in-house developed highly pure electronic grade diamond thin films.



Optimized 3x3x1 super cell structure of lithiated graphdiyne

BASIC RESEARCH

research on titanium metal based alloys for exploring their potential as solid-state hydrogen storage materials. Results on Ti-Cr-V alloy system led to find of a new alloy Ti_2CrV .

Several sulphide based photovoltaic materials were synthesized chemically in powder form. These materials were prepared to use them as evaporants in the deposition of I-III-VI₂ chalcopyrite photovoltaic films. Thin films were successfully prepared by thermal evaporation using In_2S_3 powders

derived chemically as evaporants.

S.S. wire gauze supported Pt-Pd catalysts was developed for hydrogen mitigation under LOCA conditions in a nuclear reactor. A process was also developed for simultaneously depositing platinum and palladium on stainless steel wire-gauze for required noble metal loading in an electrodeless deposition bath

The possible interaction mechanism between carbon nanotubes and uranyl ions was investigated. These findings can open up a new era for actinide

speciation and separation chemistry using carbon nanotubes.

Ab initio first principles calculations are carried out to investigate Lithium dispersed two-dimensional carbon allotropes, viz. graphyne and graphdiyne, for their applications as Lithium storage and hydrogen storage materials.

Molecular Dynamics (MD) simulations were used for efficient prediction of thermodynamic, transport and structural properties for a wide



Atomic beam fluorescence spectrometer developed for high precision measurements of isotope shifts and hyperfine structure

variety of ionic liquids.

Detailed molecular dynamics simulation studies were carried out by BARC on heavy water in the temperature range of 223K to 373K along 1 atmosphere isobar. Simulations were carried out in isothermal-isobaric ensemble.

High-resolution atomic beam fluorescence spectroscopy facility for high precision measurements of isotope shifts and hyperfine structure was developed with a special resolution. The setup can be readily adopted for measurements of radioisotope shifts with adequate radiation safety measures.

Strong reducing agents such as chromous LOMI were prepared and evaluated for their capability to dissolve various oxides found in stainless steel systems of BWRs and PWRs that are not easily soluble in conventional reagents.

Batch Sorption studies were performed with a biosorbent, a chelating resin and a nuclear grade strong base anion resin for removal of radioactive antimony from the primary coolant systems of PHWR and PWRs.

Possibilities of using either sodium silicate or FeSO_4 as a sealing agent for end-shield cracks were evaluated. A titanium alloy and a modified Incoloy-800 were evaluated for their corrosion property using electrochemical polarization and impedance measurements.

Studies were carried out at Trombay on the genes involved in biofilm development, in order to

understand the molecular basis of biofilm formation by bacteria. Aerobic microbial granules with self-integrated phototrophic components were developed in an effort to converge the biodegradation potential of granular biofilms with carbon fixation capability of phototrophic organisms. The phototrophic microbial granules were capable of efficient degradation of toxic wastes and concurrent carbon fixation.

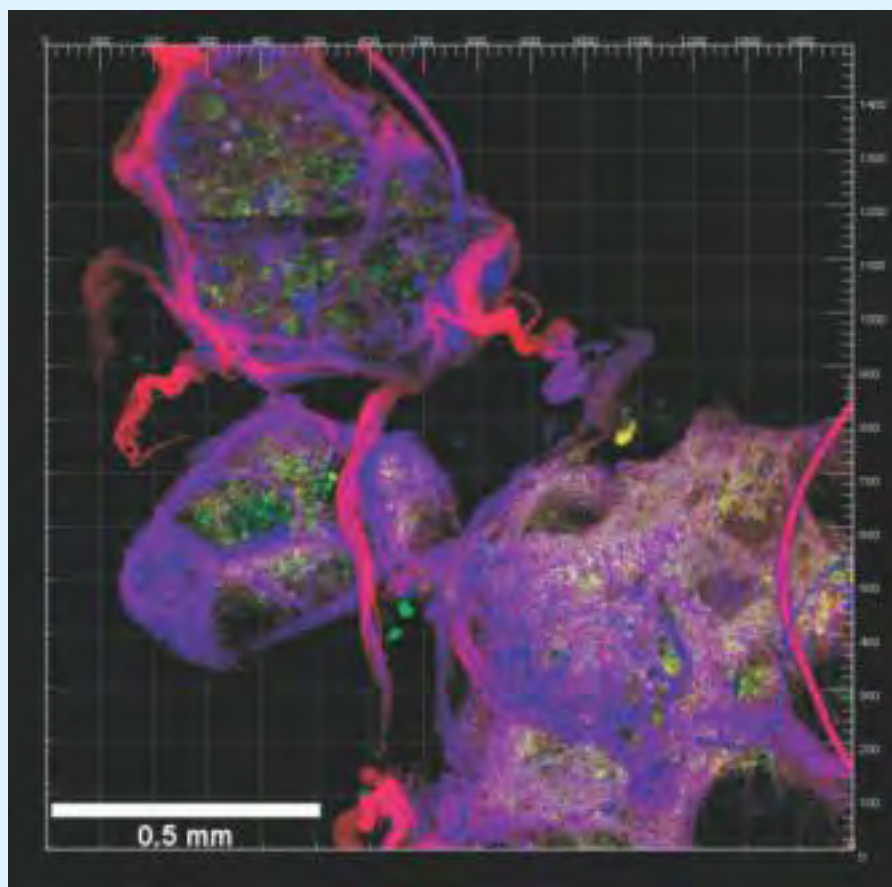
Further optimisation of the bio-denitrification process was achieved.

Analytical services were extended within BARC, and to

other DAE organisations, Private Sector and Academic Institutions.

Determination of mercury at a few parts per billion in Hepatitis B vaccine was carried out using the indigenously developed Electrolyte Cathode Atmospheric glow Discharge Atomic Emission Spectroscopy (ELCAD-AES) instrument.

Trace element characterization of ground water and whole blood samples from people, sampled through AP Council of Medical Research were carried out to provide clues to the prevalence of certain ailments specifically noted in eastern Andhra Pradesh. Accurate methods for the



Photomicrograph of phototrophic microbial granules consisting of cyanobacteria (pink and purple)

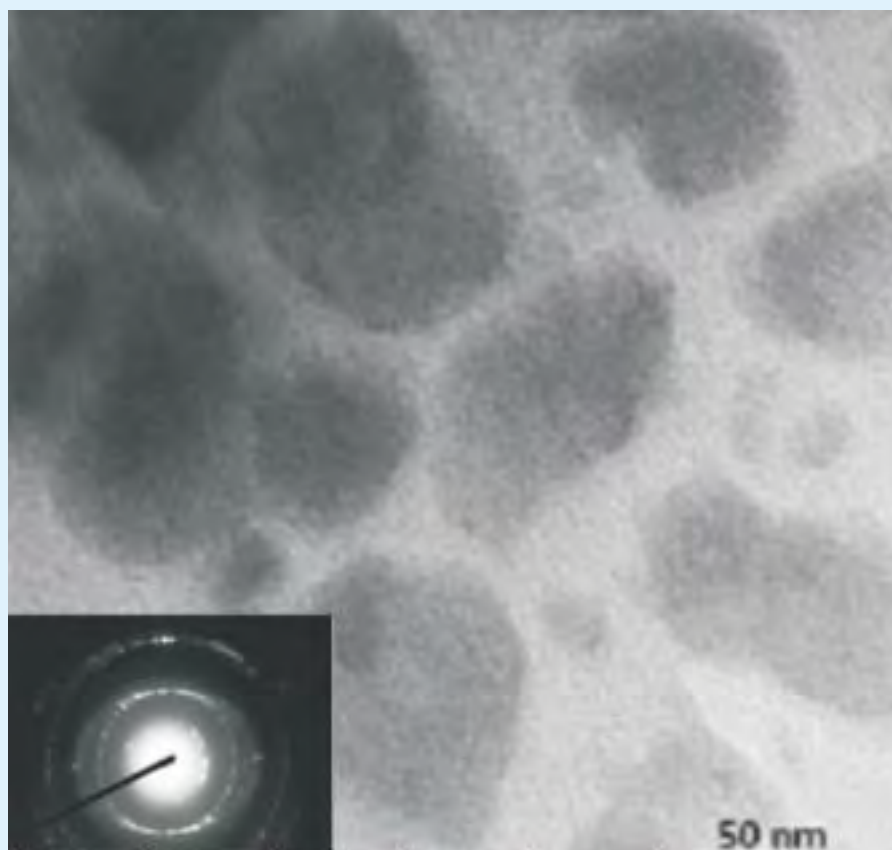
quantification of fluorine in some important drugs were developed. A method was developed for the accurate determination of DNA content at microgram levels through the determination of the stoichiometrically existing phosphorus in the DNA, as orthophosphate, after microwave assisted-UV digestion.

Thermodynamic properties of lithium based ceramic materials such as lithium ferrites and lithium silicates were measured. Thermophysical properties of uranium based alloys at high temperatures were determined as a part of metallic fuel development programme.

New actinide molybdates were synthesized by solid state route and characterized. All compounds showed positive thermal expansion on heating. Double perovskites compounds were prepared and characterized.

The triple potentiostatic pulse strategy was developed to synthesize Lead nanoparticles on a template free gold substrate. The observed monodispersity in the particle size was achieved. The pores in track-etched polycarbonate membrane were used as templates for in-situ preparation of gold-polyaniline nanocomposites.

At TIFR, characterization of bacterial protein MBP and neurotransmitter dopamine in a dopaminergic cell line were done. A crucial link was found between the conformation and the aggregation state of amyloid peptides which provided a possible explanation for the



TEM image and SAED pattern (inset) of gold nanorod after dissolution of track-etched polycarbonate membrane

mechanism of toxicity in Alzheimer's disease.

Thermostable cytochrome P450 was found to catalyse monooxygenation of fatty acids. These results opened up the possibility of using these thermostable enzyme as biocatalysts in epoxidation reactions.

NISER remained engaged, in addition to traditional chemistry, in teaching and research activity in the interface areas of biology, material sciences and medicine.

The research done at NISER generated research papers on topics: Investigating the interaction of a nitrobenzoxadiazole derivative with metal ions: photophysical and

theoretical study; Steady-state and time-resolved fluorescence behavior of Coumarin-153 in a hydrophobic ionic liquid and ionic liquid-toluene mixture, and other topics.

BIOLOGY

At BARC, molecular mechanisms underlying tolerance to radiation and agricultural stresses were elucidated in bacteria and plants.

Proteomic approaches were utilized to understand the extraordinary DNA repair contributing to the gamma radiation resistance of *D. radiodurans*. Seventy five

proteins from *Deinococcus radiodurans* were identified.

Twenty eight prominent radiation inducible proteins belonged to the major functional categories of DNA repair, oxidative stress alleviation and protein translation/folding.

A green fluorescent protein based promoter probe shuttle vector pKG was constructed and successfully used to estimate radiation inducibility of gene promoters of *D. radiodurans*.

From a large number of genetically diverse rice genotypes, a set of genotypes showing large variation in salt tolerance scores was selected for studies on multigenic salt tolerance in rice.

A hospital based newborn programme to screen for congenital malformations continued at the Low-Level Radiation Research Laboratory (LLRRL), Kollam, Kerala in collaboration with the Government of Kerala. Over 5200 newborns were screened during this period.

Transcriptome analysis on adults was also carried out on peripheral blood mononuclear cells from subjects living in High Level Natural Radiation Areas (HLNRAs) and Normal Level Natural Radiation Areas (NLNRAs) of Kerala coast in order to find out the effect of chronic natural background radiation at molecular level, if any.

Adaptive response was studied using mRNA expression of 20 genes which are either involved in



Complete set up of α -particle irradiator with control unit

different DNA repair pathways or are telomere specific. Initial findings suggested that active DNA repair process occurring in human cells exposed to elevated level of background radiation.

Transcriptome analysis was also initiated and analysis of DNA Double-Strand Breaks (DSBs) was initiated. In dose response experiments a clear cut dose response was observed. Preliminary analysis of protein expression in human peripheral blood indicates differences in intensity of few spots between control and irradiated samples.

A bench top alpha particle irradiator 'BARC BioAlpha' was designed, fabricated and assembled at BARC.

Several natural molecules were screened for their radioprotective effect using murine splenic lymphocytes. Findings revealed that the tumour

microenvironment contributes to modulation of cytotoxicity of drugs and that combination therapy may potentiate anticancer therapy.

G1-4A an arabinogalactan polysaccharide from an Indian medicinal plant *Tinospora cordifolia* is a polyclonal B cell mitogen and also protects mice against septic shock by modulating proinflammatory cytokines. G1-4A treated dendritic cells were effective in reducing the tumor burden as well as increasing life span in mice harboring EL-4 lymphoma suggesting a possible use of this immunopotential polysaccharide as an adjuvant in DC-based tumour vaccine in future.

Green synthesis of gold nanoparticles with uniform diameter and triangular nanoprisms with optically flat surface was carried out. Evolution

of morphology from pseudospherical nanoparticles to triangular nanoprisms was studied by transmission electron microscopy.

A filamentous, heterocystous brackish water cyanobacterium *Anabaena torulosa* displayed uranyl binding properties. Another cyanobacterium *Synechococcus elongatus* was also found to sequester uranium from aqueous solution. Effect of chelating agents on the uptake efficiency was under investigation at BARC.

At TIFR, a fly model system was established to understand the role of Sir2 in mediating organism survival. Studies were conducted on the functions of mitochondrial sirtuin Sirt4 in mammals. Sirt4 was found to be a key component that regulated mitochondrial functions and was required for maintaining energy (or ATP) homeostasis.

Dual origins of the mammalian accessory olfactory bulb were revealed by an evolutionarily conserved migration arising from the thalamic eminence. The interaction analysis between kinesin-2 tail and tubulin was completed and the role of KLP68D tail in olfaction was established.

The gene-rich chromosomes were shown to undergo large-scale movements during DSB repair in mammalian cells.

In the Zebrafish Epidermis Research Laboratory it was shown that epidermis maintains a dynamic balance between the cell size and cell number to maintain

the tissue integrity. In another project, the importance of cross talk between Wnt-BMP signalling in acquisition of specific cell shapes was unravelled.

Progress was made in understanding the role of 5-HT₂ receptors in the regulation of anxiety behavior. Through two RNAi based genetic screens, 31 new genes were identified that regulate cell morphology and cell adhesion.

At the TIFR's National Centre for Biological Sciences, Bangalore, major studies conducted related to the cell membrane and cancers, protein organisation & disease, and identification of neural correlates of stress induced modulation of the amygdala. Work continued on the line that memories are stored in a pattern of connections between brain cells and the brain must convert information into activity patterns, modify connections and stably retain these modifications.

At SINP, in the area of chemical biology, the effects of small molecules with potentials as transcription inhibitors were studied. As part of efforts to develop efficient drug delivery strategies for natural product based drugs, the encapsulation of several therapeutically active plant flavonoids for drug delivery was studied here. Research was carried out in hematological disorders such as thalassemia along with sickle cell anaemia, and neurodegenerative diseases such as Alzheimer, Huntington, and the prion diseases. New

initiatives were taken at SINP to characterize proteins from platelets and urine samples.

The research at the School of Biological Sciences of NISER led to publication of research papers. Some of them were : Binding studies of natural product berberine with DNA G-quadruplex; Estrogen destabilizes microtubules through an ion-conductivity independent TRPV1 pathway; Importance of Innate Mucosal Immunity and promises it holds; The role of CART in spatial learning and memory, and other topics.

CANCER

During the report period, the Medical Cyclotron at Radiation Medicine Centre (RMC) of BARC was used for producing ¹⁸F- isotope and its conversion to ¹⁸F-FDG (Fluorodeoxyglucose) and ¹⁸F-NaF (Sodium fluoride). During the year Fluorodeoxyglucose, Sodium fluoride, and Fluorothymidine were supplied to various hospitals in Mumbai and Pune.

The diagnostic investigations related to almost all the organs of body were routinely carried out at RMC. Radioiodine therapy for thyroid cancer cases continued. Patients with neural crest tumours and cases of bone metastases were regularly treated. Diagnostic nuclear medicine operations using the various ^{99m}Tc-radiopharmaceuticals, continued.

The Advanced Centre for Treatment, Research and

Education in Cancer (ACTREC) remained engaged in its cancer research programmes.

To meet the needs of increased number of patients, the Day Care Ward was upgraded from 10 beds to 13 beds. In the same area. As a part of various translational or clinical research projects, over 3500 new patients were referred to ACTREC for investigations or treatment.

Basic Research activities in the Cancer Research Institute saw the initiation of several new areas such as stem cells in skin, solid and haematological malignancies; Complex vector systems to monitor chemo and radiation resistance in vitro and in vivo, and establishment of in vivo imaging techniques for diagnosis and treatment, and to monitor complex intra and inter cellular molecular networks using confocal microscopy. Several investigations monitored the distribution of specific labelled molecules using the micro PET-SPECTCT to evaluate their diagnostic and therapeutic potential. Characterization of somatic mutations in cancer using an integrated next gen sequence approach along with high end computing and bioinformatics, also received attention.

The on-going molecular profiling investigations moved ahead towards defining signatures for risk assessment and prognosis in oral, cervical, breast and brain cancer and acute lymphocytic leukemia. Founder mutations in BRCA1 gene were identified in hereditary breast ovarian cancer families from specific geo-ethnic

origins.

The cancer biology investigations provided insights into histone modifications in gene regulation, specific molecules and their molecular networks regulating cell cycle, DNA damage and repair and cell transformation. The importance of glycosylation in cell invasion and metastasis revealed the intricacies of sugars and their engagement with cell surface molecules. Studies on gamma delta T cell provided insights into the immune surveillance mechanisms in cancer.

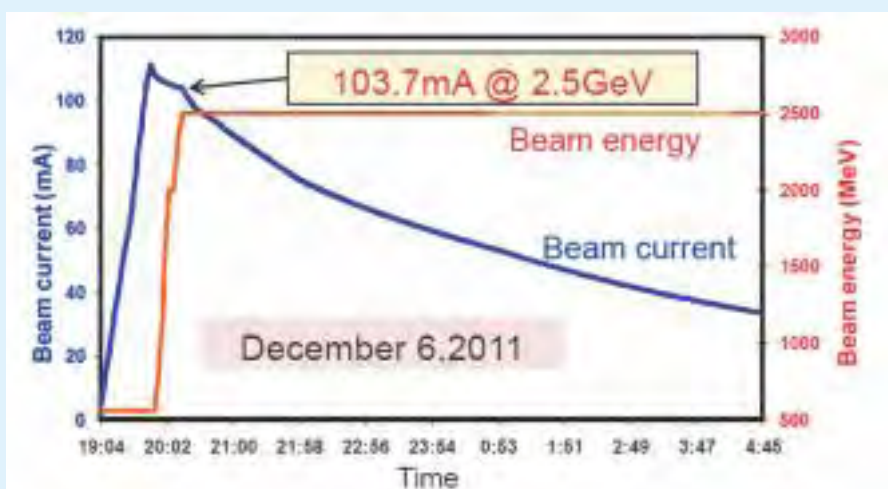
In depth biophysical investigations identified key structural signatures for proteasomal recognition and degradation, apoptotic regulation, BRCA1/2 interacting partners involved in breast cancer and the utility of Raman spectroscopy as a noninvasive tool for diagnosis.

SYNCHROTRON & THEIR UTILISATION

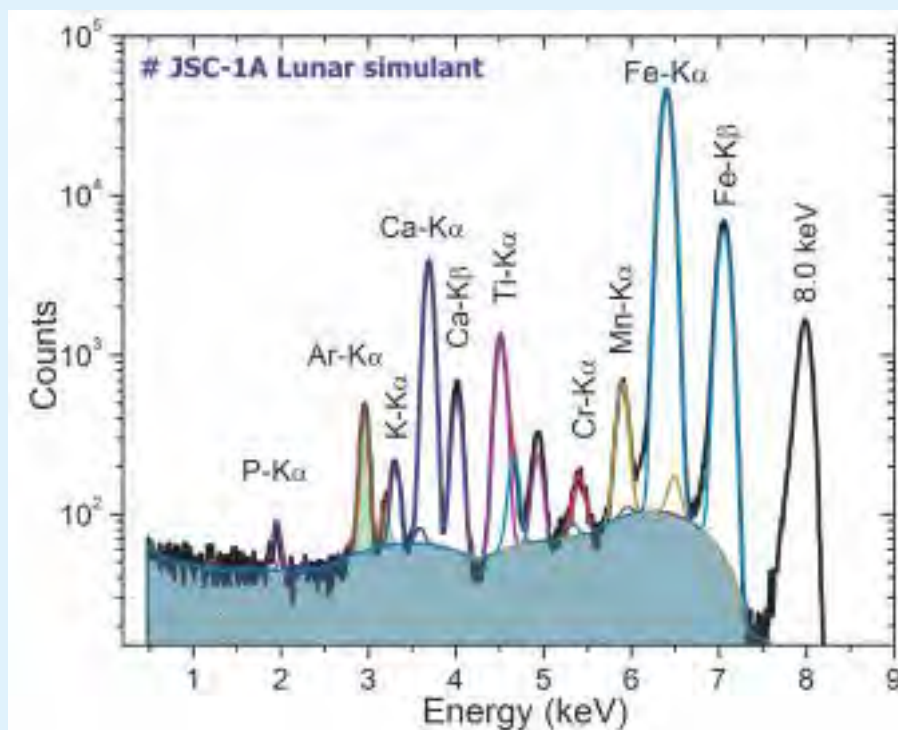
Indus Synchrotrons

At RRCAT, the Synchrotron Radiation Sources, Indus-1 and Indus-2, continued to operate in the round-the-clock mode -- Indus-1 at 450 MeV energy, 100 mA current, and Indus-2 at 2.0 GeV energy, 100 mA current. With the integration of the solid state RF amplifier units, Indus-2 was successfully operated at 2.5 GeV, 100 mA. It was for the first time that high power solid state amplifiers operating at high frequencies were developed and successfully deployed in a synchrotron radiation source.

The increase in the beam life time of Indus-2 to 22 hours at 2 GeV, 100mA operation, was accomplished due to closed orbit correction and improvement in vacuum in the ring. Experiments were performed to accumulate higher beam current and finally 251mA beam current was accumulated at injection energy, the maximum current accumulated so far. The duration of beam storage was tested to



Indus-2 beam energy and current profiles achieved on December 6, 2011



*XRF microprobe analysis of simulated Lunar samples,
Chandrayan mission project, ISRO*

ascertain the operational reliability of various subsystems. The beam was stored for 41 hours which was the longest time for which the beam was stored so far. This indicated the increased reliability of various subsystems of Indus-2.

The Indus-1 beam was offered to users for around 3000 hours during January to December 2011. Five beamlines in operation, were used by various researchers from various institutions. On Indus-2, RRCAT commissioned three additional beamlines. Thus a total of six beamlines were in operation.

The Extended X-ray Absorption Fine Structure (EXAFS), Energy-Dispersive X-Ray Diffraction (EDXRD) and Angle-Dispersive X-ray Diffraction (ADXRD) beamlines

were used by researchers for various studies on samples and the results provided useful information.

The microfocus X-ray fluorescence beamline on Indus-2 covered a wide photon energy range from 4 to 20 keV and a wide range of investigations. The beamline also offers other modes of X-ray fluorescence characterization. The X-ray fluorescence microprobe was used for many studies such as analysis of uranium-thorium samples for trace impurities, elemental composition of archaeological samples, simulated lunar samples for Chandrayan project etc.

The soft and deep X-ray lithography beamline on Indus-2 offered X-rays of energies from 1.5 to 20 keV. The beamline was used for fabrication of compound refractive lens, photonic band gap materials, microfluidic devices and high speed bearing related structures.

To study the influence of colloids on migration of actinides



*High speed bearing related structures developed
by using X-ray lithography beamline on Indus-2*



X-ray lithography beamline on Indus-2



Experimental station at PX beamline

BASIC RESEARCH

from the deep geological repository to the nearby aquatic environment, BARC utilized Indus-2 Synchrotron at RRCAT for extended X-ray absorption fine structure study of actinides adsorbed on mineral oxide surfaces.

The applicability of Micro-XRF beam line at Indore for uranium and thorium determination in mixed uranium-thorium oxide, was investigated by a BARC team. Improvement in the analytical results compared to the tube excited source was evaluated.

A cryostat for extended X-ray absorption fine structure studies at low temperatures was commissioned at EXAFS beamline at Indus-2. Extensive investigations of vacuum ultra violet spectroscopy of molecules were carried out using this synchrotron source. Gas phase photo-absorption studies of several polyatomic molecules of interest in environmental sciences were completed using photo-physics beamline and high resolution VUV beamline on Indus-1. The spectroscopy beamlines were upgraded with

new data acquisition and control systems.

CYCLOTRONS & THEIR UTILISATION

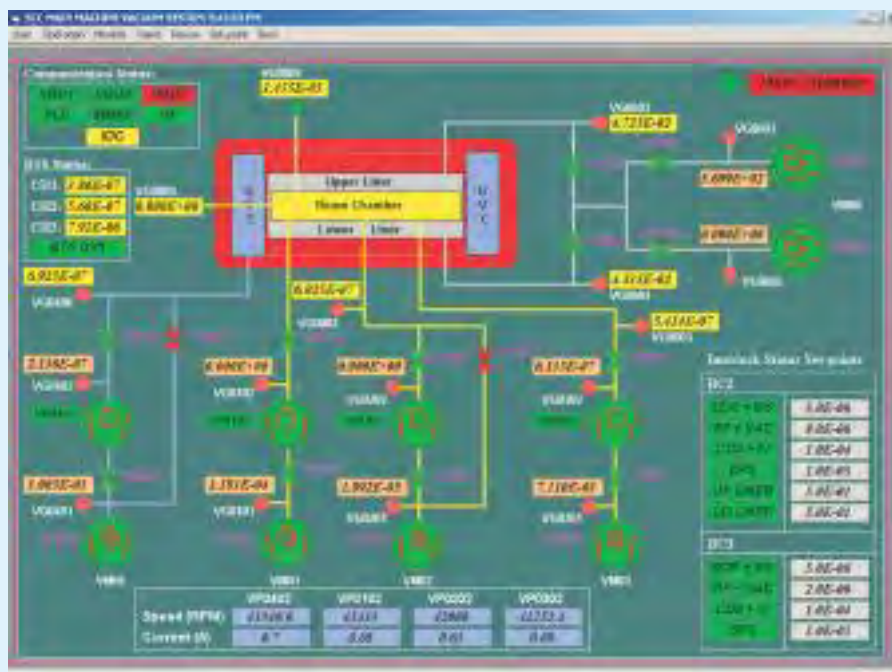
K-500 Superconducting Cyclotron

The superconducting cyclotron at VECC is the first compact superconducting cyclotron in Asia. Many kinds of beams have been accelerated on this facility so far.

During the report period, one 222.2 meter long external beam line was commissioned up to the



K-500 Superconducting Cyclotron with one of its external beam lines



Graphic User Interface of vacuum control system for Superconducting Cyclotron

experimental vault. The beam loss due to scattering by residual gases was arrested and good beam intensity at the extraction radii was achieved.

Several diagnostics were installed to improve the beam diagnostics to understand the beam behaviour prior to extraction, which is essential for beam extraction.

Three cryopanels placed inside the lower dees in the superconducting magnet help in achieving high vacuum in the accelerating chamber. The improved vacuum considerably reduced beam loss in the superconducting cyclotron.

Accelerator systems demand a reliable and fast control system to satisfy the monitoring and control criteria of a large number of parameters. At VECC, for the Room Temperature Cyclotron

and the Superconducting Cyclotron (SCC), control systems were designed and implemented.

The major maintenance / upgradation activities carried out included : Installation of control database system for SCC;

Upgradation of beam diagnostic system for Variable Energy Cyclotron and Superconducting Cyclotron, and Upgradation and maintenance of vacuum system and low conductivity water system for SCC.

During the report period, the K-500 Superconducting Cyclotron operated in full swing. DEE voltage is one of the critical parameters of the cyclotron that is measured by an X-ray detector. Commissioning of X-ray detector set up for this type of measurement of the voltage, was completed.

The Variable Energy Cyclotron (K-130) regularly delivered proton and alpha beams of various energies and intensities, for different types of experiments in the existing three beam lines. A few up-gradations and modifications on this accelerator were carried out. The cyclotron delivered beam on target for more than 2100 hrs for



X-ray detector with feed through and cabling

BASIC RESEARCH

conducting various experiments.

Medical Cyclotron

The high intensity proton beam from the DAE-Medical Cyclotron coming up at Kolkata will be used for production of radioisotopes for medical use and materials science research. There will be two different beamlines : Beamline-1 for high dose irradiation and Beamline-2 for short time and low dose experiments. For the Cyclotron, a general purpose target chamber was designed for use in Beamline-1.



Inductively Coupled Plasma Ion Source based focused ion beam setup

Heavy Ion Irradiation / Implantation Facility

A unique low energy heavy ion irradiation/implantation facility was developed at VECC for materials science and atomic physics research. High ion flux available from this machine is suitable for generating high defect

densities. This facility is already in use.

Production of Heavy Ion Beam

At VECC, a multipurpose high brightness Inductively Coupled Plasma Ion Source was developed successfully to produce high current density focused ion beam

as well as high current broad beam for synthesis of high quality thin films.

Several experiments were carried out to measure the beam spot size and the available current density in the focused spot. The performance of system was found



Electron Cyclotron Resonance (ECR) based Low Energy Ion Beam Facility



Magnet assembly with inflector

to be very stable over long period of operation. It is very useful in various applications such as high speed milling of hard materials.

High current ion source

At the Variable Energy Cyclotron Centre, Kolkata, a 2.45 GHz microwave ion source was developed which will produce proton beam at 80 keV. Presently it was under testing for beam characterization and inflection study.

To study the inflection and transmission of high beam current through the spiral inflector, a small magnet having a similar characteristics as the central region of 10 MeV cyclotron was designed and fabricated.

PLASMA & FUSION TECHNOLOGIES

At the Institute for Plasma Research (IPR), Aditya Tokamak

operated regularly and experiments related to breakdown and startup for generating necessary inputs for first plasma operation in Superconducting Steady-state Tokamak (SST-1) were carried out. Plasma production was done in Aditya with indigenously developed Ion-Cyclotron Resonance Heating system.

SST-1 refurbishment activities progressed significantly and their thorough technical review was also carried out. Engineering validation of refurbished SST-1 is planned to begin shortly.

Research continued on the 'SYMPLE' (SYstem for Microwave - PLasma Experiments) which aimed at studying the interaction between plasma and high power microwave. In the field of plasma theory and simulation, work related to electron magneto-hydrodynamics (EMHD)

simulations, analysis of EMHD waves in large volume plasma device, strongly coupled plasmas, wave breaking and phase mixing studies, particle acceleration studies, and other works continued at IPR.

At IPR, the activities relating to the Indian Predictive Integrated Tokamak Modeling and future fusion machines were initiated.

International Thermonuclear Experimental Reactor (ITER)

BARC in collaboration with the Institute for Plasma Research, has been contributing to the ITER-Project.

At BARC, welding process and fixtures of 9Cr-1Mo (P91) steel and molybdenum alloy for manufacture of test blanket modules for ITER, and components of high temperature molten lead loop, respectively were developed.

Towards development and fabrication of Niobium-Tin (Nb₃Sn) based superconducting wires, and flow characteristics of Cu/Sn composite were carried out.

Setting up of an innovative space saving on-line fabrication facility continued.

IGCAR successfully developed reduced activation ferritic-martensitic steel for Test Blanket Module for ITER. This steel was found to have better combination of creep strength, ductility and toughness, recommended as the optimum composition for the material. Activated tungsten inert gas



On-line cable-in-conduit-conductor (CICC) fabrication facility at Trombay where fabrication of 100m long 30kA Nb-Ti based hybrid CICC is in progress

welding technology was developed at this Centre for welding reduced activation ferritic-martensitic steel plates of upto 10 mm thickness.

MATERIAL SCIENCE

In the field of material development, BARC's major achievement were : Synthesis of oxide nano-powders; Initiation of indigenous production of Aluminium - Beryllium composites for inertial systems and satellite applications of ISRO; Development of dye-sensitized solar cells; A new

process for preparation of optically transparent ceramics, and synthesis of nanocomposite microcapsules of silica and surfactants.

At IGCAR, some of the important research activities relating to material science included: Study of phase stability and interfacial reactions in Yttria/Zirconia systems; Development of multifunctional smart nanofluid; Demonstration of tunable magnetically polarisable soft matter system; Molecular dynamics calculations towards thermo-physical properties of UO_2 , and recording

of Raman spectrum of uranium.

Using analytical modeling and molecular dynamics simulation technique, several successful studies were performed at VECC. These included the lattice resistance to dislocation motion in nano-structures, inertial oscillations of pinned dislocations and dislocation-nanovoid interactions. For the first time a pronounced variation in the dislocation velocity in thin films was reported which would play an important role in deciding mechanical properties at the nanoscale.

A superconducting magnet for



Trapped magnetic field and levitation force

ion trap was installed at VECC site and commissioning was under progress. During commissioning of the magnet, a precise magnetic field measurement will be carried out. For the purpose, a scan tube was designed to facilitate the NMR probe entry into the liquid helium

space maintaining the temperature of probe at around room temperature.

A detailed study of field-induced electron emission from nanorod arrays was made at TIFR that showed that the emission properties can be enhanced by tuning the geometry of the array.

Progress was made in understanding magneto-optical Kerr rotation spectral line shapes in semiconductor quantum wells. Plasmonic crystals were fabricated successfully and photonic crystal micro-cavities with high-Q were designed and fabricated.

At TIFR, nanofabrication facilities including metal-dielectric deposition, patterning using lithographic techniques and pattern transfer were established.

At BARC, a layer (about 2 micro metre) of alpha-Aluminium Oxide was formed by oxidation on Superalloy-690 substrate. The adhered aluminide layer was found to be very effective.

The process conditions for preparation of beta silicon carbide powder by silicon carbon reaction and its subsequent dispersion into ultrafine powder, were established to produce near theoretical density product after incorporation of desired additives. A three axis trapped



50mm dia ceramic-to-metal seal



Elements fabricated from Nd:YVO₄ crystals

magnetic field and levitation force measurement system was fabricated and commissioned for characterization of the YBCO components.

Experiments were carried out at BARC for determination of critical heat flux of different nanofluids for various concentrations. Thorium metal powder was produced by calcio-thermic reduction of thorium. Green compacts of varying thicknesses were sintered and later cold rolled to produce sheets and foils which were supplied to various agencies for neutron and photo fission/reaction studies and for evaluation of thermo-physical, thermodynamic and transport properties of alloys of thorium.

Study of Yttria based nano-structured materials assume importance because of their applications in oxide dispersion strengthened alloys, solid oxide fuel cells and thermal barrier coatings. At IGCAR, high temperature X-ray diffraction studies of Yttria/Zirconia multilayers were conducted which made useful observations.

Lüders bands are localized bands of plastic deformation in carbon steels during tensile deformation. The phenomenon of Lüders bands in medium-carbon steel, in water-quenched and tempered conditions, during tensile testing at ambient temperature, were studied using acoustic emission technique. Studies were also carried out at IGCAR in the field of material science that included : Evaluation of tensile properties of cold

worked type-304 stainless steel; Enhancement in corrosion resistance of materials; Development of multifunctional smart nanofluid; Demonstration of tunable Fano-like resonance in magnetically polarisable soft matter system; Calculation of thermo-physical properties of UO_2 ; Raman spectrum of uranium using a sub-surface enhanced Raman scattering technique, and Superconductivity in Ru-substituted $\text{BaFe}_2\text{-xRu}_x\text{As}_2$.

Studies were carried out at RRCAT on the effect of externally applied hydrostatic pressure on the functional properties of magnetic materials. Nd:Yttrium ortho vanadate crystals were grown here in optical floating zone equipment and characterized.

INTERDISCIPLINARY AREAS

At BARC, crystal structures of two drug-resistant mutants (M36I and N88S) of HIV-1 protease were determined to resolutions of 1.6 and 2.0 angstrom respectively. Structure of alkaline phosphatase enzyme from *Sphingomonas* for uranium precipitation was refined to 2 angstrom resolutions. The X-ray structure provided insight into evolution of alkaline phosphatases.

At TIFR, the activities in the interdisciplinary areas related to fabrication of a tunable low power photon irradiation system to study photoinduced fragmentation of proteins and DNA to study the energy dependent resonant

damages to plasmid DNA. The experimental work carried out demonstrated the utility of using intense laser pulses to produce molecular species of the type that were normally inaccessible.

Identification of metabolites in urine, serum, liver and brain, that are altered during the progress of *Plasmodium berghei* ANKA infection in murine model of malaria, was achieved. Some metabolic signatures involved in transition of non-cerebral malaria into cerebral complications were tracked in the experimental cerebral malaria in mice. Pleural effusion is unique to cerebral malaria. The composition of this fluid was investigated in comparison to that of serum.

A set up for measuring water transport at the back of the eye by the retinal pigment epithelium, was installed. The major pathways and electrolytes that drive fluid transport through the mammalian retinal pigment epithelium were characterised. A high sensitivity, low-noise stage scanning confocal fluorescence microscope was developed.

At TIFR, regular O&M of both Pelletron and Linac were done. There was a successful completion of Phase-I experiments of INGA (~ 20 nos). Microprocessor base control instrumentation was developed for cryogenics and steers and pelletron operating software was upgraded.

For the Neutrinoless Double Beta decay Experiment, high capacity cryogen free Dilution Refrigerator was under

development alongwith tin microcalorimeter development and background simulation studies.

For the India based Neutrino Observatory Project, possession of land for the surface facilities of the Observatory at Pottipuram village of Tamil Nadu, was a major step forward. After development of Resistive Plate Chambers in-house, action was taken towards involving industry for their large scale production.

For Gravitational Wave Prototype Detector, Ultrastable Nonplanar Ring Resonator (Laser for the gravitational wave prototype detector was procured and tested at TIFR. Pre-isolation system and the UHV pumping systems were designed and finalized. Design was made of the 3-metre interferometer for prototype detector programme.

A Zebrafish Research Facility was established at the National Centre for Radio Astrophysics, Pune.

INTERNATIONAL RESEARCH COLLABORATION

International Research Collaboration

Design study was conducted at BARC to employ a sample carrier in Jules Horowitz Reactor to study materials' behaviour under irradiation.

BARC continued to participate in the study related to Fuel Modeling at Extended Burn up (IAEA CRP FUMEX-III),



Cooling channels assembled for brazing and (right) brazed with copper strip



wherein a number of fuel pins from pressurized water reactor and pressurized heavy water reactor were analyzed up to a burn up of 50 GWD/T.

Containment analysis for severe accident conditions was carried out for 700 MWe CANDU reactor under IAEA Coordinated Research Project. Volumetric hydrogen and carbon monoxide concentration with time was evaluated and plotted on Shapiro diagram for hydrogen and carbon monoxide gases for checking the flammability limits.

In a collaborative India-UK project, with the Open University, UK, a technique was developed to join stainless steel (grade-304L) to grade-2 Titanium following the active metal brazing route. The cross section of the joint was

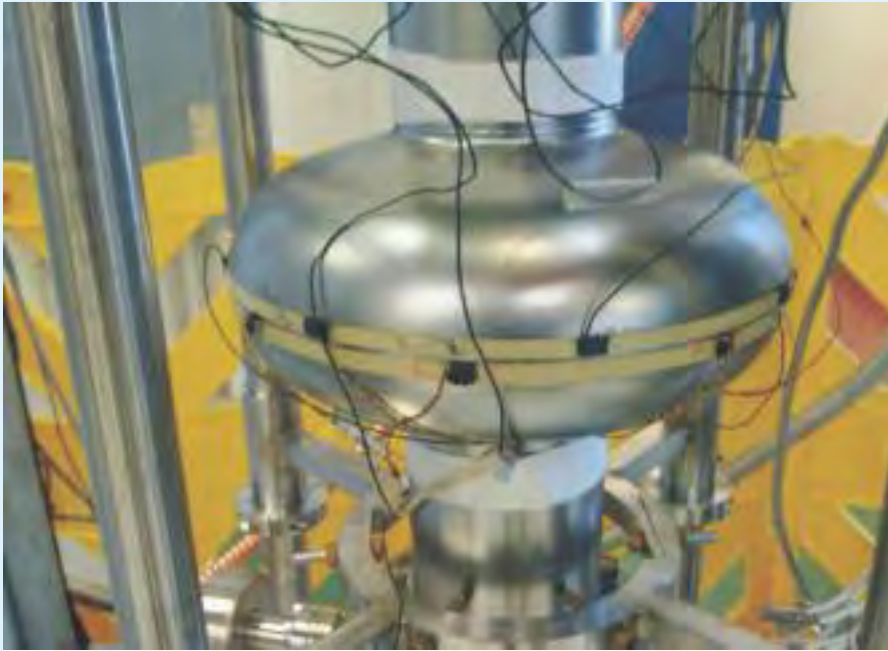
characterized in detail and microanalysis of the brazing zone was carried out.

Design and fabrication of sample module for RE-4/2 and RE-4/3 chambers of the Resistive Plate Chambers for CERN collaboration progressed at Trombay. The final assembly of brazing between copper sheets and tubes were tested for the rated cooling water pressure.

Towards developing fundamental understanding of the correlation between eddy size and temperature fluctuation during thermal striping, an experimental test facility was established by IGCAR at IIT-Kanpur.

Under an International collaborations, IGCAR participated in the life-test programme performed on Phenix

BASIC RESEARCH



1.3 GHz Single cell Superconducting Radio Frequency Cavities for Fermi Lab

reactor and the numerical simulation of pool thermal hydraulics experiments carried out in Japanese reactor Monju.

RRCAT successfully developed two 1.3 GHz single cell Superconducting Radio Frequency Cavities under the

collaboration with Fermi Lab, USA. The Centre also fabricated a waveguide RF Coupler for LINAC-4 project at CERN.

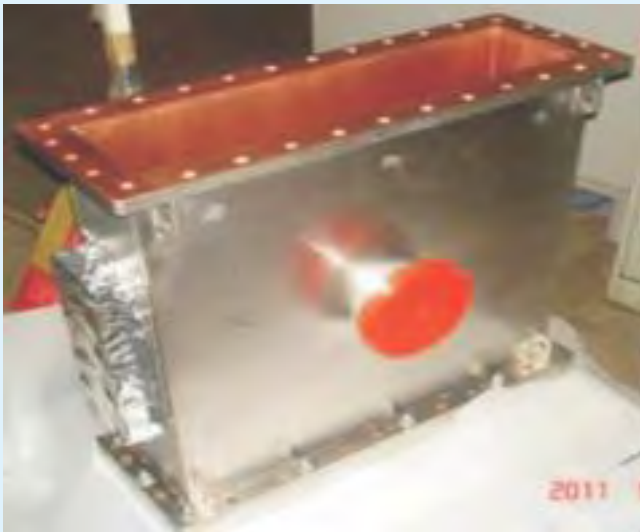
A Vertical Test Stand Cryostat for testing Superconducting Radio Frequency Cavities at 2K was designed and fabricated

jointly in collaboration with Fermi Lab. The fabrication will be completed shortly and the cryostat will be installed at RRCAT.

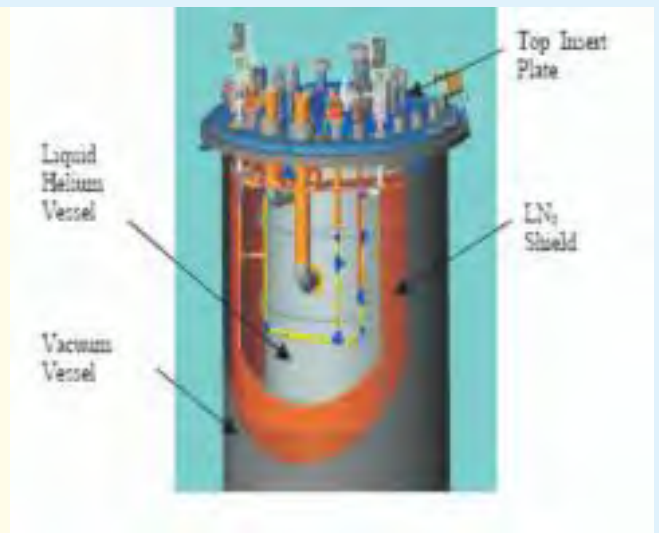
International collaborative efforts of VECC for the search and study of the Quark Gluon Plasma were continued with active participations in the STAR Experiment at Brookhaven National Laboratory, ALICE experiment at CERN and Compressed Baryonic Matter (CBM) Experiment.

The Photon Multiplicity Detector, installed by VECC in the year 2003 in the STAR experiment, completed data taking. The detector was decommissioned and dismantled in August 2011. The components of the detector will be utilized at VECC in setting up a new experiment on cosmic muon scattering from heavy materials.

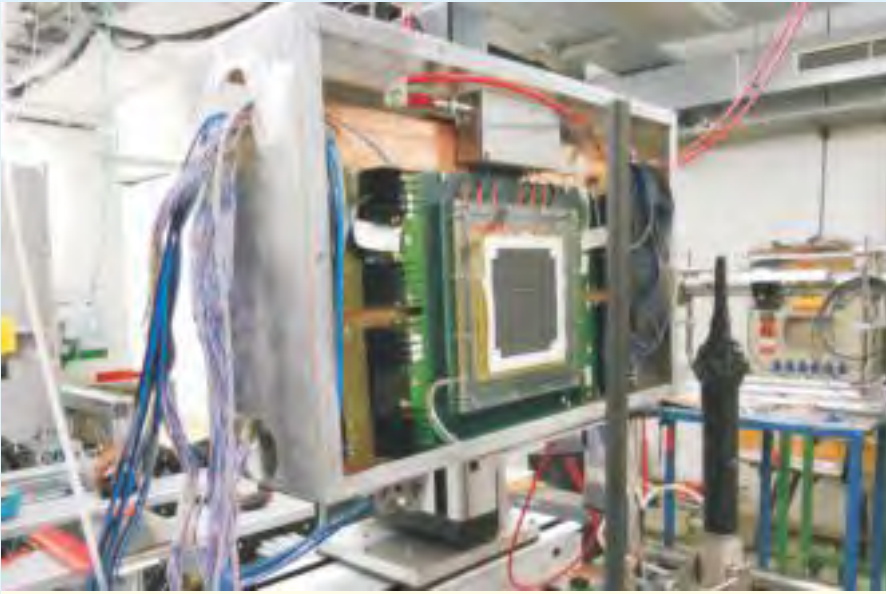
The research team of VECC took a leading role in the search



Waveguide RF power coupler for LINAC 4 project at CERN



Schematic of Vertical Test Stand Cryostat for testing superconducting RF cavities at 2K



Two GEM detectors (in a box) installed in JESSICA test beam line at COSY

for the Critical Point by analyzing the higher moments of net-proton and net-charge distributions, and other intriguing signatures. In the next phase of activity, a prototype multi-gap Resistive Plate Chamber was constructed for the Muon Tracking Detector of the STAR experiment.

The Photon Multiplicity Detector in the ALICE experiment took data successfully for proton-proton and Pb-Pb collisions at the Large Hadron Collider of CERN. As part of future upgrade of detectors in ALICE, the VECC research team propose to install a Forward Electromagnetic Calorimeter.

The Tier-2 ALICE GRID centre at VECC was upgraded. A dedicated centre for data monitoring and analysis for the ALICE experiment was setup VECC for remote monitoring of the detector components.

VECC has been taking part in

the activities related to the upcoming FAIR accelerator facility at Darmstadt, Germany, in building the superconducting magnets for the FAIR accelerator

and in developing the muon detection system for the CBM experiment for FAIR. Development of a Gas Electron Multiplier (GEM)-based Gas Detector System was underway at VECC.

Development of radiation resistant high density electronics for CBM experiment was under planning stage at VECC. As a first step towards achieving this goal, fabrication of ten Readout Controllers Boards were made with the help of Indian Industry. These boards will form the integral part of all the further research and development test setups in CBM.

In the domain of relativistic heavy ion collisions, hydrodynamical models were applied to explain RHIC and LHC data. A systematic study of QGP fluid evolution under viscous



One read-out controller board built in India for CBM research and development

hydrodynamics at RHIC energies was also performed.

TIFR continued research collaborations with the International Centre for Theoretical Sciences (ICTS), Belle Experiment, and CMS Experiment at the Large Hadron Collider. Major activities under these collaborations were as follows:

ICTS organized in all sixteen programmes during the year 2011-12. The programmes covered many scientific subjects as well as interdisciplinary topics.

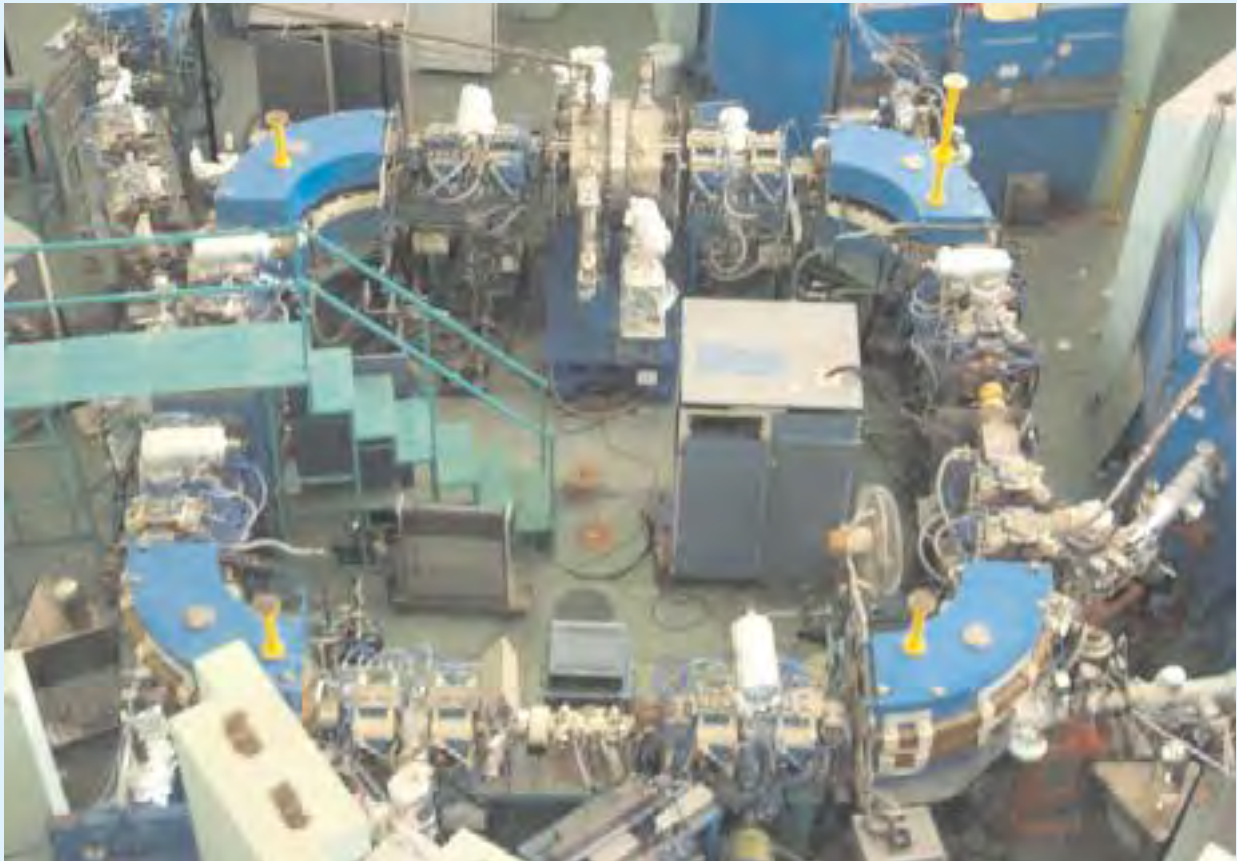
The Belle detector had collected enormous amount of data that involved study of CP violation, rare B-meson decays and observation of new particle states. One of the group members was leading the activities of the

Hadronic B Decay analysis group of the Belle Collaboration.

CMS Experiment of LHC has collected very high quality data. TIFR scientists were involved in data taking, detector monitoring and data analysis. These efforts led to 40 papers in scientific journals. The topics ranged over Electroweak physics, QCD, SUSY and Higgs.

CHAPTER : 6

RESEARCH EDUCATION LINKAGES



Indus-1 is operating round the clock at 100 mA current





Art of communication : BARC doctors at ATI

CHAPTER : 6

RESEARCH EDUCATION LINKAGES

HUMAN RESOURCE DEVELOPMENT AND KNOWLEDGE MANAGEMENT

Homi Bhabha National Institute

The Homi Bhabha National Institute (HBNI), that completed six years of its existence, continued to grow steadily. Till date, a total of 576 results were declared and over 260 DAE officers completed their M.Tech programme requirements. In the Ph.D programme too, 105 scholars completed all the programme requirements. Since 2006, the number of enrolments rose to nearly 2880, with Ph.D enrolment alone being 1320. The enrolment under the Post-Graduate Medical Programmes was close to 200. The results of the first batch of successful students in the M.D, D.M and M.Ch. medical programmes under the Health Sciences discipline, were declared. Two batches of a new scheme of DGFS-Ph.D students in Engineering Sciences with post-graduate qualification, totaling 28, were inducted into the academic programmes of HBNI.

HBNI continued to strengthen its linkages with the premier research and academic institutes. MoUs were signed with the Jadavpur University and the Indian Statistical Institute. Both these institutes are in Kolkata.

Training School

During the current financial year, the ongoing Orientation Course for Engineering Graduates & Science Post-Graduates (OCES-2010) and DAE-Graduate Fellowship Scheme (DGFS-2010) courses, and placement of Trainee Scientific Officers of OCES-2010 was completed by the BARC Training School.

The schedule for the selection process and course work commencement was advanced by one month from the current academic year resulting in improved number and quality of candidates selected. The screening tests for recruitment were conducted twice (Science and Engineering Disciplines) at 21 centres in the country.

To streamline the process due to the increasing number of candidates, BARC Training School proposes to implement the On-Line Test.

To strengthen the DAE-University linkages, the practical training (1-2 months) and project work (2-12 months) in BARC for BE/B.Tech/M.Tech/Engg Diploma/MSc/MCA students from different universities were coordinated. About 475 students from all over India have undergone Practical Training / Project Work in various divisions of BARC.

Under 'QUEST - A Continuing Education Programme', a scheme

for offering advanced courses to staff members of DAE units located in Mumbai and HBNI students, and four advanced courses, each of 48 hours duration, were offered to eligible employees during this year.

A 2-year Post-Graduate Diploma in Nuclear Medicine (DRM) for medical graduates under the HBNI, and 1-year Diploma Course under HBNI for science graduates to propagate nuclear medicine throughout the country, was offered. In addition to regular courses, short term training programmes were also conducted for post-graduate students in various Divisions of BARC.

At the IGCAR-Training School, the fifth batch of 37 trainee scientific officers, completed training, and they were placed in various units of DAE. In the current academic year, 35 Trainee Scientific Officers continued their training, 34 Research Scholars were inducted to pursue their doctoral programmes in the frontier areas of engineering and basic sciences, and 50 employees pursuing higher studies in HBNI, also underwent coursework at the Training School.

OCES programme of BARC Training School-AMD Campus, Hyderabad was continued with Geology (12) and Geophysics (9) Trainee Scientific Officers. Under the AMD studentship programme, 104 M.Sc./M.Tech.

Students of different Universities completed their project work till now.

NPCIL focused on performance-improvement of human resource by way of investment in enhancement of knowledge through training and skill development. The human resource initiatives were directed towards achievement of organizational goals of attracting, motivating and retaining the Human Resource. These measures included developing strategic and incremental packages from time to time for effective Human Resource Management to meet the aspirations of the employees. Optimization of manpower continued to be an important strategy towards best utilization of human resource. Training and Development initiatives covered competence development for fresh as well as experienced manpower across hierarchy.

The Institute of Physics has been contributing in a significant way towards quality human resource development in the form of a 1-year Pre-Doctoral course followed by a Ph.D. Programme. More than 60 students who did Ph.D. at the Institute, occupied faculty positions in almost all the leading research centres, IITs, central and state universities in the country. Further, 9 post-doctoral fellows were attracted towards the research programmes of the Institute.

The Institute remained engaged in promoting interactions with colleges,

universities, academic institutions and laboratories by means of visitor programmes, workshops, symposia and other academic events. Advanced String School was organized by IoP in Puri.

The Rural Programme for Scientific Awareness through the Samanta Chandra Sekhar Amateur Astronomers' Association, formed an important part of the Outreach Programme. The physics open discussions for NISER students was also pursued actively this year.

NISER continued with its teaching and research activities in the fields of basic sciences. Under its outreach programmes, NISER functions as a nodal centre in the eastern part of India to provide training in mainstream mathematics. It also has alliance in the field of scientific research and knowledge exchange with other research centres and industries that are engaged in research and development.

IMSc remained engaged in its regular academic programme that included selection of students at the graduate and postgraduate levels each year. This 2-year course-work is followed by a doctoral thesis work for award of PhD degree by HBNI. The Institute also pursues summer vacation programme that offers opportunity of learning to the students who spend upto six weeks in projects with faculty members. There are also short term projects provided by the Institute to the student community.

Through Associateship Programme and Refresher Courses for college teachers, IMSc had an active interaction with the researchers of other universities.

At TMH, over 60 students were registered for various postgraduate medical courses. Various short-term and long-term training programmes were conducted for doctors, nurses and technicians on continuing basis. Short term observership and summer training were provided to more than 350 doctors, nurses, technicians and B.Sc/M.Sc. students.

TMC academia contributed more than 200 international/national publications in indexed peer reviewed journals.

Administrative Training Institute

The Administrative Training Institute (ATI) arranges a wide range of training programmes for professional development of all levels and various cadres of officials working in DAE. During the period of report, ATI conducted 80 training programmes that included :

- a) Special Management Development programme for SC/ST officers.
- b) Programmes on Hindi software for officials of Hindi cadre.
- c) Management Development Programmes with the support of Dr MCR HRD Institute of AP and Administrative

RESEARCH EDUCATION LINKAGES

Training Institute, Mysore.

d) Special programmes on accounts related subjects such as Performance Audit, Cash and Accounts etc.

e) Programmes for Union / Association representatives on soft skills, computer applications, RTI etc.

f) Workshops on Soft Skills

g) Programmes for Scientific and Technical and other officers sponsored by Department of Science and Technology.

h) Special programmes on computer applications at the doorstep of the units located in remote areas such as Shillong, Kota, and Manuguru.

With a view to build-up an efficient team and match needs of specific operations, a large number of officers of DPS were imparted training. The entire staff of the Central Purchase Unit and

Number of officials trained during the year 2011			
Cadre	Officers	Staff	Total
Purchase	10	11	21
Stores	9	9	18
Accounts	1	-	1
Administration	1	5	6

other Regional Units, where e-tendering was implemented, were given training. As a part of employee welfare, a one day “Workshop Towards Healthy and Happy Life” for the female family members of employees was also organized.

To ensure overall development of the officials apart from generic academic knowledge and skills, ATI used a variety of methodologies in its training programmes. Apart from the conventional lecture method, participative methodologies were

used.

Most of the programmes are arranged in-house. Around 120 in-house faculty members within DAE have been developed. Some of the programmes are conducted with the help of professional agencies/State Administrative Training Institutes / premier Management Institutes such as IIMs, MDI etc.

SPONSORED RESEARCH

Board of Research in Nuclear Sciences (BRNS)

The Board of Research in Nuclear Sciences (BRNS), an advisory body of DAE, 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, in research groups outside DAE and to derive benefits from their expertise. BRNS therefore funds research projects, symposia / conferences / workshops on topics of relevance to the programmes of DAE.

BRNS also plays a proactive role in tapping talented young scientists and technologists by



A view of ATI Class Room

offering K.S. Krishnan Research Associateship (KSKRA). DAE-Graduate Fellowship Scheme (DGFS) of BRNS encourages Graduate Level students doing M.Tech. at IITs and NITs to initiate them in a career to pursue scientific research. Select scientists are awarded fellowship under DGFS to work on research projects in any one of the DAE Organisations, 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 Univ. Centre for Excellence in Basic Sciences (CBS) and Homi-Bhabha Centre of Science Education (HBCSE).

During the year 2011-12, over 200 new research projects were sanctioned till January 2011. In addition, BRNS also entered into three new MoUs for coherent collaborative research work with various academic institutes. These are : (a) Programme in Autonomous Robotics with IIT-Delhi (Rs 7.5 Cr. for five years), (b) Development of state-of-the-art Analytical Electron Microscope facility of high resolution imaging and analysis in the nanoscale as a National Facility (Phase II) with I.I.Sc. Bangalore (Rs.2.093 Cr. for five years), and (c) Upgradation and utilization of National Facility of Texture & OIM (phase II) with IIT-Bombay (Rs. 1.35 Cr. for five years).

Sixteen new DAE-SRC fellowships amounting to Rs. 16

Cr. were awarded to 9 DAE & 7 Non-DAE fellows. Four new Prospective Research Fellowships amounting to Rs. 2.62 Cr. were granted this year.

Eleven KSKRA fellows were selected during 2011. Under the DAE-Graduate Fellowship Scheme (DGFS), 20 M.Tech. from IIT's and 34 Ph.D students were offered/awarded fellowships.

Financial support of 3.2 Cr. was extended for funding 275 seminars, which were conducted by professional organizations on various topics of relevance to DAE. Out of these 90 symposia were organized by the DAE fraternity and they were fully funded by BRNS. Nine 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) promotes excellence in higher mathematics education and research in the country. This Board functions under the aegis of DAE.

The year 2012 is the 125th birth anniversary year of Ramanujan. The Government of India has declared Ramanujan's birthday December 22, as National Mathematics Day, and December 22, 2011 - December 22, 2012 will be celebrated as National Mathematics Year. NBHM is extending its support to these programmes.

The Board has been promoting scholarship and proficiency in mathematics through various programmes. Scholarships are awarded to talented students to pursue studies at Masters and Ph.D. levels. Also, fellowships are provided to teachers at universities to undertake Ph.D. studies.

NBHM operates Mathematics Training and Talent Search (MTTS) programme for the undergraduate level, and the Advanced Training in Mathematics (ATM) programme for the postgraduate level. In these programmes supplementary training is imparted to the selected students during vacation periods. Workshops along the lines are also held for college teachers, to refresh and strengthen their mathematical aptitude.

During the current fiscal, NBHM supported 34 mathematicians to attend the International Congress of Industrial and Applied Mathematics held at Vancouver, Canada.

NBHM organizes 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. At the 52nd International Mathematical Olympiad held at Amsterdam, Netherlands, the six-member Indian team secured a Gold medal, a Silver medal, two Bronze medals and two Honorable mentions.

NBHM conducts Madhava

RESEARCH EDUCATION LINKAGES

Mathematical Competition for the undergraduate students. This competition is designed so as to generate interest in mathematics in early years of college.

NBHM continued to provide grants to Mathematics Libraries for the purchase of books and journals in mathematics. Around 80 such libraries took advantage of this scheme of NBHM and updated their collections of Journals/Books in mathematics. NBHM also distributed selected books to various postgraduate institutions under its book distribution scheme.

NBHM gives grants to various mathematical centres engaged in 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 provides 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, undertaking collaborative research and funds for organizing conferences etc. Financial support was provided to 39 national and international conferences held in India, 17

Instructional Schools for advanced training in mathematics and 28 research projects. Travel grants were given to 54 mathematicians to enable them to participate in conferences held in India and abroad.

Sixteen institutions were provided faculty support in the form of Visiting Professors, to strengthen the research and teaching potential at the institutions.

Post-Doctoral Fellowships were awarded to 39 (including the ongoing ones) researchers for a period of 3 years.

NBHM took steps to create a web-based interactive system for communication, evaluation of proposals etc.

GRANTS-IN-AID

Grants to Aided Institutions

The aided institutions are an integral part of DAE, and there is

a growing synergy between these institutions and the research and development organizations of the Department. Several joint projects have been undertaken by the DAE Organizations and the Aided Institutions, and frequent interaction between academicians of the aided Institutions and scientists of these R&D Organisations has been taking place.

The Department has eight Aided Institutions and one Education Society that are fully funded in terms of their recurring and non-recurring expenditure. The funds (Plan & Non-Plan) allocated to these Aided Institutions by DAE during the financial year 2011-12 were as under:

Grants to Cancer Hospitals

DAE has been releasing grant to Dr. B Barooah Cancer Institute, Guwahati through a Tripartite

Sl. No.	Name of the Institutions	Budget Provision BE 2011-12 (Rs. in crore)
1.	Tata Institute of Fundamental Research (TIFR), Mumbai	510.38
2.	Tata Memorial Centre (TMC), Mumbai	277.56
3.	Saha Institute of Nuclear Physics (SINP), Kolkata.	117.05
4.	Institute of Physics (IOP), Bhubaneswar	29.60
5.	Institute of Mathematical Sciences (IMS), Chennai	28.00
6.	Harish-Chandra Research Institute (HRI), Allahabad	25.80
7.	Institute for Plasma Research (IPR), Gandhinagar.	564.48
8.	National Institute of Science Education and Research (NISER), Bhubaneswar	210.00
9.	Atomic Energy Education Society (AEES), Mumbai	54.00

Funds (Plan & Non-Plan) allocated to Aided Institutions by DAE during the financial year 2011-2012

Agreement signed among DAE, the North-Eastern Council and the Government of Assam. This hospital is a Regional Cancer Centre (RCC) for cancer treatment and control in the North-Eastern Region. The Department's total share as per the Tripartite agreement upto the year 2011-12 was approximately Rs.24.49 crore for revitalization of the BBCI which included the cost of construction for expansion of the hospital as well as the procurement of major radiation related equipment during its Revitalization Project which had commenced during the year 2004-05.

The Department also extended

financial assistance to Cancer hospitals located in other parts of the country. The budget provision for the year 2011-12 for such partial financial assistance, has been to the tune of Rs.11 crore.

An increasing need was also 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 will include 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. For this purpose, an Apex Committee was

formed under the Chairpersonship of Director, TMC. The Apex Committee met 19 times so far and deliberated on indigenous development and manufacturing of equipment related to radiation oncology such as Bhabhatron, Cobalt-60 Teletherapy machine, 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.

CHAPTER : 7

TECHNOLOGY TRANSFER AND COLLABORATIVE PROGRAMMES



TEA CO₂ laser-based paint stripping system





Radiotherapy Simulator

CHAPTER : 7

TECHNOLOGY TRANSFER AND COLLABORATIVE PROGRAMMES

At the Research and Development organizations of DAE, spin-off technologies generated out of their core programmes, are developed and transferred to industry for commercial exploitation. Over a period of time, a number of technologies have been transferred to industry.

DAE organizations also enter into scientific collaborations with public and private sector organizations. This interaction has given beneficiary organizations a technological edge.

TECHNOLOGY TRANSFER

During the report period, technologies were transferred from BARC to industry, as follows:

1. Vibro Thermal Disinfector,
2. Dip-N-Drink Membrane Pouch,
3. Quadrupole Mass spectrometer
4. Digital Radiotherapy Simulator

The technologies in the process for transfer included: On-line domestic water purifier based on ultrafiltration polysulfone membrane, Membrane Assisted Defluoridation Process for Safe Drinking Water, and UF Membrane Assisted Device for removal of Iron from contaminated water for drinking

purposes.

Licenses for the following technologies transferred earlier, were renewed for a period of five years: Auto TLD Badge Reader, Impedance Cardio Vasograph and Cardiac Output Monitor, USB-MCA: High resolution 8K MCA with USB interface, Production of Dysprosium Doped Calcium Sulphate Thermoluminescence Dosimetry Phosphor Powder, Production of CaSO₄: Dy Embedded Teflon Discs, TLD-Cards technologies, FDK-Fluoride Detection Kit for Groundwater, On-Line Domestic Water Purifier Based on Ultrafiltration polysulfone Membrane, and Medical Analyser Software.

Also, BARC renewed agreements with Ultra-Tech Laboratories (P) Ltd, Bhilai, and M/s Avanttec Laboratories (P) Ltd., Chennai for Personnel Monitoring Services of Radiation Workers using TLD Badges.

The IPR's Facilitation Center for Industrial Plasma Technology (FCIPT), besides executing its committed projects, also signed new projects funded by government organisations, autonomous bodies and private sector companies.

COLLABORATIVE PROGRAMMES

During the year of report, six scientific collaborative MoUs were signed by BARC with

various organisations. These included:

- Design and development of 3.0 MW S-Band Turnable Pulse Magnetron (Electron Beam Centre);
- Manufacture of additional Dual Axis Barker Coil System (Indian Institute of Geomagnetism);
- Development of Oxidant Transfer System for P-Series Equipment of Indian Navy (Indian Navy);
- Extension of MoUs to jointly Setting up of Electron Beam Centre and Develop Industrial Accelerator, and Jointly Develop Industry Interface Institution, both at Belapur, Navi Mumbai (SAMEER);
- Evaluation of Seismic Performance of RC frames without and with Haunch Retrofit Solutions (Central Power Research Institute), and
- Creep behaviour of Zirconium Alloy Components over a range of temperature & stress (National Metallurgical Laboratory)

Alumina Based Humidity Sensors were developed and tested by BARC in association with Central Glass & Ceramic Research and Jadavpur



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 framework, 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.

Under the DAE's societal initiative, a MoU was signed by BARC with Shri Vithal Education and Research Institute, Pandharpur, Maharashtra, to set up Rural Human & Resource Development Facility.

DAE's Akruti Programme is spreading fast. So far 3 Akrutis, 12 Krutiks and 61 Force nodes were established. Technologies deployed and activities generated under the AKRUTI initiative are described below.

- Nisarg-Runa Biogas Plant (7 plants operational of which 3 generate electricity);
- Direct Water Purifiers (300 units deployed in households);
- Foldable Solar Dryers (17 units sold);
- Soil Organic Carbon Detection Kits (740 fields

University, Kolkata. The Capacitive sensors are based on adsorption and absorption of water vapour inside dielectric layer of alumina thin film, as a result of which dielectric properties change. These sensors are proposed to be a part of Leakage Detection System (LDS) required for LBB implementation in Main Steam Line for PHWRS.

For the validation of the Nonlinear static pushover analysis for seismic assessment of reinforced concrete structures, two exactly same models of a three storey-two bay reinforced

concrete structure were tested at the Structural Engineering Research Centre, Chennai.

The PRISM project (Project for Interdisciplinary Science and Modelling) at IMSc is in its fifth year. It initiated and fostered collaborative research on a wide variety of topics, enabled visitors from diverse fields to visit IMSc, funded PRISM members to visit other institutions and high-profile conferences, and generated high-quality research that was published in top interdisciplinary journals.

tested, 30 kits in use; Field workers were trained);

- Seeds (7 varieties; 4310 kg sown on 250 plots);
- Isotope Hydrology investigations (1 investigation successful, 4 more sites under trial); Tissue Culture Facility for Banana (1 Lab with field hardening facility);
- Vibro Thermal Disinfector (2 units in use);
- Products locally developed using Foldable Solar Dryers (more than 35);
- Brackish water filtration plant for drinking (300 lph capacity) by Akruiti Parivartan; Organic Horticulture : Planted and nurtured (over 750 plants);
- 20 variety of fruit trees using Nisarg-Runa;
- Manure and SHRI sludge

More than 50 scientists and engineers from BARC who developed above technologies, were involved actively and provided technologies and field guidance.

To promote rural technopreneurs, BARC signed two Akruiti Tech-Pack Agreements. This makes a total of ten Rural Technopreneurs with two women entrepreneurs.

BARC-Vizag Akruiti - SEZ : Akruiti

Advisory committee was formed and technology equipment such as foldable solar dryers, direct water purifiers, and others, and workshop tools & tackles and machines, were procured.

BARCIT

Under the infrastructure development work at BARCIT, five Technology Incubation Cells were made ready for operation in Phase-1.

INTELLECTUAL PROPERTY RIGHTS

DAE-IPR Cell constituted by the Department, works as a nodal agency for all the 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 2011, six regular DAE-IPR cell meetings were held during which eighteen 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 9 new patent applications, while other inventions are in advanced stages of filing. Patents filed include five in India, two in USA, one each in the European Union and Canada.

During the year 2011, eight of the previously filed patents were granted to the Department -- all of them are patents granted in

foreign countries.

1. Calcium potassium ferric amide prophylactic mixture comprising this compound and the use thereof for decorporation of Radio-cesium in subjects affected by nuclear radiation (granted in USA and Japan)
2. Color Indicator Dosimeter for measurement of ionizing radiation (granted in USA)
3. Emergency Leak Arresting Device for a collared pipe (granted in Canada)
4. Single Stage Purification of Uranium Refining (granted in South Africa)
5. A penetration enhancing flux formulation for Tungsten Inert Gas welding of austenitic Stainless steel and its application (granted in UK, USA and Ukraine)

IGCAR licensed a technology titled "A penetration enhancing flux formulation for Tungsten Inert Gas welding of austenetic stainless steel and its application"

During the year, 37 patent applications were referred to the Department by the IP India, to screen for the applicability of section 20 (1) of the Atomic Energy Act, 1962, i.e., whether the application was 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 55th batch of the Training School (OECS-2011) students covering all the aspects of

intellectual properties, protection and rights emanating thereof. For the first time, IP awareness programme was also organized for NPCIL employees to make them aware of the IP issues

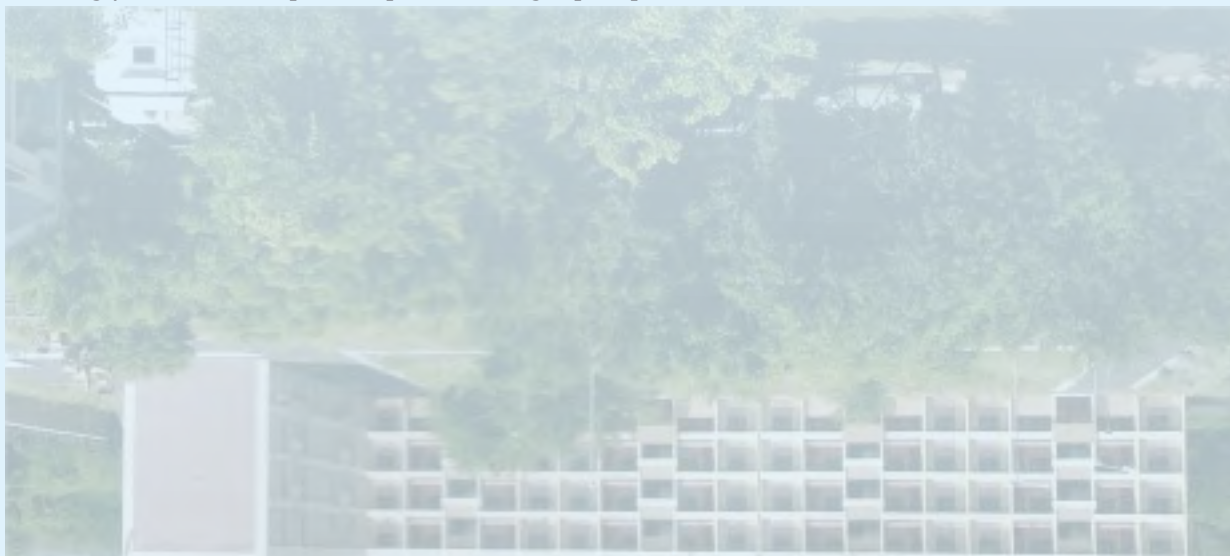
relating to the developmental work carried out under collaborative research with industries under various contracts / MoUs.

CHAPTER : 8

INFRASTRUCTURE



Housing for AMD at Jaipur completed during report period





Development of Parks

CHAPTER : 8

INFRASTRUCTURE

CONSTRUCTION, SERVICES & ESTATE MANAGEMENT

Infrastructure support to various organizations of DAE are provided by the Directorate of Construction, Services & Estate Management (DCSEM). DCSEM is involved in executing construction works for housing, schools, hospitals, laboratories, various public buildings and other infrastructure. This Directorate is also responsible for operation and

maintenance of various services, estate management and security for the housing colonies of DAE at Mumbai.

During the year of the report, construction works for the proposed Convention Centre/ Senior Officers' Guest House and Administrative Training Institute Complex, Residential Quarters for CISF personnel, Restoration / Renovation of Old Houses (Phase-I) and Creche Facility at Anushaktinagar progressed. Renovation of main gates of

Anushaktinagar, Upgradation of services and development work for 356 residential quarters were in the process of completion. Soil investigation for extension of V.S Bhavan and prequalification of contracting agencies was completed. Re-tendering for hostel for trainees of BARC / HBNI was taken up.

Major work orders were issued by DCSEM for construction of academic township, sports complex & residential township for NISER, Bhubaneswar, SINP



*Under construction :
Convention Centre at Anushaktinagar*



Fast Reactor Fuel Cycle Facility Project

Canteen, Computer & Information Centre and Construction of Pre-Engineered Multipurpose Hall at Rajarhat at Kolkata. In addition, the construction work on Medical Cyclotron Building, internal / external works for Radioactive Ion Beam (RIB) Building, Fire Station & Anunet substation Building at VECC, Kolkata, were in progress. Work orders were also issued for civil works at GCNEP, Haryana, FReT project TIFR, Hyderabad, DAE-Nodal Dispensary at Kharghar, Navi-Mumbai and Group I, II & III Buildings at Anushaktinagar.

In addition to the above works, DCSEM completed development work for 96 flats for TIFR at New Mandala, construction of Physical Training & Aquatic facility for AEES at

Anushaktinagar, 24 flats of type B & 64 flats of type C quarters for IIT-B Mumbai at Powai, Housing for AMD at Jaipur, and Integrated Facility for Radiation Technology (IFRT) for BRIT at Vashi.

The DCSEM also took up works relating to extension of School-6 and School-4 of AEES at Anushaktinagar, construction of Computer Centre And Computer Science & Engineering Complex Building / Type-B quarters and apartments for QIP/DRDO for IIT-Bombay at Powai, and auditorium / director's bungalow / flatlets for the Indian Institute of Geomagnetism at Panvel. Tender action was taken up and works will be started for (First Research and Teaching) FReT Block for TIFR at Hyderabad and Construction of Training School, Core Library,

hostel, guest house and staff quarters for AMD at Cherlapally, Hyderabad.

Engineering Services Division of DCSEM maintained residential flats (9821) and public buildings of the department in Mumbai including execution of up-gradation works required for the buildings which were of minor capital in nature.

This Directorate is also responsible for the operation & maintenance as well as up-gradation of electrical power distribution, lifts, water supply distribution, sewer lines, sewage treatment plant, fire fighting system, rain water harvesting and energy conservation of the services in the Anushaktinagar township.

The Estate Management Section of DCSEM continued to

manage the estate of DAE and allotment of residential flats (9821), shops including public buildings and the security for the DAE Estate in Mumbai.

Schemes worth Rs 201.71 crore were under execution for various DAE units and other departments, including the projects for DCSEM worth Rs.80 crore.

PURCHASE & STORES

The Directorate of Purchase & Stores (DPS), a service organization of DAE, shoulders the responsibility of materials management activities related to the constituent organisations of DAE.

A gist of the quantum of work carried out by DPS during the financial year 2011-12 is given below :

In spite of increased quantum of work, DPS could achieve its set goals and better its procurement lead time.

Other Activities

Uranium Fuel Imports

During the report period, DPS successfully carried out imports of uranium from TVEL Russia and Kazatomprom, Kazakhstan. With the long term contracts already in place, additional supplements were signed with the respective governments.

e-Procurement, Materials Management Application and Other IT Initiatives

Keeping pace with the development of information technology across the government and business domains, DPS geared up to

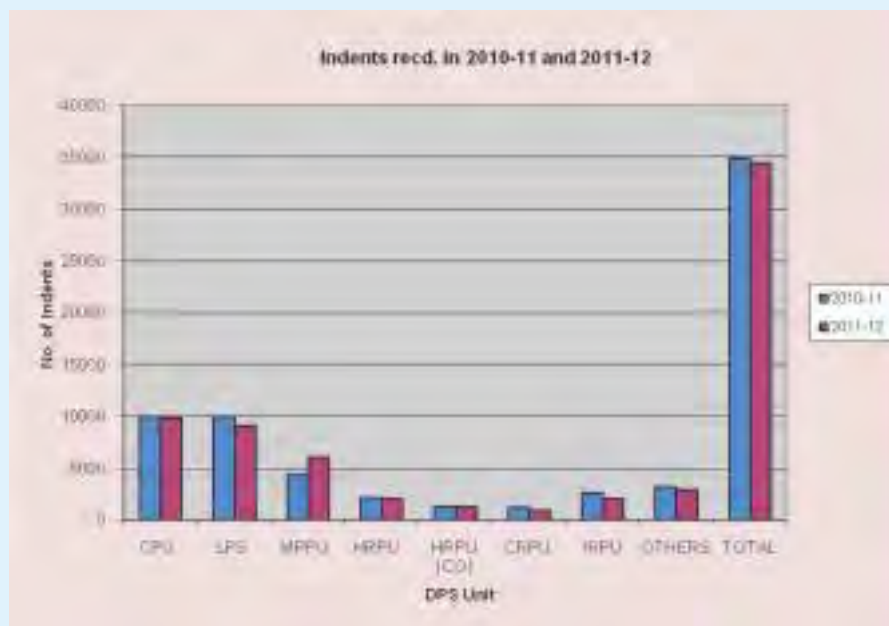
leverage the benefits of information technology that included e-tendering process. e-Tendering system was in operation at the Local Purchase Section in DPS, and Regional Purchase Units in Chennai and Hyderabad.

This system will be extended to all the other purchase groups of the Central Purchase Unit, Mumbai. The Local Purchase Section of DPS in Mumbai issued 1,825 tenders by e-mode. This was 23% of the indents received by this Section. DPS has a target to issue hundred percent e-tenders by the next financial year. Integration of the e-tender activity with the work flow automation of respective units of DPS was also under way.

At DPS, an Integrated Software Materials Management System was under development. Towards this end, development of a digital data repository of BARC and DPS was initiated. This system will provide on-line information, approvals and workflow across the intranet of these two organisations.

DPS website

To enhance transparency and accountability in various operations of the Directorate, re-design and development of DPS-Web site was taken up. This Web-site will comply with the "Guidelines for Indian Government Websites" published in the Central Secretariat manual of Department of Reforms and Public Grievances, Government of India.



Quantum of work carried out by DPS during the financial year 2011-12

Uniform Codification System of Items

Uniform Codification System - Technical evaluation was completed. The Uniform Codification System will lead to better competition, fair & transparent system and reduction in purchase lead time.

IT Security Audit

An IT Security Audit was carried out by DPS and vulnerabilities identified were fixed.

Stores Procedure

DPS revised the existing Stores Procedure that aimed at achieving maximum efficiency, speed and transparency, as well as accountability in the system to maintain a seamless supply chain activity. This proposed Stores Procedure is now under consideration of DAE.

GENERAL SERVICES ORGANISATION

The General Services Organisation (GSO), Kalpakkam

takes care of the common facilities such as housing, medical, transport, water supply, civil and electrical maintenance in the Atomic Energy Townships at Kalpakkam and Anupuram, catering to the needs of various DAE Organisations located at Kalpakkam. Also, GSO renders administrative support to various advisory committees common to both DAE and NPCIL, and provides infrastructural facilities and support to Kendriya Vidyalayas (KVs), Atomic Energy Central Schools (AECS), Atomic Energy Central Higher Secondary School, Nuclear Employees Sports and Cultural Organisation.

GSO carries out the departmental administrative work relating to Kalpakkam Nuclear Installation Local Authority. In addition, Grant-in-aid provided by DAE to AECS and KVs, is administered through GSO. This organisation is also involved in various activities under the Neighbourhood Development Programme, a part of social welfare in the villages in and

around Kalpakkam.

The following Services and facilities were provided by GSO during the year of report:

The Kalpakkam and Anupuram Townships together have more than 5900 houses of various types, and a number of public buildings such as schools, guest house, hostels, hospital etc. GSO, through its Civil Engineering Division carries out the maintenance as well as construction activities pertaining to civil works at both these townships. Besides, the essential auxiliary services viz., sanitation and horticulture etc. in these townships, are also managed by CED.

CED carried out construction of housing, public building and infrastructure facilities like construction of 283 Nos. of houses, 240 Nos. of Efficiency Plus Apartments, Hostel cum Guest house, 15 bed hospital as well as augmentation and refurbishment of the infrastructure facilities under the XI plan projects.

CHAPTER : 9

PUBLIC SECTOR UNDERTAKINGS (FINANCIAL PERFORMANCE)



A modern Control Room built by ECIL for PHWR





Release of 1st Resident Identity Card manufactured at the Tirupati facility of ECIL, by Shri P. Chidambaram, Home Minister, Government of India, at Portblair

CHAPTER : 9

PUBLIC SECTOR UNDERTAKINGS

(FINANCIAL PERFORMANCE)

Financial performance of the public sector undertakings of DAE, namely the Nuclear Power Corporation of India Ltd., Uranium Corporation of India Ltd., Indian Rare Earths Ltd. And the 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.

During the current financial year, the company registered Profit After Tax (provisional) of Rs. 1497 crore up to December 31, 2011. For the year 2010-11, the Profit After Tax was Rs. 1376 crore. The improvement in profit is mainly due to better capacity utilization of the stations under IAEA safeguards for which imported fuel is available in the required quantity. 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 during the year 2010-11

increased to Rs. 750.26 crore as against Rs. 545.38 crore in the previous year with a 37.56% rise. The profit after tax was Rs. 101.53 crore as against Rs. 46.26 crore in the previous year with an increase of 119%.

INDIAN RARE EARTHS LTD.

For the financial year 2010-11, the Sales Turnover of IRE was Rs. 388.50 crore and Profit Before Tax (PBT) was Rs. 52.44 crore. As against this, for the financial year 2009-10, the Sales Turnover and PBT were Rs. 337.10 crore and Rs. 47.81 crore respectively. During the year 2010-11, IRE had earned foreign exchange of Rs. 91.76 crore. It paid 20% dividend on the paid-up capital, amounting to Rs. 17.27 crore.

The sales turnover of the company for the financial year 2011-12 is expected to be around Rs. 428 crore.

ELECTRONICS CORPORATION OF INDIA LIMITED

The 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 meeting the varied needs of atomic energy, defence, aerospace, security, information technology and e-governance

sectors. ECIL is a key player in the strategic electronics space.

Performance

Performance During the financial year 2011-12, against the annual target of Rs. 1340 crore each of production and sales, ECIL achieved a production of Rs. 769 crore and a sales (net) of Rs. 747 crore upto December 2011 as compared to Rs. 846 crore and Rs. 774 crore respectively, for the corresponding period during the year 2010-11. However, the company is confident of meeting the targets for the year 2011-12. The order book position has improved with new and repeat orders from defence and security segments.

ECIL took major initiatives to introduce new products to mitigate information security concerns. The significant activities and achievements of the company during the year 2011-12 were as follows :

i) Atomic Energy Sector

- ◆ Supply of Control & Instrumentation (C&I) equipment and Operator Training Simulator to PFBR Project,
- ◆ Supply of C&I Package to Project P3A of BARC,
- ◆ Development and supply of C&I equipment to DFRP, IGCAR, Portable Radiation Sensors and Beta Gaseous Activity Monitor units to

Detectors for Neutron, Gamma and Beta Detection developed by ECIL



Doorway Monitor



Vehicle Monitoring System



Limb Monitor



SNM Baggage System



Detectors: GM tube Type: 7134 LND



Isotope Identifier



The control room of PFBR installed by ECIL.

ECIL has the unique distinction of supplying Control & Instrumentation Systems to all the operating Nuclear Power Plants in India. ECIL has launched a massive capacity building exercise to support the programmes of DAE for indigenous Nuclear Power Plants and reprocessing facilities.

Hindustan Shipyard Limited, Visakhapatnam.

ii) Defence Sector

- ◆ Supply of M7 Radios, V/UHF Tx Rx 3060 Equipment, Supply of HF Tx Rx TR 2400 Radio,
- ◆ Supply of MSRS-II equipment,
- ◆ Supply and Commissioning of Divyadrishti System in collaboration with DRDO for the Services,
- ◆ Universal Fuzes, Development of ETF Fuze for ARDE, Pune,
- ◆ Supply of Ground Support Systems to BrahMos and Akash Projects.

iii) Space Sector

- ◆ Progressive proof assembly of 21M Telescope for MACE project of BARC,
- ◆ Supply and commissioning of Aircraft Terminals to ICNS project.

iv) Security Sector

- ◆ Integrated Security System to BARC, Kalyan,
- ◆ Baggage Inspection Systems to Tuticorin Port,
- ◆ Video Surveillance Systems at Delhi city markets

v) Other Sectors

- ◆ e-Services to Government of Karnataka,
- ◆ Soil Test Equipment to Dept. of Agriculture, Govt. of Punjab,
- ◆ Check-post Monitoring System to Government of Orissa,

- ◆ Supervisory Control and Data Acquisition Equipment to Oil and Steel industries,
- ◆ Electronic Energy Meters for West Bengal Electricity Board,
- ◆ Electronic Voting Machines to Election Commission of India / State Election Commissions,
- ◆ 11M Ku-band Antenna to BISAG

vi) National Population Register and Socio-Economic Caste Census Projects

ECIL is associated with the creation of the National Population Register project for digitization of census data and also acquire biometric information relating to the population. The corporation also remained associated with the socio-economic and caste census being carried out by the Government of India.

Research & Development

The in-house R & D programme of ECIL is guided and supported by the Technology Development Council. The following products were developed during the fiscal 2011-12:

- Asphalt Gauge,
- Automatic Weather Station,
- Pulse Power Supply,
- Digital Notch Indicator,
- Mark II EVM with advanced security features and EVM with Voter Verifiable Printer Audit Trail, V.35 Channel Encryptors and C-band

Monopulse Feed for Antennas, and

- S-band Feed System for Tracking Radar and Earth Station Antenna for Remote Sensing.
- Under Vehicle Surveillance System,
- In-cell Monitor and Neutron REM Monitor, Portal Monitoring System and Vehicle Monitoring System,
- 3-Phase 4 Wire Static Energy Meter and Automatic Power Factor Controller
- BF₃ Gas Filled Neutron Detector,
- Multi Chip Module for Time to Amplitude Converter,
- Power Series Programmable Logic Controllers

New Products Introduced

- Beta Gas Activity Monitor, Low Intensity Conflict Electronic Warfare Systems (LIC),
- Mobile Automatic Spectrum Monitoring & Direction Finding Systems (MASM & DF)
- EVM Totalizer,
- Integrated IT solution for Border Check-post Automation, covering needs of Road Transport and Commercial Tax Departments of State Governments

Certification of the applicable Quality Management Systems

Audits for ISO certification (ISO-9001, ISO 14001:2004,

Major Atmospheric Cerenkov Telescope Experiment (MACE)



21m diameter imaging telescope at the high altitude (4200m) observatory site at Hanle in the Ladakh region of Northern India. Operating at an energy threshold of ~ 20 GeV this telescope is expected to detect a large number of sources in the GeV sky.

ISO 18001 OH&S) were conducted and recommendations received for continuation of certificate(s) for quality management, environmental management and occupational health & safety management. ECIL obtained SHE certification by integrating all these management systems.

Collaborations

The Company has entered into the following strategic tie-ups to strengthen its activities:

- MoU with M/s. BDL to enhance business in the area of Missile Electronics and Weapon Support Systems and address the requirements of major defence programs.
- ToT agreement with IIT, Mumbai for engineering, manufacturing and marketing of 3 models of Carrier Class Routers.
- MoU with Swedish Space Corporation, Sweden for supply of Earth Station Antennas.
- MoU with M/s. Canberra, France for indigenization of Nuclear Instrumentation for NPCIL through ToT and setting-up of repair facility for High Purity Germanium Detectors.

Outlook for 2012-13

The company is aiming to achieve a target of Rs. 1650 crore during 2012-13 covering following supplies and services:

Atomic Energy :

- ◆ C&I equipment for various Nuclear Power Plants of NPCIL, PFBR & B1 / B2 Projects,
- ◆ C&I equipment for BARC, P3A Project of NRG / BARC
- ◆ RDEs for Sea Ports and airports

Defence :

- ◆ M7 Radios, V/UHF Tx Rx 3060 Equipment, HF Tx Rx TR 2400 MSRS-II, Universal Fuzes, VT Fuze for Pinaka
- ◆ Ground Support Systems for Project BrahMos and Project Akash
- ◆ Speech Secrecy Equipment, Low Intensity Conflict Electronic Warfare Systems, Mobile Automatic Spectrum Monitoring & Direction Finding Systems (MASM & DF)
- ◆ Submarine terminals for Rukmani project of Indian Navy

Aero Space :

- ◆ Supply, Installation & Commissioning of Direct Reception System and Direct Communication System at Antarctica for National Centre for Antarctica & Ocean Research through National Remote Sensing Centre, ISRO
- ◆ Actuators for UAV
- ◆ Solid State Cockpit Voice Recorders

Security :

- ◆ Video surveillance for Delhi city -Phase 2.

- ◆ Mobile Container Scanning System for Directorate of Logistics, Ministry of Finance
- ◆ X-ray Baggage Inspection Systems

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.
- ◆ Replication of Integrated border check-post Project in other states
- ◆ NPR biometric enrolment
- ◆ Socio-Economic & Caste Census (SECC) project of Government of India
- ◆ Network Routers

CHAPTER : 10

OTHER ACTIVITIES



Dr. Srikumar Banerjee, Chairman, AEC and other senior officers of DAE in a meeting at DAE with Mr. Gary Locke, Secretary of Commerce, USA along with the US delegation



Participants of the 23rd DAE All India Essay Contest with the Officials of the Public Awareness Division, DAE

CHAPTER : 10

OTHER ACTIVITIES

NATIONAL SECURITY

B A R C continued implementation of the necessary research and development as well as manufacturing activities required for national security.

CRISIS MANAGEMENT

The Crisis Management Group (CMG) is a standing Committee of senior officials of the DAE who are responsible for coordinating the Department's response to a radiation emergency in the public domain. Such an emergency could be due to events taking place within any nuclear facility, an accident involving transport of nuclear material, events at other facilities, handling radioactive materials, such as hospitals or industries, or even due to any deliberate attempt to cause disruption in public activities by involving radioactive material.

Because of the inherent design features and deployment of multiple safety systems, 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 of the DAE in the field of radiation measurement and protection and medical treatment of radiation injuries. The objective is to make these specialized technical support facilities available to public officials who would be handling various types of disasters or emergencies related to radiation/radioactive materials in the public domain.

The Crisis Management Group formally meets once in six months to review the crisis management plan at different facilities to discuss on issues related to radiological incidence occurred 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.

To ensure that the emergency plans are in a 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. During the year 2011, the following exercises were carried out:

- Communication Exercises (306)
- Fire Emergency Exercises (78)
- Plant Emergency Exercises (64)
- Site Emergency Exercises (8), and
- Off-Site Emergency Exercises (2)

The Off Site Emergency Exercises were carried out in the public domain in the vicinity of nuclear power stations at Kaiga in Karnataka and Heavy Water Plant, Manguru. 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 the six Nuclear Power Plant sites, to harmonise the procedure for conduct of mock emergency exercises, and to bring better awareness among the district officials on their roles and responsibilities.

The Emergency Response System of DAE is also available

OTHER ACTIVITIES

to respond to a request from any public official in the event of the reported presence or suspected presence of radioactive material. For this purpose, guidelines were circulated to all the State Governments and Union Territories.

A significant component of the Emergency Response System of DAE is the availability of two emergency communications rooms in Mumbai, which are manned on a round-the-clock-basis throughout the year. These have multiple modes of communication and remain in constant contact with various nuclear facilities in the country, as well as with IAEA.

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

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 the operation of variety of radiation installations in BARC, the BARC-Safety Council Secretariat had prepared Regulatory Guidelines, which specifies 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

For co-operation in the field of peaceful uses of atomic energy, India has bilateral agreements with a number of countries. Under these agreements, India offers training facilities, fellowships, scientific visits, etc. to foreign scientists, and provides the services of its scientists for expert assignments to other countries.

India has been a designated member of the Board of Governors of the International Atomic Energy Agency (IAEA) since its inception, and has been taking active part in policy management and programmes of the Agency.

Following describes the major activities and the role that India had played during the period of report, in the field of international relations.

Bilateral Agreements

Following Bilateral Agreements were signed during the year 2011 :

- ◆ Agreements with the Governments of the Republic of Kazakhstan and Republic of Korea, for Cooperation in the

Peaceful Uses of Nuclear Energy

- ◆ Memorandum of Understanding between DAE and the State Atomic Energy Corporation “Rosatom” of Russia, on cooperation with the Global Centre for Nuclear Energy Partnership of India

India also signed a tripartite agreement with the International Atomic Energy Agency (IAEA) and Namibia, for donation of one Bhabhatron Teletherapy unit to Namibia.

Discussions continued with the vendors from France, Russia and USA on setting up of Nuclear Power Plants in India.

Legislation

The “Civil Liability for Nuclear Damage Act, 2010” notified on 22 September, 2010, came into force on 11 November, 2011. A set of rules titled “Civil Liability for Nuclear Damage Rules, 2011” was also notified on 11 November, 2011.

Global Centre for Nuclear Energy Partnership

At the Nuclear Security Summit organized in Washington DC during 12 -13 April 2010, Hon'ble Prime Minister had announced India's decision to set up a Global Centre for Nuclear Energy Partnership (GCNEP) in India. India signed a MoU on GCNEP with ROSATOM on 20 June 2011.

OTHER ACTIVITIES

International Atomic Energy Agency (IAEA)

Mr. Yukiya Amano, Director General, IAEA visited India during 16-19 January, 2011.

Chairman, AEC led an Indian delegation to the 55th General Conference of IAEA in Vienna from 18-25 September, 2011. Along the margins of the General Conference, the Chairman had bilateral meetings with France, United States, Jordan, Argentina, Sri Lanka, Vietnam and Kazakhstan. The Indian delegation also had meetings with the Director General of IAEA and the Director General of OECD, NEA. India actively participated in other important IAEA meetings including the Board of Governors, Programme and Budget Committee, Technical Assistance and Cooperation Committee etc. India continued to be represented in a number of committees of IAEA related to safety, safeguards, nuclear engineering and applications.

India continued to offer training facilities, fellowships, and scientific visits etc. to various countries, and made available the services of its scientists as experts to various countries under the IAEA Technical Co-operation scheme in the field of peaceful uses of atomic energy.

International Conferences, Symposia etc.

More than 2500 foreign scientists and a number of Indian scientists/engineers participated in international symposia, workshops, conferences and

meetings held in India under the auspices of the IAEA and various international / multinational organizations. India hosted 5 IAEA and 85 non-IAEA meetings / symposia on important issues such as High Pressure Science & Technology; Structural Mechanics in Reactor Technology; Lepton Photon Interactions at high Energies; World Thorium Resources; Fuel Cycles for Innovative Nuclear Energy Systems based on Integrated Technologies.

Deputations Abroad

Over 1000 scientists from India were deputed abroad to attend international symposia, workshops, conferences and meetings conducted by IAEA and non-IAEA organizations.

Chairman AEC visited: Kazakhstan as a member of PM's delegation (April 14-16, 2011), Moscow to attend the Annual India-Russia Summit (December 15-17, 2011), Ukraine to attend 'Kyiv Summit on Safe and Innovative Use of Nuclear Energy' (April 18-21, 2011), France to attend the Ministerial Seminar on Nuclear Safety (June 6-8, 2011), Austria to participate in IAEA Ministerial Conference on Nuclear Safety (June 20-24, 2011) and Republic of Korea for signing the Indo-Republic of Korea Agreement on Cooperation in the Peaceful Uses of Nuclear Energy (July 23-27, 2011).

World Nuclear Association

Three units of DAE i.e. NPCIL, NFC and AMD are

members of the World Nuclear Association (WNA). DAE scientists participated in various WNA activities including in their Summer School.

European Organization for Nuclear Research

India is an Observer in the European Organization for Nuclear Research (CERN) and continued collaborative work in the framework of the developments of computing and computational Grid technology for Large Hadron Collider Project (LHC) based on the 1991 agreement.

World Association of Nuclear Operators

In 2011, NPCIL hosted WANO Peer Review of its plants which were carried out by teams consisting of experts from several countries representing global nuclear safety standards and found it to be very useful in bringing in international perspective to our plants.

Operational Safety Review Teams (OSART)

IAEA's OSART programme assists member states in enhancing the operational safety of specific nuclear plants and to promote the continuous development of operational safety within all the Member States by dissemination of information on IAEA safety standards and good international practices.

During the year 2011, India offered one of its Nuclear Power Plants for OSART review.

OTHER ACTIVITIES

MANAGEMENT SERVICES

The Management Services Group (MSG) provided project monitoring, information services, computer network and systems support at the DAE Secretariat. It continued to provide Information Technology facilities on a round-the-clock basis to DAE headquarters and contributed actively to its e-governance initiatives.

MSG continued to manage the local area network connecting all officers and sections. It also provides connectivity to Anunet - a DAE-wide network connecting all the units of DAE, and provided support in the Secretariat for data, voice and video conferencing connectivity with all the Units of DAE. Furthermore, internet facilities were provided using a separate isolated network.

DAE was connected to the National Knowledge Network of India that interconnects various research and educational institutions across the nation through high speed communication links.

An information system on the performance of all the operating units and progress of projects under construction, was maintained. This information was used for preparation of periodic information reports that is sent by the Department to the Prime Minister and the Atomic Energy Commission.

MSG maintains the internet information portal for the Indian Atomic Energy Programme through DAE's web site

(<http://www.dae.gov.in>). The website, that acts as a window to the public to communicate its activities, is a repository of various acts, rules, agreements, orders, publications, achievements of the Department, and provides downloadable forms for the benefit of the public. It also has links to DAE and all its constituent organisations. The IT infrastructure in DAE Secretariat was continuously upgraded to keep pace with technology.

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 the conduct of computer penetration tests of various systems of all DAE units connected to the internet.

Officers of the MSG participated in various committees and task forces of the Department in the field of Information Technology.

VIGILANCE

The overall responsibility of the vigilance administration rests with the Chief Vigilance Officer (CVO) of the Department. 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 of DAE, full time Chief Vigilance Officers are available to co-ordinate the vigilance activities.

During the report period, the vigilance functions included timely transmission of various vigilance returns to the Central Bureau of Investigation (CBI), Department of Personnel & Training (DoPT) and Central Vigilance Commission (CVC), issuance of prosecution sanctions, processing of vigilance and disciplinary cases, monitoring the progress of inquiry proceedings, investigation of complaints etc.

As advised by CVC, the corruption prone areas were continuously identified and corrective measures were taken.

As per the directives of CVC, Vigilance Awareness Week, 2011 was observed from 31st October to 5th November, 2011 in the Department as well as its Constituent Units, Public Sector Undertakings and Aided Institutions. On the eve of the Vigilance Awareness Week, various participative programmes were organized. These included lectures, essay writing competitions, quiz competitions, drawing competitions, and seminars for promoting vigilance awareness. A workshop on "Jan Lok Pal Bill" was also organized.

A special icon on vigilance was made available on the DAE website incorporating the details of Vigilance Officers of Constituent Units and CVOs of Public Sector Undertakings / Aided Institutions of the Department.

OTHER ACTIVITIES



Shri A.P. Joshi, Additional Secretary, DAE, administering pledge on the eve of Vigilance Awareness Week-2011

Uploading of Immovable Property Returns in respect of Group “A” officers of the Department in the official website of the Department continued.

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 13th All India Rajbhasha Sammelan on 2nd and 3rd November, 2011 at the

Institute of Physics and National Institute of Science Education and Research, Bhubaneswar and various lectures and programmes were organized during the course of Sammelan. A souvenir in Hindi on the proceedings of the Sammelan was also brought out

- The third meeting of the Joint Hindi Advisory Committee of the Department of Space and Department of Atomic Energy was held on 21st February, 2012 in Bangalore. The members of the Committee appreciated the work done by DAE in the field of Hindi

- The Parliamentary Committee on Official Language inspected DPS, NPCIL, ECIL, Tirupati and IRE, Manavalakuruchi. The Drafting and Evidence Sub-Committee of the Parliamentary Committee on Official Language held discussion programmes with the heads and some of the members of the Town Implementation Committee at Mumbai
- DAE as well as its various Units / PSUs / Aided Institutions inspected their subordinate offices and sections
- 38 Seminars and 27 Talks in

OTHER ACTIVITIES

- Hindi on diverse subjects, mostly related to Nuclear Science, were organized and the Souvenirs in Hindi on the proceedings of the Seminars / Conferences were brought out
- All Gazette Notifications, Cabinet Notes, Annual Reports and other documents furnished to various Committees of the Parliament, and the Agreements and MoUs were prepared bilingually
- Through Hindi workshops 2,450 Officials were imparted training in Hindi Noting and Drafting. Cash awards were given to 575 Officials for writing original notes and drafts in Hindi
- 246 Officials, 35 Typists and 31 Stenographers were imparted training in Hindi, Hindi Typing and Hindi Stenography respectively. 226 Officials, 62 Typists and 35 Stenographers were undergoing training in Hindi, Hindi Typing and Hindi Stenography respectively. 629 Officials, 44 Typists and 23 Stenographers were given cash awards and other incentives for successfully passing Hindi, Hindi Typing and Hindi Stenography examinations
- Hindi books worth over Rs. 3,11,000/- were purchased and books worth over Rs. 3,00,000/- are proposed to be purchased

- Quarterly meetings of OLICs were held regularly and the progress of implementation of Hindi was monitored through OLIC meetings and review of the Quarterly Progress Reports
- DAE and 19 of its establishments have their Websites in bilingual form that are updated regularly. Presently, there are 18,968 bilingual computers and another 1,752 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
- 32 House Magazines and 04

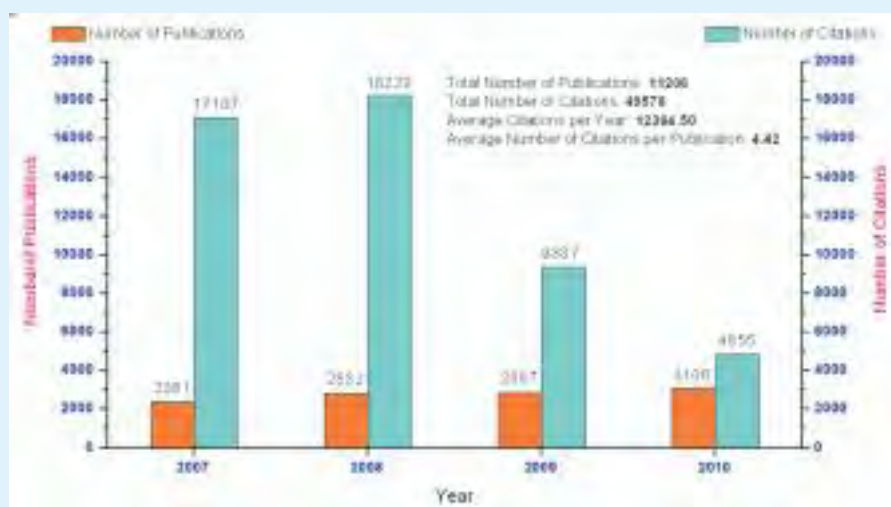
News Letters were brought out by various establishments of DAE

- The total strength of Hindi Staff in DAE and its constituent Units, PSUs, and Aided Institutions is 124

SCIENTIFIC INFORMATION & RESOURCE MANAGEMENT

The Scientific Information Resource Centre (SIRC) of Department of Atomic Energy during the report period procured many new books, periodicals and other audio-visual materials. The centre continued its user services to its patrons such as Circulation, News Clipping Service (News Watch), Interlibrary loans, Reprography, Referrals etc.

During the year the



Year-wise Distribution of Publications and Citations of DAE Institutions during 2007-2010

OTHER ACTIVITIES

Publications Unit of the Department published many literatures for internal use as well as for distribution amongst general public. These include Annual Report, Outcome Budget, Accounts at a glance, Telephone Directory, Reports of the Working Groups for XII plan proposals, Diary, brochures, leaflets etc. A new state of the art digital franking machine was purchased for the dissemination of the published literature through mass mailing.

The Library and the Information facility of BARC is one of the biggest information centres in the world in the field of nuclear science and technology.

This information centre was regularly upgraded with state-of-the-art facilities and technology infrastructure to provide seamless access to information users and also extended its facilities to other DAE organisations.

Upgradation of network infrastructure in BARC was carried out. Access was provided for more than 3500 online journals through Online Information Gateway Lakshya. Other than e-journals, BARC also provided access to other online resources such as INIS, Medline etc., bibliographic databases, standards, encyclopedia, references and others, to users in BARC on their desktop.

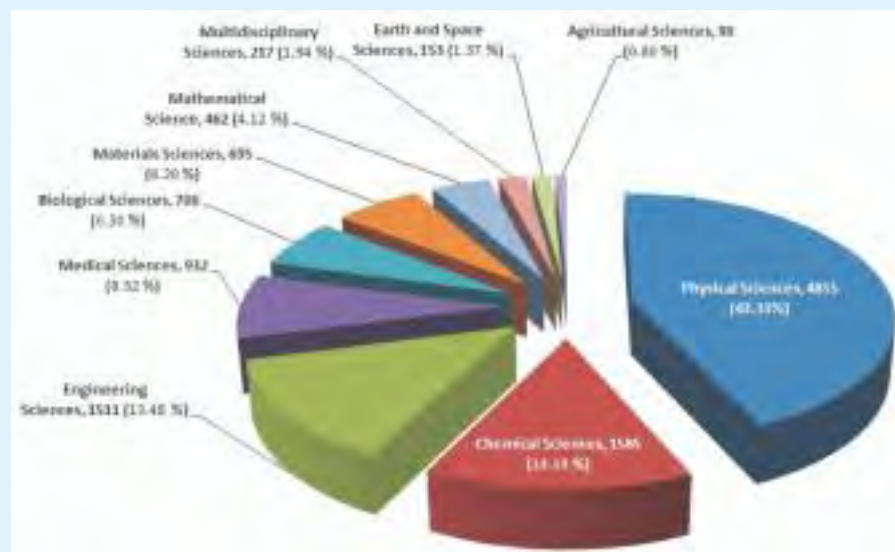
A mirror site of Online Information Gateway Lakshya facility was setup at BARC Computer Centre. Digital Portal Saraswati was upgraded for faster access to digital collection. Open source based digital repository e-Sangrahalay now holds more than 5200 journal articles. To provide state-of-the-art facility at Central Library, RFID (Radio Frequency Identification) based document circulation was under implementation.

Research activities carried out in library & information science and scientometrics on various topics related to nuclear science and technology and other thrust areas. Over 19 papers were published. A report on scientific Productivity and Impact of DAE Institutions was prepared. Over 11,200 publications were published and about 49,600 citations were received to these publications during 2007-2010. The highlights are given below.

Regular publication of BARC-Newsletter, Scientific Information Resource Bulletin, Pulse and several internal, external and restricted reports, brochures, and others were carried out. In addition, 26 External, 14 Internal and 7 Restricted reports of BARC were also produced.

At IGCAR, digital library infrastructure was enhanced with high performance computing & storage architecture. Mobile storage systems to accommodate hard copy of technical reports and journal back volumes were installed. Radio Frequency Identification (RFID) based library management system was implemented with improved facilities.

Initiatives were taken to build knowledge domains on various aspects of nuclear technology which aimed to empower meaningful information retrieval. Subject gateways on metallic fuel and fuel reprocessing were developed with necessary bibliography & full text information. The existing digital



Subject-wise Distribution of Publications of DAE Institutions during 2007-2010

OTHER ACTIVITIES



DAE Pavilion during the 99th Session of the Indian Science Congress, Bhubneshwar, Odisha

resources were augmented with the International Centre for Diffraction Data-PDF4, IEEE-ASPP, e-Books and more online journals.

PUBLIC AWARENESS

DAE and its organizations, in their efforts to promote mass awareness about various ongoing programmes and the peaceful uses of atomic energy in the correct perspective, with special emphasis on societal benefits, organized and participated in a host of events. These comprised exhibitions, seminars, workshops, essay and quiz contests. In addition to these, literature in the form of brochures, fact-sheets and handouts, was brought out on various aspects of nuclear energy, to keep the public abreast of current developments in the field.

The 99th Session of the Indian Science Congress was held at the

Kalinga Institute of Industrial Technology, Bhubaneshwar during January 3-7, 2012. A Mega Expo, Pride of India was held parallel to the Science Congress. DAE participated in this exhibition by providing detailed information in the areas of nuclear power, applications of radioisotopes in healthcare, agriculture, food processing, industry, hydrology, desalination, advanced technologies etc. The main highlight of the pavilion was the extensive use of multimedia presentations and films through a specially created display system to disseminate information. The Atomic Minerals Directorate for Exploration and Research, Indian Rare Earths Limited and the Uranium Corporation of India Limited were also a part of the DAE pavilion. They displayed detailed information on their respective activities. Over 45,000 people including students, members of the general public,

academicians benefitted from the event.

The 23rd All India Essay Contest on Nuclear Science & Technology was organised in October 2011. Essays were received on three topics and in three languages. The winners were taken around various facilities of DAE. Certificates and cash prizes were awarded during the Founder's Day Celebrations.

Vigyan Sakshrata Utsav-2011, a Science & Technology Workshop-cum-Exhibition was held at Hisar, Haryana, during April 28-30, 2011. The sub-themes for the event were science and technology for healthcare, agricultural and food security, energy resources and the importance of nuclear energy and conservation of natural resources. DAE participated in this event showcasing its contributions and activities in these areas with emphasis on the need for nuclear power, keeping in mind the futuristically planned nuclear reactors at the close by site of Gorakhpur, Haryana. Several members from the rural public, farmers etc visited the exhibition and were provided detailed information on the significance and benefit of nuclear energy.

DAE participated in the 11th Edition of the Bangalore India-Bio, held at Bangalore, during May 4-6, 2011. The Department's activities in the area of biotechnology, healthcare, agriculture, radiation processing of food etc. were brought out in this exhibition. More than 25,000 visitors including rural public,



Dr. R. Chidambaram, Principal Scientific Adviser to the Government of India at the DAE pavilion



Bangalore India-Bio 2011 : Visitors being briefed at the DAE pavilion



*Bharat Utsav-2011, Hyderabad :
Students showing keen interest
in the DAE exhibits*



*Career counseling to students
during Bharat Utsav-2011*



*15th National Exhibition at
Belgharia, Kolkata :
A view of the DAE Pavilion*

OTHER ACTIVITIES



*Inauguration of the Integrated Irradiator Project at Rahuri, District Ahmadnagar, Maharashtra :
Shri Sharad Pawar, Minister of Agriculture & Minister of Consumer Affairs,
Food & Public Distribution, Government of India,
inaugurated the project, and
Shri Prithviraj Chavan, Chief Minister of Maharashtra, presided over the function*

students and farmers benefited from this event. Some private entrepreneurs were provided information regarding setting up of private radiation processing plants.

An Integrated Irradiator Project was set up at Rahuri, District Ahmadnagar, Maharashtra by M/s Hindustan Agro Co-operative Limited during June 5-6, 2011. The project

was inaugurated by Shri Sharad Pawar, Minister for Agriculture, Government of India and presided by Shri Prithviraj Chavan, Chief Minister, Maharashtra. An exhibition on the societal vision of DAE with special focus on agriculture and food processing / preservation, was put up which was visited by dignitaries and a number of local farmers and private entrepreneurs.

A Seminar on Nuclear Energy was organized by the R.D. National College and the W.A. Science College, Mumbai, during July 2011. While the inaugural address was made by Dr Anil Kakodkar, former Chairman AEC, the other talks included the Indian Nuclear Power Programme, Safety in Nuclear Power Stations, Public Perceptions about Atomic Energy

OTHER ACTIVITIES



*Exhibition-cum-Fair on
Multidimensional Development and Technology, Pokhra, Garhwal :
Shri Satpal Maharaj, Member of Parliament (Lok Sabha) and Chairman,
Standing Committee on Defence, Member,
Public Accounts Committee, at the DAE Pavilion*



Interaction with students

achievements in Science & Technology, Industry and Management was held at Hyderabad during August 18-24, 2011. The event comprised a Science & Technology Expo, seminars, competitions for students etc. DAE participated in the expo highlighting all its activities. Over 40,000 visitors to the DAE pavilion, mainly students and faculty members from various schools and colleges, benefitted from this event. Several other government departments like ISRO, CSIR, DRDO, DST, ICMR etc also took part in this event.

A National Conference on Science, Technology and Applications of Rare Earths-2011 was organized by the Rare Earths Association of India, Indian Rare Earths Ltd. during August 19-20, 2011 at Munnar, Kerala. DAE participated in the conference and also put up an exhibition on its various activities with special focus on thorium reserves in India and its importance in the future. An invited talk on the Future of Thorium Technology was also delivered during the conference.

DAE took part in the 17th All India National Expo at Kalyani, Nadia, West Bengal during August 24-28, 2011. The theme of the event was 'Science, Agriculture, Environment and Communication'. Information on the uses of atomic energy towards societal benefit was displayed in Bengali and English. Over 30,000 members from the general public and students visited the DAE pavilion.

Myths versus Realities etc. Over 300 participants comprising students at the undergraduate level, faculty members,

educationists etc. attended this seminar.

The Bharat Utsav 2011, an event focusing on India's

OTHER ACTIVITIES

The 15th National Exhibition with theme as 'Evolution of India as a Great Nation in the 21st Century' was held during September 7-11, 2011 at Belgharia, Kolkata. DAE along with VECC Kolkata, participated in this exhibition. Information (in Bengali and English) and several working models were displayed in this expo. The DAE pavilion had as many as 35,000 visitors.

At the instance of Shri Satpal Maharaj, Member of Parliament (Lok Sabha) and Chairman, Standing Committee on Defence, Member, Public Accounts Committee, DAE Participated in the Exhibition cum Fair on Multidimensional Development & Technology during September 16-18, 2011 at Pokhra, Garhwal, Uttarakhand. Information about DAE's activities was displayed in Hindi. Students from over 240 schools visited the DAE pavilion. Some of the other major government organizations that participated were ISRO, DRDO and DST.

India Nuclear Energy 2011, the 3rd International Exhibition and Conference was held at Mumbai during September 29 to October 1, 2011. The event was a unique platform for showcasing latest cutting edge nuclear technology. DAE exhibited 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. Several other countries such as France, USA, Russia, Finland etc also



*Inaugural Session of the
Indian Analytical Science Congress-2012 (IASC-2012)
at Kanyakumari, Tamil Nadu*



Visitors at the DAE Pavilion

OTHER ACTIVITIES

participated in this event. In addition, many Indian companies supplying nuclear components towards our nuclear power programme also took part in the exhibition.

The International Atomic Energy Agency (IAEA), in co-operation with the Indian Rare Earths Limited, organised the 'International Technical Meeting on World Thorium Resources' at Thiruvananthapuram, Kerala during October 17-21, 2011. DAE put up an exhibition on the Indian Nuclear Power Programme with special focus on the available thorium resources in India and the future significance of thorium for India's three stage nuclear power programme. Professionals engaged in thorium exploration and production, safety experts, researchers and officials from Member States interested in thorium resources also participated in the event.

The 21st International Conference on Structural Mechanics in Reactor Technology (SMiRT 21) was held at the India Habitat Centre, New Delhi, during November 7-11, 2011. The DAE pavilion showcased its achievements in the area of nuclear power, applications of radioisotopes etc. Dr A.P.J. Abdul Kalam, former President of India, inaugurated the conference.

A seminar on 'Environment Awareness' and exhibition on the activities of DAE was organized by the Institute of Science at Nagpur, Maharashtra in December 2011. About 200

college students, faculty members attended the seminar.

DAE participated in the 5th Science & Technology Expo-2011 during December 11-13, 2011 at Bhopal, Madhya Pradesh. The theme of the event was 'Infrastructure, Education, Healthcare, Science & Technology'. Information on the contributions of the Department towards societal development was displayed in Hindi and English. Members of the general public and students visited the DAE pavilion.

The Indian Analytical Science Congress-2012 (IASC-2012) was organized by the Indian Society of Analytical Scientists at Kanyakumari, Tamil Nadu during January 27-28, 2012. An exhibition on the Indian Nuclear Power Programme, with special emphasis on safety, thermal ecology, environment, etc. was put up. The visitors comprised members of the academia and

general public. Booklets on Frequently Asked Questions (FAQs) about the Kudankulam Nuclear Power Project in Tamil and English were made available to the public.

DAE took part in the Chennai Science Festival 2012, held at Chennai, Tamil Nadu during January 27-30, 2012. This year being the Year of Sustainable Energy, various units of DAE participated in the event. The Atomic Energy Regulatory Board also displayed information on regulatory aspects pertaining to nuclear power stations. Booklets on FAQs about Kudankulam Nuclear Power Project in Tamil and English were distributed to the public. Faculty members from schools and colleges, students, and members of the general public visited the pavilion.

Consequent to the incident at Fukushima, Japan that occurred in March 2011, there has been a strong impact on the perception of



Students appreciating the exhibition

OTHER ACTIVITIES



Interactive session during the Authors' Workshop

the public not only in India, but the world over, towards nuclear power. Keeping in mind the ambitious nuclear power programme being pursued in India, there has been a multi-fold increase in the Public Awareness activities of DAE during the year. These activities are focused on allaying baseless fears harboured by the public and are being executed in mission mode as a concerted effort by DAE and all its constituent units spread over different regions in the country.

During the report period, NPCIL carried out various communication activities for the dissemination of information on nuclear power to different target groups. Country's First-Ever Nuclear Gallery, a permanent exhibition "Hall of Nuclear Power", was launched at Nehru Science Centre, Mumbai with the aim to communicate nuclear science in an interactive way to

the general public. A national level Scientific Press Meet on Occupational Health Safety was organised in Mumbai. During this meet, a booklet "Retrospective Analysis of Health Profile of Employees of Nuclear Power Corporation of India Limited - Operating Sites" was also released.

To enhance the public outreach activities, NPCIL initiated a partnership with Vigyan Prasar (Department of S&T, Govt. of India) at national level. To reach a large section of the public, the company tied-up with UFO movies to screen short films promoting nuclear energy at multiplexes and theatres across the country. Animated comic films "Ek tha Buddhia" and "Buddhia Ki Sair" were launched in multiple languages to remove apprehensions about nuclear energy. The company provided financial assistance to several

institutions and events.

Nu-Power - an international journal of nuclear power was published and the Company's website (www.npcil.nic.in) was updated regularly.

At BARC, an Exhibition on 'Fusion Engineering' was held as a part of the National Science Week on 28th February 2011. The exhibition had many exciting posters, books, highly cited papers and an exhaustive scientometric study done on fusion engineering were on display. A touch screen based Kiosk with personalised login was indigenously designed and developed covering the brief contents of the exhibition. A website was designed in-house covering all the digital resources and information available in the exhibition. About 600 scientists and engineers visited the exhibition.

In order to create awareness and enhance the scientific productivity among BARC scientists and engineers, an 'Authors' Workshop' was organized by the Scientific Information and Resource Division (SIRD) on 12th August 2011. About 700 scientists and engineers participated in the workshop. The importance of a scientific publication, citations and the indicators like impact factor, H-index, various ethical issues involved in scientific publication such as plagiarism and plagiarism detection tools etc., were discussed.

To promote awareness among the public about the peaceful uses

OTHER ACTIVITIES

of atomic energy, BARC conducted several public awareness programmes across the country for the benefit of students, teachers and farmers. In all, 32 public awareness programmes were conducted during the period. In addition, media coverage to the various events organized at BARC was also provided. Also, to deal with the general public in the event of crisis and emergency, a BARC Media Committee was constituted.

The Atomic Minerals Directorate for Exploration and Research continued its public awareness programme in cities as well as in remote field areas.

On behalf of Indian Nuclear Society, ECIL organized “INSAC 2011”, the 22nd Annual Conference of the Society, during November 24-26, 2011 in Hyderabad. The theme was “Strategic Electronics : Instrumentation, Controls, Communications and Computing”.

SOCIAL WELFARE

NPCIL continued to take up its responsibility towards society around its site locations and environment, for long-term impact and sustainable development. Various corporate social responsibilities (CSR) related activities, mainly in the areas of health, education and infrastructure development, were pursued by the Corporation to support the community in and around its nuclear power plants.

Every identified CSR project

of NPCIL has a time-frame with milestones for the purpose of monitoring and social audit. During the year of report, the identified CSR projects were implemented through specialized agencies for which NPCIL empanelled NGOs/Trusts as per the guidelines on CSR from Central Public Sector Enterprises.

The support in health measures included organizing regular medical check-ups and extending medical assistance in emergency cases, blood donation camps, eye camps, etc. The support in education consisted of provision of educational infrastructure development essentially the school building, laboratory equipment, furniture, teaching aids, such as computer and study materials to school etc. The infrastructure supports included construction of roads and buildings, drinking water, electrification, etc.

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 comprise BARC Hospital, its 13 zonal dispensaries, 2 occupational health centres, pathology and radiology lab, and pharmacy. The healthcare facilities of CHSS are also extended to the retired employees and their families.

Children's Education

The Atomic Energy Education Society (AEES) meets the educational needs of the children of the DAE employees and its organisations. With its 30 schools/Junior colleges at 15 centres located all over the country, AEES provides education to over 27,000 students.

Several positive measures such as the strengthening of infrastructure facilities, enrichment of the school libraries, computer-aided education and improvement of sports facilities and in-service training programmes for the teachers as well as enrichment and educational programmes for the students have contributed significantly to the objective of providing quality education.

During the report period, AEES set new records both in academic and non-academic areas of education. In the All India Secondary School Examination and the Higher Secondary Examination the pass percentages were 99.9 and 92 respectively. The Excellence Index of AEES students stood at 70.41, and three schools of AEES (Manuguru, Kaiga and Jaduguda) achieved 100 percent result. Scholarship for Higher Education under the Innovation in Science Pursuit for Inspired Research (INSPIRE) was awarded to three students of AEES, Mysore.

Over 200 students from AEES schools secured admission to various professional courses. In the National Talent Search

*Medical Check up at
Ghivali Village, Tarapur*



*Construction of
approach road to Ghivali*



*Construction of
Rooms & Labs for Science wing
of the State Govt. (Girls)
Sr.Hr. Sec. School
at Rawatbhata, Rajasthan*



OTHER ACTIVITIES

Examinations, 17 students performed well, 21 students were placed in the top ten of the National Standard Examination in Physics, Chemistry, Biology & Astronomy 2010-2011, and in the Mathematical/Science Olympiad, one student received special merit award in the 13th Indian National Astronomy Olympiad. In the Annual All India UN Information Test / Annual All India General Knowledge Test, a number of students of AEES schools secured good marks. In the Junior Science and Mathematics Olympiad Tests conducted on 17 May 2011, Six students from different AEC schools were awarded medals and prizes.

During the year, AEES held Inter AECS-Hindi Vigyan Prashna Manch in the four zones in the country. This was conducted by the Hindi Sahitya Parishad of BARC. AEES is also recognized as a separate entity by NCERT to participate at the Jawaharlal Nehru National Science Exhibition which is an annual event.

TIFR Art Festival Consolation prize was bagged by one student from AECS-3, Mumbai. The Poster Drawing competition organized by the Directorate of Vigilance, NPCIL went to a student of AECS-2, Kalpakkam, and Best Logo Design to a student of AECS-1, Hyderabad.

An All India AEC School Art Competition was organized by AEES.

Students of Atomic Energy Schools and colleges participated in a number of National level

sports tournament and athletics meets, and bagged prizes in Volleyball, Choikwang, Table Tennis, Itosu-Ryu Karate, Chess championship. One student of AECS-4, Mumbai-represented India in “2nd Inter Continental Asia WUKO Open Karate Championship” and won Silver and Bronze medals. In collaboration with DAE-Sports & Cultural Council, AEES organized Summer Sports Coaching Camp for students. A large number of students also participated in various programmes of NCC.

Talent Nurture Programme

For the benefit of the bright children belonging to socially and economically weaker tribal communities, including rural children residing in the vicinity of AEC Schools, AEES runs a Talent Nurture Programme. Under this programme children are selected for admission in Class-I. These students also receive a monthly scholarship, medical facilities, school uniforms, books and notebooks. This programme runs at 10 centres of AEES, and over 1100 children are benefited by this programme.

Faculty Improvement Programme

To foster the professional development of its staff members, AEES had earlier launched the Faculty Improvement Programme under the XI Plan. Under this Programme, AEES sponsors its

staff for MS in Educational System Management at BITS, Pilani. Under the UK-India Education and Research Initiative (UKIERI), AEES forged a partnership with the schools in Derbyshire, UK. This project runs in 12 schools of AEES in Mumbai, Jaduguda, Hyderabad and Manuguru centres.

A number of workshops, seminars & orientation programmes were organized for teachers of AEES to empower them to plan and execute various classroom activities. Project Based Learning workshop for the teachers was jointly organized by AEES and HBCSE.

Educational infrastructure

To create and sustain interest of students in science, AEES is setting up Science Parks in all its schools, in a phased manner. To enrich libraries, AEES schools have been entrusted with the responsibility of selecting and purchasing books.

Satellite Educational Programme

AEES had started Satellite Educational Programme for its school at various sites in the country. For sometime, the transmission of the programme has been held up due to some problem with the satellite transponder. This programme is likely to be made available to the students soon. In the meantime, AEES continued with the in-house programme production.

OTHER ACTIVITIES

DAE SPORTS & CULTURAL ACTIVITIES

The DAE-Sports and Cultural Council (DAE-S&CC) looks after the promotion of sports and cultural activities among the DAE employees and their families, located at various units all over India.

The XXVII DAE Sports & Cultural Meet was organized that included eleven different sports and cultural events at eleven units of DAE in the country. These inter-DAE meets aimed at encouraging DAE employees to give expressions to their talents as also to encourage synergetic team work.

More than 1000 employees took part in the final meets. Playing facilities at various units were upgraded and the events were conducted in the best traditions of the Department.

The Council, in association with the AEES, conducted Annual Summer Sports Camps at various centres for promoting and encouraging budding talent amongst the school-going children of the DAE family. About 1500 children participated in these camps and the children, with excellent performance and aptitude, were selected for advanced coaching in various sports.

The scope of advanced coaching in cricket was expanded from 15 to 40 numbers of children placed in two levels. A new advanced level (level IV) was constituted in table tennis to cater to children who excelled in

district level meets. The advanced coaching scheme instituted for talented children from the summer camps assisted more than 150 children in pursuing advanced training in sports such as badminton, table tennis, tennis, cricket etc. At outstations, advanced coaching subsidy was provided in other sports and games like swimming, athletics, hand ball, volley ball etc. Over the years, the advanced coaching programme of the Council has proved to be instrumental in enabling DAE children excelling in state and national level competitions.

For creating positive environment and promoting competitiveness in employees and their children, a combined sports and cultural meet SPLASH-2011 was organized at Anushaktinagar, Mumbai, in which more than 700 people participated. Under its Health and Fitness activities, “Healthy

Living” programmes and regular yoga activities and camps were organized at different centres. Copies of Yoga Magazines were supplied to all the schools and units of DAE. To further encourage Yoga and Fitness, DAE units were encouraged and financially supported to set up Fitness Centres for their employees and family members.

Every year, DAE S&CC organizes an All India level painting competition for school going children of DAE family. This year, the painting competition was held at the AEES Centre, Mumbai.

In the Nature and Adventure Programme, DAE's all india trekking programme “Girisanchar-23” was organized with the approval of the Indian Mountaineering Federation, in the dense forest region of Dang and Tapi districts of Gujarat near Kakrapar Atomic Power Station. During the trek, the trek convener



DAE Himalayan Trek-2 to Dodital

OTHER ACTIVITIES

and trek leaders conducted programmes for local villagers along the route. This gesture was widely appreciated and helped to spread DAE's message amongst the local population.

The DAE Himalayan Trek-2 was organized high up in the mountains to Dodital lake through high altitude grasslands and dense virgin forests. The Himalayan Trek-3 was also undertaken from Gangotri through Chidvasa, Bhojvasa, Gaumukh and Tapovan. A large number of DAE employees participated in this supervised-treks programme.

As a part of infrastructural development and promotional activities, DAE S&CC also supported the organization of various sports and cultural equipment and activities in many of the residential colonies of the Department.

Being affiliated to various sports bodies at the national level, training and participation of DAE teams in the All India National level tournaments in Bridge, Table Tennis, Badminton and Ball Badminton were also organized.

The DAE Team became an affiliated member of Indian Kabaddi Federation and took part

in Nationals. Also as affiliated members of the National bodies in Bridge, Table Tennis, Badminton and Ball Badminton, DAE team was deputed to participate in these national level events.

AWARDS & RECOGNITION

During the year of report, NPCIL units received several awards for performance in Occupational Safety and Health, Environment Protection and other areas. These included TAPS-1&2, TAPS-3&4, RAPS-1&2, MAPS, KAPS, KGS-1&2 getting the National Safety Council of India's various Safety Awards for the year 2010, and MAPS and NAPS receiving the AERB's Fire Safety Award & Green Site Award respectively for the year 2010.

NFC was also a recipient of the AERB's Industrial Safety Award (Radioactive Group) and Green Site Award for the year 2010.

Mini-Ratna status was conferred on the Indian Rare Earths (IRE) by the Government of India. AERB's Green Site Awards were bagged by OSCOM and Manavalakurichi Unit of IRE. The latter also received the National Safety Award for the

lowest injury frequency rate.

Chavara unit of IRE received two first prizes and a second prize for Mines Inspection by the Tamilnadu & Kerala Mines Safety Association. Chavara unit also won the first prize for the year 2010 of the Kerala State Pollution Control Board.

ISOMED plant of BRIT received the compliance note from the World Wide Quality Management System of M/s. Johnson & Johnson (Medical) Ethicon-USA appreciating their quality of service.

The Tata Memorial Centre bagged the Golden Peacock Innovation Award-2010 by the Institute of Directors for indigenously designed low cost limb salvage prosthesis; The Certificate of Excellence "Spirit of Humanity Awards 2011 in Oncology Research and Services" categories by the AmeriCares India; A memento of Fr. Tong Memorial Award for pioneering role in Cancer, Prevention, Treatment, Education & Research from Voluntary Health Association of India.

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.

GROUP	NUMBER OF EMPLOYEES				DIRECT RECRUITMENT								PROMOTION					
					No. of Vacancies reserved				No. of Appointments Made				No. of Vacancies reserved			No. of Appointments 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
GRP A	7031	0	1	29	0	1	2	131	0	0	1	0	0	0	28	0	0	0
GRP B	10225	6	6	55	0	2	3	95	0	0	1	0	0	0	61	0	0	0
GRP C	12098	14	20	108	0	8	7	381	0	3	1	0	0	0	108	0	0	2
GRP D	146	0	0	3	0	0	0	15	0	0	1	0	0	0	0	0	0	0
TOTAL	29500	20	27	195	0	11	12	622	0	3	4	0	0	0	197	0	0	2

Note: (i) VH stands for Visually Handicapped (Persons suffering from blindness or low vision)

(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)

ANNUAL STATEMENT FOR THE YEAR 2010-11 SHOWING THE REPRESENTATION OF THE PERSONS WITH DISABILITIES IN THE PUBLIC SECTOR UNDERTAKINGS

GROUP	NUMBER OF EMPLOYEES				DIRECT RECRUITMENT								PROMOTION							
					No. of Vacancies reserved				No. of Appointments Made				No. of Vacancies reserved				No. of Appointments Made			
	Total	VH	HH	OH	VH	HH	OH	Total	VH	HH	OH	Total	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		
GRP A	6734	5	1	42	5	6	10	313	1	0	3	0	0	0	8	0	0	0		
GRP B	5861	8	2	63	1	0	1	309	1	0	1	0	0	0	5	0	0	0		
GRP C	7425	10	14	63	7	4	2	199	0	0	5	0	0	0	57	0	0	0		
GRP D	3229	1	2	8	1	1	0	0	0	0	0	0	0	0	2	0	0	0		
TOTAL	23249	24	19	176	14	11	13	821	2	0	9	0	0	0	72	0	0	0		

ANNUAL STATEMENT FOR THE YEAR 2010-11 SHOWING THE REPRESENTATION OF THE PERSONS WITH DISABILITIES IN THE AIDED INSTITUTIONS

GROUP	NUMBER OF EMPLOYEES				DIRECT RECRUITMENT								PROMOTION					
					No. of Vacancies reserved				No. of Appointments Made				No. of Vacancies reserved				No. of Appointments 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
GRPA	957	2	1	4	0	1	10	17	0	0	0	0	0	0	0	0	0	0
GRPB	2833	4	0	14	0	2	5	50	0	0	1	0	0	0	0	0	0	0
GRPC	1421	3	1	17	0	1	1	30	0	0	0	0	0	0	51	0	0	0
GRPD	1100	1	7	10	0	2	2	98	0	0	0	0	0	0	0	0	0	0
TOTAL	6311	10	9	45	0	6	18	195	0	0	1	0	0	0	51	0	0	0

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,
Additional 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.

CITIZEN'S CHARTER

**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 SPHERES 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 COUNTRYMEN. WE SHALL DO OUR DUTY CONSCIENTIOUSLY AND ACT WITHOUT FEAR OR FAVOUR.

THIS OFFICE IS THUS COMMITTED 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,
Additional Secretary,
Public Grievances Officer & Chief Vigilance Officer,
Department of Atomic Energy,
Anushakti Bhavan, C.S.M. Marg,
Mumbai-400 001.

YOU MAY ALSO COMPLAIN TO THE :-

CENTRAL VIGILANCE COMMISSION,
SATARKTA BHAWAN, BLOCK 'A',
GPO COMPLEX, INA,
NEW DELHI 110 023.

ANNEXES

ANNEX-I

THE ORGANISATION

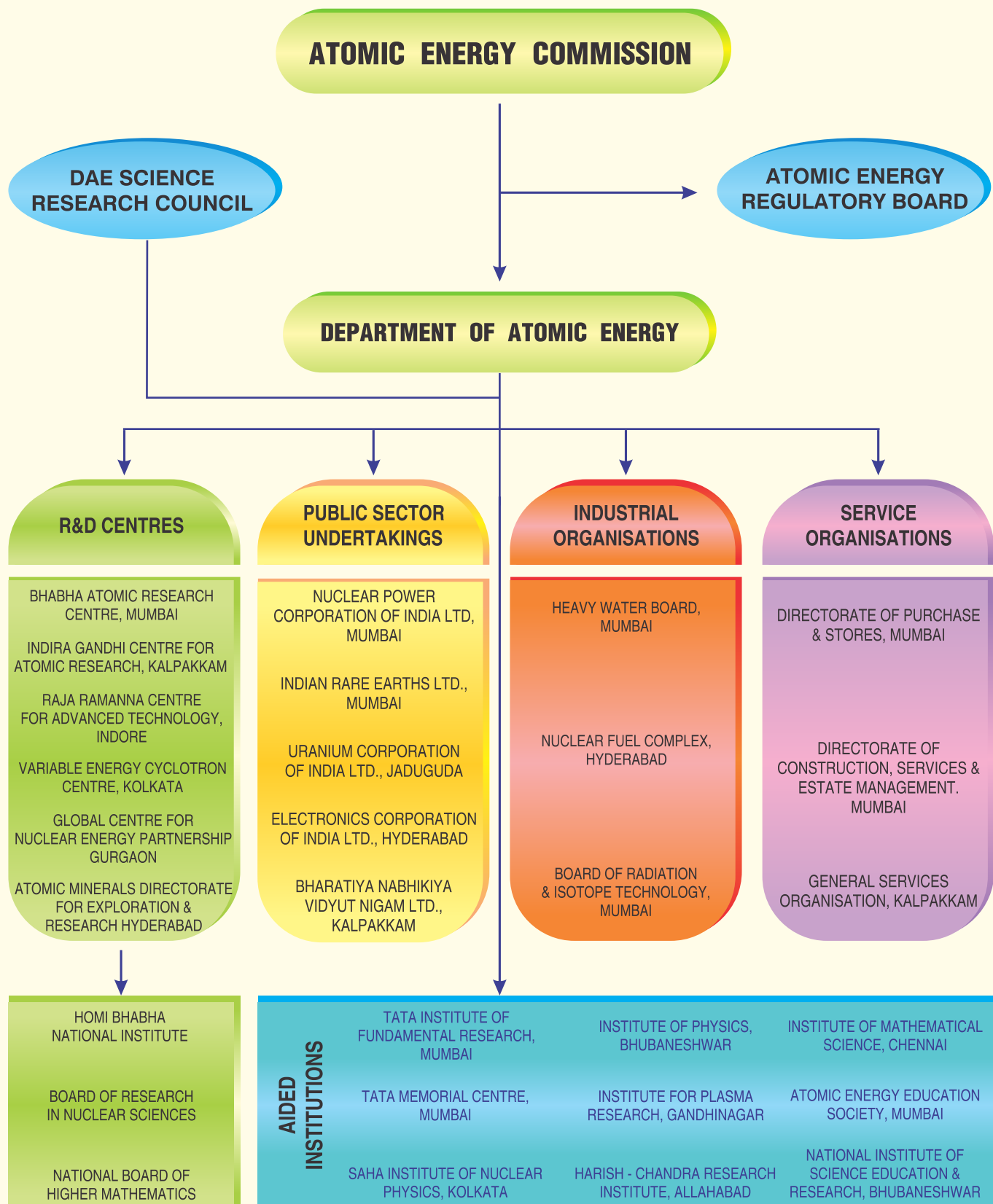
THE ORGANISATION

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.

The Organizational Structure of the Department



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 2010-NO.13 OF 2011-12 SCIENTIFIC DEPARTMENTS

Loss due to omission in the tariff notification in the Nuclear Power Corporation of India Limited

The observations of the Audit are as follows: (Report No. 3 of 2-11-12)

The Department of Atomic Energy (DAE) notifies from time to time the tariff rates for the sale of power by various units of Nuclear Power Corporation of India Limited (Company). The tariff rate consists of fixed and variable elements. The fixed cost element is determined with reference to the total estimated operating cost to the normative capacity and the variable element consists of fuel cost, income tax and insurance. The DAE notifies the tariff based on the proposal submitted by the Company. The various units of the Company raise the bills on the bulk purchasers of power at the tariff rates.

The Company negotiated (November 2000) with Rajasthan Rajya Vidyut Prasaran Nigam Limited (RVPNL) and the DAE notified (August 2001) different tariff rates applicable for the Units 3 and 4 of Rajasthan Atomic Power Station (RAPS) for the period 1 June 2000 to 30 November 2005 and 23 December 2000 to 22 December 2005 respectively. The notified tariff specifically provided that the tariff rate would not be adjusted towards Fuel and Heavy Water charges and Income Tax (IT) payable by the company would not be reimbursed by the beneficiary Boards. The Company proposed (November 2003) a Common tariff rate applicable for the Units 2,3 and 4 of RAPS and submitted a draft tariff notification to the DAE, applicable from December 2003, which contained formula for computation of Fuel and Heavy Water charges and insurance charges for dovetailing into the tariff rate but did not include the reimbursement element of IT payable by the Company. Accordingly, the DAE notified (February 2004) a uniform Tariff applicable for the Units for the period December 1, 2003 to November 30, 2008 in line with the proposal made by the Company.

The Company started (March 2005) raising demand for reimbursement of IT for the year 2003-04 onwards for an amount of Rs.84.07 crore pertaining to the billing period December 2003 to November 2005 and for Rs.21.61 crore for the period December 2005 to January 2007. The RVPNL (which was reorganised into distribution companies as DISCOMS) disputed the claim on the ground that the notified tariff did not contain a specific clause for reimbursement of IT. The DAE clarified (June 2007) that though the tariff notification issued in February 2004 did not specifically provide for the reimbursement of IT, the exemption in the earlier notification was not applicable. The DAE further clarified (December 2008) that the tariff in the power sector was based on post-tax return on equity and IT was reimbursable.

After a series of correspondence with RVPNL, the company held (February 2010) a meeting with DISCOMS and decided to Waive 50% of the IT dues pertaining to the period December 2005 to January 2007 and the balance 50% were to be paid in six equal monthly installments from July 2010. In effect, the IT claim for the period December 2003 to November 2005 for Rs.84.07 crore was fully waived along with waiver of 50% of the claim (Rs.10.80 crore) for the period December 2005 to January 2007 without seeking the approval of the Board.

The Management stated (August 2010) that the tariff notified in February 2004 was in partial modification of earlier 2001 notifications which specifically provided that IT would not be reimbursable and February 2004

notification was silent on this aspect. The reply further stated that in view of the above claim for IT reimbursement for Rs.84.07 crore for the period December 2003 to December 2005 was found legally non-sustainable and hence withdrawn.

The reply is to be seen in the light of the fact that February 2004 notification was scripted by the Company for all its Contents and the omission on IT reimbursement rested only on the Company. The argument that the claim for reimbursement of IT was not legally enforceable was in contrast to the factual position that the other state Electricity Boards/Companies of Delhi, Chandigarh, Shimla, Uttranchal, Lucknow, Punjab, Haryana and Jammu, who were also drawing power from RAPS, reimbursed IT.

Action Taken:

ATN on the C&AG para has been submitted to Audit.

ANNEX-III

REPRESENTATION OF SCs, STs AND OBCs

ANNUAL STATEMENT FOR THE YEAR 2010-11 SHOWING THE REPRESENTATION OF SCs, STs AND OBCs IN THE DEPARTMENT OF ATOMIC ENERGY AND ITS UNITS

		Number of Employees					Number of appointments made during the previous calendar year									
		Total	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	
	GRPA	7031	474	90	440	210	6	3	34	302	31	3	7	1	0	
	GRPB	10225	1812	559	1320	141	21	8	62	559	103	34	30	7	1	
	GRPC	12098	2530	1273	2459	491	76	39	213	243	68	27	6	1	2	
	Grp-D (Excluding Safai Karmacharis)	145	61	16	34	16	4	9	0	0	0	0	0	0	0	
	Grp D (Safai Karmacharis)	1	1	0	0	0	0	0	0	0	0	0	0	0	0	
	TOTAL	29500	4878	1938	4253	858	107	59	309	1104	202	64	43	9	3	

ANNUAL STATEMENT FOR THE YEAR 2010-11 SHOWING THE REPRESENTATION OF SCs, STs AND OBCs IN THE PUBLIC SECTOR UNDERTAKINGS

GROUPS	Number of Employees					Number of appointments made during the previous calendar year									
	Number of Employees														
	Total	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
Grp A	6734	707	176	622		328	42	10	97	949	112	30	17	2	0
Grp B	5861	915	364	1053		309	36	16	104	397	75	13	1	1	0
Grp C	7425	1331	1042	1796		217	55	48	70	646	126	25	1	0	0
Grp-D (Excluding Safai Karmacharis)	3051	303	1252	568		1	0	0	0	9	5	0	0	0	0
Grp D (Safai Karmcharis)	178	108	1	16		0	0	0	0	0	0	0	0	0	0
TOTAL	23249	3364	2835	4055		855	133	74	271	2001	318	68	19	3	0

ANNUAL STATEMENT FOR THE YEAR 2010-11 SHOWING THE REPRESENTATION OF SCs, STs AND OBCs IN THE AIDED INSTITUTIONS

GROUPS	Number of Employees					Number of appointments made during the previous calendar year									
	Total	SCs	STs	OBCs	Total	By Direct Recruitment			By Promotion			By other methods			
						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
GRPA	957	35	5	58	20		0	1	3	7	0	0	0	0	0
GRPB	2833	377	81	325	55		8	2	18	7	4	1	0	0	0
GRPC	1421	292	78	240	34		7	2	9	56	19	0	1	0	0
Grp-D (Excluding Safai Karmacharis)	859	240	27	130	68		23	1	17	0	0	0	0	0	0
Grp D (Safai Karmacharis)	241	215	3	10	30		23	0	3	0	0	0	0	0	0
TOTAL	6311	1159	194	763	207		61	6	50	70	23	1	1	0	0

ABBREVIATIONS

ADS	Accelerator Driven Sub-critical System	mCi	Million Curies
ALARA	As Low As Reasonably Achievable	MeV	Million Electron Volt
BWR	Boiling Water Reactor	MRPC	Multigap Resistive Plate Chamber
CCCM	Centre for Compositional Characterisation of Materials	MIBG	Meta Iodo-Benzyl Guanidine
CCRM	Coolant Channel Replacement Machine	MOX	Mixed Oxide Fuel
CERN	Organisation Européenne pour la Recherche Nucléaire	MSF-RO	Multi-Stage Flash Reverse Osmosis
CHTR	Compact High Temperature Reactor	MWD/Te	Megawatt day per tonne
CORAL	Compact Reprocessing Facility for Advanced Fuels in Lead cells	MWe/t	Megawatt (electrical)/ (thermal)
CWMF	Central Waste Management Facility	NLNRA	Normal Level Natural Radiation Areas
DFRP	Demonstration Fast Reactor Reprocessing Plant	NDT	Non-Destructive Technique
DSRDM	Diverse Safety Rod Drive Mechanism	PHWR	Pressurised Heavy Water Reactor
ECCS	Emergency Core Cooling System	PWR	Pressurised Water Reactor
ECR	Electron Cyclotron Resonance	PREFRE	Power Reactor Fuel Reprocessing Plant
ECRH	Electron Cyclotron Resonance Heating	PDSC P	project Design & Safety Committee
ESL	Environmental Survey Laboratory	QC/QA	Quality Control / Quality Assurance
FBTR	Fast Breeder Test Reactor	QGP	Quark Gluon Plasma
FDG	Fluoro Deoxy Glucose	QMS	Quadrupole Mass Spectrometer
FRFCF	Fast Reactor Fuel Cycle Facility	RAPS/P	Rajasthan Atomic Power Station / Project
HLNRA	High Level Natural Radiation Areas	RM	Rare Earth Minerals/Metals
HPU	Health Physics Unit	RFQ	Radio Frequency Quadrupole
HWP	Heavy Water Plant	RFID	Radio Frequency Identification
IAEA	International Atomic Energy Agency	RIA	Radioimmuno-assay
ICP-MS	Inductively Coupled Plasma Mass Spectrometer	RIB	Radioactive Ion Beam
ICRH	Ion Cyclotron Resonance Heating	RHIC	Brookhaven's Relativistic Heavy Ion Collider
ICRP	International Commission on Radiological Protection	RIMS	Resonance Ionisation Mass Spectroscopy
IERMON	Indian Environmental Radiation Monitoring Network	RMC	Radiation Medicine Centre
IRMA	Immunoradiometric Assay	RO	Reverse Osmosis
ISI	Inservice Inspection	RPC	Resistive Plate Chamber
ITER	International Thermo-nuclear Experimental Reactor	RRMC	Regional Radiation Medicine Centre
keV	Kilo Electron Volt	SCADA	Supervision Control & Data Acquisition System
KARP	Kalpakkam Fuel Reprocessing Plant	SQUID	Super-conduction Quantum Interference Device
lpd	Litres per day	SRS	Synchrotron Radiation Source
LHC	Large Hadron Collider	TPD	Tonnes Per Day
LINAC	Linear Accelerator	TAPS	Tarapur Atomic Power Station
LTVE	Low Temperature Vacuum Evaporation	TBP	Tributyl Phosphate
		TLD	Thermo Luminescence Detector
		UHF	Ultra High Frequency
		VSAT	Very Small Aperture Terminal
		WDXRF	Wave Dispersion X-Ray Fluorescence

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