

ANNUAL REPORT

2013-14



सत्यमेव जयते

Government of India
Department of Atomic Energy



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Front & Back cover: A collage of the pictures portraying DAE activities in the field of Nuclear Science & Technology.

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EXECUTIVE SUMMARY

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

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

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

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

During the year 2013-14, the programmes of the Department achieved impressive growth in all the segments and domains. These are described below.

NUCLEAR POWER PROGRAMME: STAGE 1

PRESSURISED HEAVY WATER REACTORS

Nuclear Power Corporation of India Ltd. (NPCIL), a public sector undertaking of DAE and a dividend paying company with AAA credit rating by CRISIL and CARE, is responsible for the design,

construction, commissioning and operation of nuclear power reactors. At present, it operates 19 nuclear power reactors (excluding RAPS-1) with an installed capacity of 4680 MWe. Two light water reactors at Kudankulam (KKNPP-1&2) with installed capacity of about 2000 MWe are in commissioning stage. Of these units, KK-1 (1000 MWe) was synchronized to the grid for the first time on October 22, 2013 and is currently operating at 73% of full power in accordance with the regulatory clearance. It has generated till March 31, 2014 about 1106 MU's infirm power. The second unit (KK-2) is also in advanced stage of commissioning. Four Pressurised Heavy Water Reactors (PHWRs), two at Kakrapar in Gujarat and two at Rawatbhata in Rajasthan, each of 700 MWe capacity, are under construction.

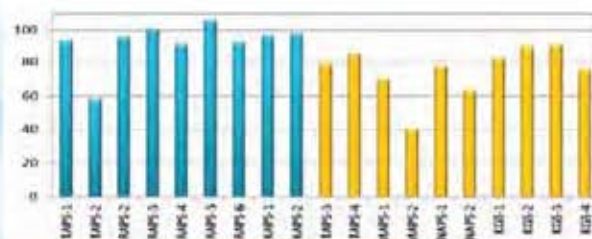
Power Generation

During the year 2013-14 NPCIL recorded highest ever generation of 35333 MU's (including 1106 MU's infirm power generation from KK-1, which was synchronized to the Southern grid on October 22, 2013).

KGS-1 & RAPS-5 achieved continuous run of more than a year during the year. So far 15 reactors have registered continuous run of more than a year. KGS-3 also registered about one year of continuous run (342 days) during this financial year.

The overall plant load factor (PLF) and availability factor (AF) for all the existing reactors (excluding KK-1) in operation were 83.48% and 88.20% respectively during the financial year 2013-14. Reactors under IAEA safeguards registered overall plant load factor of about 94% and those operating on domestic fuel of 77% during the current financial year.

Capacity Factors of Operating Reactors (FY 2013-14)



Projects under Commissioning

During the financial year 2013-14, Unit-1 of Kudankulam Nuclear Power Project successfully attained first criticality on July 13, 2013 and the unit was synchronized to the southern grid for the first time on October 22, 2013. Since then the unit has been generating infirm power and power level has been raised up to 73% of full power in accordance with stage wise regulatory clearance. In Unit-2, 'spillage to open reactor' and 'containment-testing-Integrated Leak Rate Test (ILRT)' were completed on April 15, 2013 and February 2, 2014 respectively.



Chairman AEC and CMD NPCIL at Kudankulam on the occasion of first criticality of Unit-1

Projects under construction

The construction works continued on the first pair of indigenously designed 700 MWe PHWRs, at Kakrapar Atomic Power Project Unit-3&4 (2x700 MWe PHWRs) and for the second pair at Rajasthan Atomic Power Project Unit-7&8 (2x700 MWe PHWRs). KAPP-3&4 achieved cumulative physical progress of about 61% and 48% respectively and RAPP-7&8 achieved cumulative physical progress of about 43% and 33% respectively as on March 31, 2014. These projects are expected to be completed by the year 2016-17.



KAPP-3&4, view of main plant construction area

New Projects

Kudankulam Nuclear Power Project Units-3&4

The Kudankulam Nuclear Power Project Units-3&4, an expansion program of Units-1&2, located in Tirunelveli district of Tamilnadu, is planned with the co-operation of Russian Federation. Project Administrative approval and Financial sanction for Kudankulam Nuclear Power Project (KKNPP-3&4, 2x1000 MWe LWRs) from the Government was obtained during the year 2013. Site was ready for launch. All statutory clearances like environmental clearance, Coastal Regulation Zone (CRZ) and regulatory clearance namely siting consent were obtained. About 84% work of Contract for first priority design work was completed. Work of engineering service contract for designing of balance of plant was completed. Phase-I site infrastructure works like inner fencing and peripheral road work was completed. Phase-II Site infrastructure works like Project office complex, road works etc. are under progress.

Jaitapur Nuclear Power Project (JNPP) Units-1&2

In respect of JNPP-1&2 project, land was acquired and statutory clearances like environmental clearance, CRZ clearance etc. were obtained. The reactors proposed to be set up are Evolutionary Pressurized Water Reactor (EPWRs) in technical co-operation with France in phases of 2x1850 MWe. Techno commercial negotiation to evolve an appropriate business model for implementation of the project is currently under progress.

Gorakhpur Anu Vidyut Pariyojana Harayana (GHAVP) Units-1&2

The Gorakhpur Anu Vidyut Pariyojana Harayana (GHAVP) is planned to be implemented in two phases of 2x700 MWe each. Phase-1 is planned for launch in XII Plan. The land was already acquired and environmental clearance was obtained during the year. Hon'ble Prime Minister of India laid the foundation stone for the project on January 13, 2014. Preparation for launch of the project in June 2015 is in full swing.

New Sites

Notifications were issued for land acquisition in respect of Mahi Banawara in Rajasthan, Chutka in Madhya Pradesh and Kovvada in Andhra Pradesh. EIA study was completed in respect of Chutka site in Madhya Pradesh. Public hearing was successfully organized at Chutka on February 17, 2014.

Pre-project activities including land acquisition process, Environmental Impact and other studies for Environmental clearance by Ministry of Environment and Forest (MoEF) and AERB are in various stages of progress at other new sites, having in-principle approval of the Government, namely Inland sites at Bhimpur in MP, Mahi Banawara in Rajasthan, expansion of existing site at Kalga in Karnataka to set up 700 MWe PHWRs, and coastal sites at Kovvada in AP, Chhaya-Mithi Viridi in Gujarat & Haripur in west Bengal to set up 1000 MWe or larger capacity Light Water Reactors based on foreign technical cooperation. A preliminary contract was signed with M/s Westinghouse electric Company for sharing technological details for the reactors to be set up at Chhaya Mithi Viridi. Term of Reference (TOR) for EIA study in respect of Mahi Banawara was prepared by October 31, 2013 by M/s Meccon India Limited.

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 Pressurised Heavy Water Reactors, also constitute a major programme segment of the Nuclear Power Programme.

DAE has wide-ranging capabilities in uranium mining and mineral processing, and is self-sufficient in the production of heavy water, zirconium alloy components and other materials and supplies, for pressurised heavy water reactors. The Nuclear Fuel Complex at Hyderabad manufactures fuel assemblies for Pressurised Heavy Water Reactors, Boiling Water Reactors and Fast Breeder Reactor.

Heavy Water Production

The Heavy Water Board (HWB) contributed

successfully to the first stage of Indian Nuclear Power Programme (NPP) by producing Heavy Water for all Pressurised Heavy Water Reactors (PHWRs) in a cost effective manner, enabling DAE to provide nuclear power at an affordable cost to the common man.

HWB has emerged as the largest global producer and a coveted supplier of heavy water. HWB also made major progress in its extended mandate in the field of development, demonstration and deployment of technologies for various in-core and out of core material inputs for the NPP. To support the second stage of Nuclear Power Programme, HWB successfully delivered the entire quantity of enriched Boron for the first core of PFBR.

Performance of the Board during the year 2013-14 was very good with respect to heavy water production, specific energy consumption, on stream factor, safety performance and environment management.

The Heavy Water Board achieved more than 99% of targeted production for the financial year 2013-14.

During the year 2013-14, HWB bagged 6 export orders worth 16.2 Million USD from United States and France for supply of heavy water for non-nuclear applications. This included the first time supply of 200 kg heavy water to M/s. Concert Pharmaceuticals, USA, the leading pharmaceutical Research and Development Company. The Indian heavy water will be used in their R&D work for developing and manufacturing active pharmaceutical ingredients (API).



20th Heavy Water Export Consignment being custom cleared for shipping to M/s Cambridge Isotope Laboratories, US for Non-Nuclear Application

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

Diversification Activities

HWB made major progress on its extended mandate in the nuclear fuel cycle, mainly centred around three broad areas i.e., (I) Solvents for front and back end hydrometallurgical operations of nuclear fuel cycle application, (II) demonstrating Solvent Extraction (SX) technology for extraction of various rare materials, (III) producing stable isotopes like ^{10}B for Fast Breeder Reactors (FBR) and ^{18}O for societal applications.

Solvent Technology

In the area of Solvents, both the newly installed industrial facilities at HWP, Baroda and Talcher for production of TBP and D2EHFA have performed very well. Developmental efforts were put in place at HWP, Tuticorin for new and futuristic Solvents. HWB successfully demonstrated the SX technology at industrial proto-type scale at its Technology Demonstration Plant for extraction of rare materials

Boron Enrichment

Boron Enrichment Exchange Distillation (BEXD) plant at HWP Talcher and Boron enrichment Plant (BEP) based on Ion Chromatography at HWP, Manuguru operated very well. HWB now acquired comprehensive capability in this area by achieving enrichment levels beyond 95% in multiple chemical forms. India thus found a place in the handful of countries possessing such a capability.

Sodium Metal

Sodium is another important input for FBRs, used as coolant in the reactor. HWB initiated the development of indigenous technology for the production of nuclear grade Sodium. Networking with the Indian R&D organizations, it has developed closed electrolytic cells of successively larger size with the ultimate intent of an industrial scale set up. Accordingly, a 2000 Amp test cell is operational at HWP, Baroda yielding valuable process and technology data. Based on these inputs, a 600 MT

per annum plant is proposed to be set up at HWP, Baroda.

Mineral Exploration and Mining

Atomic Minerals Directorate for Exploration and Research (AMD) continued the accelerated pace of exploration activities during the Annual Programme 2012-13 and 2013-14 (part). This resulted in the establishment of over 18,300 tonnes of additional uranium oxide reserves in the areas of Andhra Pradesh, Rajasthan, Meghalaya and Jharkhand. The country's uranium resources currently stands updated to over 2, 04,964 tonnes of Uranium Oxide.

Significant uranium anomalies were located in the parts of Tamilnadu, Rajasthan, Andhra Pradesh, Chhattisgarh and Madhya Pradesh. About 2, 75,750 m of drilling was carried out to establish additional uranium reserves in the known occurrences and subsurface continuity of mineralisation in the new promising areas.

AMD carried out geochemical surveys (3725 sq km) and ground geophysical investigations (722 sq km). Airborne survey and Remote Sensing by ground checking of airborne survey anomalies was carried out over 1276 sq km.

Rare Metal and Rare Earth Investigations resulted in location of new occurrences of columbite-tantalite and beryl bearing pegmatites at Ghorejhar, Bhandara district, Maharashtra and Pakkanadu-Mulakkadu, Krishnagiri & Salem district, Tamil Nadu.

Beach Sand and Offshore Investigations surveys resulted in establishing potential heavy mineral zones mainly along the east coast. Significant zones of Total Heavy Mineral (THM) concentration were located in Odisha, Andhra Pradesh and Tamil Nadu. Heavy mineral resources were updated to 1,064.79 million tonnes.

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

The overall performance of the company was satisfying. The Tummalapalle mine achieved the ore production capacity of 2000 TPD and about 13 lakh tons of ore were stockpiled. Efforts of finding safe procedure for mining of Hang-Wall lode are in progress. About 9.66t of U_3O_8 was dispatched to NFC and 5t per month is expected to be dispatched regularly.

Surface exploration for extension of Jaduguda ore lenses in deeper levels beyond Trukocha fault are being carried out by AMD. Four boreholes were drilled and all the borehole assay results gave positive indication of additional lenses. Mohuldih underground mine in Jharkhand was commissioned in March 2013 and the production of ore has started.

UCIL initiated modernisation of Bhatin mine towards improvement of the production efficiency. The proposal endeavors at increasing production upto 400TPD. The activities involve deepening and developing the mine, modifying and debottlenecking of underground infrastructure and the supporting surface infrastructure with temporary suspension of production, and phasing out low capacity, inefficient pneumatic underground production equipment by introducing modern high capacity diesel-hydraulic and electro-hydraulic equipments.

A unique R&D project named The Underground Remote Asset Tracking System was implemented at Narwapahar mine in partnership with M/s TCS and M/s Cisco.

At IREL, the major achievements during the year included the commissioning of HPRE plant at RED, Alwaye; Rare Earth Metal making process; production of acceptable quality of mixed $ReCl_3$ during hot commissioning trial at Monazite processing plant (MoPP); Value addition of ilmenite & zircon to produce high pure TiO_2 and ZrO_2 ; Production of nuclear grade uranium at RED, Alwaye from uranium bearing metallic radioactive waste from BARC and elimination of froth flotation in monazite up-gradation plant at OSCOM.

Three international patents were filed during the year. These included the inventions of a device for electrostatic separation of minerals based on their electrical resistivity; An improved Electrostatic plate

separator for mineral separation based on difference in electrical resistivity and size of minerals; A mineral separation equipment based on differential forces experienced by moving charged particles in magnetic field.

Project for up-gradation of monazite at Manavalakurichi and Chavara, using IREL patented equipment namely modified electrostatic separators and high tension roll separators was successfully completed. Reduction of project cost by Rs 530 lakhs at Chavara and Rs 109 lakhs at Manavalakurichi was achieved due to elimination of procurement of RED and RERMS.

Fuel Fabrication

Nuclear Fuel Complex (NFC) manufactures and supplies fuel bundles for Pressurised Heavy Water Reactors (PHWRs) and Boiling Water Reactors (BWRs) of NPCIL. Highest ever production of PHWR fuel bundles, PHWR fuel tubes, Zirconium Sponge, Niobium metal and SS tubes and job orders was achieved during the period.

All critical components and various sub-assemblies to meet the commissioning schedule of 500 MWe PFBR were manufactured and supplied. Balance quantity of fuel sub-assemblies, blanket sub-assemblies and special sub-assemblies were in the process of supply.

About 873 pressure tubes were successfully manufactured during the period with excellent material recovery after successfully establishing manufacturing process route for pressure tubes of 700 MWe PHWRs through new route of double radial forging of billets.

Production of 5 charges of UNS 8800 U-bend Steam Generator tubes for 700 MWe PHWRs was completed.

Significant developmental activities completed during the year included a new method of processing of sodium di-uranate at plant scale to produce UO_2 powder with consistent quality; Manufacturing of critical components for AHWs like Grid plate, Inner band and spacer tube for Grid spacer; Automatic pellet loading system with online weight measurement, which avoids manual handling



A carrier tube assembly of PHWR fuel bundle

and radiation exposure to working personnel; Hot Extrusion of Al-6Mg alloy tubes for indigenisation of components for M/s BrahMos; Prototype carrier tube assembly with dumb-bell shape tubes to evaluate the irradiation effects on different materials; Double clad tubes with dilute Zr-Sn liner for high burn up fuel of AHWR-LEU; Niobium needle tubes of 2mm OD and 1mm ID for BARC.

NFC launched 19 new projects during the XII plan to meet the fuel and zircaloy requirements of forthcoming 700 MWe PHWRs and 300 MWe AHWR. In addition to augmentation and modernisation of the present production facilities to 900 tpy, in line with the demand from NPCIL. Financial sanction was received for 13 projects which are in various stages of activities. The Zirconium Complex (New Zirconium Oxide & Sponge Project) was successfully completed and financial sanction was obtained for setting up of NFC-Kota with an outlay of 2401 crores.

Site selection activities regarding NFC-5&6 green field projects for meeting the fuel and zircaloy requirements for 16 forthcoming 700 MWe PHWRs are in progress.

Activities are in progress for establishing Niobium Thermit Production Facility (NTPF) to meet the Niobium requirement of VSSC (Dept. of Space) indigenously.

A process scheme comprising leaching followed by separation cum purification of uranium values from the leach slurry using 'resin-in-pulp' (RIP) technology and direct precipitation of uranium peroxide from the eluate was developed at BARC to give high purity yellow cake with minimum steps.

BACK END FUEL CYCLE

Fuel Reprocessing and Waste Management

Power Reactor Fuel Reprocessing Plant (PREFRE-II), Tarapur reported an outstanding plant performance in terms of production and process parameters. Power Reactor Fuel Reprocessing Plant (PREFRE-I), Tarapur continued to carry out aged Pu purification work and Spent Fuel casks received and spent fuel of PHWR was stored in fuel pool and all services / facilities for PREFRE-II were provided. Regular operation of KARP continued to reprocess the spent fuel of PHWRs.

Installation of Automated Charging Facility (ACF) and Charging cask was completed at Power Reactor Fuel Reprocessing Plant – 3 (P3A), Kalpakkam. Procurement of Critical equipment for Integrated Nuclear Recycle Plant (INRP) was initiated.

Plutonium Plant, Trombay achieved a milestone by completing 50th year of safe and successful operations. A radiological facility based on Indigenous R&D efforts called "Actinide Separation Demonstration Facility (ASDF)" was commissioned at BARC, Tarapur to address the challenging technology of 'partitioning'. With the commissioning of this facility, India became the first country to have adopted this technology on the industrial scale, taking a lead role towards reducing the long term concerns of High Level Liquid Waste (HLLW).

R&D Support to Power Sector

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

BARC carried out an experimental study to establish an analytical model DBHUPA for analyzing PHWR debris bed heat up useful for severe accident analysis for PHWRs. An Ultrasonic technique (UT) for the measurement of pressure tube ID was developed for periodic in-situ measurement of ID of pressure tubes with a remotely operated drive system. A



Experimental Setup with debris

Surface Replication Tool for pressure tubes of 220/540MWe PHWR was developed.

A new fabrication route was developed for Zr-2.5 Nb alloy pressure tubes for 700 MWe PHWR to achieve improved in-reactor performance. Nine types of process sensors for compact LWR were indigenously developed and qualified. Design, development and manufacturing of automated vertical radiometry scanning system for radiometry of fuel pin after filling completed.

An analytical technique was developed to quantify the traces of boron in $U_3Si_2 + Al$ and $U (Al, Si)_2$ after matrix separation employing pyrohydrolysis followed by Inductively Coupled Plasma-Mass Spectrometry analysis.

HEALTH, SAFETY & ENVIRONMENT

NPCIL recorded about 384 reactor years of safe operation of reactors by the end of March 2014. The Review of safety of operating stations was carried out on a regular basis. The individual and collective occupational exposures of radiation workers at various NPPs were maintained within the budget approved by Atomic Energy Regulatory Board by following the principle of ALARA (As Low as Reasonably Achievable) and maintaining the highest standards of safety within the Nuclear Power Plants (NPPs). The radioactive effluents from NPPs to the environment were maintained very low in comparison to the limits specified by AERB. NPCIL continued to maintain low radiation exposure in the public domain due to operation of nuclear power stations. The average exposure for the year 2013 was only 0.745% of the technical specification limit set by AERB. The Environmental Management System (EMS) and Occupational Health and Safety Management System (OHSMS) as per ISO-14001: 2004 and IS-18001: 2007 respectively were maintained at all the stations.



Measurement of Radon/Thoron in Exhaled Breath

Online Thoron Mitigation System (OTMS) was indigenously developed at BARC to control the Thoron (^{220}Rn) gas emission into environment through stack of upcoming Power Reactor Thorium Reprocessing Facility (PTRRF) based on charcoal adsorption technique. Environmental Surveillance around Nuclear Power Plant (NPP) sites and BARC was carried out for radiological impact assessment of general public. For the prevention and response to radiological emergencies including threat of Radiological Dispersal Device (RDD - 'Dirty Bombs'), a Quad-rotor based Aerial Radiation Monitoring System (QARMS) was developed. Under the Indian Environmental Radiation Monitoring Network (IERMON) programme, 150 Environmental Radiation Monitors (ERMs) were installed which raised the strength of ERMs deployed in the country to 340.

NUCLEAR POWER PROGRAMME: STAGE 2

FAST BREEDER REACTORS

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

The Fast Reactor Programme of IGCAR is supported by its research and development endeavour in a range of disciplines such as reactor engineering, metallurgy, materials science, instrumentation, safety, and others. The Fast Breeder Test Reactor (FBTR), operating at Kalpakkam for over 25 years, also caters to technology development related to fast reactors.

Based on the fast breeder reactor technology developed by IGCAR, a 500 MWe 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 & development and manufacture of fuels for fast reactors, technology for reprocessing of fuels, waste management and health and safety of the work force.

Prototype Fast Breeder Reactor

PFBR is a pool type reactor using mixed oxide of uranium and plutonium as fuel. The coolant used is liquid sodium. The project is located 500m south of the existing Madras Atomic Power Station.

The entire civil structural work for nuclear island buildings was completed. The construction of sea water intake structure is nearing completion.

Erection of most of the equipments of Nuclear Steam Supply System (NSSS) was completed. Erection of long components such as Delayed neutron detector housing, hot pool level detector housing, periscope, control plug which houses absorber rod drive mechanism were completed. About 9 nos. of control and safety rod drive mechanisms and 3 nos. of diverse safety rod mechanisms were erected and the dummy control and diverse safety rod sub-assemblies were replaced with actuals.

Major sodium system components such as Intermediate heat exchangers, sodium to sodium

heat exchangers and two nos. of sodium to air heat exchangers were erected. Erection of Primary ramp, primary tilting mechanism, secondary ramp and secondary tilting mechanism which forms a part of inclined fuel transfer machine was also completed.

All the three stages of HP, LP and IP turbine rotor were erected and Turbine was put on barring gear. Auxiliary boiler was also commissioned.

Commissioning of all the four Diesel Generators from main control room, 230 KV gas Insulated switchyard and 6.6 KV switchgear was completed. All the three outgoing transmission lines from switchyard were charged and connected to the southern grid.

Preheating of the main vessel by air was commenced as a part of integrated commissioning of the reactor and the temperature was raised up to 65°C and the inspection work is in progress. Also reactor containment building leak test is in progress and the containment was pressurized up to 103 millibar and inspection works are in progress.

The project achieved an overall physical progress of 97.5% at the end of March-2014.

Fast Breeder Test Reactor

During 2013-14, three irradiation campaigns were completed at a power level of 20.3 MWth with the turbo-generator synchronized to the grid generating a maximum power of 4MWe. Total reactor operation time was 2117 hours; high power operation time of the reactor was 1770 hours and TG was in operation for 1073 hours. The total thermal energy developed during the period was 31.2 GWh and electrical energy produced was 3.39 MU. Irradiation of various types of fuel pins, structural materials and newer fuel was continued. The periodic Safety Review of FBTR was completed and license to operate FBTR upto June 2018 was issued by AERB.

FBTR Fuels

Plutonium bearing fuels for the Fast Reactor Programme are supplied by BARC. Mixed carbide fuel pins for FBTR at Kalpakkam were supplied as per requirement. Fabrication of (U-Pu)O₂ mixed oxide



Overall view of Turbine floor

(MOX) fuel pins for 500 MWe Prototype Fast Breeder Reactor (PFBR) of BHAVINI was continued. Third fabrication line was commissioned to increase the production. Development of (U-PuO₂) Cermet fuel was initiated. Heat Treatment of (U-20%PuO₂) was done and characterization studies were carried out.

Fast Reactor Fuel Reprocessing

Compact Reprocessing facility for Advanced fuels of Lead cells (CORAL) continued to perform satisfactorily with improved performance. The experience gained in this reprocessing activity has provided valuable inputs for the Demonstration Fast reactor fuel Reprocessing Plant (DFRP) and the PFBR reprocessing plant being built as part of Fast Reactor Fuel Cycle Facility (FRFCF). Significant progress was also made towards completion of construction activities in DFRP and it is envisaged to start cold commissioning with uranium in the coming year. Several important milestones in terms of infrastructural development, improvement in the flowsheet, instrumentation, development of equipment, and reduction in waste volumes were achieved in this complex technology which is possessed by only few countries. The construction work at site is ready to start with the receipt of construction clearance as well as the financial approval for the Fast Reactor Fuel Cycle Facility.

FBR Related Technologies

To reduce the design cycle and enhance the quality of design and development with respect to EMI/EMC requirements, a pre-compliance level EMI/EMC test facility for Conducted Emission and Conducted Susceptibility was established as a part of electronics and instrumentation programme.

Future FBRs

Towards design and improviation in technology of future reactors, the design of integrated reactor assembly and the design of permanent reactor components were completed based on thermal hydraulics and structural mechanics investigations. A facility for carrying out experiments to address severe accident scenarios in pool type Fast Reactor based on tests and evaluation viz. inter wrapper flow, decay heat removal, innovative core catcher design, molten coolant fuel

interaction and post accident heat removal was established. Studies of sodium concrete interaction, dispersion of sodium aerosols and their environmental impact were also completed. The bi-dosimetry laboratory received an accreditation from AERB till 2016.

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.

Advanced Heavy Water Reactor

AHWR Thermal Hydraulic Test Facility (ATTF) located in the facility PARTH (Facility for Proving Advanced Reactor Thermal Hydraulics) jointly built by BARC & NPCIL at Tarapur was commissioned. For the development of fuel pellets for AHWR-LEU, production trials with 1 kg batch of ThO₂-13% UO₂ and ThO₂-30% UO₂ compositions were carried out.

Critical Facility for Advanced Heavy Water Reactor (AHWR) was operated on more than sixty occasions for various experiments including experiments for measuring level coefficient of reactivity.

Other Reactor Systems

Studies carried out on the neutronic characteristics of cylindrical core pebble bed of 10 MWth HTR reactor design showed that 17% and 19.5% enriched UO₂ fuel with 10% loading of TRISO fuel particles in pebble results in reasonably high burn-up, negative coolant void reactivity and low fissile inventory.



Fuel Transfer Equipment Test Set Up

Sol-gel process was used for the fabrication of dense and high purity ceramic fuel ThC_2 in the form of microspheres. TRISO coated particle for Compact High Temperature Reactor (CHTR) using natural uranium oxide as kernel in a single batch was developed. Preparation of Intermediate product beryllium hydroxide for making beryllia ceramic was continued with the standardized process and about 15 kg of hydroxide was prepared.

Detailed project report for the XII Plan project 30 MW High Flux Research Reactor (HFRR) was prepared & design of various reactor systems is in progress. Work on overall layout of Research reactors, fuel fabrication, reprocessing, waste management & other related facilities at Vizag progressed as planned.

Accelerator Driven Sub-critical Systems

A subcritical assembly driven by a D-D / D-T neutron generator was developed and commissioned at BARC for studying the dynamic

characteristics of Accelerator Driven System. Sub-critical core was coupled to the Indigenously developed Purnima Neutron Generator.

Kalpakkam MINI (KAMINI) Reactor

KAMINI reactor was in regular operation upto a maximum power of 30kW throughout, for neutron radiography of pyro-devices for VSSC / ISRO, calibration of neutron detectors from ECIL, activation analysis of samples from users and for neutron radiography of fuel elements.

Research Reactors

Work on up-gradation of APSARA reactor to a 2 MW reactor progressed as planned. A plate fuel development & fabrication laboratory was commissioned for the fuel requirements of modified APSARA core and for the upcoming research & test reactors using dispersion type plate fuel.

Research reactor DHRUVA continued to operate at an availability factor of about 80%. Recently, power of the reactor was raised to 70 MW to increase the specific activity and quantity of radioisotope production. This step would go a long way in our contribution towards the health care for the people of our country.

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.

Accelerators

The experimental nuclear physics programmes were carried out extensively by VECC during the year using the light ion beams from K-130 cyclotron and with different state of art detection

systems available at the centre. Several detector systems were developed and used to conduct experiments of K-130 cyclotron at room temperature. Low energy light ion beam was targeted for the first time in the K130 machine.

Acceleration in the fifth harmonic mode and development of proton beam in the third harmonic mode was also carried out for the first time. The vacuum of the beam chamber of the K-130 cyclotron was improved by repairing the resonator tank-Dee tank interface air leak. Prototypes of true bipolar switch-mode power supplies are being developed for steering magnets.

Radioactive Ion Beam (RIB) ^{111}In was recently produced at the VECC's RIB facilities. A Linac designed for a resonant frequency of 75.6 MHz was commissioned and a 10 MeV injector for the e-Linac is presently being developed in collaboration with TRI University Mason Factory (TRIUMF), Canada.



VECC e-Linac test area in the NSAC-II hall at TRIUMF, Canada

The phase of the circulation beam with respect to the RF voltage was measured and a detailed magnetic field mapping was carried out using NMR probes in order to understand and rectify the problems related to the extraction of beam from Super Conducting Cyclotron (SCC). To correct the field errors a few shims were placed inside the cyclotron and the geometry of the central region was modified. To accommodate these changes the central RF cover and the coll tank liners were modified appropriately.

A magnetic field mapping jig was designed to fit in the narrow gap of RF liner in SCC. High rigidity and homogeneity bending magnets were designed to transport high energy beam from the K-500 SCC to different experimental stations. Provision phase

control for the RF system of the K500 SCC was developed to meet the stringent criteria of the various RF parameters. Multipacting analysis and prototype fabrication and testing of 650 MHz, $\beta=0.61$, Superconducting RF linac cavity was also carried out at VECC.

A 0.6MJ prototype of Superconducting Magnetic Energy Storage (SMES) system was developed and is currently being integrated. A 4.5MJ SMES is also being designed. The magnetic design was completed and the cable was customized to meet the requirements.

An indigenously developed 400 keV, 4 vane Radio Frequency Quadrupole (RFQ) was commissioned at BARC and related technologies such as RF power coupler and high-power RF system were developed. A DC electron accelerator was used for development of flue gas treatment process for pollution control in collaboration with BHEL Ranipet.

Laser Technology Development and Applications

At RRCAT, an OPCPA (Optical Parametric Chirped Pulse Amplification) based Nd: glass laser system of 40 TW peak power was developed. A prototype model of 20 kW peak power industrial Nd: YAG laser with dual-port fiber optic beam delivery was developed. A 200 W rugged all-fiber single transverse mode Yb-doped CW fiber laser-amplifier system was developed. A compact soft x-ray laser based on a capillary discharge set up (total length 60 cm) was developed. A prototype model of a Nd: YAG laser operating in cw mode was developed for indigenization of the laser radiator of missile firing system of T-90 tank.

The technology developed at RRCAT for various applications included Laser-Driven Ion Acceleration; Photo-sensitizer for Photodynamic Therapy of Cancer; Fabrication of Titanium Structures with Different Porosity using Laser Rapid Manufacturing; Laser Shock Peening of Reactor Components for Improving Material Strength; Development of Technology for In-situ Laser Cutting of Bellow Lip Weld Joint without Removal of Peripheral Obstacles and Hand-held Photon Counting based Uranium Analyzer.



Prototype model of 20 kW peak power industrial Nd: YAG laser



200 W all-fiber Yb-doped CW fiber laser

A high resolution and high dispersion Thomson Parabola spectrometer (TPS) with time-of-flight unit was developed at BARC, for both radioactive and non-radioactive materials.

Electronics & Instrumentation

Tracking and stabilization system for the Seeker targeted for use in Brahmos missile was developed by BARC and integrated with rest of the Seeker at ECIL. Mono-pulse tracking chain was validated through outdoor tracking tests. Stabilized satellite tracking terminals for use in Airborne platform were developed for DRDO in collaboration with ECIL and are now under deployment.

Nuclear Instrumentation Systems consisting of Source Range Monitors and Intermediate Range Monitors employing Boron lined proportional counters and gamma compensated ion chambers and High range gamma monitors (10mR/hr to



Brahmos Seeker under demonstration at ECIL



Nuclear instrumentation systems

100R/hr) were developed and used for conducting experiments in P4- BPR & P4-Cold Facility.

A Tele Distress Alarm Device, named "Nirbhaya", was developed and the technology was transferred to ECIL for mass production. It is a small, rechargeable battery operated electronic device, used in any distress like fear of attack or medical emergency. Single-button, single-press activation device sends SMS alerts with GPS coordinates, through user's cell phone, to near and dear ones including police. Once activated, the device continues to send the message and latest GPS



Nirbhaya: A Tele Distress Alarm Device

location every minute to the same phone numbers. Device operates on and pairs with user's cell phone via Bluetooth.

A 12-Channel battery operated portable ECG Machine was developed. A micro-SD card stores several ECGs locally and transfers to the PC using blue tooth connection. Also a low noise, low power, 12-channel analog ECG front end ANUSPANDAN ASIC was designed for portable ECG instrument. This ASIC was tested successfully meeting its designed specifications.

Electronics Corporation of India Limited (ECIL) is engaged in the design, development, manufacture, supply, installation and commissioning of a wide variety of electronic equipment for the Atomic Energy, Defence, Aerospace, Security, Information Technology and e-Governance verticals. ECIL is a key player in the strategic electronics space in the country and has unique multi-disciplinary competences. ECIL has emerged as a major player in providing integrated security solutions to vital installations of the country.

ECIL played an important role in the recently concluded General Elections with the Electronic Voting Machine (EVM) Mark-V and the Voter Verifiable Paper Audit Trail (VVPAT) printers.

Other new products introduced during the report period were Laundry monitor, Plastic Scintillator based Portal Monitoring System, Combat Command and Control Centre and Mobile System for Missile Checkout for the army version of Akash missile program and 1.6m and 0.73m antenna systems and Submarine SATCOM Terminal.

Robotics

Spot picker robot, an indigenous three-axis robotic system was designed by BARC for precise spot excision to accurately pick spots from 2D gel electrophoresis (2DGE).

DORAbot (Detection Of Radiological Activity using a Robot) is a tracked mobile robot with cameras and radiation sensor packs to scout radioactive areas in and around nuclear installations in the event of a radiological emergency.



Autonomous Neuro-Navigation: a high precision parallel robot

A parallel robot for conducting high precision neurosurgical procedure was developed. Assistive tools for conducting neuro-registration and neuro-navigation were also developed. Several experiments on neuro-navigation were conducted on a phantom.

BARC also developed the Liquid Handling Robot for extracting DNA from different types of cells by magnetic bead separation method. A software interface allows the user to define reaction sequences using simple predefined steps.

Cryogenics

At BARC, the helium refrigeration unit achieved its targeted refrigeration load capacity. The high pressure turbo expander developed along with its aerostatic gas bearing system exhibited efficiency in excess of 72% during continuous test operation. Four nos. plate fin heat exchangers were developed for validation of in-house design codes for multi-stream plate fin heat exchangers.



Inter-stage blower

New cryogenic turboexpanders catering to 250W at 4.5K helium refrigerator were designed and fabrication drawings along with 3-D solid models were prepared. The relevant drawings and solid models were developed for fabrication.

An Inter-stage blower specified to operate with 1.3 bar (abs) suction pressure, 3 bar (abs) discharge pressure and capacity varying from 200 to 500 l/hr was designed and developed towards indigenous capability. Major piping for cryogenic systems was completed. Commissioning of a large air screw compressor was completed.

RADIOISOTOPES & RADIATION TECHNOLOGY AND THEIR APPLICATIONS

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

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

Agriculture

In the area of mutation breeding for crop improvement, a high yielding yellow mosaic virus (YMV) resistant black gram variety TU-40 was released for commercial cultivation in south zone. Under the Breeder Seed Programme for Trombay groundnut varieties, 286 quintals of breeder seed of

TAG-24, TG-37A, TG 38, TPG-41 and TG 51 was produced and distributed to the National Seeds Corporation and State Farms Corporation of India.

Black gram selection TU-18 was promoted from Initial varietal trial (IVT) to Advanced varietal trial (AVT-I) in All India Coordinated Research Project on Mungbean, Uradbean, Lentil, Lathyrus, Rajmash and Pea (MULLaRP). Five bruchid resistant selections of black gram (TU-26, TU-40, TU-68, TU-72, TU-80) were entered into the third year entomology trials of MULLaRP.



Newly released Black gram variety TU-40

Nineteen promising lines were selected at M3 using ion beam radiation on TG26 and TG68 groundnut seeds. Gibberellin insensitive dominant dwarf groundnut mutant TGM, sub-orbicular leaflet mutant TGM 38 and funnel leaflet mutant TGM were registered with National Bureau of Plant Genetic Resources (NBPGR), New Delhi.

A technology for a rapid, continuous and renewable method for production of the anti-cancer drug "Camptothecin" was developed. A rapid molecular method for detection of gliotoxin-producing strains of *Trichoderma virens* was developed. Several new terpene cyclase genes were identified in seven *Trichoderma* genomes using bioinformatics approach.

Twelve technology transfers of *Nisarguna* plants and two technology transfers of an inexpensive growth medium for mass production of the biofungicides *Trichoderma* spp. were processed. Sixteen *Nisarguna* plants were commissioned in 2013. More plants are under construction at Tihar Jail, New Delhi and Chennai Municipal Corporation and several MoUs are under discussion. Total number of *Nisarguna* plants now stands at 160.

Food Technology

Research work in the area of radiation processing of food and agricultural commodities continued with emphasis on development of new products and applications at BARC. This included the use of radiation for extending the shelf life of ready to bake chappatis, minimally processed vegetables, Ready-To-Cook (RTC) potatoes, drumstick, cauliflower and cabbage as well as Ready-To-Eat (RTE) Apple, Methi Thepalas, Chicken Pulao and Jawla Tikki.

New glass based dosimeters were developed for measurement of absorbed dose in the range of 250-1000 Gy and 1-10 kGy. Trial runs for establishing efficacy of a 200 kg capacity solar dryer designed for dehydration of different foods products were carried out.

The electron linac facility set-up at RRCAT was used for mutation breeding experiments. A large variety of seeds such as wheat, soya, lentils, beans, black gram, cowpea and chickpea seeds were irradiated using 7.5 MeV beam from the electron linac. A triode type electron gun with 50 kV, 1Amp peak capability was successfully designed, developed and deployed for the 10 MeV electron linac. This linac will be used for irradiation of food items in the agricultural radiation processing facility of RRCAT.



Irradiation of seeds by 7.5 MeV beam from electron linac

Nuclear Medicine and Healthcare

Nearly 200 Freeze-dried kits of TRODAT were supplied to various nuclear medicine centers in hospitals. Preparation and use of ^{99m}Tc -HYNIC-TOC, ^{99m}Tc -TRODAT & ^{99m}Tc -TETROFOSMIN in human

patients were demonstrated using the freeze-dried formulation prepared at BARC.

Preparation of patient doses of ^{177}Lu -DOTA-TATE using ^{177}Lu produced at BARC was demonstrated in 9 hospital radiopharmacy units for treatment of more than 1000 patients suffering from neuroendocrine cancer. More than 200 Ci of $^{177}\text{LuCl}_3$ was produced and deployed to 8 nuclear medicine centres across the country.

^{177}Lu -EDTMP is a new therapeutic radiopharmaceutical for palliative care of bone pain due to metastasis. Six batches of ready-to-use ^{177}Lu -EDTMP suitable for administration into human patients were prepared and supplied to nuclear medicine clinics as per their requirement.

In addition to regular production and supply of radiopharmaceuticals BRIT added many new products, services and developed new production processes facilitating increased production capacity and higher quality products. During the year, over 30,000 consignments of ready to use radiopharmaceuticals of ^{131}I , ^{177}Lu , ^{32}P and ^{153}Sm containing nearly 1000 Ci were supplied to various Nuclear Medicine Centers for therapeutic and diagnostic purposes.

A new facility for production and supply of ^{131}I – NaI high dosage therapeutic capsules for thyroid cancer was started after approval by AERB. The production capacity and frequency of supply of injectable ^{131}I MIBG, an important therapeutic and diagnostic product for treatment of neuroendocrine cancers has improved considerably. ^{131}I radiopharmaceuticals accounted for nearly 600 Ci radioactivity supplied in about 20,000 consignments.

Medical cyclotron facility at Parel supplied about 220 consignments of ^{18}F based PET radiopharmaceuticals to nuclear medicine centres with PET scanning facility in Mumbai which accounted for nearly 380 Ci of radioactivity.

BRIT had started a facility for production of ^{99}Mo - ^{99m}Tc Generator under the brand name 'COLTECH'. A new package for COLTECH generator was designed, developed and tested. Over 300 Ci of ^{99}Mo in the form of Sodium molybdate solution was

supplied for solvent extraction generator and for ^{99}Mo - $^{99\text{m}}\text{Tc}$ Gel Generators and additionally 375 Ci of ^{99}Mo as alumina column generator were also supplied.

BRIT started supplying four new TCK products viz. TRODAT kit for imaging of somatostatin receptors in tumor imaging, HYNICTOC kit for Dopamine receptors for studying neurological disorders, Tetrofosmin kit for myocardial perfusion imaging and HSA-nanocolloid kit for sentinel node detection. More than 15,000 consignments of cold kits for labelling and prepreparation of $^{99\text{m}}\text{Tc}$ radiopharmaceuticals were supplied to various Nuclear Medicine centers during the year.

RIA procedure for the measurement of insulin in rat serum was developed after modification of human Insulin RIA kit. A simple two-step RIA procedure for free T3 as per the guidelines of American Thyroid Association was developed. IRMA kit formulation for human C-peptide was completed. A trial batch of 25 kits were produced for the evaluation of its long term stability. Around 4500 consignments of radioimmunoassay (RIA) and immunoradiometric assay (IRMA) kits were produced.

Regional Centre BRIT, Delhi supplied 900 consignments of ready to use Tc-99m Radiopharmaceuticals injections. 2000 technetium cold kits were also supplied to nuclear medicine hospitals in Delhi and NCR Delhi.

Regional centre, Bengaluru supplied 300 consignments of ready to use $^{99\text{m}}\text{Tc}$ formulations. Around 600 TCK cold kits were sold through retail outlet for radiopharmaceuticals. 2500 Blood bags were irradiated using BI 2000. Radioanalytical laboratory was inaugurated by Director, KMIO Hospital at regional Centre, Bengaluru for residual radionuclide determination and certification in domestic and export commodities.

At regional Centre Kolkata civil work of DAE Medical Cyclotron is expected to be completed by March 2014. $^{99\text{m}}\text{Tc}$ produced by $^{100}\text{Mo}(p,2n)$ reaction was separated using Dowex-1 resin and HNO_3 and it was found to be suitable for preparation of Tc-radiopharmaceuticals. ^{68}Ge - ^{68}Ga generator was evaluated by the optimized method of purification and the average yield of purified ^{68}Ga was around 75

percent. A new SnO_2 based generator was prepared using the isolated ^{68}Ge .

The Regional Centre, Dibrugarh located at Assam Medical College & Hospital rendered the RIA and IRMA diagnostic services for the benefit of patients of the entire north-eastern region. More than 10,000 patients availed the services offered by this centre for analysis of hormones like T3, T4, TSH, LH, FSH, PRL, beta-HCG, Ferritin and Insulin.

The Regional Centre, BRIT Hyderabad supplied 1300 consignments. These comprised ^{32}P nucleotides, ^{32}P orthophosphoric acid, ^{35}S amino acids, LCK Kits, Taq Polymerase and PCR Product, radiopharmaceuticals cold kits (TCK products). A project to develop Real time PCR based M tuberculosis detection kit was initiated. It planned a centralized radio pharmacy laboratory for supply of $^{99\text{m}}\text{Tc}$ as sodium pertechnetate. The laboratory is ready and will be functional for supply of radiopharmaceuticals after regulatory and quality clearance.



Hot cell Facility for radiopharmaceutical production

For the societal benefits an automated $^{99\text{m}}\text{Tc}$ -TCM-AUTOSOLEX module was developed indigenously at VECC in collaboration with BRIT. The system was thoroughly tested and put to use at RRMC, Thakurpukur. Under the IAEA CRP work on direct production of $^{99\text{m}}\text{Tc}$ in cyclotron, separation of technetium radionuclide from the irradiated target by a new method was studied and the quality was ascertained suitable as compared to those produced by standard methods.

Alternative Applications of Heavy Water

Considering the immense potential of

application of Deuterium and heavy water in life sciences, pharmaceuticals and technology areas, HWB put in place an action plan to facilitate and nurture R&D activities in this area. HWB has entered into an MoU with BRIT for developmental activities on deuterium labelled compounds and allied value added products like NMR solvents.

Realizing the potential requirements of ^{18}O having application in nuclear medicine and biochemical research, HWB initiated technology development for enrichment of ^{18}O at HWP, Tuticorin. Doubly Labeled Water (DLW) having certain concentration of D_2^{18}O is used for measuring energy expenditure, total body water content, etc. ^{18}O finds use in Positron Emission Tomography (PET) for detection and staging of malignancies. An isotopic purity of 95% was already achieved in the prototype distillation column for ^{18}O water enrichment at HWP Tuticorin. This column can be used for recycling used ^{18}O water received from RMC and other PET centres.

As part of developmental activities on non-nuclear uses of Heavy Water, methods for synthesizing deuterated NMR solvents viz. Acetone- d_6 , Acetonitrile- d_3 , Chloroform- d , Dimethyl Sulfoxide- d_6 were developed at laboratory scale. Process optimization was also done to minimize the consumption of Heavy Water used for synthesizing these molecules. As part of MoU signed between HWB & BRIT, BRIT already started marketing these solvents to various reputed research institutes in the country. The synthesis route for deuterated NMR solvents like Di-chloro-methane- d_2 and Benzene- d_6 were also developed and process optimization is in progress.

Cancer Diagnostics & Treatment Services

The Tata Memorial Centre, comprising Tata Memorial Hospital (TMH), the Advanced Centre for Treatment, Research and Education in Cancer (ACTREC) and Centre for Cancer Epidemiology (CCE) continued its activities in diagnosis, treatment, research and education in cancer.

A state of the art Molecular Facility for Research and Service was commissioned at the Tata Memorial Centre (TMC) during the report period.

Upgradation and procurement of several new equipments was done which included CT-DSA Miyabi system; Mammography; Anaesthesia Delivery System; Minimal Invasive Surgery Instrument sets, Operating microscopes, Neurosurgical instruments with accessories, Endoscope Hopkins, Computer on wheels, Network computers, printers, Deep freezers, portable ECG Machine, Dental Ultra Sound Scaler, Night vision web camera, Floor cleaning machine and Linear accelerator. Upgradation of systems and softwares in Radiation Oncology, Accounts, administration, pathology, Clinical information system and TO modules was completed.

The TMC initiated the establishment of "National Hadron Beam Facility & Cancer Centre for Women & Children. The foundation stone for this facility was laid by Honorable Prime Minister of India Dr. Manmohan Singh on 10th January 2014.

Industrial Applications of Radiolabels & Radiation

Irradiator sources with total activity of around 2000 kCi were supplied by BRIT in eight consignments to various radiation processing plants in the country. A record single consignment of 882 kCi supplied to NIPRO, Satara.

About 1400 radiography consignments of Ir-192 and Cobalt-60 sources with total activity of approx. 80 kCi were supplied to various radiography camera customers in the country. Radiation Sources for Nucleonic Gauges and other uses were made with the two isotopes Co-60 and Cs-137. A total of 5 Ci of radioactivity was supplied for reference and custom made sources during the year 2013-14. One Gamma Chamber (GC 5000 unit) was loaded with 14 kCi of Co-60 radioactivity in 25 source pencils for the GC 5000 unit.

The Regional Centre RAPPCOFF, Kota continued excellent work in processing, production and transportation of Cobalt-60. A record 2 MCi of Cobalt-60 was processed during the period. Customized W-91 pencils for install and operate irradiator were prepared.

Radiation Processing

During the year, the ISOMED facility

engaged in contract gamma radiation processing services for terminal sterilization of the medical products processed 7400 m³ of product. The average plant utilization factor was around 95%. The certifications issued to ISOMED facility complying with the requirements of various International Standards facilitated the desired cutting edge to the facility in the radiation sterilization sector in the country.

Radiation Processing Plant, Vashl treated about 42 MT of spices and other products during the financial year 2013-2014 registering a growth of about 18 %. New products like lead impregnated rubber sheets and Corncob for animal bedding were added for commercial processing. BRIT excelled in meeting customer requirements.

M/s Kumaka Industries Ltd., Vadodara signed a MoU with BRIT for setting up a radiation processing facility. The facility will come up at Sanand II, Gujarat for treatment of spices, chilled meat, poultry products, sea food etc. Electron Beam commercial processing services were continued at ILU-6 facility at Vashl.

Radiation Technology based Equipment & Services

Eight Gamma Chamber-900 units, one PANBIT facility and one Gamma Shine 1000 units were decommissioned for the disposal of their decayed cobalt-60 source from different institutions.

Two Blood Irradiator 2000 units (BI 2000) and one Low dose Irradiator were supplied and installed at JIPMER, Pondicherry & ISM & SUM hospital, Bhubaneswar with nearly 2000 Ci of Cobalt-60 radioactivity.

A 3 MCI multipurpose Irradiator was set up at Colombo, Sri Lanka jointly with a private company and was commissioned. BRIT also carried out repatriation of 3 gamma chambers which were earlier exported to Sri Lanka from Colombo and Kandy on chargeable basis.

Ninety new radiography exposure devices were supplied by BRIT. BRIT continued its radiography services. A Medical Sterilizer cat II

batch Irradiator with a source strength of 100 kCi of Co-60 for sterilization of medical product for in-house application of hospitals was successfully designed and a scale down model was fabricated. A X-Ray based low dose Irradiator was designed for Biological studies in cancer, biotechnology, stem cell research, small animal work etc.

A 120 Ci Co-60 based Radiography Exposure Device for Industrial application was designed and it is under fabrication. The cold commissioning of install & operate Irradiator is completed and the cask was loaded with 45 kCi of Co-60 at HIRUP Hot Cell.

BARC manufactured 34 Bhabhatron machines. Twenty seven machines are in operation and remaining machines were under various stages of installation and commissioning.



Irradiator and control console parts of gamma calibration system

Computer controlled multi source gamma calibration system containing ¹³⁷Cs, ⁶⁰Co and ²⁴¹Am gamma sources was developed indigenously and used for the QA of country wide TLD personnel monitoring programme.

A silicon diode based pocket dosimeter for neutron Dosimetry was developed at BARC. Design, development and manufacture of the shadow shield whole body monitor to measure Radionuclide accumulation in the human body was completed.

Isotope Hydrology & Water Desalination

An Isotope hydrological investigation was carried out at 4 locations in Uttarakhand (Brahmikhail, Pipeya, Kakodakhail and Isala) and at 2 locations in Himachal Pradesh (Surla and Dhauli/Kandela) in collaboration with Himalayan Environmental Studies and Conservation Organisation (HESCO), Dehradun to rejuvenate the drying springs in the sub-Himalayan

region by artificial recharge methods. Tirumal Village, Madurai, in collaboration with DHAN (Development of Humane Action) Foundation, to demarcate the area of influence of recently renovated Urapparedy cascade of irrigation tanks (4 tanks) to quantify their contribution to the groundwater recharge.



Membrane based water purification plant near Imphal

A membrane based water purification plant for removal of iron contaminant from ground water was set up in remote location for community-use near Imphal (Manipur). To alleviate the problem of turbidity present in the water used in autoclaves in hospitals, BARC designed and developed a membrane based system of capacity 300 liters/day for hospital use.

A solar water purification system was developed by BARC. After carrying out endurance test and performance evaluation, the know-how of high quality solar water purification system was transferred to entrepreneurs to make clean purified water accessible in remote locations.

A jumbo membrane based water purification unit developed by BARC was installed in one of the schools in Navi Mumbai for school children. Thin Film Composite Polyamide (TFC-PA) membranes for water desalination under Indian conditions were developed using BARC R&D efforts.

BARC is setting up a sea water desalination plant of 5 million liters per day based on hybrid Reverse Osmosis- Multi Effect Distillation technology for producing potable water for drinking and other uses as well as distilled water for high end industrial application.

BASIC & APPLIED RESEARCH

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

Mathematics & Computational Sciences

BARC developed a new supercomputer, "ANUPAM-Aggra" using parallel processing technology. This supercomputer is the largest and fastest in the ANUPAM series of supercomputers. The system consists of 8160 processor cores, 40960 Graphics Processing cores and 32 Terabytes of memory. Peak performance of the system is 150 Teraflops and sustained performance measured using the High Performance LINPAC benchmark is 109 Teraflops.



ANUPAM-Aggra Supercomputer

The computing facility of VECC was augmented by addition of blade system with 32 nodes in 2 chassis, 36 GB memory per node, Infiniband interconnect and 300 GB disk per node.

The School of Mathematics of TIFR proved some new results about pure extensions of commutative rings. The Centre for Applicable Mathematics continued its research activity focusing on PDE, analysis and applications. Various properties of solutions of elliptic equations in Euclidean spaces and hyperbolic spaces were explored. A novel numerical scheme for the Euler

equations of compressible flows that conserves entropy and has kinetic energy consistent fluxes was developed. New results on rates and communication requirements of secure communication/computation were obtained at the School of Technology and Computer Science. An online algorithm with 2-approximation for maximizing the throughput in communication system with arbitrary energy arrivals was found.

At SINP, the spectrum of the SU (n) spin Sutherland model associated with the BN root system was computed including the exact degeneracy of all energy levels. The combined effect of a conical topological defect and a Coulomb charge impurity on the dynamics of Dirac fermions in gapped graphene was studied.

The Mathematics group of HRI contributed significantly in research and through vibrant outreach programmes. In Analysis and Geometry, extensive work was done on the analyticity of the Schrodinger operator on the Heisenberg group. Work was done on holomorphic Quillen determinant line bundles of integral compact Kahler manifolds. Specific non-special finite p-groups having Abelian automorphism groups were constructed in Group theory and Lie Algebra. Irreducible modules for the derivatives of the rational quantum torus were studied. Extensive work was done on the evaluation of certain classes of convolution sums in Number Theory. Work was done on Liouville numbers and Schanuel's conjecture and also on the distribution of residues and prime roots. Monochromatic configurations for finite colourings of the plane were studied. Erdos- Ginzburg- Ziv theorem for finite commutative semi groups was investigated.

The Institute of Mathematical Sciences (IMSc) remained involved in the various projects with national and international institutes on Mathematical Sciences without Walls; Developing tools for dynamical modelling of C elegans neuronal network activity; Interplay of non-linearity with quantum effects and curved geometry - some applications; Computational Study of Functionalized Nanoparticles; INO Project; Algebraic Problems; Provably Efficient Re-processing Algorithms; National Initiative in Mathematics and Potential Theory on Infinite Networks and Trees.

The School of Mathematical Sciences at the National Institute of Science Education and Research (NISER) continued its teaching and research activities. In addition to formal courses and research, seminars were conducted regularly. A state-of-the-art Computing facility and a High Performance Computing Cluster for theoretical calculation was provided.

Physics

BARC developed a Surface-Enhanced Infrared Absorption (SEIRA) spectroscopic technique for the study of organic and biologically important molecules.

The TACTIC telescope at Mt. Abu was deployed for TeV (10^{12} eV) gamma-ray observations of extragalactic objects. About 450 h of observation data was collected from Mrk421, Mrk501, 1ES1218+304 and 3C279.

For the MACE telescope being proof-assembled at ECIL Hyderabad, prior to its final erection at Hanle, Ladakh, the Telescope Control Servo system consisting of Telescope Control Unit and Telescope Drive Unit were installed at the proof-assembly at ECIL and initial drive tests for AZ axis was carried-out.

At VECC, the Large Area Modular BaF₂ Detector Array (LAMBDA) was used for neutron measurement. Nuclear level density parameters obtained by the LAMBDA spectrometer were found to be consistent with those obtained by the BC501A neutron detector, indicating that the spectrometer can be efficiently used as a neutron detector to measure the NLD parameter. A complete kinematical measurement of inelastic scattering of beam of 60 MeV from Variable Energy Cyclotron (VEC) machine on ¹²C target was performed to study the various decay channels of Hoyle state with relatively higher in statistics compared to the previous measurements.

Several studies were carried out both theoretically and experimentally to understand the functional dependence of nuclear level density on the key parameters, such as excitation energy, angular momentum and isospin. In Theoretical Physics, the effects of the nuclear equation of state (EoS) & symmetry energy on the proton fraction in neutron

stars and the location of the inner edge of their crusts and their core-crust transition density and pressure, thermodynamically were investigated.

At TIFR, a new unambiguous and easy procedure to analyze event planes correlators data measured by the ATLAS collaboration at LHC was presented. In Astronomy and Astrophysics, the testing and calibration of CZTI and CPM packages for ASTROSAT were completed. The assembling and testing of CZTI flight models of payload are going on. The flight models of LAXPC payload of ASTROSAT is getting ready to be delivered to ISRO. The Soft X-ray Imaging Telescope (SXT) for ASTROSAT was delivered to ISRO. Several new and exotic pulsars were discovered by searching for pulsations associated with sources identified by the LAT Instrument aboard the Fermi satellite at the National Centre for Radio Astrophysics. A highly unusual spiral host galaxy that has undergone multiple episodes of radio activity was discovered.

In Condensed Matter Physics, rarely known multiglass phenomenon in $\text{Ca}_2\text{Co}_2\text{O}_7$ was investigated and evidence for a novel phase co-existence phenomenon due to magneto-electric coupling was found. A variety of single crystals of strongly correlated electron systems were grown and their anisotropic physical properties were studied. Several patterns on the surface of GaAs were made and THz antenna was fabricated. In High Energy Physics, VHE gamma ray observations with HAGAR telescopes continued and the results were finalized. Three-level laser cooling of Potassium (39K) down to 12 micro-Kelvin was achieved for the first time. The Nuclear and Atomic Physics study demonstrated, for the first time, the bond-selective fragmentation of a molecule using ultrashort, carrier-envelope-phase stabilized laser pulses.

At SINP, the state of art of major capital equipments like cryogen free room temperature bore 9T for grain oriented, magnetocaloric effect studies, custom built UHV versatile thin film deposition set-up to fabricate high performance magnetic/nonmagnetic hybrid nano-structure, SQUID VSM for magnetic properties, thermal expansion, thermal transport experimental systems were installed. The two experiments, ALICE and CMS collected data with a very high efficiency and

SINP took active parts in the data collection, data analysis and extracting important physics results from these experiments. SINP was involved in the development of the front-end electronics chip, fabrication of the second tracking station of the Muon Spectrometer and development of the di-muon high level trigger for ALICE. The institute made a strong presence in the Compact Muon Solenoid (CMS) experiment participating in the upgrade project of the hadron calorimeter and has successfully made part of the back end electronics of the future calorimeter system.

One of the most important works pertaining to LHC physics which discusses higher order corrections in the total cross section for Higgs Boson production in hadron collisions came from HRI. Application of formal string theory to practical issues in cosmology and hydrodynamics constitute vital contribution of HRI. Discovery of magnetic superatoms is one of the more striking pieces of condensed matter research in the recent past which involved HRI theorists. Scientists of HRI have been playing a pioneering role in understanding the flow of classical and quantum information in quantum many body systems. Work on quantum information aspects of non-equilibrium many body systems and resonating valence bond systems was an important contribution.

During the year 2013-2014, the Institute of Physics (IOP) undertook active research in various areas of theoretical and experimental physics. The high energy physics group remained actively involved in pursuing research in String theory, Cosmology and Particle physics. Research areas in Condensed Matter Physics (CMP) theory included mesoscopic systems, statistical mechanics for non-equilibrium systems and biophysics. In nuclear Physics, research was focused on nuclear structure and nuclear reaction. The mechanism for the formation of superheavy elements in astrophysical objects, nucleus-nucleus reaction, study of cluster decay properties were pursued. Major activities in experimental physics included studies on accelerator based materials science, surface and interface physics, and nano systems. Investigations in these areas were carried out by using the state-of-the-art facilities developed at the Institute.

The School of Physical Sciences of NISER continued to provide the five year Integrated Master of Science programme and research programmes leading to doctorate in physics. The broad areas of research work in physics included subjects such as String theory, Lattice Quantum Chromodynamics, Experiments at Large Hadron Collider (LHC), Switzerland, Electronic structure of matter, Colloids, Soft-condensed matter and statistical mechanics, density functional theory, magnetism, superconductivity, low-temperature physics, semiconductors and nano-fabrication, spectroscopy, Ultra-cold atoms and Bose-Einstein condensation (experimental), Photonics-Nonlinear optics, Laser Physics and Nano-photonics.

Synchrotrons and their Applications

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

During the year, both the synchrotron radiation sources, Indus-1 at 450 MeV energy, 100 mA current and Indus-2 at 2.5 GeV energy and up to 150 mA current operated in the round-the-clock mode. Indus-2 synchrotron radiation source is the largest size and also the highest energy accelerator built in the country.



A section of Indus-2 tunnel of 172.5 m circumference



Indus accelerator control room

Various subsystems of Indus-2 were upgraded. The output power of the solid state RF amplifiers was increased to 225 kW. The Indus-2 current was increased to more than 180 mA at 2.5 GeV energy. A local fast orbit feedback system was developed to take care of high frequency beam perturbations.

During the report period, four more beamlines such as Scanning EXAFS beamline, X-ray Diagnostic beamline, Soft X-ray Absorption beamline and X-ray Imaging beamline were commissioned on Indus-2. Total twelve beamlines on Indus-2 are now operational.

The existing X-ray micro-focus beamline was upgraded with the total external reflection x-ray fluorescence facility. X-ray lithography beamline was used for fabrication of compound x-ray refractive lenses. Micro-fluidic channels were made in SU-8 photo-resist for an ultra-sensitive glucose sensor using the x-ray lithography beamline.

A new laboratory was set up to investigate protein crystals starting from gene cloning to elucidating protein structure using the protein crystallography beamline. Structure of several proteins were solved.

Fusion and Other Plasma Technologies

In the Steady-state Superconducting Tokamak-1 (SST-1) the first plasma was successfully obtained after an elaborate and extensive engineering validations. With this achievement, India joined the elite club of countries (after Russia, France, Japan, Korea and China) having superconducting Tokamaks capable of conducting steady state experiments. Integration of other subsystems and advanced diagnostics systems is on full swing along with installations planning for first wall components.

A new technique for avoiding disruptions was demonstrated in ADITYA tokamak through stabilization of Magneto-Hydrodynamic (MHD) modes. Contributions were made to the disruption data base of the international tokamak physics activity (ITPA) group.

The auxiliary heating systems consisting of Electron Cyclotron Resonance Heating (ECRH), Ion Cyclotron Resonance Heating (ICRH) and Lower Hybrid Current Drive (LHCD) are getting ready for operations and efforts are on to use them in SST-1.

The development of fusion technologies relevant to the fusion reactor is advancing very well. For magnet technology, long length Niobium-Titanium (Nb₃Ti) based cable-in-conduit-conductors (CICC) superconductors were indigenously developed. A High Heat Flux Test Facility with 200 kW power in steady-state operation mode, for testing and characterizing materials for divertor modules was made operational. For the Cryo-pump development, designs were made for cryo-panels, radiation shields, baffles etc. Different experimental systems for characterizing adsorbents for the cryo-pump were setup and some developed sorbents are being tested.

An innovative space saving online fabrication facility was set up for the fabrication of long length Cable-In-Conduit-Conductor (CICC) in the existing facility.

The notable achievements of Facilitation Center for Industrial Plasma Technology (FCIPT) included installation of plasma pyrolysis system for hospital waste disposal in Srinagar Medical College, Srinagar; Plasma Nitriding system at Central Tool Room, Ludhiana and Plasma Activation system at M/S Triton Valves, Mysore. Work on development of low temperature atmospheric pressure plasma which can be used for infected human skin treatment and for modification of properties of seeds were in advanced stages.

At the Center for Plasma Physics, Guwahati the experiments like double-plasma experiment, dusty plasma experiment and the pulsed power experiment are all progressing well the thermal plasma laboratory is developing a segmented plasma torch assisted Divertor Simulator system.

Chemistry

Research work in the field of Chemistry in BARC led to identification of a mono-triazinyl-phenanthroline and a sulphur-containing CYANEX 301 analog as two potential solvents for the

separation of trivalent actinides and lanthanides from the high level nuclear wastes.

An efficient and inexpensive iron oxide based catalyst (Fe_{1-x}Cr_xO₃) was developed for the sulphuric acid decomposition step of sulphur-iodine cycle (S-I cycle).

Good progress was achieved in the development of hydrogen storage materials based on carbon nanotubes, ionic liquids and metal organic frameworks.

A novel consortium consisting of sulphate reducing bacteria and green sulphur bacteria was developed for bioremediation of industrial effluents containing sulphate. A novel phototropic granular biomass was developed for denitrification of industrial effluents without having to supplement organic carbon.

Two rare flavonoids (C₂₁H₂₄O₁₇ and C₂₄H₂₈O₂) of nutraceutical value were isolated from the weed, *Coronopodium*, by developing a rapid, novel and economical process.

The significance of low-frequency ring deformation modes in driving ultrafast ET reaction with anthraquinone acceptors was unraveled at TIFR. Sensors for biologically relevant small molecules and metal ions were developed. Site specific hydroxylation of mono-unsaturated fatty acids by mutation of thermostable cytochrome P450 enzyme which may have potential implication in fatty acid metabolism in biology was achieved.

The School of Chemical Sciences at NISER imparted high quality undergraduate and postgraduate level of knowledge to students coupled with cutting edge research activity. In addition to traditional organic, inorganic, physical and theoretical chemistry areas, the school embarked on teaching and research activity in the interface areas of Biology, Material Sciences and Medicine. GC Mass and ESI Mass Spectrometers, State-of-the-art NMR Spectrometer for 1D and 2D Experiments and Time-Resolved Fluorescence Spectrometers were the facilities that were provided by the school.

Biology

Applied research for environmental

monitoring and clean-up using recombinant DNA technology was actively pursued at BARC. A biosensor for detection of ppt levels of the pesticide lindane was designed, constructed and its specificity, efficacy and stability were demonstrated.

An experimental setup was made available for studying biological effects in cells at 3 MeV proton beam using Folded Tandem Ion Accelerator at BARC. The setup facilitated precision irradiation of cultured mammalian cells to known doses for quantifying the damage due to proton charged particles on model biological systems. Various biological endpoints such as micronucleus induction, survival, chromosomal aberration and apoptosis were studied.

TIFR developed an *in vitro* assay to study the biogenesis of lipid droplets in liver which allows to understand how metabolic stimuli regulate the formation, storage and use of lipids in liver. A new model system using phagosomes isolated from *dictyostellum* was developed. A novel role for oxidative stress signaling in cytoskeletal remodeling in a morphogenetic movement that resembles wound healing was uncovered.

A key role of an enhanced 5-HT₂ receptor signalling in mediating the paradoxical anxiogenic and depressive behavioral effects caused by early life treatment with the antidepressant Prozac was identified. A role for key epigenetic machinery in programming long lasting behavioral effects of early Prozac treatment was demonstrated.

The National Centre for Biological Sciences, Bangalore discovered new nucleic acid motifs based on both DNA and RNA and their potential use in creation of nano devices as sensors for bio-imaging and cell specific delivery.

Studies on insect flight as a system to understand how sensory modalities evolve novel solutions to solve the problems of fast sensory acquisition and how the motor system optimizes speed and accuracy of response in different situations were established.

At SINP, in the areas of chemical and structural biology, studies on the recognition of multiple stranded DNA (Quadruplex) and putative

anticancer agents from plant source have shown that one such agent, ellipticine binds to DNA with a 3:2 stoichiometry in terms of ellipticine: DNA. A two color single molecule FRET imaging set up for real time monitoring of complex macromolecular systems was developed. Modes of interactions of a cyanine dye with proteins were investigated using spectroscopy, crystallography and theoretical docking study.

Research in the area of Disease Biology focusing on two major disorders the hematological and neurological are ongoing. The widely prevalent disease of Eastern India, HbE-thalassemia, along with sickle cell anemia and leukemia were studied as model for hematological disorders while Alzheimer's, Huntington's and the Prion diseases were studied for the neurodegenerative diseases.

The School of Biological Sciences at NISER continued its research and teaching with harmonious synthesis of classical and modern biology. The various facilities for research and teaching provided included Confocal Microscope Facility, DNA sequencing and Surface Plasmon Resonance Facility and Micro-array facilities for Genomics.

Materials Science

Studies on nickel aluminate diffusion barrier coating formed on superalloy 690 in a low Al-containing pack continued and advanced microstructural characterisation was carried out at BARC.

Zr and Hf-based bulk metallic glasses were synthesized using rapid solidification techniques and characterized using advanced techniques.

In a collaborative India-UK project with Open University, UK, the Ga-assisted diffusion bonding method was developed to join stainless steel to titanium to form joints without any defects such as cracks, discontinuities and pores between the two materials. The interfaces of the joints were characterized at different length scales using various microscopic and microanalysis techniques to establish the mechanism of bonding.

Large size Nd: glass laser rods were indigenously developed at RRCAT under a collaborative activity between CGCRI and RRCAT

and tested for their lasing performance. The electrical and magnetic properties of the superconducting Ti-V alloys were studied as materials alternative to niobium in a high neutron-irradiation environment. Coaxial / stripline circulator was developed using calcium vanadium garnet disk resonators and tested at 1 kW.

At IGCAR, UHV based magnetic transport system consisting of various mechanical/electrical RF components was designed completely in-house and fabricated in India. The commissioning of low energy positron beam is accomplished by recording the 511 keV annihilation gamma ray i.e., slow positron signals, at the target. RF pulsing electronics and necessary components are incorporated in the beam line and fine tuning of electronics for optimizing the pulse width of bunched positrons is in progress.



Low energy pulsed positron beam lifetime spectrometer developed at IGCAR

Successful research activities in Condensed Matter Physics and Materials at VECC included the development and physical studies of nanostructured multifunctional materials like multiferroic and conducting polymer based super capacitors with application in energy cells; Irradiation Induced growth of nanostructures like nanoripples; Perovskite & Double perovskite materials used as ferroelectric relaxors; Radiation damage studies of mechanical & crystal structure properties of alloys employed as nuclear structural materials in power reactors and Studies of Dislocation dynamics in materials.

Studies in material science at TIFR observed multiferroicity in any element for the first time. Ferromagnetism and ferroelectricity were found to coexist in elemental, single crystalline Se microtubes below 40K. Plasmonic quasicrystals for broadband, polarization and launch angle independent excitation of plasmons were designed and demonstrated. GaAs was grown on graphene. Growth of semi-polar

oriented AlInN was demonstrated. A simple and robust method to produce large 2-dimensional and quasi-3-dimensional arrays of tunable liquid microlenses using a time varying external electric field as the only control parameter was demonstrated. Self assembling single amino acid fibers were formed and evaluated. Aligned nanofibers of TiO_2 were formed directly on FTO for dye-sensitized solar cell applications.

Cancer Research

The Advanced Centre for Treatment, Research and Education in Cancer (ACTREC) at Kharghar continued to take rapid strides forward particularly in its patient care and research programs.

The Clinical Research Centre (CRC) at ACTREC initiated many new procedures like the use of state-of-the-art Intraoperative Image-guided surgery techniques, specifically navigable 3D ultrasound based surgery and fluorescence guided-resections of malignant gliomas by the neurosurgery service.

Established programs of CRI and several Principal Investigator-led laboratories continued to focus on cancers that are a major cause for concern in the Indian context at the chromosomal, DNA, RNA and protein level.

INTERNATIONAL RESEARCH COLLABORATIONS

India is a scientific member country of Institut Laue-Langevin (ILL), France through an MoU with BARC. BARC made contributions to ILL by providing overall mechanical engineering support in fabrication, assembly, testing and supply of aluminum and steel housings for neutron guides and Lead shields.

BARC provided an overall mechanical engineering support to the work of Resistive Plate Chamber (RPC) Upescope (RE4), CERN, Geneva, Switzerland.

As part of collaborative work between BARC and CALCE University of Maryland, USA, R&D work on development of Prognostics and Health



The first 650 MHz SRF cavity

Management (PHM) of electronics component was continued.

IGCAR participated in the Coordinated Research Program on Control Rod Withdrawal and another on Sodium Natural Circulation Tests performed during the PHENIX End-of-Life Experiments along with ANL from the USA, CEA and IRSN from France, IPPE from the Russian Federation, JAEA from Japan, KIT from Germany and PSI from Switzerland. Prediction from IGCAR was very close to the measured values and close to other participants.

RRCAT set up the infrastructure for SRF cavity fabrication, processing and testing. A number of single-cell prototype cavities at 1.3 GHz had been earlier developed and tested under the framework of Indian Institutions Fermilab Collaboration (IIFC). The first 650 MHz single-cell niobium cavity was fabricated by RRCAT and IUAC and tested at Fermilab. A 500 W solid state amplifier at 650 MHz was designed and developed under the Indian Institutions- Fermilab Collaboration (IIFC).

TIFR continued to actively participate in the data harvesting phase for the Belle Experiment. TIFR shall be building the silicon micro-vertex detector (SVD) of the upcoming Belle II experiment. In particular the 4th layer (L4). For the CMS experiment, half of HC detectors were fitted with Silicon photo multipliers, while from the rest half the older photo detectors were removed.

At the International Centre for Theoretical Sciences a pipeline for searching for gravitational waves for spinning black hole binaries was demonstrated. The structure of the posterior distribution for Burgers equation was investigated and it was related to the problem of observability. In the area of heat conduction in low-dimensional systems, large-scale simulations were performed to clarify the question of universality and to verify recent predictions on the hydrodynamic description of anomalous heat transport. A novel resolution to recent formulations of the information paradox, by constructing operators that describe the interior of the black-hole in the AdS/CFT correspondence was found. The Chern-Simons theories coupled to matter that describe novel excitations called anyons which interpolate between bosons and fermions was investigated.

HRI scientists took a leading role in the collaboration between Indian institutions and the Fermilab, USA. HRI participated in the Long Baseline Neutrino Experiments (LBNE) where scientific contributions of HRI faculty were pivotal.

At IPR, the fabrication of Resonant Magnetic Perturbation (RMP) coils for Joint European Torus (JET) has been started by interacting closely with experts from Culham Center for Fusion Energy (CCFE), United Kingdom. In the other collaborative work, the JET neutron yield calibration was done by direct measurements using a calibrated ^{252}Cf neutron source deployed inside the JET vacuum vessel. An agreement was signed to cooperate on tokamak WEST project (Tore Supra Upgrade) at CEA, France.

Joint projects of IMSc with other international institutes included Indo-Austrian Joint Research Project on Parameterized Complexity of Local Search; CEFIPRA: Arithmetic circuits computing polynomials with University of Paris; Indo-German research grant of the Humboldt Foundation for research on the graph isomorphism problem; British Royal Society project on above guarantee kernelization with University of London; LIA-Informal Project on Concurrency and Automata theory with University of Bordeaux and ENS-Cachan; INRIA-Indo-French-Singapore project on Logic, Games and Control theory; India-EU programme on mathematics for health and disease; ITRA - Media

Lab Asia project on decongesting India's transportation networks using mobile devices.

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.

During the year, for the ITER project 14 Procurement Arrangements (PA) were signed. Three major contracts for the manufacturing of ITER components were also signed. Indian contractor assigned to build the largest vacuum chamber made substantial progress in full scale mock-up production/ process qualification at factory and erecting the workshop at French site. Identification of vendors for other procurements is in progress. In the meantime project management, quality assurance and control, safety etc. are being implemented to the required international levels.

India is developing Lead-Lithium cooled Ceramic Breeder (LLCB) Test Blanket Module (TBM) for testing in the ITER. Under Large Cryogenic systems development, conceptual design of various sub-systems and components was completed and testing of prototypes in smaller scales were started. Various physics based small basic experiments are being conducted under the fundamental plasma sciences. BARC completed full scale 3-D MHD numerical simulation of the Indian TBM.

Design and detailed engineering of scale down system of critical equipments outside the domain of open literature of laboratory scale experiment for Tritium Extraction System (TES) of Test Blanket Module (TBM) for ITER were completed at BARC. Laboratory scale material/component testing of De-Oxo bed was completed.

OTHER ACTIVITIES

Research Education Linkages

DAE supports synergetic interaction amongst the national laboratories and the university systems mainly through grants-in-aid to institutes of national eminence, funding of extra-mural research,

DAE-UGC Consortium for Scientific Research and others. During the report period, the major activities relating to Research Education Linkages included the following.

A number of research scholars from various academic institutions in the country utilized Dhruva, the only facility for radioisotope production and national facility for neutron beam research under the aegis of the UGC-DAE Consortium for Scientific Research

The Indus-1 and Indus-2 beamlines were used by a large number of researchers from several universities, IITs, IISERs, national institutes like PRL, IISc, BARC, TIFR, IGCAR, UGC-DAE-CSR and RRCAT.

HUMAN RESOURCE DEVELOPMENT AND KNOWLEDGE MANAGEMENT

Homi Bhabha National Institute

HBNI continued to strengthen its linkages with premier research and academic institutes in the country and abroad. It has MoU with various Institutes such as Institute of Chemical Technology, Mumbai; Indian Institute of Science, Bangalore; Indian Institute of Technology, Bombay; Indian Institute of Technology, Madras; Indian Statistical Institute, Calcutta; Jadavpur University, Kolkata; Indian Institute of Technology, Kanpur; Tata Institute of Fundamental Research, Mumbai; The University of Virginia; The Commissariat à l'énergie atomique et aux énergies alternatives, France; University of North Texas, USA.

During the report period, HBNI awarded 321 Ph.D, 588 M.Tech, 8 M.Phil, 111 M.Sc. 23 M.Sc. (Engg), 157 diplomas in radiation protection, 42 diplomas in medical radioisotope technology, 36 diplomas in radiation medicine and 106 post graduate medical degrees.

Training

The academic programmes of the 56th batch of BARC OCES were continued and screening test for 57th was organized. To popularize the atomic energy and to encourage eligible students in the

north-east, BARC teams visited the engineering colleges in Assam.

During the period of report, three advanced courses under 6th set of QUEST which commenced in August, 2012 were continued and completed. Infrastructural facilities such as Library, Computer labs, Nuclear Physics (RDM) and process control labs etc. were updated and well maintained for the benefit of the TSO's.

At IGCAR, the seventh batch of 52 trainee scientific officers completed their training in six disciplines and were placed in various units of DAE. In the present academic year, 54 Trainee Scientific Officers are undergoing training at the Training School. Nineteen Research Scholars were inducted to pursue their doctoral programmes in the frontier areas of engineering and basic sciences and employees who are pursuing higher studies under the aegis of Homi Bhabha National Institute (HBNI) were also undergoing coursework at the Training School.

RRCAT extended the available research facilities for training of university students in the areas of accelerators, lasers and their applications. Total 130 such students pursued their project work at RRCAT during 2013.

At AMD, activities related to Human Resource Development were continued with in-house and external institute training programme for staff and officers. BARC Training School AMD Campus, Hyderabad continued its activity in the fourth year with Geology and Geophysics Trainee Scientific Officers (TSO).

The Administrative Training Institute (ATI) of DAE continued to arrange a wide range of training programmes for the professional development of officials of the Department of Atomic Energy. More than 480 programmes covering over 13,500 employees were organized by ATI till now.

During the year, The National Centre for Radio Astrophysics, TIFR organized two major student training programs Pulsar Observing for Students (POS-2013) and Radio Astronomy Winter School for College students (RAWSC-2013)

In NPCIL, the Human Resource Initiatives are directed towards fulfilling the NPCIL's mission and vision by providing guidance, support and advice on the effective implementation of the strategy, policies, procedures and tools for recruitment and retention of talent. About 200 trainee engineers were taken for NPCIL Batch-20 during the year as a part of annual program for Induction of young talent into the Organization. Training and Development initiatives covered competency development for fresh as well as experienced manpower across hierarchy. Further, well developed internal training programs, customized management development programs with the involvement of professional training institutes and experts were also organized for higher levels. About 3400 man-days of training were imparted during the year.



Interregional training course at Jamshedpur

UCIL in association with International Atomic Energy Agency (IAEA) organized an Interregional training course at Jamshedpur (Jharkhand) on "Uranium exploration strategy, mining and processing techniques" during April, 2013. Thirty nine participants from twenty three IAEA member countries participated in this event. Experts from IAEA, Canada and India (UCIL, AMD, DAE, BARC, NFC, Forest Research Institute, Jadavpur University) imparted training on various aspects of uranium industry.

The Institute of Physics (IOP) contributed in a significant way towards quality human resource development in the form of a one year pre-doctoral course followed by the Ph.D. program. Ten post-doctoral fellows joined the Institute in the year 2013-14. Further this year, eight doctoral scholars received their Ph.D. degrees, while eleven scholars joined the pre-doctoral programme. The Institute actively promoted interactions with colleges, universities, academic institutions, and other national laboratories

by means of visitor programmes, workshops, symposia, and other academic events.

IMSc provided an intensive teaching programme with a high level quality. Students were selected at the graduate and postgraduate level each year through an all India joint entrance screening test followed by an interview. They underwent two years of rigorous course-work, and after successful completion they joined the doctoral thesis work under the supervision of a faculty member. The qualified thesis work was submitted to the Homi Bhabha National Institute which is a deemed University of which IMSc is a part for award of PhD degrees.

To nurture world class scientists for the country who will take up challenging research and teaching assignments in universities, R & D laboratories and various industries, the exemplary teaching and research attributes of the faculty of National Institute of Science Education and Research (NISER) inspired the motivated bright young students to dedicate their lives for scientific research. With over 300 students, NISER operated five batches of students admitted to the flagship MSc programme through NEST in Biology, Chemistry, Physics and Mathematics and Doctoral Programme in all Basic Sciences.

SPONSORED RESEARCH

Promotion of Extra-mural Research In Nuclear Sciences

The Board of Research in Nuclear Sciences (BRNS) is an advisory body of the Department of Atomic Energy (DAE) which 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.

During the year 2013-14, 264 new research projects were sanctioned by BRNS till December 2013. In addition, six new MOU's were formulated for collaborative research work with various academic institutes and creation of facilities at academic institutes.

Two new and nine ongoing prospective research fellowships (PRF) amounting to ₹.7 Crores

were granted this year. Under DAE Graduate Fellowship Scheme (DGFS), 25 M.Tech. In seven different IIT's & NIIT's and 5 Ph.D. students were offered/awarded fellowships.

Financial support to the tune of 2.5 Cr. was extended for funding 230 seminars, which were conducted by professional organizations on various topics of relevance to DAE. Out of this 14 symposia were solely organized by the DAE fraternity and they were fully funded by BRNS. Thirty-eight fellowships were offered/awarded under the Raja Ramanna Fellowship Scheme (Senior Scientists Scheme) & Homi Bhabha Chair.

Promotion of Mathematics

The National Board for Higher Mathematics (NBHM) established under the aegis of DAE promotes excellence in higher mathematics education and research in the country.

NBHM with the help of the Homi Bhabha Centre for Science Education (HBCSE) conducted the Mathematics Olympiad activity. The six-member Indian team secured 2 Silver medals and 3 Bronze medals at the 54th International Mathematical Olympiad held at Santa Marta, Colombia.

NBHM conducted Madhava Mathematical Competition for the undergraduate students. NBHM provided grants to various mathematical centers engaged in activities of promoting higher mathematics. The Chennai Mathematical Institute that runs a high quality undergraduate programme in mathematics is a regular recipient of grants from NBHM. The Kerala School of Mathematics, Calicut; The Institute of Mathematics and Applications, Bhubaneswar and the Bhaskaracharya Pratishthana, Pune are the other institutes getting grants from NBHM based on various programme proposals.

The board provided scholarships and fellowships to the students, selected through nationwide competitive tests to pursue studies at masters and Ph.D. levels. The Board also provided grants for promotion of activities in pure and applied mathematics, under several schemes, including support to research projects, travel grants for participation in workshops, conferences and

undertaking collaborative research, funds for organizing conferences etc.

NBHM provided grants to mathematics libraries around the country to purchase the latest books and journals in mathematics. Around 96 of 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.

Financial support was provided to 92 national and international conferences held in India and 14 Instructional Schools for advanced training in mathematics and 44 research projects. Travel grants were provided to 101 mathematicians to enable them to participate in conferences held in India and abroad. Four 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 60 researchers for the period of 3 years.

GRANTS-IN-AID

Grants to Aided Institutions

The aided institutions of the Department of Atomic Energy are an integral part of the Department in as much as there is a growing synergy between these institutions and the Research and Development Units of the Department. Several joint projects were undertaken between the Units and Aided Institutions and there is frequent interaction between the academicians of the aided institutions and the Scientists of the R&D Units.

The Department has nine aided institutions fully funded in terms of their recurring and non-recurring expenditure. The funds (Plan & Non-Plan) allocated to these Aided Institutions by the Department of Atomic Energy during the financial year 2013-14 were Tata Institute of Fundamental Research (TIFR), Mumbai (₹ 655.75 crores); Tata Memorial Centre (TMC), Mumbai (₹ 746.04 crores); Saha Institute of Nuclear Physics (SINP), Kolkata (₹153.37 crores); Institute of Physics (IOP), Bhubaneswar (₹33.11 crores); Institute of Mathematical Sciences (IMS), Chennai (₹49.59 crores); Harish-Chandra Research Institute (HCRI),

Allahabad (₹44.96 crores); Institute for Plasma Research (IPR), Gandhinagar (₹671.80 crores); Atomic Energy Education Society (AEES), Mumbai (₹53.40 crores); National Institute of Science Education and Research (NISER), Bhubaneswar (₹220.00 crores)

Grants to Cancer Hospitals

The Department of Atomic Energy (DAE) is releasing grant to Dr. B. Barooah Cancer Institute (BBCI), Guwahati through Tripartite Agreement (signed among DAE, the North-Eastern Council (NEC) and the Government of Assam). This hospital is a Regional Cancer Centre (RCC) for cancer treatment and control in the North-Eastern Region (NER). The Department's total share as per the 4th tripartite agreement upto the year 2013-14 is approximately ₹ 3941.60 lakh for revitalization of the BBCI which includes the cost of construction for expansion of the hospital as well as the procurement of major radiation related equipment. During the year 2012-13, an amount of ₹ 4.02 crore was released by the department.

The Department also extended financial assistance to Cancer hospitals located in other parts of the country. The budget provision for the year 2013-14 for such partial financial assistance was to the tune of ₹ 20.25 crore. An increasing need was felt to use the expertise available in the DAE funded Tata Memorial Hospital for creating a better network between cancer institutions all over the country. An Apex Committee was formed under the Chairpersonship of Director, TMC, for this purpose. The Apex Committee met on 18 times and deliberated on indigenous development and manufacturing of the equipment related to radiation oncology such as Cobalt 60 Teletherapy, Low Energy Linear Accelerator, High Energy Linear Accelerator, simulator development, Brachytherapy.

Olympiad Programme

The Department of Atomic Energy 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.

During the year, The Homi Bhabha Centre for Science Education conducted nine exposure and orientation camps for Olympiad, NIUS (National Initiative in Undergraduate Science) and STME (Science, Technology and Mathematics Education) students and teachers. Testing and standardisation of equipment was completed for the 10th International Junior Science Olympiad held in December 2013. Laboratory upgrades were carried out in physics and chemistry. Outline of project-based learning at school level is being prepared.

INFORMATION TECHNOLOGY APPLICATION DEVELOPMENT

At IGCAR, a prototype development and Implementation of a Knowledge Management Portal was undertaken and it was integrated with many work processes. A 64 Tera-byte storage capacity for storing scientific data was commissioned and integrated with centralized computing facility at RRCAT. The aggregated computing power of computing clusters stood at 13.28 TeraFlops with integration of Kahlil-3.

A web-based facility for online submission of Immovable Property Return (IPR) for Group-A gazetted officers of VECC was developed at VECC. A PC based software was designed and developed at VECC for interfacing a Pulse Link Extended Range Neutron Area Monitor that can measure neutrons of energy from thermal to 1 GeV. An "RFID-based Automatic Key Management System" has been designed to allow or restrict the employees of an organization to access room keys by using their RFID based identity card and also record all key transactions.

TECHNOLOGY TRANSFER

Various new technologies such as Smart Radon Monitor Technology; Preparation of Thin Film Composite (TFC) Charged Nanofiltration (NF) Membranes; Mass Multiplication medium of biofungicide *Trichoderma* Spp; Insitu Testing of HEPA

Filter Installation; *Trichoderma* Chitinase Gene Construct for Plant Transformation; Production of Intumescent Rigid Polyurethane Foam; Portable Radio Isotope Detection and Identifier (PRID); Process for retaining pericarp colour and extending shelf life of litchi; Technology of "Distress alarm device- Nirbhaya" were introduced by BARC in the public domain and were transferred for commercialization. Total 47 technologies were transferred by BARC during the year 2013-14. Two agreements were signed during the report period taking the total tally to twenty seven. While completing and executing the committed projects, various new projects were also accepted at Facilitation Center for Industrial Plasma Technology (FCIPT), IPR.

COLLABORATIVE PROGRAMMES

Six MoUs from various divisions of BARC were signed for collaborative developmental work. BARC Centre for Incubation of Technologies (BARCIT) activities were initiated with signing of five MoUs.

SOCIETAL INITIATIVES

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

To spread AKRUTI Programme in and around Pandharpur, DAE Out Reach Centre (DAE-ORC) was set up in Pandharpur in collaboration with SVERI. Four new AKRUTIs were set up in surrounding villages around DAE-ORC. Technologies such as Environmental Radiation Monitors-IERMON Installation, Nisargruna, Soil Organic Carbon Detection & Testing kit, Vibrothermal Disinfector as a training facility in Rural Human & Resource Development Facility were set up by BARC.

INTELLECTUAL PROPERTY RIGHTS

DAE-IPR Cell constituted by the Department, works as a nodal agency for all Intellectual Property Rights (IPR) related matters including filing of patents within India and abroad for all the Units including Public Sector Undertakings and Autonomous Institutions under DAE. During the financial year 2013-14, two regular DAE-IPR cell meetings and one special meeting to discuss other issues were held. Eight new inventions were reviewed for the patentability. DAE filed fifteen new patent applications including eleven in India and four in USA.

During the year 2013-14, eight of the previously filed patents were granted to the Department. Six out of the eight patents were in foreign countries, five in European Union and one in USA.

During the year, 104 patent applications were referred to the Department by the Controller General of Patent, Intellectual Property (IP) India to screen for the applicability of section 20 (1) of Atomic Energy Act, 1962, i.e., whether the application is related to or useful for atomic energy and give its opinion. Directions of the Department were communicated to the Controller of Patents in India.

PUBLIC SECTOR UNDERTAKINGS**(Financial Performance)**

Financial performance statistics of DAE's public sector undertakings namely, the Nuclear Power Corporation of India Ltd., Uranium Corporation of India Ltd., Indian Rare Earths Ltd. and Electronics Corporation of India Ltd. are given below. (BHAVINI is yet to commence commercial operations)

Nuclear Power Corporation of India Ltd.

The provisional net profit after tax (PAT) for the year 2013-14 was ₹ 2117 crore. The net profit after tax for previous FY 2012-13 was ₹ 2101 crore. The NPCIL bonds continued to be rated at AAA (Highest Safety) by CRISIL and CARE.

Uranium Corporation of India Ltd.

The overall performance of the Company in terms of MoU signed with DAE was rated as "Very Good" for the year 2012-13. The total income of the Company during the year 2012-13 was ₹ 855.12 Crore as against ₹ 707.28 Crore in the previous year. The Company is consistently making profit year after year and the profit before tax during the year 2012-13 was ₹ 144.17 Crore as against ₹ 86.26 Crore in the previous year and registered an increase of 67%. On the basis of compliance with guidelines on Corporate Governance, Department of Public Enterprises awarded "Excellent" grading to UCIL for the year 2012-13.

Indian Rare Earths Ltd.

During the year 2013-14, the Sales Turnover was ₹416.22 Crores (provisional) and the Profit before tax in 2013-14 was ₹36.31 Crores (provisional). As against this, for the financial year 2012-13 the Sales Turnover and PBT were ₹533.48 Crores and ₹237.43 Crores respectively. The fall in revenue for 2013-14 was mainly on account of the extensive damage to OSCOM Plant due to cyclone Phailin which resulted in production losses and deferment of shipments which were effected from Vizag Port in place of Gopalpur Port.

Electronics Corporation of India Ltd.

Against the target of ₹ 1800 Crores each for production and sales the company achieved a production of ₹1406 Crores and a net sales of ₹ 1430 Crores for the financial year 2013-14 as compared to ₹ 1678 Crores and ₹ 1600 Crores respectively for a production and net sales for the year 2012-13.

INTERNATIONAL RELATIONS

India, a designated member of the Board of Governors (BoG) of the International Atomic Energy Agency (IAEA) since its inception, continued to take active part in policy management and programmes of the Agency. India was represented on a number of committees of IAEA on safety, safeguards, nuclear radiation, nuclear engineering and application, nuclear law etc. India hosted several IAEA Workshops, Technical Meetings etc., and offered the services of its experts under the IAEA Technical

Cooperation Scheme in a number of fields. India also made an extra-budgetary contribution of USD 50,000 to the Innovative Nuclear Reactors and Fuel Cycles (INPRO) of the IAEA. Various activities funded out of India's contribution of USD 1 million to the IAEA's Nuclear Security Fund (NSF) were also undertaken in cooperation with the IAEA.

In addition to participation in the Annual General Conference of the IAEA in September, 2013, India was represented at both the International Ministerial Conference on Nuclear Power in the 21st Century (St. Petersburg, June, 2013) and the International Ministerial Conference on Nuclear Security (Vienna, July, 2013). India also remained involved with nuclear security issues within the Nuclear Security Summit process and the Global Initiative to Combating Nuclear Terrorism.

The foundation plaque for Global Centre for Nuclear Energy Partnership (GCNEP) was unveiled by the then Prime Minister Dr. Manmohan Singh at Jhajjar in Haryana on January 3, 2014. Thirteen training/public outreach programmes were conducted by GCNEP during January 2013 to March 2014.

Cooperation at the multilateral level in regard to the peaceful uses of nuclear energy was also maintained through the European Organisation for Nuclear Research (CERN), the International Thermonuclear Experimental Reactor (ITER), and the Nuclear Energy Agency of OECD.

Intensive discussions under the existing bilateral Inter Governmental Agreements on cooperation in the peaceful uses of nuclear energy took place with the major partner countries. Discussions were held on conclusion of IGAs with Japan and Australia.

The 5th meeting of the India-US Civil Nuclear Working Group (CNWG) was held in Mumbai on 17-18 July, 2013. Discussions on collaboration under the MoU concerning cooperation with the Global Center for Nuclear Energy Partnership were held on the margins of the CNWG meeting. The Arrangement for the Exchange of Technical Information and Cooperation in Nuclear Safety Matters between the Atomic Energy

Regulatory Board and the United States Nuclear Regulatory Commission was signed on 9 October 2013.

The 11th India-France Joint Committee meeting on Civil Nuclear Cooperation was held at Cadarache during 4-5th November 2013.

DAE delegations visited Kazakhstan and the Republic of Korea during the year. DAE was also part of the delegation led by Ministry of External Affairs to the Nuclear Security Summit (NSS) at the Hague, Netherlands.

The appropriate arrangement between the Department of Atomic Energy and the Canadian Nuclear Safety Commission, pursuant to the agreement between the Government of the India and the Government of Canada for Cooperation in Peaceful Uses of Nuclear Energy was signed in March 2013 and it entered into force on 20 September 2013. The first meeting of the joint committee under the agreement took place in Mumbai on 29 November 2013. A delegation of the Canadian nuclear industry participated in the India Nuclear Summit 2013.

Follow-up mission of IAEA's Operational Safety Review Team (OSART) visited RAPS 3&4 during February 3-7, 2014. The results of the follow-up mission were considered to be excellent by the OSART.

CRISIS MANAGEMENT

The Crisis Management Group (CMG), a standing Committee of the Department of Atomic Energy (DAE) is responsible for coordinating the Department's response to any radiation emergency in the public domain. 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. A response system is in place to tackle emergency situations by mobilizing the expertise of the DAE in the field of radiation measurement and protection and medical treatment of radiation injuries with an objective to make these specialized technical support facilities

available to public officials who would be handling various types of emergencies related to radiation / radioactive materials in the public domain. The CMG also provides its expertise in various forums in the field of disaster management at both National and International levels.

The Crisis Management Group formally meets to review the crisis management plans at different facilities, to discuss on issues related to radiological incidents 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 incidents.

The Emergency Response System of DAE is also available to respond to any request from public officials in the event of a reported presence or suspected presence of radioactive material. For this purpose, guidelines have been circulated to all State Governments and Union Territories.

A significant component of the emergency response system of DAE is the availability of two emergency communication rooms at Mumbai which are manned on a round-the-clock basis throughout the year. These have multiple modes of communication and are in constant contact with various nuclear facilities in the country as well as with the International Atomic Energy Agency (IAEA) in Vienna.

During the report period, India not only ensured its participation in all IAEA conducted International exercises (popularly known as ConvEx exercises) but also met all the convention requirements identified under the Early Notification and Assistance Conventions (ENAC). India's participation was facilitated by Crisis Management Group (CMG) of DAE and its Emergency Communication Room (ECR) which is also the national contact point for nuclear and radiological emergency.

A few of the achievements were as follows:

- IAEA's IEC (Incident and Emergency Centre) Newsletter No. 44, Second Quarter 2013, specifically mentions about India's prompt response during ConvEx-1a Exercise conducted on 19th March 2013.
- During ConvEx-2a (2013) exercise conducted on 23rd Oct, 2013, India could successfully meet all the requirements of IAEA's Convention on Early Notification.
- In ConvEx-2b (2013) exercise conducted during 11-12 June, 2013, India offered its assistance in real time to the affected country Slovenia and when Medical Assistance was asked for, all arrangements could be completed within the stipulated time-period (which was appreciated by IAEA) and India's medical team found a place in IAEA's Assistance Mission to Slovenia.
- India participated in the International Exercise ConvEx-3 (2013) conducted by IAEA during 20-21 November 2013. This is the largest exercise in the field of nuclear and radiological emergency which is conducted by IAEA once in 3-5 years. Total 57 States and 10 international organizations registered their participation for the exercise. India though participating for the very first time in this large scale exercise was among those few countries which opted for the highest level (Level-B) of participation. Response of various states were continually monitored and assessed by IAEA, both for the content as well as for promptness. Based on the evaluation of responses of the states, towards the end of the exercise, Final Assistance Action Plan was prepared by IAEA. In this final document, only three countries could find the place; out of them, one assistance offer each of Turkey and Mexico were selected and India could achieve the status as the only country which was selected by IAEA to offer assistance in the four areas of expertise.

To ensure that the emergency plans are in high state of readiness, major nuclear facilities like nuclear power stations and hydrogen sulphide based heavy water plants periodically carry out a variety of emergency exercises. The numbers of exercises carried out during the year were: Communication Exercises-402; Fire Emergency Exercises-62; Plant Emergency Exercises-47; On-Site Emergency Exercises-12 and Off-Site Emergency Exercises-7 nos.

Off-Site Emergency Exercises were carried out in the public domain in the vicinity of nuclear power stations at MAPS, Kalpakkam in August 2013;

at KAPS, RAPS & NAPS in October 2013 and TAPS, Kalga and HWP, Manuguru in December 2013. These Off Site Exercises were conducted by the concerned district officials (the District Magistrate or Collector) and information flows were established to the CMG as well as to the National Crisis Management Committee of the Union Government.

During the year, "National Mitigation Plan for Nuclear Radiological (N/R) Emergencies" was finalized by CMG and submitted to Ministry of Home Affairs (MHA).

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. The reload core for Arihant went critical and a major milestone in national security was achieved. The vessel presently is undergoing harbour trials.

VIGILANCE

Vigilance functions of DAE included timely submission of various vigilance returns to the Central Bureau of Investigation (CBI), Department of Personnel and Training (DoPT), Central Vigilance Commission (CVC); issuance of sanction for prosecution; processing of vigilance and disciplinary

cases; monitoring of the progress of inquiry proceedings, investigation of complaints and others.

During the year, a one day workshop on CVC guidelines on tendering process was organised by DAE to sensitize various guidelines issued by CVC. "Vigilance Awareness Week 2013" was observed in the Department of Atomic Energy, Mumbai from 28/10/2013 to 02/11/2013. Competitions such as Slogan Competition, Poster Competition, Essay writing competition etc. were held during this week. Vigilance Awareness Week was also observed in the Constituent Units/ Public Sector Undertakings and Aided Institutions of the Department.

SCIENTIFIC INFORMATION RESOURCE MANAGEMENT

Scientific Information Resource facilities of BARC were continuously upgraded/equipped with the state-of-art facilities and technology infrastructure to provide seamless access to information to BARC scientists and engineers in their day-to-day R & D activities and it also extended its facilities to other DAE institutions. Around 950 books, various standards, codes, patents and complete sets of standards were procured during the report period. More than 2600 scientific and technical reports and about 1550 bound periodicals were added to the collection. BARC subscribed to about 1400 periodicals and 9 Databases.

At IGCAR, Redhat Linux Virtualization high performance server and IP SAN (Internet Protocol Storage Area Network) based advanced digital library infrastructure was commissioned to host various applications and e-resources of SIRD. Patron Information was integrated into the RFID based employee identity card which enabled library transactions through the same card. Compact shelving system to accommodate hard copy of technical reports and back volumes has been installed.

PUBLIC AWARENESS

The Department of Atomic Energy (DAE) carried out a gamut of public outreach programmes on a mission mode to alleviate unwarranted fears, misconceptions, to address apprehensions harboured against nuclear energy and to keep the

public abreast with the contributions of atomic energy towards societal welfare. DAE participated in and organised a host of events comprising exhibitions, seminars, workshops, essay and quiz contests in different regions of the country which were well received by the target audiences.

Some of the major events are elaborated below.

The 101st Indian Science Congress was held at Jammu University, Jammu during February 3-7, 2014. The theme of the exhibition was India Vision 2020, with focal theme as "Innovations in Science & Technology for Inclusive Development". DAE participated in the exhibition displaying all its activities.

The 25th All India Essay Contest on Nuclear Science and Technology was held in October 2013. About 500 essays were received out of which the authors of thirty three were selected for making an oral presentation at Mumbai. The selected participants visited various DAE facilities. Prizes, in cash were awarded on Founder's Day, October 30, 2013.

With an objective to further strengthen the Department's public outreach activities, several advertisement films showcasing the major contributions of DAE were produced and telecasted on National and regional channels of Doordarshan. These films, developed with the help of Prasar Bharati, highlighted the areas of nuclear power generation, food security, healthcare management, research & education among others. Dubbed versions of these films in selected regional languages were also developed. Department of Audio-Visual Publicity (DAVP) was engaged for the production of further thematic advertisement films to convey the DAE roles and contributions more effectively. Conventional methods of public awareness such as lectures and seminar in schools and colleges, public awareness events, participation in science fairs and exhibitions etc. are also continuing.

Nuclear Power Corporation of India Limited (NPCIL) carried out a gamut of public outreach activities conveying the facts on nuclear power in a



Exhibition on wheels

simple transparent and credible manner addressing apprehensions and concerns of the people.

During the year about 12,60,000 persons were reached out through the multi-pronged initiatives. About 8000 students from Mumbai Municipal Corporation and Atomic Energy Education Society schools visited the Hall of Nuclear Power at Nehru Science Centre developed by NPCIL in collaboration with Nehru Science Centre. NPCIL participated in more than 60 exhibitions across the country to make around 9.25 lakh people aware, reaching out to around 47,000 students and teachers, educationalists, environmentalists and media persons through lectures and seminars. Two scientific meets on radiation and cancer were organized for the doctors and site visits of around 63,000 people were carried out.

Several innovative public awareness programmes were conceived and implemented for communities around the Indian nuclear power plant sites as well as at several other locations across the nation. Use of TV commercials, advertisements, digital cinema, radio jingles, single-sheet print publications, innovative comic books and animated films, etc. In vernacular languages, enhanced interaction with press and media, e-public awareness campaigns, rallies in support of nuclear power are a



Promotion of Nuclear Power through street plays

few among many modules that were adopted to supplement the scaled up outreach activities. NPCIL has entered into partnership with several special agencies like Vigyan Prasar of the Department of Science & Technology.

Other innovative moves in Public Outreach Activities included Farmers Integration Programme (FIP), Promotion of Nuclear Power through an Innovative Medium-Street Plays, Exhibition on wheels, Nuclear Awareness through EduSat, Newspaper in Education (NIE) Programme with Times of India, Media Students Adaptation Programme (M-SAP), Comic books & Animation Films, Capacity-building for outreach, Development of Books and Films on Nuclear Energy by Vigyan Prasar, KV Teacher Adoption Programme and Web based Public Awareness.

Two awareness programmes at Chiplun, Maharashtra and Mangalore, Karnataka were held by BARC for University students, teachers and farmers. Senior scientists from BARC, NPCIL and TMC addressed the audience about various issues related to peaceful uses of nuclear energy. Similarly, more than five different visits to BARC and/or Bhabha plant at Anushakti Nagar were organized for school and college students, staff and farmers from rural Maharashtra.

SOCIAL WELFARE

Corporate Social Responsibility

NPCIL the largest PSU of DAE aims to function as responsible corporate entity while discharging its social responsibilities towards all



Water Supply Scheme at Dhurandhoop Village near Ramnathpet



Construction of a School at Uchchamala Village near Kalrapur

stakeholders including consumers, employees, local communities and society at large. The three major areas in which CSR work was done were education, healthcare, and Infrastructure development. Skill development projects were also initiated under education area.

During the report period, total eighty projects were taken up which included thirty projects in education and skill development, fifteen projects in health and twenty six projects in infrastructure category. Sustainable development projects were planned and implemented during the year and ₹.2.75 Crore was allocated for sustainable development activities.

RIGHT TO INFORMATION ACT (RTI) COMPLIANCE

The Right to Information Act of Government of India which came into force on 12th October 2005 has been implemented at DAE and all its constituent units.

During the year, IGCAR received 108 applications under RTI Act of which 5 applications were transferred to other PIOs and for all the remaining applicants, information was provided. RTI related issues were dealt efficiently at AMD. Total 116 RTI applications were received during the year out of which 98 were replied, 5 were transferred and 13 were returned in original (RIO). Out of 19 first appeals, 19 were replied and 4 CIC hearing appeals were attended. At NPCIL, the mandatory information required under the RTI act was posted on its website. Out of 240 RTI appeals received 230 appeals were replied. IREL received 152 RTI queries and all were replied. UCIL received and replied 74 RTI queries during the report period and replies to 3 queries were under process. The no of RTI queries received in SINP was 45 and 37 queries were replied. DCSEM

received 166 RTI queries out of that 157 were replied and replies to the remaining 9 queries was in process. NBHM received 4 RTI queries and these were answered during the period.

AWARDS & PRIZES

The units of Nuclear Power Corporation of India Limited received several awards during the year for performance in safety, environment protection and other areas. TAPS-3&4, RAPS 1&2, RAPS-3&4, KAPP-3&4 and KGS-1&2 bagged National Safety Council of India's various Safety Awards for the year 2012 and KGS-3&4 for the year 2013. AERB's Safety awards for the year 2012 for industrial safety and fire safety were bagged by TAPS-1&2, TAPS-3&4, KAPP 3&4 and KAPS 1&2 respectively. NAPS-1&2 won the Golden Peacock Award for Environment and for Training functions. KAPS-1&2 received Gujarat State Safety Award-2011 for outstanding safety performance. KGS-3&4 received Safety award from Ministry of labour & Employment for the year 2011 for accident free year.

UCIL was awarded with "Greentech HR Silver Award" by Greentech Foundation in "Training Excellence" for the year 2013. It also bagged "BT Star PSU Excellence Award" for excellence and best practices in PSU business by Bureaucracy Today and Greentech Foundation. For "The Underground Remote Asset Tracking System" project UCIL won "Engineering Excellence Award" as an Engineering Marvel of India under people's choice category in the magazine "Engineering Watch".

The awards received by ECIL during the year were the SCOPE Gold Trophy Award for Excellence in R&D, Technology Development & Innovation; the ELCINA Research and Development Award and the DAE environment award from AERB. ECIL won the "Rajbhasha Trophy" for implementation of official language from Town Official Language Implementation Committee (TOLIC). ECIL's quality circles received the "Par Excellence" and "Excellence" awards for their solutions at a national level competition.

The Board of Radiation and Isotope Technology (BRIT) received the INS Industrial Excellence Award.

HWP, Kota won Rajasthan Energy Conservation Award-2012: First position in Chemical Sector, consecutively 2nd time and also Certificate of Appreciation by National Safety Council of India, Safety Awards-2011 in Manufacturing Sector. HWP, Kota won AERB's Fire Safety Award in Category-I for the Year 2012. HWP, Hazira received National Safety Award-2011 for outstanding performance in Industrial Safety from Ministry of Labour & Employment. It also obtained IS: 18001 recertification from M/s BIS. Atomic Energy Regulatory Board conferred "Industrial Safety Award-2012 on HWP, Thal. The plant was also awarded Rajiv Gandhi Environment Management Award. RCF Thal complex including HWP-Thal bagged Greentech Safety Excellence Award-2012 from Greentech Foundation, New Delhi for outstanding achievement in Safety management. Quality Circle (Astiva) of HWP Instrument Section received 3 stars (Top most rating) at 'International Quality Circle Convention' held in October 2012 at Kuala Lumpur, Malaysia.

Prof Rajesh Gopakumar of HRI was awarded the TWAS physics prize in October 2013 and he also won the G D Birla prize in physical sciences for the year 2013. Prof Aditi Sen De received the Birla foundation award of the Indian Physics Association for the year 2013. Prof Raj Gandhi was awarded the "Fermilab Intensity Fellowship".

Dr. Tejon Basu, fellow of Institute of Plasma Research, Gandhinagar was awarded Indra Gandhi Award (third) by Hon'ble president for writing a scientific book in Hindi.



Shri P. Sudhakar, CEO, ECIL receiving the SCOPE Award for R&D, Technology Development & Innovation for the year 2011-12 from the Hon'ble President of India.

CHAPTER-1

NUCLEAR POWER PROGRAMME STAGE-I



**The then Prime Minister Dr. Manmohan Singh during the foundation
stone laying ceremony of GHAVP**



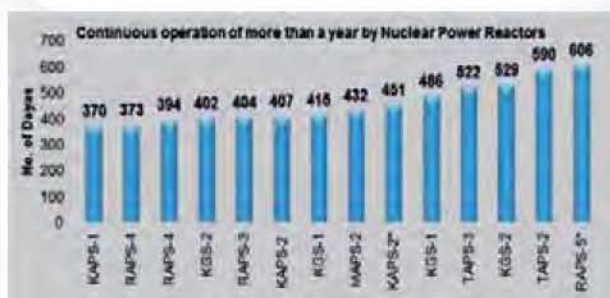
PRL lowering in reactor building in KAPP Unit-3

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

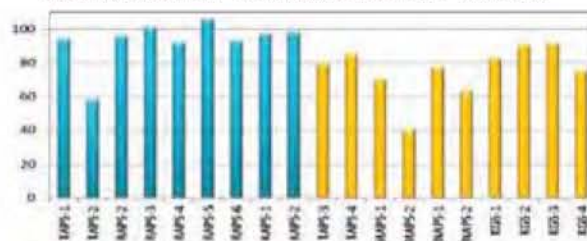
Nuclear Power Corporation of India Ltd. (NPCIL), a public sector undertaking of DAE and a dividend paying company with AAA credit rating by CRISIL and CARE, is responsible for the design, construction, commissioning and operation of nuclear power reactors. At present, it operates 19 nuclear power reactors (excluding RAPS-1) with an installed capacity of 4680 MWe. Two light water reactors at Kudankulam (KKNPP-1&2) with installed capacity of about 2000 MWe are in commissioning stage. Of these units, Kudankulam Unit-1(KK-1) (1000 MWe) was synchronized to grid for the first time on October 22, 2013 and is currently operating at 73% of full power in accordance with the regulatory clearance. It has generated till March 31, 2014 about 1106 MU in firm power. The second unit of Kudankulam (KK-2) is also in advanced stage of commission. Four Pressurised Heavy Water Reactors (PHWRs), two at Kakrapar in Gujarat and two at Rawatbhata in Rajasthan, each of 700 MWe capacity, are under construction.

Operating Reactors

During the year 2013-14 NPCIL recorded highest ever generation of 35333 MU (including 1106 MU in firm power generation from KK-1, which was synchronized to the Southern grid on October 22, 2013). In the previous financial year 2012-13 the electricity generation was 32863 MU. Thus, electricity generation during the fiscal 2013-14 recorded highest ever generation which was 7.5% higher than the previous year.



Capacity Factors of Operating Reactors (FY 2013-14)

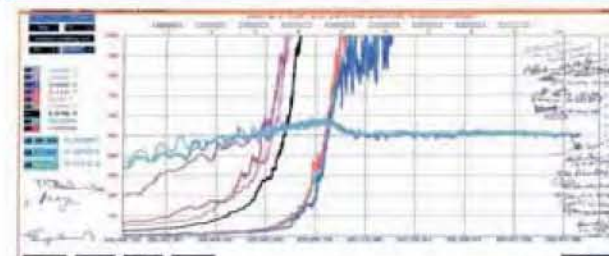


During the year KGS-1 & RAPS-5 achieved continuous run of more than a year [KGS-1: 415 days and RAPS-5: 606 days till March 31, 2014 (still running)]. So far, continuous operation of more than a year has been achieved 14 times by various reactors of NPCIL. KGS-3 also registered about one year of continuous run (342 days) during this financial year.

The overall plant load factor (PLF) and availability factor (AF) for all the existing reactors (excluding KK-1) in operation were 83.49% and 88.20% respectively during the financial year 2013-14. Nine reactors (excluding RAPS-1) with installed capacity of 1840 MWe are under IAEA safeguards and operating on imported fuel and ten reactors with installed capacity 2840 MWe are under AERB safeguards and operating on domestic fuel. PHWRs on domestic fuel continued to operate at power level matching fuel supply. Reactors under IAEA safeguards registered overall plant load factor of about 94% and those operating on domestic fuel of 77% during the current financial year. During the year TAPS-2 and MAPS-2 underwent longer shutdowns for regulatory inspections and generator transformer maintenance works respectively.

Projects under Commissioning

During the financial year 2013-14, Unit-1 of Kudankulam Nuclear Power Project successfully attained first criticality on July 13, 2013 and the unit was synchronized to the southern grid for the first time on October 22, 2013. Since then the unit has been generating infirm power and power level has been raised up to 73% of full power in accordance with stage wise regulatory clearance. In Unit-2, 'spillage to open reactor' and 'containment-testing-Integrated Leak Rate Test (ILRT)' were completed on April 15, 2013 and February 2, 2014 respectively.



KKNPP Unit-1 Achieved First Criticality on July 13, 2013 at 23:05 hrs. and synchronized to the grid for the first time on Oct. 22, 2013 at 2.45 hrs

Projects under Construction

The construction works continued on the first pair of indigenously designed 700 MWe PHWRs, at Kakrapar Atomic Power Project Unit-3&4 (2x700 MWe PHWRs) and for the second pair at Rajasthan Atomic Power Project Unit-7&8 (2x700 MWe PHWRs). These projects are expected to be completed by the year 2016-17.

Kakrapar Atomic Power Project-3&4 (2x700 MWe PHWRs)

KAPP-3&4 is India's first NPCIL designed Nuclear Power Reactor of 700 MWe series. The construction of the project commenced with First Pour of Concrete (FPC) on 22nd November 2010.

Civil works on all fronts are in full swing. Calandria vaults of both the units were completed. Construction of control building at Elevation 111 m in KAPP-3 was completed on May 31, 2013. Concreting of Inner Containment (IC) wall of Unit-3 has been completed up to elevation 126.5 and that for Unit-4 up to an elevation of 116.5. Various equipment like Startup Transformer (SUT), Calandrias, End-shields, Moderator pumps, Primary Coolant pumps, Shutdown Cooling pumps, Emergency Core Cooling accumulators, Diesel Generators, Chillers, Calandria tubes, Coolant tubes etc. have been delivered at site. Another important achievement is the dispatch of



PRL lowering in reactor building in KAPP Unit-3

Deaerator storage tank (a large pressure vessel of about 5 m diameter, 40 m long & weighing 140 MT) fabricated & transported as a single piece to site. Manufacturing of other equipment is in progress and the equipment are being put at their respective locations progressively. FM Bridge and Columns of North and South FM Vault of KAPP-3 are installed, piping and cable erection works are also in progress.

For the first time in Indian PHWR, a carbon steel liner is being provided in the Inner Containment (IC) for better leak tightness. As a construction advancement technique and to accelerate the construction, the technique of Prefabricated Ring Liner (PRL) has been developed. The first PRL was successfully fabricated, lifted and erected at the designated location of IC wall of KAPP-3 on December 31, 2013. Units-3&4 achieved cumulative physical progress of about 61% and 48% respectively as on March 31, 2014.

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

The construction on these units commenced with First Pour of Concrete on 18th July 2011. Civil works on various fronts are in progress. In Unit-7, milestone 'Release of Calandria Vault (CV) for End-shield erection' was achieved on September 9th, 2013. Concreting of Inner Containment (IC) wall is in progress in Unit-7. In Unit-8, raft of nuclear building and Concreting of Calandria Vault 2nd lift is completed.

Various equipment like Calandria, Chillers, Startup Transformers, Calandria tubes, Primary Coolant pumps, Shutdown Cooling pump, SS&CS



RAPP-7&8, view of main plant construction area

pipes, Diesel Generator, etc. have been delivered at site. Commissioning of 220 KV Switchyard is being taken up. Units-7&8 achieved cumulative physical progress of about 43% and 33% respectively as on March 31, 2014.

New Projects

Kudankulam Nuclear Power Project Units-3&4

The Kudankulam Nuclear Power Project Unit-3&4, an expansion program of Unit-1&2, located in Tirunelveli district of Tamilnadu, is planned with the co-operation of Russian Federation. Project Administrative approval and Financial sanction for Kudankulam Nuclear Power Project (KKNPP-3&4, 2x1000 MWe LWRs) from the Government was obtained during the year 2013. Site has been made ready for launch. All statutory clearances like environmental clearance, Coastal Regulation Zone (CRZ) and regulatory clearance namely siting consent have been obtained.

About 84% work of Contract for first priority design work is completed. Work of engineering service contract for designing of balance of plant is completed. Phase-I site infrastructure works like Inner fencing and peripheral road work is completed. Phase-II Site Infrastructure works like Project office complex, road works etc. are under progress. Preparation of procurement specifications for First priority equipment / system under Indian scope of work was completed on October 15, 2013. All efforts are being made to launch these reactors in the current financial year 2014-15.

Jaitapur Nuclear Power Project (JNPP) Units-1&2

In respect of site for the project, land has been acquired and statutory clearances like environmental clearance, CRZ clearance etc. have been obtained.

Application for siting consent was submitted to AERB and it is under review. Construction of boundary wall of 2.8 km at plant site towards land side was completed. Work was completed for on shore geo-technical investigations. Ninety percent (90%) work was completed for boundary fencing toward sea side. Construction of liaison office complex at Ratnagiri was completed and made operational. Erection of permanent meteorological station at plant site was completed and data collection was started. Construction of site office cum core storage, Concrete Testing Laboratory and Meteorological laboratory at JNPP plant site are in progress. Completion of JNPP site low tension power supply distribution work was achieved on December 22, 2013.

The reactors proposed to be set up are Evolutionary Pressurized water Reactors (EPRs) in technical co-operation with France in phases of 2x1650 MWe. Techno commercial negotiation to evolve an appropriate business model for implementation of the project is currently under progress.

Gorakhpur Anu Vidyut Pariyojana Harayana (GHAVP) Units-1&2

The Gorakhpur Anu Vidyut Pariyojana Harayana (GHAVP) is planned to be implemented in two phases of 2x700 MWe each. Phase-1 is planned for launch in XII Plan. The land is already acquired and environmental clearance was obtained during the year. Hon'ble Prime Minister of India laid the foundation stone for the project on January 13, 2014. The administrative approval and financial sanction of the first phase (2x700 MWe) was obtained from the Government on February 3, 2014. Procurement activities for long delivery equipment like End-shield, Calandria, Steam Generator and other equipment were initiated. 'PSAR-PART A, Section-3, Part-1 Buildings & Structures- Nuclear Building' and 'PSAR-



The then Prime Minister Dr. Manmohan Singh during the foundation stone laying ceremony of GHAVP

PART A, Section-2, Siting & Environment Data' were issued on August 23, 2013 and November 29, 2013 respectively for GHAVP. Various studies like Geotechnical investigation, meteorological studies, siesmotechtonic studies, flood studies, etc. were completed and submitted during the year for AERB siting consent. Preparation for launch of the project in June 2015 is in full swing.

New Sites

Notfications were Issued for land acqulsiton in respect of Mahi Banswara in Rajasthan, Chutka in Madhya Pradesh and Kovvada in Andhra Pradesh.

EIA study was completed in respect of Chutka site in Madhya Pradesh. Public hearing was successfully organized at Chutka on February 17, 2014. Meteorological study and flood studies were completed. Geotechnical investigation work and Seismotectonic Studies are in progress.

Pre-project activities including land acquisition process, Environmental Impact and other studies for Environmental clearance by Ministry of Environment and Forest (MoEF) and AERB are in various stages of progress at other new sites, having in- principle approval of the Government, namely inland sites at Bhimpur in MP, Mahi Banswara in Rajasthan, expansion of existing site at Kaiga in Karnataka to set up 700 MWe PHWRs, and coastal sites at Kovvada in AP, Chhaya-Mithi Virdi in Gujarat & Haripur in west Bengal to set up 1000 MW or larger capacity Light Water Reactors based on foreign technical cooperation. Term of Reference (TOR) for EIA study in respect of Mahi Banswara was prepared by October 31, 2013 by M/s Mecon India Limited.

A preliminary contract was signed with M/s Westinghouse Electric Company for sharing technological details for the reactors to be set up at Chhaya Mithi Virdi.

FRONT-END FUEL CYCLE

Heavy Water Production

The Heavy Water Board (HWB) contributed successfully to the first stage of Indian Nuclear Power Programme (NPP) by producing Heavy Water for all Pressurized Heavy Water Reactors (PHWRs) in a cost effective manner, enabling DAE to provide nuclear power at an affordable cost to the common man.

HWB has emerged as the largest global producer and a coveted supplier of heavy water. HWB also made major progress in its extended mandate in the field of development, demonstration and deployment of technologies for various In-core and out of core material inputs for the NPP. To support the second stage of Nuclear Power Programme, HWB successfully delivered the entire quantity of enriched Boron for the first core of PFBR.

Performance of the Board during the year 2013-14 was very good with respect to heavy water production, specific energy consumption, on stream factor, safety performance and environment management.

Refurbishment of Upgrading plant was carried out and system such as steam supply systems and cooling water piping system modified.

More than twenty five year old system for heavy water upgrading packing module fabrication and testing facility was refurbished incorporating extra safety features and better controllability.

The Heavy Water Board achieved more than 99% of targeted production for the financial year 2013-14.

Following are the highlights of performance of the various Heavy Water Plants:

Heavy Water Plant, Manuguru

The performance of Heavy Water Plant (HWP), Manuguru during the year 2013-14 was excellent achieving 105.3% of target production and on stream factor close to 1.0. Throughout the period, system gas purity was consistently maintained at around 99.3 % and average system gas pressure at 19.3 kg/cm²g.

The smooth operation of Auxiliary Steam Turbo Generator (TG-4) and installation & commissioning of Variable Frequency Drives (VFDs) reduced the power consumption enabling export of surplus power as per the agreement with PTC resulting revenue receipts of Rs.30.88 crore. Installation of Mist Cooling system for effluent treatment plant made progress.

As an initiative towards utilization of renewable energy resources and also to meet mandatory requirement of Renewable Power Purchase Obligation (RPPO), a 12 MWp Solar Photo Voltaic Power Plant is being set up at HWP, Manuguru.

In the field of environment management, the Manuguru plant has drawn up a road map for fly ash management which includes complete disposal of dry fly ash through supply of fly ash to cement industries, ash bricks making, land filling and other uses.

Boron Enrichment Plant for production of Enriched Boric Acid and Elemental Boron Plant to convert KBF₄ into elemental boron are in operation. A facility for converting elemental boron to boron carbide pellets is being set up at HWP Manuguru in which trial for the production of natural Boron Carbide pellets were carried out.



Pre-fabricated building for storage of D₂O at HWP, Kota

Heavy Water Plant, Kota

Performance of HWP, Kota was excellent with respect to production, specific energy consumption and on-stream hours, as a result of thorough maintenance and up-keep activities taken up during the EMTA-2013. Heat recovery as well as deuterium recovery of the plant has improved considerably and Plant has exceeded the production target set for the year 2013-14.

To reduce raw water consumption, Exchange Unit effluent is being cooled through Mist Cooling System and being utilized as make up for Cooling Tower, regeneration of WTP sand filter beds and in-house gardening.

Heavy Water Plant, Hazira

At Hazira, the performance of the plant during the year 2013-14 was affected due to low supply pressure of feed gas from Ammonia plant of M/s KRIBCHO. Efforts are on hand to get over this constraint in close coordination with the fertilizer plant.

Heavy Water Plant, Thal

During the year 2013-14, performance of the Heavy Water Plant at Thal was affected mainly due to non-availability of sustained feed gas supply from Ammonia plant of M/s RCF as well as intermittent ingress of impurities in feed gas to HWP causing choking of internals and high pressure drop in the exchange towers. Shut down of the plant was taken to attend to this problem and feed processing rate has improved since October, 2013.

As a step towards energy conservation, VFD is installed for ammonia reflux pump which is now giving about 11 KW of power saving as envisaged. Additional air pre-heater is installed in Cracker-B to recover waste heat from flue gas and reduce natural gas consumption and is giving more savings than envisaged.

Heavy Water Plant, Baroda

The 130 MT per annum capacity Tributyl Phosphate (TBP) Plant and the Potassium Metal Plant operated to achieve the target productions.

To improve the performance of ETP for the TBP plant, a system was developed for the recovery of Butanol from the effluent. The existing column was modified for processing effluent with indirect heating in Multiple Effect Evaporator (MEE). The recovered Butanol is re-cycled after purification. POCL₃ drum un-loading system was improved by incorporating fume extractor and thus reducing the personal exposure during connecting / disconnecting the unloading pipe.

In the area of nuclear grade Sodium, the 2000 Amp test cell for production of Sodium metal was operated and 140 kg sodium was produced. Based on the operational experience, actions were taken to set up an industrial facility for production of sodium metal with 600 MT/annum capacity at HWP, Baroda. Applications were submitted to AERB for siting clearance as well as to Gujarat Pollution Control Board (GPCB) for consent.

HWP, Baroda continued to receive 25% exemption in water cess, for the fourth consecutive year, from Gujarat Pollution Control Board as quality of effluent water complies with the stringent specifications of GPCB.

Heavy Water Plant, Tuticorin

Synthesis campaigns of Tri-iso-amyl phosphate (TIAP), Mono ester of Ethyl Hexyl phosphonic acid (D2EHFA-II) and Di-hexyl octanamide (DHOA) were completed at the Versatile Solvent Synthesis Pilot Plant (VSSP) at HWP, Tuticorin. Fine tuning of synthesis process parameters are in progress. Samples of DHOA & TIAP were sent to BARC and NFC for Solvent Extraction studies and D2EHFA-II was sent to IRE, Cochin for product evaluation. The effluent generated was characterized and treated to meet the Tamil Nadu Pollution Control Board norms. The effluent treatment process is optimized.

The solvent "DODGA" useful for back end fuel cycle activities of fast reactors, synthesized at HWP Tuticorin laboratory was also tested successfully by IGCAR.

Plant has also taken up various developmental activities in Lab & Bench scale for Synthesis of new un-symmetric Di-Glycolamide

(DGA) solvents as prescribed by IGCAR, optimization of operating parameters for synthesis of D2EHFA-II & DHOA, establishing the process of Purification of enriched O¹⁸ product for reduction of conductivity and developing the solvent extraction process for recovery of rare elements.

Heavy Water Plant, Talcher

At HWP, Talcher, the production facilities for D2EHFA and TBP were operated continuously to meet the target production. In TBP facility, reduction of effluent generation was achieved by a new step of reusing reject water from Butanol Distillation Unit for preparation of alkali solution. Previously, this reject water, which contains slight amount of butanol, was sent for treatment in effluent treatment plant. A special solvent, Tri-Octyl Phosphine Oxide (TOPO) was taken up for synthesis and industrial scale production has been established with tonnage level product.

Boron Enrichment Facility at HWP, Talcher was operated continuously and B¹⁰ enrichment beyond 95% and B¹¹ enrichment beyond 99.5% were achieved. More than 110% of design recovery and feed processing rate has been established and targeted production was surpassed. Chemical conversion of enriched BF₃-Ether complex to KBF₄ was carried out in the KBF₄ conversion unit and the product has been sent to HWP, Manuguru for producing elemental Boron.

Technology Demonstration Plant (TDP) at Mumbai for recovery of Rare Materials (RM) successfully achieved intended deliverables. TDP plant is operational and process development and energy optimization are in progress. The facility is providing vital process and technological inputs which will go a long way in achieving efficient configuration of industrial scale facilities.

Mineral Exploration

In the Annual Programme of work 2012-13 (November 2012 to October 2013 and 2013-2014 part) a total of 18,311t of uranium oxide has been added making XIIth Plan total to 29,954t and progressive total to 2,04,964t, since inception.

AMD continued uranium investigations in the thrust areas for unconformity related, strata-bound, metamorphic, QPC, metasomatite types in Proterozoic basins; sandstone type and calcrete type of uranium mineralisation in Phanerozoic basins.

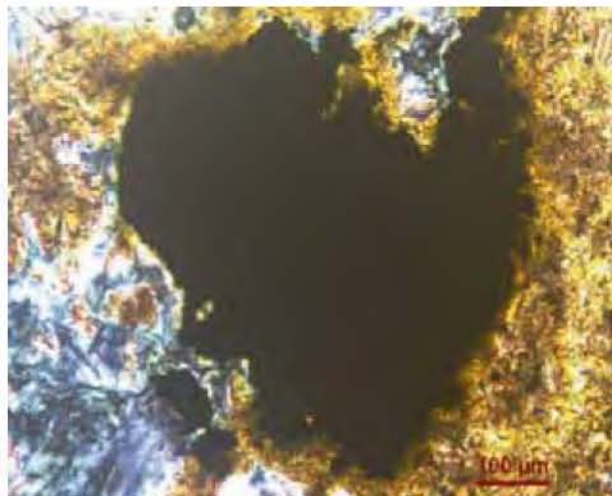
Substantial inputs of geophysical surveys, reconnaissance/detailed radiometric surveys, geochemical survey, and drilling helped in identification of the new areas / blocks and delineation of ore bodies.

In addition, pegmatite belts of Chhattisgarh, Odisha and Karnataka for rare metals, rare earths and sand bodies of coastal stretches were explored for augmentation of rare metals, rare earths and heavy mineral resources of the country.

All laboratories of AMD contributed wholeheartedly by providing speedy analytical support.



Brannerite crystals within quartz-barite Veins



Photomicrograph of Uraninite in chloritized calc silicate rock



Photomicrograph of Metamict REE mineral in alkali granite



Photomicrograph of Davidite rimmed by sphene in hornblende bearing albitite

Some of the significant achievements are summarized below:

Uranium Investigations

Ground radiometric surveys

Reconnaissance (9,074 sq km) and detailed (267 sq km) surveys helped in locating promising new uranium anomalies/extension of known occurrences in the following geological environs:

Dharmapuri Shear Zone, Tamil Nadu: Quartz barite veins within epidote hornblende gneisses/charnockites near Kalarapatti and Tirtham, Vellore district.

Delhi Supergroup, Rajasthan: Ferruginous muscovite schist at Chenpura, Ajmer district.

Nandgaon Group, Chhattisgarh: Fractured rhyolites at Koilari, Kawardha district.

Chilpi Group, Chhattisgarh: Phyllites and intercalation of quartzite at Kanhari, Kawardha district.

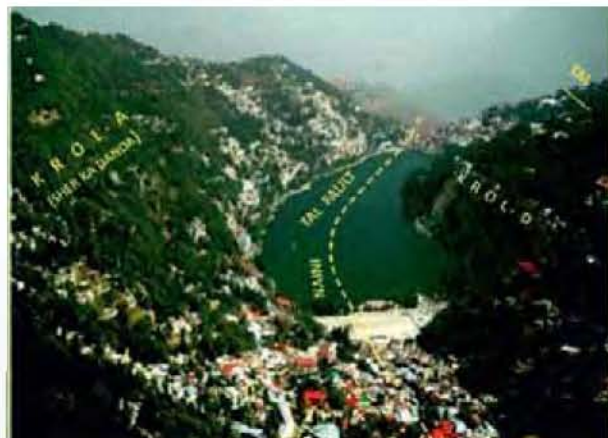
Betul Gneissic Complex, Madhya Pradesh: Granite/quartz-syenite at Jamundhana, Betul district.

Nimar Formation, Madhya Pradesh: Calcareous cherty and gritty sandstones at Jogardi, Umda and Padalya Dhar and Alirajpur districts.

Vempalle Formation, Andhra Pradesh: (a) Dolostone at Reddypalli and ferruginised quartz veins within granite at Mamillapalli, Ananthapur district and (b) Dolostone at Nandimandalam, Kadapa district.

Geochemical Surveys

Geochemical surveys were carried out over 3,725 sq km in different parts of the country. Uranium values from 0.5 to 184ppb were recorded in 450 water samples in Karansar Jamsar tract, Churu and Bikaner districts, Rajasthan. Five hydro-uranium zones around Chhattargarh-Sattarsar; Kawani-



Naini Lake (Nainital) showing strike and Dip slip faults



A section of Krol-Tal sequence in Nainital

Jamsar, Saraswati river paleochannel, Palana-Gurha and Rirkhela were demarcated. In Tanda-Dudhari sector, Betul District, Madhya Pradesh, water samples analysed forming anomalous zones aligned along NNW-SSE and NE-SW directions.

Ground Geophysical surveys

Ground geophysical survey was carried out in different geological domains. Conductors associated with the fault/fractures and alteration zones extending in NW-SE direction were deciphered in Nalpani, Bhimdo, Killekoda and Chipra areas, Balod district, Chhattisgarh. High chargeability and low resistivity zones, indicating the possible presence of sulphides in quartz biotite schist were delineated in Barkhada-Kotri, Sikar district, Rajasthan. A N-S trending gravity gradient attributed to the litho-teconic contact between basic rocks and rhyolites was recorded at Kudi-Tavidar, Jalore District, Rajasthan. Three low order magnetic anomalies in NNE-SSW direction were inferred from the total magnetic image, indicative of parallel shears at Vellimalai, Dharmapuri shear zone, Tamil Nadu.

Airborne survey and Remote Sensing

In lieu of the heliborne geophysical ground checking of airborne survey anomalies was carried out over 1276 sq km in Malani, Jogi ka Talai and Sambura (Rajasthan), Shillong (Meghalaya), Srisailam (Andhra Pradesh), Bhima (Karnataka) and Mahakoshal (Madhya Pradesh), Singbhum Shear Zone (Jharkhand) and Dharmapuri (Tamil Nadu) areas/basins.

Interpretation of VTEM data on Nathdwara sector, Rajasthan has indicated the presence of NNE-SSW trending high conductivity zone over the dolomite/ferruginous dolomite and phyllites of Udaipur Group of Aravalli Fold Belt. Drilling at Karoi, Rajasthan to test the potential targets delineated by the interpretation of heliborne geophysical data has indicated that the higher conductivity and magnetic susceptibility is correlatable with albitized zone, and coincides with the presence of sulphides. Magnetic susceptibility measurement of the cores from boreholes drilled at Beldih, Purulla district, West Bengal on the basis of interpretation of heliborne geophysical data, has indicated the correlation of

uranium mineralized zones with higher susceptibility and association with magnetite and sulphides.

Integrated evaluation of heliborne geophysical data over 13,000 L km in Cuddapah basin as well as 13,000 L km in Aravalli Fold Belt and AGRS data interpretation over 6271 L km of Dharmapuri Shear Zone were carried out.

Exploration by Drilling

A total of 2,75,734m drilling was carried out to establish (a) additional uranium reserves in the known deposits/occurrences and (b) sub-surface continuity of mineralisation in the new promising areas.

About 115% Departmental drilling target and about 116% contract drilling was achieved through maximum utilization of machinery, optimizing drilling hours per day and reducing the non-drilling days and meticulous planning.

The drilling has established significant correlatable uranium mineralised intercepts / bands as listed below:

Tummalapalle, Kadapa district, Andhra Pradesh: in hangwall and footwall at Tummalapalle Block-I, Tummalapalle Block-II, Tummalapalle Block-II Deeper (500-800m), Kanampalle, Rachakuntapalle and Motunutalapalle blocks in Vempalle Dolostone.

Koppunuru (Chenchu colony), Guntur district, Andhra Pradesh: along unconformity between Banganapalle quartzite and basement granite and within the Banganapalle quartzite.

Rohil and its surrounding, Sikar district, Rajasthan: in albitite zones at Rohil Central block and North block, Ghateswar-Khandela, Hurra Ki dhani, Narsingpuri and Jahaz areas.

Wahkut and Umthongkut, West Khasi Hills district, Meghalaya: in Lower Mahadek sandstone at Wahkut and Umthongkut deposits.

Kanchankayl, Yadgir district, Karnataka: associated to limestone, in a similar geological setup as that of Gogi uranium deposit.



Bore hole core recovered from drilling operation at Gudipadu-Ramapuram



Borehole online survey system with video imaging and deviation measurement

Devri, Surguja district, Chhattisgarh: associated with brecciated granite, grey granitic and granite-gneisses in Devri, which is situated between Dumhath and Jajawal uranium deposits.

Nalpani, Balod district, Chhattisgarh: Bortalao sandstone of Khairagarh Group and also in Pitepani metabasics of Nandgaon Group (Dongargarh Supergroup) near the unconformity.

Narwapahar Deeper, East Singhbhum district, Jharkhand: associated with quartz-chlorite-sericite schist at 600-800m depth.

Banadungri-Singridungri, East Singhbhum district, Jharkhand: associated with quartz-chlorite-sericite schist.

Bangurdih, Seraikella-Kharswan district, Jharkhand: associated with zones of secondary silicification and magnetite-apatite veinlets.

Jaduguda North and Hitku block, East Singhbhum district, Jharkhand: associated with quartz-chlorite-sericite schist.

In addition to above, the potential/significant blocks identified through sub-surface exploration included Gorir-Ilakher, Jhunjhunu district, Rajasthan; Rambas-Kishanpura-Dhancholl, Mahendragarh district, Haryana; Loarkha, Dehradun and Tehri-Garhwal districts, Uttarakhand; Raslmal and Pakkanadu, Vellore district, Tamil Nadu; Beldih and Kutni-Dandudih, Purulla district, West Bengal and Sie Rimi-Dupu-Maró-Baririzo, West Siang district, Arunachal Pradesh.

Exploratory Mining

Uranium Resources

AMD has established additional reserves of 18,311 t uranium oxide (U_3O_8) as detailed below:

- 12,364 t U_3O_8 established in Tummalapalle and its extensions (updated to 84,545 t), Kadapa district, Andhra Pradesh.
- 1,149 t U_3O_8 established in Rohil areas (updated to 7,233 t), Sikar district, Rajasthan.
- 194 t U_3O_8 in Wahkut (updated to 1,974 t) and 98 t U_3O_8 in Lostoin (updated to 869 t), West Khasi Hills district, Meghalaya.
- 11 t U_3O_8 at Bangurdih (updated to 1,275 t), 1,928 t U_3O_8 at Banadungri-Singridungri (updated to 6,228 t) and 679 U_3O_8 at Narwapahar deeper (updated to 1,564 t).

The reserves at Jaduguda (1,338 t) and Bhatin (550 t) were updated after recasting to 8,038 t and 1,700 t respectively.

The country's uranium reserves were updated to 2,04,964 t of U_3O_8 as on 31.03.2014.

Rare metal and rare earths Investigations

Reconnaissance (1,385 sq km) and detailed (8 sq km) surveys resulted in location of new occurrences of columbite-tantalite and beryl bearing pegmatites in Karnataka, Odisha, and Chhattisgarh. Additional reserves of 2,956 kg of columbite-tantalite are estimated in pegmatites at Arehalli, Hasan district, Karnataka; Domapara, Bastar district, Chhattisgarh and Jangapara, Jharsuguda district, Odisha.

The production of columbite-tantalite (3,122 kg) and beryl (2,750 kg) as by-product was achieved in the field units of Pandikimal and Jangapara unit,



Heavy mineral concentration at the Confluence of Sharavati river with Arabian Sea, Karnataka



Columbite-Tantalite recovery plant at Marlagalla, Karnataka

Jharsuguda district, Odisha; Bodanar, Bastar district, Chhattisgarh; Marlagalla, Mandya district, Karnataka and xenotime concentrate (2,300 kg) was achieved at Siri River, Jashpur district, Chhattisgarh.

Beach Sand and Offshore Investigations

To establish additional beach sand heavy mineral resources, surveys (Reconnaissance - 402 sq km and detailed - 20 sq km) and exploration (drilling, sampling and evaluation) were continued



Xenotime recovery plant at Lotapani, Siri River, Chhattisgarh

along the coastal tracts of Andhra Pradesh, West Bengal, Odisha, Karnataka and Tamil Nadu.

Exploration/Evaluation

2,360 boreholes with a cumulative depth of 19,082m are drilled in a grid pattern and 11,772 individual and 54 bulk samples have been generated. Composite samples are processed for resource evaluation and Bulk samples for separation of monazite and zircon.

A total of 6483 samples from various sectors/deposits in Kerala, Tamil Nadu, Karnataka and Andhra Pradesh have been analysed for slime, THM and carbonate contents.

Potential heavy mineral zones were delineated at East of Brahmagiri mineral sand deposit (1.73-20.31% THM), Puri district, Odisha; Joydebkasba-Dhobimu-Lechanpur (0.01-18.25% THM), Balasore district, Odisha; Pudumadam and Tiruppulani areas (5-15%THM), Ramnathpuram district, Tamil Nadu; and Sankaraguptam coast (THM 5-10%), east Godavari district, Andhra Pradesh.

Detailed Reports

Thirteen project reports pertaining to beach placer deposits along the east and west coasts of India were completed. A total of 62 technical reports were archived in "SANDBASE - Mineral Sand Database".

Resources

The country's total heavy mineral resources has crossed the 1,000 million tonnes (mt) mark and the total resources have been updated to 1,064.79 mt as on May 2013.

Mining & Mineral Processing

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

The overall performance of the company was satisfying. The Tummalapalle mine achieved the ore production capacity of 2000 TPD and about 13 lakh tons of ore were stockpiled. Efforts of finding safe procedure for mining of Hang-Wall lode were in progress. Related rock mechanics studies were underway. The plant is presently operating at 50% capacity and is being strengthened. About 9.66t of U_3O_8 was dispatched to NFC and 5t per month is expected to be dispatched regularly.

Surface exploration for extension of Jaduguda ore lenses in deeper levels beyond Tirukocha fault are being carried out by AMD. Four boreholes were drilled and all the borehole assay results gave positive indication of additional lenses. Mohuldih underground mine in Jharkhand was commissioned in March 2013 and the production of ore has started.

UCIL has taken up modernisation of Bhatin mine towards improvement of the production efficiency. The proposal endeavors at increasing production upto 400TPD. The activities involve deepening and developing the mine, modifying and debottlenecking of underground infrastructure and the supporting surface infrastructure with temporary suspension of production, and phasing out low capacity, inefficient pneumatic underground production equipment by introducing modern high capacity diesel-hydraulic and electro-hydraulic equipments.

A unique R&D project named The Underground Remote Asset Tracking System was implemented at Narwapahar mine in partnership with M/s TCS and M/s Cisco. The system uses Wi-Fi and RFID based tracking to locate personnel and equipment in real-time.

Nuclear Fuel Fabrication

Nuclear Fuel Complex is engaged in the production of natural uranium oxide fuel bundles for PHWRs, enriched uranium fuel assemblies for BWRs, reactor core structurals, reactivity control mechanisms and special materials like tantalum, niobium etc. In addition, NFC produces all the core sub-assemblies and other critical components like fuel cladding tubes, Hexagonal wrapper tubes etc., made out of special stainless steels/ D9 materials for

Fast Breeder Reactors. NFC also caters to the demand of high quality stainless steel tubes/ pipes and titanium half alloy products for critical and strategic application in Nuclear Power Plants, Reprocessing Plants, Defence and Space establishments.

PHWR Fuel

NFC has successfully manufactured a record no. of PHWR fuel bundles and met the requirement of fuel bundles for all the PHWRs in time. All the indigenous raw material in the form of MDU/HTUP/SDU received from M/s UCIL was converted into 19 element and 37 element fuel bundles for meeting the requirement of the reactors that are out of IAEA safeguards.

In oxide section of OSG fuel plant, design capacities of various sections of the plant have been demonstrated and the plant is well equipped to achieve higher production targets as per the requirement of M/s NPCIL. Plant has started receiving Sodium Di Uranate (SDU) from M/s UCIL, Tummalapalle and UO_2 has been produced from this material after successful completion of plant trials. Further optimisation of process parameters is being carried out. Developmental work of in-situ stabilisation of UO_2 powder in the reduction furnace is also under progress. An existing furnace used for re-oxidation of UO_2 pellets has been suitably modified and converted to reduction furnace. A new calcination furnace has been successfully commissioned and put in operation. Down trend in air activity levels has been maintained in spite of higher production levels through introduction of several engineered measures.

Modification and special works In Out of Safeguarded plants

The equaliser assembly of imported final compacting press costing 65 lakhs was indigenously fabricated at a very nominal cost and put into operation. This has improved the equipment availability as a spare equaliser is always available.

The press enclosures of final compacting presses were modified to improve negative pressure and ventilation inside the press enclosure. With this,

average air born activity in pressing area was reduced and this also facilitated easy access for die set replacement while making 19 element and 37 element pellets in the same press alternatively.

An automatic pellet discharging unit using a robot based on vision based technique was indigenously developed for discharging sintered pellets from shrouds to the rod trays. This has reduced the manual handling of the radioactive material and hence radiation exposure to the working personnel on the shop-floor.

Existing end plate welding jigs made of acrylic material were replaced with metallic jig thereby increasing its working life by 25 times.



Modifications and special works In Safeguarded plants

Scrubber exhaust system was modified to increase its efficiency while handling higher production load within limited space.

Uranyl Nitrate Raffinate (UNR) treatment process was modified by eliminating the large quantity of pre-coat material used in filtration of UNR slurry by using settling & decanting method for separating liquid and solid.

An indigenous machine was fabricated to draw UOC material contained in drums from shipping containers effortlessly. This machine is having Low Mast with sufficient Free Lift and is battery operated which can be driven into the shipping container to bring out heavy drums.

Elimination of manual charging of rejects into dissolution reactor without spillages was achieved by modification of containers for collection and transportation of rejects.

Uranyl Nitrate Raffinate cake was treated twice with dilute nitric acid followed by calcination



Scrubber exhaust system

operation resulting in 10 times reduction of its volume. This method reduced the solid effluent accumulation and storage at shed thereby reducing associated risk of radioactive exposure.

Special UO_2 pellets (Small pellets & annular pellets) were successfully fabricated at NFC and supplied to IGCAR for safety experiments that are being conducted in Reactor Design Group.

Press equaliser assembly of imported final compacting press was fabricated indigenously, assembled & operated successfully.

Designed and fabricated a mechanism for transfer of imported pellets to reduce manual handling and time; a mechanism for precise centring of profile end cap welded elements during machining on double head turning machine. Lifting tackles for loading and unloading of imported fuel containers were also designed and fabricated.



Press equaliser assembly



Mechanism for transfer of imported pellets

An additional blower was commissioned to increase air changes and improve ventilation in compaction area of Safeguarded fuel pelletising plant.

An automatic pellet loading system was developed with online weight measurement which avoids manual handling and associated pellet damage and radiation exposure to working personnel.

Material Accounting and Production Data Processing System (MAPDPS) was improvised to make the software more user friendly for easy storage and retrieval of data, generating reports in soft form and reduce paper consumption.

A force-controlled industrial robot for polishing the circumferential groove of the pilger mill



Set-up for Robotic die-polishing

die was developed for saving skilled man-power, for better quality of polished surface in a shorter span of time, as robotic polishing is uniform, consistent and untiring. The process can polish die of any size with very little inputs from the operator. Initial trials for polishing of 25VMR Die (size: 150mm diameter, Die material: H1 Steel) has been completed. Uniform surface finish of 0.4 micron all over the groove surface is achieved.

A machine vision system comprising a dual line scan camera, line illumination source and dedicated calibration grids was designed and developed for in-situ measurement of pellet and stack lengths of PHWR fuel elements. It is capable of measuring individual pellets and stack length to an accuracy of 100 micron and 200 micron respectively. These measurements will be used by high precision



High resolution in-situ pellet and stack length measurement system



Detected edges of the pellets in stacks used for length measurement

and high speed articulated robot for making final stack within tolerance of 2 mm. An algorithm was developed for minimizing the number of exchange of pellets between stacks so as to attain stacks of desired length in minimum time. The system is expected to automatically handle 20 rows of around 600 pellets in less than 6 minutes at a speed higher than manual operation.

BWR Fuel

A laser marking machine was introduced in BWR plug marking instead of manual punching machine. This has improved readability and traceability of elements in the section



LASER marking machine introduced in BWR plug



A metal transport box designed for safe transfer of BWR assemblies

A metal transport box was designed for safe transfer of BWR assemblies in place of a wooden box. The drawing for the metal transport box has been approved by NPCIL and it is under procurement.

Metallic Fuels

At the Bhabha Atomic Research Centre (BARC), two indigenously synthesized solvents mixed alkyl phosphine oxide (MAPO) and mixed substituted alkyl phosphine oxide (MSAPO) were synthesized for zirconium Extraction. Both the solvents have good potential for its industrial exploitation.

Use of dispersion liquid membrane based extraction using hollow fiber module was demonstrated with filtered waste acidic raffinate solution from Uranium Metal Plant at 60 LPH flow rate



Bench-scale setup with four Hollow Fiber modules in series



Rotary Expulsion Unit for UF₆ expulsion

with 30% TBP in dodecane as the extractant and 1M sodium bicarbonate as the strippant.

A process scheme comprising leaching followed by separation cum purification of uranium values from the leach slurry using 'resin-in-pulp' (RIP) technology and direct precipitation of uranium peroxide from the eluate was developed to give high purity yellow cake with minimum steps. A carousel type RIP unit was designed and fabricated for the semi-continuous runs.

Production of uranium ingots and metal powders for use in fuels for various research reactors was continued. A 10% reduction in HF consumption was achieved in the metal production process due to a better HF gas dispensing system based on real-time weighing of the cylinder. A newly developed rotary UF₆ expulsion system resulted in reduced batch duration and less material handling.

The hot deformation behaviour of U - 9% Mo was studied to identify the optimum hot working conditions for manufacturing different fuel forms. U - 9Mo was hot deformed in compression in the temperature range of 850 to 1000 °C and strain rate range of 3×10^{-3} to 1 s^{-1} in a vacuum of 10^{-4} mbar to obtain a processing map. This map can be used to select hot extrusion parameters to obtain a uniform microstructure.

Structural Materials & Components

Zirconium activities

Development of liquid-liquid extraction method followed by DM water stripping to extract the available free nitric acid from acidic raffinate liquid effluent generated in Zirconium Oxide Plant.

The efficiency during dissolution of crude Zirconium hydroxide was enhanced by modifying the mechanism of powder feeding into the dissolution (batch) reactors. This resulted in 3-4% increase in overall process recovery and reduced generation of solid effluent by 40%.

Achieved significant reduction in energy consumption at vacuum distillation operation (1.0 KWh/Kg of Zr sponge produced) on recurring basis along with increase in equipment availability by reducing the cycle time of operation.

Development of "high temperature vacuum drying" for drying and removal of volatiles from high density compacts made from fine turnings of zircaloy scrap for enhancing the safety in recycle chlorination operation.

Development of a method for safe chlorination of highly pyrophoric (< 1mm size) fine powder of zirconium (which was earlier being disposed-off by burning) by encapsulating it in rejected graphite coated zircaloy tubes for recovery of zirconium from rejected graphite coated zircaloy tubes and fine powder.

Zircaloy fabrication

3780 MT horizontal extrusion press is a unique facility wherein the hot working of all the materials required for various applications of DAE, Space and Defence are carried out. In addition to

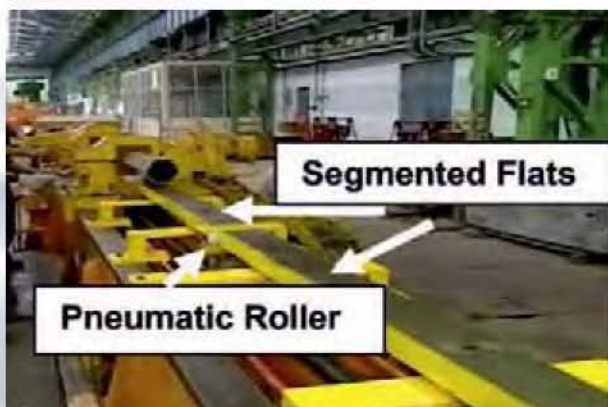
regular hot working (extrusion) of zircaloy and stainless steel materials required for PHWR, BWR and FBR programs, development of hot working for several other strategic materials such as IN-718 (a precipitation hardenable superalloy which finds application at high temperature & corrosive environment). IN-690 alloy (an important material which finds application at high temperature in tubular form) and Al-6Mg alloy for Indigenisation of components of BrahMos was carried out successfully after simulation studies. In a significant development, manufacture of 18 Cr ODS tubes for potential usage as clad tube of fast breeder reactors of high burn up was taken up. The alloy tube has been uniquely manufactured by powder metallurgy route and extrusion of hollows. The alloy tube has tremendous advantage in fuel reprocessing which is attributed to its very low dissolution rate in boiling nitric acid as compared to previously developed 9 Cr ODS clad tubes.

Ti-6Al-4V alloy tube has been developed through hot extrusion for power transmission shaft in Light Combat Aircraft (LCA) which can withstand higher cyclic load due to its high specific strength.

Core Structural

The calandria tubes for both KAPP-3&4 and RAPP-7&8 were successfully manufactured and supplied. 95% requirement of the hexagonal tubes for manufacturing PFBR fuel and special subassemblies was completed during the year.

After successful completion of trials in the previous year for fabrication of Zr-2.5Nb pressure



System for in-situ bow and twist measurement of hexcans & square sections

tubes based on double radial forging, extrusion and single pass pilgering route, production of large number of pressure tubes was undertaken. More than 500 tubes were manufactured and requirement of pressure tubes for KAPP-3 was successfully completed.

System for in-situ bow and twist measurement of hexcans & square sections was successfully implemented. In order to facilitate measurement in-situ obviating the need for shifting the tube on to the surface plate, precisely ground and levelled segmented plates were fixed on the profile straightening machine. Rollers actuated by pneumatic cylinders facilitate easy movement of hexcans to segmented flat plate.

Hexcans of SS D9 were successfully developed as an import substitute. These tubes were produced on a machine designed for a lowest size of 60mm. Several modifications including development of pass schedule, main toolings, auxiliary tooling and fixtures etc. were made to facilitate pilgering of 47.3mm (across flat) hexcans. Hexcans produced met all specifications of the customer.

Reactivity Mechanisms

For the forthcoming 4x700 MWe reactors, several reactivity control mechanisms are taken up for manufacturing and 91 nos. were manufactured till the report period.



A dismountable type cobalt absorber assembly for 700 MWe PHWRs

To ascertain the irradiation properties of different Zircaloy materials, a carrier tube assembly is envisaged. The assembly is mainly a 19 element PHWR fuel bundle where two nos. of inner elements have been replaced with dumb bell shape tubes which are welded with integrally manufactured twin end plug by EB welding. Dumb bell shape tubes were manufactured by drawing circular tubes into dumb bell shape. A prototype assembly was successfully manufactured. Thicker appendages were welded on the adjoining tubes to maintain uniform gap between elements.

A dismountable type cobalt absorber assembly for 700 MWe PHWRs is envisaged for easy retrieval of cobalt pencils after irradiation. A prototype assembly was successfully manufactured. This assembly will undergo mechanical tests and final assemblies will be manufactured based on the results.

Modification in the Girdle wire of Garter Springs

A welded girdle wire design which can have creep expansion was suggested for easy detection of garter spring position during ISI. A simple sinusoidal girdle wire, with optimization of curvature required for smooth expansion & fabricability, optimisation of corrugation length and optimization of overlap was conceptualised. The fabrication of gadgets, testing, welding process qualification & demonstration of type tests were successfully completed and one core requirement of garter spring with modified griddle wire was manufactured.

Fuel Tubes & Components

A record production of Fuel tubes and components was achieved for meeting requirement of highest ever production of PHWR fuel bundles. Efforts were made to improve the recovery by reducing the manufacturing steps such as pickling & grinding. The productivity was also improved by increasing process parameters such as feed & speed for various pilger mills. Two nos. of pilger mills were commissioned to increase the production. In addition, Zr-1% Nb and Zr-4 fuel tubes required for strategic applications were also produced meeting the stringent technical specifications.

Development of double clad tube with dilute Zr-Sn liner inside Zr-2 tube was done through co-extrusion followed by co-pilgering for high burnup fuel of AHWR-LEU.

Development of thin wall SuperNi-42 alloy tube through extrusion followed by pilgering with intermediate annealing was done for higher fuel burn up in LWR due to its resistance to radiation embrittlement.

Development of Niobium needle tube of 2 mm OD and 1 mm ID was done for BARC through pilgering and tube drawing.

Manufacturing process was developed for critical components of AHWR viz., Grid plate, Inner band and spacer tube for Grid spacer, plenum tube for fuel pin, structural tube and slit bush for control rod assembly.

Commissioning of Zirconium dust collector unit using vacuum suction and wet scrubbing was completed for tube polishing machine to avoid fire hazard.

Commissioning of computerised burst testing machine for Zircaloy and SS tubing of wide range of sizes and upto 1 mm wall thickness with advanced control and testing features was completed.

Special Materials

NFC developed Zirconium-Hafnium alloy in three different compositions for Variable Energy Cyclotron Centre (VECC), Kolkata through EB melting route for systematic studies of nature of defects generated during the rolling or extrusion of zirconium alloy.

Collaborative work was taken up with Material Processing Division, BARC for development of Nb-1%Zr-0.1%C alloy for high temperature applications through in-situ alumino-thermic reduction of niobium oxide, zirconium oxide and carbon.

Collaborative programme was taken up with Defence Metallurgical Research Laboratory, Hyderabad towards development of Nb-1%W and Nb-1%W-2.5%Zr alloys for strategic applications in Defence. Two alternative routes were studied with

raw material in powder form and consolidated metal form and statistical analysis is under progress.

Requirement of antimony trioxide filled stainless steel capsules was met for 3 nos. of Source SAs for 1" partial core of PFBR.

Commercial activities

Seamless Stainless Steel Tube Plant (SSTP) manufactures tubes of SS & Special alloys for nuclear and strategic applications. SSTP has manufactured clad and core structural components made in D9 for Prototype Fast Breeder Reactor (PFBR) meeting stringent specifications with respect to close dimensional tolerances, mechanical and metallurgical properties, controlled chemistry, Eddy current Testing (ET) and Ultrasonic Testing (UT). In the wake of global nuclear renaissance, plant has geared up and developed a unique technology for manufacturing of 25 metre long U-bend steam generator tubes required for 700 MW PHWR. These are U-Bend Glass bead shot peened tubes bent in 72 radii from 91mm Centre Line Radius (CLR) to 1014mm CLR, meeting all specification requirement viz UT, ET, Boroscopy, visual, dimensions, ovality, out of roundness, leg length etc. with special packing requirement. Similarly, 29 metre long modified 9 Cr-1 Mo steam generator tubes for PFBR were also successfully supplied.

SSTP has also taken up developmental challenges for manufacturing nickel based super alloys, titanium alloys and special alloys for nuclear and non-nuclear strategic applications like boiler tubes for Advance Ultra Super Critical Thermal power plant, Ti- half alloy tubes for LCA and PSLV applications etc.

I) Fast breeder reactor requirements

D9 Fuel Clad Tubes and Blanket clad tubes

Blanket clad tube requirement for PFBR was completed meeting all stringent requirements like visual, dimensional, ET, UT apart from controlled chemistry & mechanical properties and supplied to FRFCF. Additional requirement of D9 fuel clad tubes was partly supplied and production of the balance quantity is in progress.

ODS fuel clad tubes for future FBRs

After successfully producing 9 Cr ODS fuel clad tube, 18Cr ODS which is a promising grade future candidate material for clad tubes was taken up and successfully made through pilgering route to final size and handed over to IGCAR for characterisation studies.

II) Pressurised heavy water reactor Steam Generator (SG) tubes

Production of 5 sets of UNS 8800 SG tubes for 700 MW PHWRs have been completed out of which 3 sets have been despatched. Production of 6th set of steam generator tubes is in advance stage of completion.

iii) Aerospace application:

Process development of Titanium half alloy hydraulic tubes of four different sizes (6, 8, 10 & 12 mm dia) for Light Combat Aircraft (LCA) application is being carried out. Plant is further fine tuning the process to achieve consistent impulse fatigue properties in various sizes of tubes.

Projects

Green field Projects of NFC

NFC-Kota: A green field project at NFC-Kota, Rawatbhata, Rajasthan is being established to produce 500 tpy of UO₂ Pellet and 65 tpy of Zircaloy Products at present to meet the fuel requirement of four 700 MWe PHWRs viz RAPP 7&8 and Kakrapar 3&4. Project status is as follows:

- Financial sanction is obtained for setting up the project with an outlay of 2401 crores.
- NFC Safety committee of AERB cleared the proposal for siting consent.
- Preparation of DBRs by consultant M/s EIL is nearing completion for submission to AERB for obtaining construction consent.
- Tenders were floated for site grading & levelling, construction power supply and some of the long delivery items.

NFC-5 & 6: Site selection activities for these two green field projects were in progress. In this connection, site offered by AP Government was

visited by Site Selection team. Letters were written to the Chief Secretaries of Orissa, Karnataka, Gujarat, Rajasthan and Madhya Pradesh for identification of suitable land.

New XII Plan Projects at NFC

Financial sanction was obtained for thirteen new projects. Fabrication of equipment/execution of work, processing for placement of PO/WO, tendering, finalising of specifications were in progress for various projects.

Zirconium Complex

Zirconium Complex (ZC), Pazhayakayal, Tuticorin, Tamil Nadu has been set up to produce 250MT per annum of nuclear reactor grade zirconium sponge. Plant was commissioned in November 2009 and production activities for both zirconium oxide and zirconium sponge production were continued on regular basis.

Desalination Plant with two streams each of capacity 30 m³/h of product water is being set up at Zirconium Complex. Construction of RCC storage tanks for sea water, product water & reject water were completed and civil construction works for plant buildings were in advanced stage of completion. Purchase orders were released for all the equipment and about 70% of equipment were received. Physical progress of about 65% has been achieved.



Township facility of Zirconium Complex

Construction of quarters in the township for Staff & CISF personnel and amenity buildings were completed. STP for township and black topping of roads was completed. The New Zirconium oxide and sponge project was successfully completed.

Niobium Thermit Production Facility

Civil works were in progress towards the establishment of Niobium Thermit Production Facility (NTPF) to indigenously meet the requirement of special grade Niobium for VSSC, DOS. This Niobium will be used for manufacturing niobium based alloys such as Niobhat alloy used in PS-4 as nozzle and AOCS & LAM in INSAT programmes.

BACK END FUEL CYCLE

Fuel Reprocessing

Power Reactor Fuel Reprocessing Plant (PREFRE-II), Tarapur has reported an outstanding plant performance in terms of production and process parameters. Plant has operated over its full capacity during the period. Efforts at waste minimization have yielded good results. Environmental discharges were within authorization. Plant was operated safely and received Directors' Safety shield.



ADU facility augmented to match the higher throughput of PREFRE-II

Spent Fuel Storage Facility (SFSF), Tarapur has been continuously in operation for storage of spent fuel according to the given parameters. Power



Fuel Pool in SFSF, Tarapur

Reactor Fuel Reprocessing Plant (PREFRE-I), Tarapur continued to carryout aged Pu purification and Spent Fuel casks received and spent fuel of PHWR was stored in fuel pool and all services/facilities for PREFRE-II were provided.

Kalpakkam Reprocessing Plant (KARP) & Spent Fuel Storage Facility (SFSF), Kalpakkam achieved all time record in capacity utilization. Regular operation of KARP continued to reprocess the spent fuel of PHWRs. Introduction of modified process resulted in a reduced recycle volume and an increase in throughput.



Automated Charging Facility (ACF)



Fume Hoods with ducts

Installation of Automated Charging Facility (ACF) and Charging cask was completed at Power Reactor Fuel Reprocessing Plant – 3 (P3A), Kalpakkam. In-Cell Equipment erection and piping were completed. Erection of different sub systems like Dilution Hot Cell, Fume hoods with associated SS ducting in analytical laboratory were completed. Piping work for Samplings blisters was completed. Calibration of tanks in chemical preparation area (508 S Building) was completed.



Heat Exchangers & piping

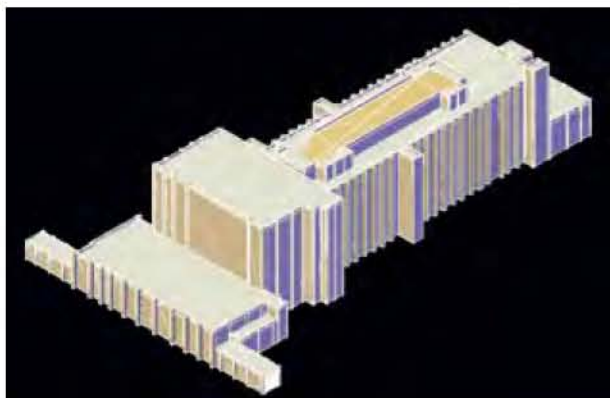
Erection, pre-commissioning testing of ACVE system, DM water plants and steam generation plants was completed. Erection of Furnace Oil Storage Tanks (FOST), Boiler & Associated systems was completed.

Erection and installation of Spent Fuel Chopper (SFC) system would be nearing completion. GA & Architectural drawings for all major process blocks for Integrated Nuclear Recycle Plant (INRP) and Additional Spent Fuel Storage Facility (ASFSF) were prepared. Civil structural drawings were prepared for RP blocks, Control and Laboratory Block, PCW & Chemical preparation Block.

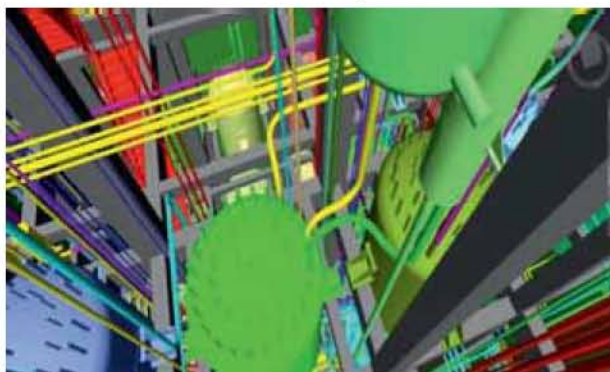


FOST erected

Process flow sheet, P&ID and 3D piping layout were prepared for reprocessing blocks. The detailed engineering activities of INRP are in progress. Design and detailed engineering of process, mechanical, electrical, utility and auxiliary system were nearly completed for front end process



3D Architectural drawing of RP Block



3D piping for in-Cell process systems

blocks of INRP. Preparation of structural framing plans for detailed engineering for RP and waste management blocks were completed. Design and analysis work of FE modeling of 13 m³ horizontal condensate storage tank was completed. Equipment design of Hold-up vessels of different sizes was completed. Design basis report on Fire safety system and the system design reports, Engineering Flow Sheet and Piping for RP blocks were reviewed.

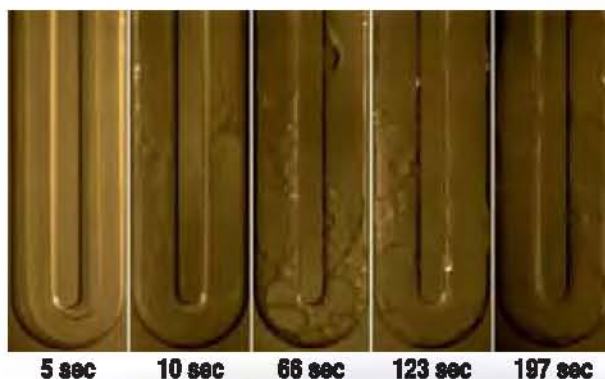
Procurement of Critical equipment for INRP was initiated. Construction of Additional Spent Fuel Storage Facility (ASFSF) is progressing. Procurement, Construction and Commissioning of underground fire water storage tank, Pump House and fire water line for ASFSF were completed.

Process development for synthesis of di-tert-butyl di benzo 18 crown 6 (DTBDB18C6) and di-tert-butyl cyclohexano 18 crown 6 (DTBDCH18C6) was continued with emphasis on improvement in yield and purity. The process was demonstrated at 5 L scale reactor producing about 450 gm of crude with 95% yield. Subsequent purification steps gave 15 gm

of about 95% pure compound which will be hydrogenated to get DTBDCH18C6.

The functionalized resin (CMPS) and CNT was designed, screened and synthesized for isotope separation of Li. The CMPS-DB18C6 shows promising results for isotope separation. The amorphous nature of Merrifield resin was confirmed from the image of SEM and XRD. Even, CMPS-DB18C6 resin adsorbs Sr²⁺ metal ions from acidic media.

Numerical simulations of drop formation at a single nozzle hole in a plate were carried out to understand the effects of velocity, geometry and physical properties on drop formation phenomenon. Correlations to predict drop size at a single plain hole and nozzle hole were obtained. Numerical simulations to understand two-phase hydrodynamics in pulsed column were carried out based on Euler-Euler two fluid model with assumption of mono-dispersed droplets. The results of numerical simulations were validated using experimental data reported in literature for TBP- nitric acid system. Several drag models were evaluated for their capability to correctly predict the holdup for given throughputs and pulsing condition.



Flow patterns observed in a serpentine microchannel for O/A = 1/1 with TBP-Nitric acid system for different values of contact times

Studies on microchannels as devices for intensification of solvent extraction processes continued. Demonstration of single-stage solvent extraction at a total throughput of 1 LPH in parallel microbore tubes, along with a small pipe settler was taken up. A configuration that gives high stage efficiency with low pressure drop and quick settling has been identified. Using this configuration, single-

stage extraction has been demonstrated with TBP-nitric acid and Zn-D2EHPA systems. High speed imaging was used to study liquid-liquid flow patterns in the serpentine and the split and recombine microchannels.

Continuous synthesis of 1-Ethyl-3-methylimidazolium ethyl sulphate for the iodine-sulphur thermochemical process was carried out in a 250 μ L microreactor in solvent free mode. Even at a reaction temperature of 900°C a colorless product was obtained and the yield obtained was 88.6% for a residence time of 286 sec at a reaction temperature of 500°C. This highlights the need of using microchannels for highly exothermic reactions.

Several experimental runs were carried out for denitration of synthetic ammonium nitrate solution in 300 mm fluidized bed reactor during which parameters like feed ammonium nitrate concentration, spray nozzle with low air to liquid volume ratio (ALR), bed as well as free board temperature were optimized to get better conversion. The optimized conditions gave consistent conversion of 70% at 30 lph flow rate. Plasma nitriding of the nozzles resulted in less erosion of spray nozzle.



Denitration column

A new denitration column of size 300 NB with modified location of feed nozzles and jet grinding nozzles and induction heaters coils has been fabricated and installed in the pilot plant for taking denitration runs with uranyl nitrate solution. The new reactor has been commissioned with water and synthetic ammonium nitrate runs.

Waste Management

Plutonium Plant, Trombay achieved a mile stone by completing 50th year of safe and successful operations. The entire spent fuel from CIRUS reactor was reprocessed including irradiated thorium bearing J Rods. Processing of the spent fuel received from DHRUVA was also carried out.

During the current year, Waste Immobilization Plant, Trombay (WIP) achieved a major mile stone by processing & vitrifying 35 m³ of fresh high level liquid waste (HLLW) for the first time. 45 ci/l with Ru-106 of 1 Ci/l was handled deploying all the three induction based metallic melters giving an overall plant processing throughput of 35 l/h.

Additional Waste Tank Farm (AWTF), Tarapur was in regular use for safe storage of High Level Liquid Waste (HLLW), Intermediate Liquid Waste (ILW) & Organic Liquid Waste (OLW) generated from regular operations of PREFRE-II. Total 882 liters of ILW from AWTF was transferred to TWMP for further processing.

Plant adoptable process for sulphate bearing legacy HLLW was demonstrated. This gave a tenfold reduction in the vitrified waste canisters for eventual disposal in Geological Disposal Facility (GDF).

Historic Intermediate Level Waste at Trombay is characterized by the presence of high contents of problematic Aluminium. In-house



A view of shielded IX- Columns & Valve Station at Pump House for treatment of Historic ILW



Actinide Separation Demonstration Facility, Tarapur – In-Cell Piping & Service Gallery

processes developed were applied and 800 M³ of these wastes of Tank-4 were processed with no secondary waste and discharged directly.

A radiological facility based on indigenous R&D efforts, called "Actinide Separation Demonstration Facility (ASDF)" was commissioned at BARC, Tarapur to address the challenging technology of 'partitioning'. India is the first country to have adopted this technology on the industrial scale, thereby taking a lead role towards reducing the long term concerns of HLLW. Besides reduction in radio-toxicity of HLLW, partitioning will reduce the vitrified waste volume qualifying for Geological Disposal Facility.

Irradiated thoria rods (J rods) were reprocessed in Uranium Thorium Separation Facility (UTSF), Trombay and complete recovery of thorium was achieved by solvent extraction process from the thorium bearing liquid raffinates. Nearly 20 m³ of this thorium lean raffinate were processed for total removal of fission products (Cs & Sr) based on the indigenously developed specific sorbents. The resultant fission product lean wastes having aluminum and fluoride were vitrified for the first time. This technology demonstration established Indian capability to address back end cycle for thoria based fuels.

Decontamination solution (U-Decon) as an import substitute to ATLONTAL was developed and out sourced for commercial production. Performance of this commercial bulk solution is far superior compared to imported one used in the Reprocessing Plants.



Stripable Gel for decontamination of Fumehood

Stripable gels for decontamination were developed and deployed in Reprocessing Plants addressing decontamination of alpha contamination in Glove Boxes.

High Level Waste (HLW) was vitrified in Advanced Vitrification System (AVS) and Tons of VWP was poured in canisters. Vitrified glass over packs from AVS and WIP Trombay were emplaced in storage vault and kept under continuous surveillance in solid storage surveillance facility (SSSF).

Alpha waste transit storage facility at Waste Management Plant in Tarapur (TWMP) was commissioned and presently in operation to facilitate uninterrupted operation of fuel fabrication facility.

Low level liquid waste generated at TAPS 1 & 2 was processed at Tarapur Radwaste Augmentation



Alpha Waste Transit Storage Facility, TWMP



Cobalt SPND storage operation at TWMP

Plant (TRAP) and activity discharge to sea was lowest in the history of TAPS 1 & 2 operation. ILW from reprocessing plant was processed through ion exchange columns. Modified technique was developed for safe disposal of self-powered neutron detectors after its usage in reactors. Solid waste disposed in engineered disposal systems included SPNDs from TAPS 3 & 4 having radiation field in the range 3000-5000 Sv/hr.

Liquid Effluent Treatment Plant, Solid Waste Management Facility and Decontamination Centre were operated satisfactorily to provide radioactive waste management services to various units of DAE at Kalpakkam. Pressure Tube Management campaign was started and 201 of 300 pressure tubes have been retrieved, volume reduced and safely stored in tile holes. A process for treatment of technetium containing waste from WIP has been developed and will be employed at CWMF for treatment of the waste before discharge.

Hot commissioning of WIP (K) plant was inaugurated by the President of India.

The optimum conditions for the hot working of Inconel 693 were determined and these conditions were tested at HAL, Bangalore by successful



An Inconel 693 dome which failed during hot working



Domes of Inconel 693 successfully forged using optimised process

conversion of 10 mm thick sheets of Inconel 693 into defect-free hemi-spherical domes as shown in the figure. Changeover of the dish end material from Inconel 690 to Inconel 693 is expected to increase the life of shells by more than 3 folds. These shells are used for vitrification of high level radioactive waste.

Safety Performance of Reactors

Reactor Safety & Analysis involves carrying out the deterministic and probabilistic safety assessment of Indian Nuclear Power Plants for obtaining regulatory clearances including design, siting, commissioning of new projects; safe operation, periodic safety review and extension of operating license/life management of operating plants.

Complying with review requirements of visiting IAEA Operational Safety Review Team (OSART), fire hazard analysis, fire PSA and external flood PSA were completed to enhance safety levels and safety review of RAPS-3&4 post Fukushima.

During the follow-up mission which was carried out by the IAEA team comprising of nuclear power experts from Belgium, Finland, the UK and the IAEA in February 4-7, 2014 assessed that significant progress was made in all areas including improvement in the condition of cable trays, power and control cables, provision of strong inspection and maintenance programmes for fire doors, enhanced surveillance testing programme to assure functionality of safety systems and an enhanced root cause analysis to systematically identify all root causes and learning opportunities.

Complying with commitments to CNS convention; generic Severe Accident Management guidelines for Indian PHWRs were developed for operating 540 MW and 220 MW.

HEALTH, SAFETY AND ENVIRONMENT

NPCIL recorded about 394 reactor years of safe operation of reactors by the end of month March 2014. The Review of safety of operating stations was carried out on a regular basis. The individual and collective occupational exposures of radiation

workers at various NPPs were maintained within the budget approved by Atomic Energy Regulatory Board by following the principle of ALARA (As Low as Reasonably Achievable) and maintaining the highest standards of safety within the Nuclear Power Plants (NPPs). The radioactive effluents from NPPs to the environment were maintained very low in comparison to the limits specified by AERB. NPCIL continued to maintain low radiation exposure in the public domain due to operation of nuclear power stations. The average exposure for the year 2013 was only 0.745% of the technical specification limit set by AERB. The Environmental Management System (EMS) and Occupational Health and Safety Management System (OHSMS) as per ISO-14001: 2004 and IS-18001: 2007 respectively were maintained at all the stations.

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

BARC Carried out Personnel Monitoring of about 15,000 radiation workers of DAE using TLD badges to ensure radiation safety of the workers and the installations. Personnel monitoring support is also provided to the Emergency Response Centres in the country. More than 90% of the radiation workers in the country receive very low occupational doses of less than 0.5 mSv/y (against a regulatory dose limit of 20 mSv/y). A method has been developed for separating the background and

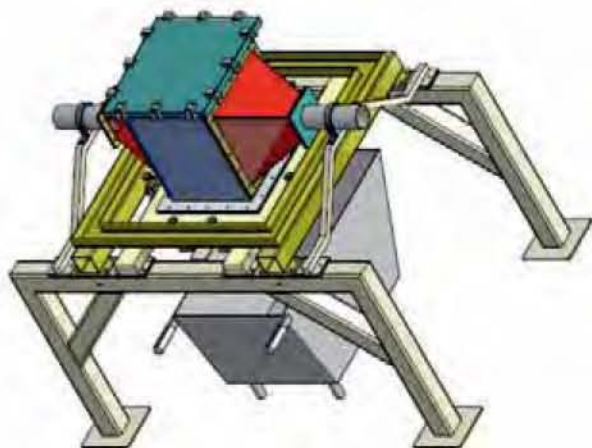


Grass sample collection for analysis of deposited radionuclides

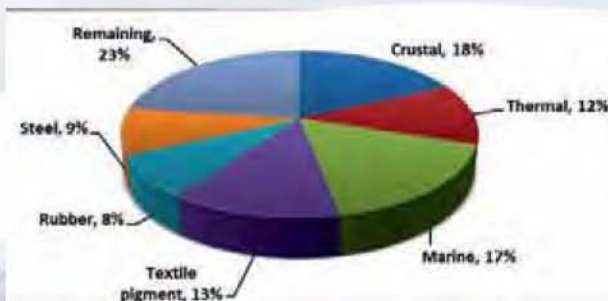
radiation induced components from the gross signal obtained for an exposed dosimeter based on the glow curve analysis of Thermoluminescence readout of the dosimeter.

To control the Thoron (^{220}Rn) gas emission into environment through stack of upcoming Power Reactor Thorium Reprocessing Facility (PTRRF), an indigenous Online Thoron Mitigation System (OTMS) has been developed. The OTMS is based on charcoal adsorption technique and can be effectively used to control the ^{220}Rn at the generation point of the facility. The system is now ready for installation at PTRRF.

Environmental Surveillance around NPP sites and BARC, Trombay was carried out by Environmental Survey Laboratories for radiological impact assessment of general public. Public dose calculation for the proposed Nuclear Power Plant sites namely 700 MWe PHWR stations at Chutka (Madhya Pradesh) and for AP-1000 station at Mithi Viridi (Gujarat) was carried out for obtaining regulatory/environmental clearance from MoEF & AERB. Public dose calculations were carried out for the DFHRR Plant and Modified APSARA at BARC,



Online Thoron Mitigation System (OTMS) for PTRRF



Environmental Analysis Data

Trombay and BARC Special Material Facility at Challakere for dose apportionment.

Under project entitled "Comprehensive Environmental Impact/Risk Assessment of Nuclear Power Plant, Thermal Power Plant and Pollutants from other industries", radionuclides, trace and toxic elements, organic contaminants were analysed in various environmental matrices using advanced analytical techniques.

For the prevention and response to radiological emergencies including threat of Radiological Dispersal Device (RDD - 'Dirty Bombs'), a Quad-rotor based Aerial Radiation Monitoring System (QARMS) has been developed.

Under the Indian Environmental Radiation Monitoring Network (IERMON) programme, 150 Environmental Radiation Monitors (ERMs) were installed raising the strength of ERM's deployed in the country to 340. These have been deployed at various locations in India covering DAE facilities like Nuclear Power Plants, uranium mining sites etc, major metropolitan cities, boarder areas etc. Installation of IERMON systems at police stations in Mumbai, Delhi and Bangalore was also completed. Installation at Hyderabad, Thane and Navi Mumbai is under progress. Public awareness displays on natural background radiation and their variation were installed at Nehru Science Centre in Mumbai and at DAE locations in Srinagar and Gulmarg.

Assessment of internal exposure of 3600 occupational workers from various facilities of BARC



The 3-axis mechanical manipulator employed for the waste assay

and Tarapur was carried out by whole body/lung counting and bio-assay analysis. Base line levels of natural uranium excreted in urine of workers from Technology Demonstration Plant, Heavy Water Board was established.

A standing type QUICK SCAN whole body monitor was designed, developed and commissioned in BARC Hospital for screening of large number of workers and members of public for internal contamination in case of radiological emergencies. The system can screen for radioactivity in 1-2 minute counting duration with detection limits much lower than the specified annual limits.

The releases from the Fukushima Daiichi Nuclear Power Station (FDNPS) due to the accident which occurred on March 11, 2011 were estimated for the aquatic and atmospheric route based on large amount of data in the public domain made available by several international agencies. The estimated release rates were in good agreement with those estimated by various international agencies.

A system was designed and installed at Cirus Reactor for estimating the presence of low levels of ^{137}Cs and ^{60}Co isotopes in standard waste drums, which can qualify for clearance levels during future decommissioning of nuclear facilities. An attenuation corrected spatial distribution of activity is estimated for each drum for accurate detection of low levels of activity.

RESEARCH & DEVELOPMENT

Thrust areas on Developmental activities in NPCIL, are aimed at Indigenization of nuclear equipment, components and materials including alternate vendor development, testing & verification of new designs/systems/components through R&D facilities, advanced development of remote tools for inspection & repair of reactor core components and technology demonstration & adaption for construction time minimization of new projects.

Major Achievements and ongoing activities during the financial year 2013-14 were as follows:

Test Facilities

Design of Containment Filtered Venting System (CFVS) was completed on August 23, 2013.

Full scale prototype test facility at TAPS-3&4 is being set up for qualification/ validation (Phase-III) of the design. Part of Integrated Test Facility viz. PARTH was completed and inaugurated by President of India in November, 2013.

A number of tests of Passive Recombiner Devices (PARs) were carried out in the Hydrogen Recombiner Test Facility (HRTF) and have demonstrated Hydrogen recombining process. An alternate design of these devices were also tested during the period at the facility which have shown expected results.

A 700MWe Fuelling Machine Test Facility (FMTF) was erected with FM test carriage, support structure and control room with control PLs/



CFVS-Full scale prototype test features for Qualification/Validation of design



Arrangement of PARs in HRTF



700 MW FMTF Erection

Consoles. The software development was in progress. Delivery and installation of balance equipment and channel components made progress.

Indigenization initiatives

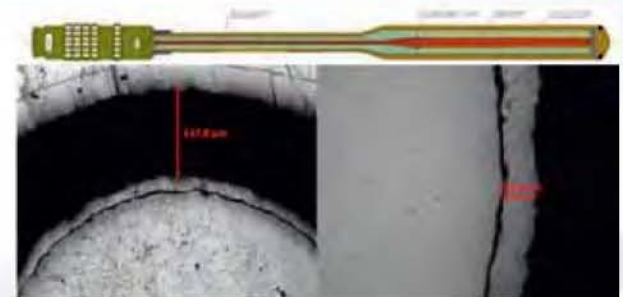
NPCIL developed a local vendor for In-line Relief Valves for use in Fuelling Machine coolant circuit. These valves were tested for Set Pressure, Reseat Pressure, Leakage Rate and Hydrostatic Integrity and are proposed to be taken up for performance evaluation at Fuelling M/c Test Facility.

Development of different types of Electrical Penetration Assemblies (EPAs) with enhanced leak-tightness has been completed and it is being implemented in on-going 700MW PHWR projects.

Development of first forging (shell-IV) of Steam Generator Forgings at LTSSHF completed on January 27, 2014. Four types SG forgings have been made and pre-machined. Heat treatment, final machining, mechanical testing & NDT activities are being taken up for balance shell forgings.

Development Orders were placed for alternate indigenous source for Shutdown Cooling Pump and Fuelling Machine Supply Pump.

Indigenous development for alternate source of 6 MWe Primary Coolant Pump Motors for 700 MWe PHWR was taken up.



Development of 3-Pitch Platinum Clad Inconel Self Powered Neutron Detectors



Development of Pressure Transmitter

Factory Qualification of 3-Pitch Platinum clad Inconel Self Powered Neutron Detectors (SPNDs) was completed and planned to be installed in TAPS-3&4 for in-core performance evaluation during the coming BSD.

Development, qualification and testing of Prototype 700 MW Cobalt Adjuster Rods at Test Station at R&D centre was completed on January 30, 2014. This is for production of Co⁶⁰ with high specific activity in 700 MW reactors as required by BRIT to meet country's industrial and medical application requirements. Fabrication of first Co AR assembly is in advanced stage at Nuclear Fuel Complex, Hyderabad. All associated manufacturing processes were established. Full scale test facility set up for the same and design of associated tools are in progress.

Electronic Pressure and Differential Pressure Transmitters (PT/DPT) for nuclear application were developed through participation of two vendors. Functional tests and radiation qualification up to 1.0 MRad, LOCA/MSLB qualification for V2 area was successfully completed. Balance type tests are being taken up at NABL approved labs.

Remote Tooling

Triangular Block Cutting Laser tool for RAPS-3 developed & tested at R&D Centre mock up facility. Carrier tube assembly removal concept for 540MWe finalized, design detailing is in progress. Double radius V type shear cutter trials completed. The following figure shows mock up/carrier tube inside die after cutting by V-Type shear cutter. Full-fledged coolant channel inspection campaigns using BARCIS & Steam Generators (SG) lancing carried out in several 540/220 MWe units.



Mock up/carrier tube inside die

Engineering & Construction Time Minimization

Design of a single large Nuclear Building of a size 100 M by 100 M was transformed into reality for the first time in nuclear industry for 4 units of 700 MW, 2 each under construction at Kakrapar Atomic Power Project and Rajasthan Atomic Power Project.

The concept of a metallic liner inside the Inner Containment of Reactor Building was also implemented successfully during construction of these units which helped in achieving faster construction progress. These are full ring liners of 5m height that replaced the conventional shuttering arrangement and is a unique added safety feature of these units.

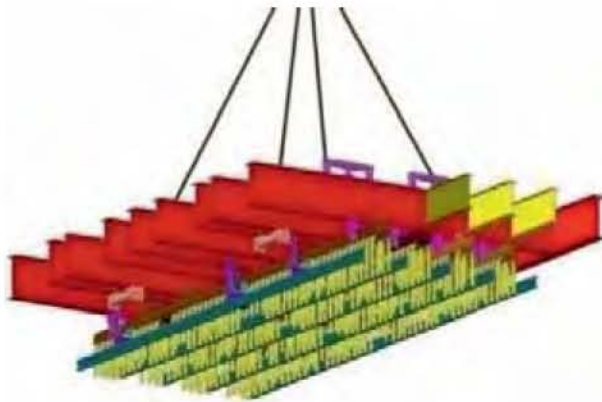
Detailed engineering for the above 700 MWe units was brought in advance stage of completion. Required deliverables were furnished to site for achieving progress on the construction and erection front that were progressively being made available.

Use of state-of-the-art technique of 3D modeling of systems, structures and components has started showing positive results in terms of clash free layout leading to a remarkable pace of construction.

After multi stage evaluation of design and feasibility along with project contractor, implementation of Preformed Ring Liner (PRL) installation for RB inner containment metal liner is adopted at KAPP-3&4 to save construction time and cost. The following photograph shows the PRL work status of November month.



PRL Implementation at KAPP-3&4



Composite beam floor along with header'

Concept and design/analysis for construction module consisting of 'Composite beam floor along with Primary Heat Transport system Header' in 700 MWe PHWR' was completed.

Automated welding of medium and large size piping has been established and it is being implemented stage wise. The scheme for Calandria-End shield modular installation in 700 MWe PHWR was conceptualized and computer simulation was taken up.

Safety was given the utmost attention during the stage of design and detail engineering. Review of design for all the systems for these units was also completed by Atomic Energy Regulatory Board and clearance for major equipment erection is expected shortly. The design has incorporated all the recommendations post Fukushima. Timely Engineering assistance to operating stations has helped in minimizing the downtime during Biennial shutdown of the units.

Development In R&D-Electronic systems

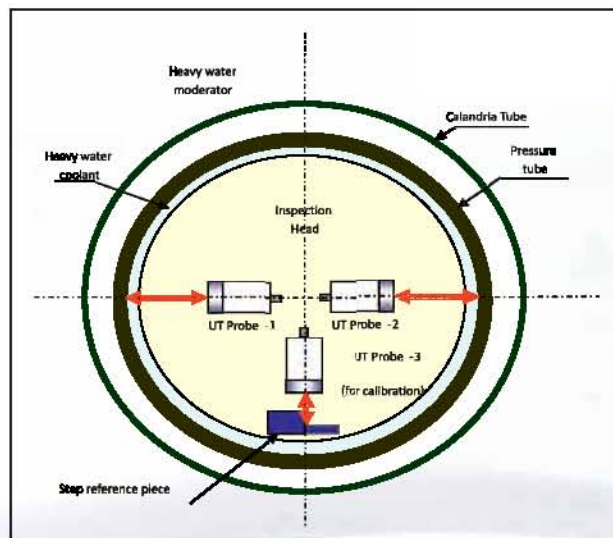
The R&D for Electronic Systems in NPCIL is focused on enhancement of plant safety, improvement in plant performance parameters, reducing project gestation period, indigenization of plant components. R&D in Electronic Systems includes specifying System Architecture, Hardware and Software Development of Digital Instrument & Control Systems and subsequent deployment in indigenous Nuclear Power Plants and providing support to Operating Stations by retrofitting the Computer based systems. Development of both

'Operator Work Stations Common Software Modules' and 'Configurable Software for testing the Integrated Hardware of a Digital I&C System' were achieved on January 31, 2014.

R&D relating to PHWR

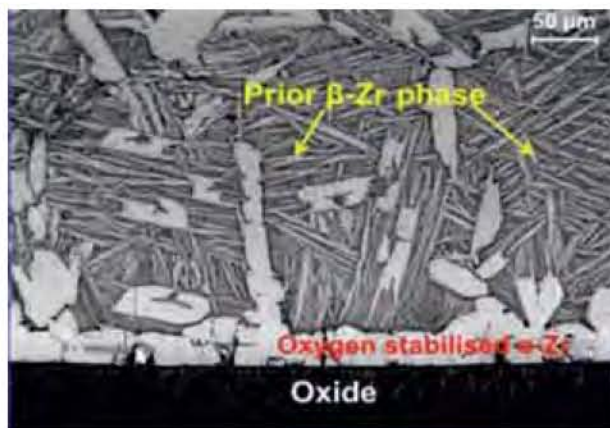
Bhabha Atomic Research Centre (BARC) carried out an experimental study to understand the debris bed formation for PHWR during a Severe Core Damage Accident (SCDA) scenario like Station Blackout (SBO). The generated information is used to establish an analytical model DBHUPA to assess the time margin for Severe Accident Management action.

An Ultrasonic technique (UT) ID for the measurement of pressure tube ID was developed for periodic in-situ measurement of ID for pressure tubes with a remotely operated drive system. The UT ID measurement is based on the measurement of heavy water paths of the Diameter probes by measuring the time of flight of the interface echoes from the ID of the tubes. This technique is being used with BARCIS in all PHWRs.



Probe arrangement for diameter measurement

A new fabrication route was developed for Zr-2.5 Nb alloy pressure tubes for 700 MWe PHWR so as to achieve improved in-reactor performance. The prototype tubes were qualified in terms of mechanical properties and were found to have less variability in mechanical properties and microstructure.

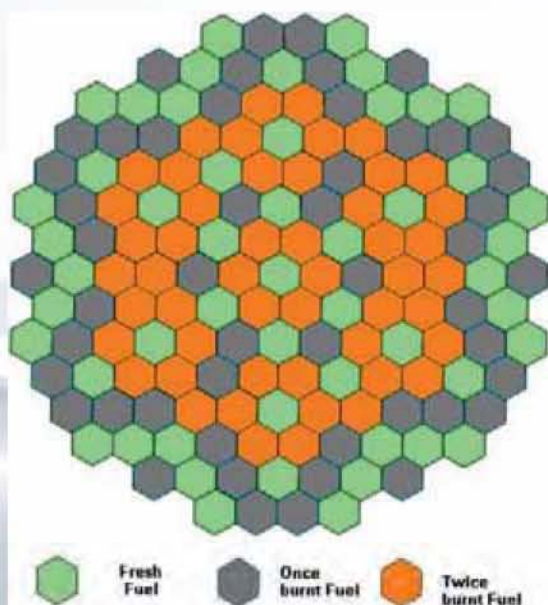


Microstructural analysis



Fabricated Large Cruciform Specimens

Microstructural analysis and microhardness testing of PHWR fuel clad tube pieces subjected to high temperature steam oxidation tests were performed on metallographically prepared samples.



Equilibrium core configuration of IPWR

To identify the different stages in the PUREX plant, the distribution of neptunium at different stages were determined using ^{239}Np tracer (β, γ emitter) and the actual samples obtained from PREFRE at various streams of PUREX process were analysed for their Np contents using alpha spectrometry.

A welding process was developed and qualified as per ASME code section IX requirements, achieving the special requirement of impact strength up to 70KJ for the weldment. A batch of four specimens were successfully fabricated; heat treated using an in house developed furnace and is ready for delivery.

R&D relating to LWR

The Indian Pressurised water Reactor (IPWR) is being designed with enriched uranium fuel and light water as coolant in a hexagonal lattice arrangement. The rated power is 900 MW(e) and the equilibrium core has been optimised with 151 fuel assemblies with 4.5% ^{235}U .

Gadolinium is used as an integral fuel burnable absorber in 24 pins optimally located in the fuel assembly to provide reactivity suppression and acceptable local peaking factors. A three batch refuelling scheme with a cycle length of 410 FPD has been formulated which gives a discharge burnup of 46 GWD/T. The critical boron concentration has been calculated at various conditions. Core uses 103 control rods grouped in 10 control groups and designed to provide enough worth under postulated transients. The cold-to-hot reactivity swings in IPWR core has been estimated.

Nine types of Process Sensors for compact LWR are developed indigenously and qualified, and thus BARC gained self-reliance in this critical technology. The technology is transferred to ECIL. The required nos. of burnable poison rods were fabricated, inspected & tested in P-4 facility and the required nos. of fuel assemblies were fabricated and delivered to P-4 facility for testing.

The design, development of manufacturing of automated vertical radiometry scanning system for radiometry of fuel pin after filling is completed.



Process Sensors for LWFR

An analytical technique was developed to quantify the traces of boron in $U_3Si_2 + Al$ and $U(Al, Si)_3$, after matrix separation employing pyrohydrolysis followed by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) analysis. An analytical methodology was developed to quantify trace metallic impurities in U_3Si_2 by ICP-MS after matrix separation.





CHAPTER-2

NUCLEAR POWER PROGRAMME STAGE-II



Overall view of PFBR site



Scanner test setup for PFBR

FAST REACTORS

The second stage of the nuclear power generation programme is geared towards setting up of fast breeder reactors. These reactors produce more fuel than what they consume. The DAE organisations that are involved in the implementation of the Fast Reactor Programme are the Indira Gandhi Centre for Atomic Research (IGCAR), Bharatiya Nabhiya 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, materials 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

Prototype Fast Breeder Reactor is a pool type reactor using mixed oxide of uranium and plutonium as fuel. The coolant used is liquid sodium. The project is located 500m south of the existing Madras Atomic Power Station.



Overall view of PFBR site



Erection of control plug

The civil construction of nuclear island buildings has been completed. The nuclear island houses 17 buildings out of which eight buildings namely Reactor Containment Building (RCB), Steam Generator Buildings (SGB)-(2Nos), Electrical Buildings (EB)-(2Nos), Control Building (CB), Radioactive Waste Building (RWB) and Fuel Building (FB) are connected together as a single structure on a common raft and is called Nuclear Island Connected Buildings (NICB).

The reactor vault of PFBR is nearing completion with all major reactor equipments in its place. All the core sub assemblies were erected except the actual fuel and blanket subassemblies. All the 12 nos. of dummy control and diverse safety sub assemblies were replaced with the actuals. The control and diverse safety rod drive mechanisms were also erected.

Critical in-situ heavy density concreting was done for Large and small rotating plugs without



Bottom side view of control plug

affecting the nuclear clean environment by maintaining foreign material exclusion procedure.

Heat transport sodium piping for secondary system erection is in the advanced stage and major sodium system components including four nos. of intermediate heat exchangers, two nos. of secondary sodium pumps were erected. Two nos. of sodium to air heat exchangers were received and erected. Two nos. of primary sodium pumps were also erected.

Control plug which houses the Control & Safety Rod drive mechanism (CSRDM) and Diverse Safety Rod drive mechanism (DSRDM) was erected over Roof slab. The secondary ramp and secondary tilting mechanism which forms as a part of inclined fuel transfer machine used for fuel transfer was fixed to grid plate. Pre-assembly of transfer arm is nearing completion for erection.

The construction of fuel building was completed and erection of major fuel handling components was also completed. Commissioning of fuel handling equipment is nearing completion.

The entire civil structural works of electrical building 1&2 was completed the electrical and instrumentation system were in advance stage of commissioning. All main control room, back-up control room and handling control room panels were erected in control building. Commissioning of all the four emergency diesel generators from control room was completed. 230kV gas insulated switchyard and 6.6 kV switchyard boards were commissioned. All the three outgoing transmission line from switchyard were charged and connected to southern India grid.

Commissioning of the conventional and auxiliary supporting systems such as raw water, emergency service water, demineralized water, compressed air were completed. Commissioning works for the plant ventilation system has advanced substantially. The commissioning of critical equipment from control room is being pursued now.

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

The civil construction work of turbine building was completed and erection of turbine

equipments and erection of all auxiliary equipments were completed. Turbine box-up and main steam piping was completed and major milestone of Turbine rolling on barring gear was also completed. Auxiliary boiler light up, safety valve floating and steam blowing activities were completed.

The construction of forebay is nearing completion. The civil construction works of sea water pump house was completed and erection of condenser cooling water pumps, auxiliary sea water pumps were also completed.

In sea water intake structure, the caisson has reached upto hard rock level. Excavation of hard rock was completed. The horizontal sea water intake tunnel and vertical shaft of the tunnel was connected and made through. Erection of stop log gates and trash racks are under progress.

Preheating of the main vessel by air was commenced as a part of integrated commissioning of the reactor and has been raised the temperature up to 65°C and inspection work is in progress. Also, reactor containment building leak test is in progress and the containment was pressurized up to 103millibar and inspection works are in progress.

The project achieved an overall physical progress of 97.5% at the end of March-2014.

Research & Development for fast reactors

Fast Breeder Test Reactor (FBTR)

During the period, three irradiation campaigns were completed. The reactor was operated up to a maximum power level of 20.3 MWt with the turbo-generator synchronized to the grid generating a maximum power of 4 MWe. Total reactor operation time was 2117 hours; high power operation time of the reactor was 1770 hours and TG was in operation for 1073 hours. The total thermal energy developed during the period was 31.2 GWh and electrical energy produced was 3.39 MU.

During the year, the major surveillance tests completed included inspection of reactor internals and observing sodium flow through emergency injection pipe and siphon break pipe using the

periscope; Reactor containment building leak test in as-is-were-is condition and visual inspection of hot roller supports and volumetric examination of weld joints in steam generators.

The periodic Safety Review of FBTR was completed and license to operate FBTR upto June 2018 was issued by AERB. While issuing licence, AERB stipulated addition as safety measures taking into account post Fukushima scenario. These include modifications to prevent water entry into the buildings taking into account the revised design based flood level (for flood and Tsunami), additional DG sets in a new seismically qualified and flood safe building, seismicity monitoring in the plant, Backup control room for the Main Control Room and improvements in the systems for post DBA (Design Based Accidents) decay heat removal and monitoring. These activities are expected to be completed in a progressive manner within the stipulated time period.

Capsules were developed and fabricated for irradiation of metallic fuel pins and sphere-pac fuel pins containing a mixture of UO_2 - PuO_2 and UO_2 micro-spheres and a reference fuel pin made of mixed oxide fuel pellets. Irradiation of both is in progress in FBTR.

A boron tri-fluoride based plutonium assay system was developed indigenously based on imported ^3He based detectors with the coordinated efforts of radioactive facilities in IGCAR. The design of the system was done by IGCAR & ECIL and the system including detectors was manufactured by

ECIL. The system was commissioned at the Radio-Metallurgy Laboratory and was subjected to various performance tests and found acceptable. It is being used to assay plutonium in drums containing alpha-bearing wastes generated during post-irradiation examination campaigns.

R&D relating to PFBR

Cell Transfer Machine (CTM) is a fuel handling machine remotely operated inside Fuel Transfer Cell (FTC) of PFBR. BARC designed the CTM. Two CTMs were manufactured, shop tested and delivered to BHAVINI. CTM mainly comprises of Gripper, Hoist drive and Long Travel drive subassemblies. Gripper provides failsafe gripping mechanism to handle fuel subassemblies.

Inclined Fuel Transfer Machine (IFTM) Control System for Prototype Fast Breeder Reactor (PFBR) has been handed over to BHAVINI after acceptance testing at ECIL. The major elements, namely, U, Pu in U-Pu-Zr alloy fuel samples were determined by biamprometry.

For determination of Zr, a methodology was developed based on solvent extraction separation of bulk U, Pu followed by intrinsically coupled Plasma-Atomic Emission Spectroscopy (ICP-AES) analysis. Since, the matrix is quite different from normal oxide and carbide matrices, an analytical method (pyrohydrolysis followed by ion chromatography) for the determination of fluoride and chloride was also developed.



Waste assay system with boron tri-fluoride detectors



Gripper SA

CTM Hoist and LT drive

Manufacture of Control Plug which houses the control rod drive mechanisms, core monitoring thermocouples, neutron detectors and failed fuel identification modules was successfully completed, transported and erected at BHAVINI site.

Thermal hydraulic analysis was carried out to ascertain the capability of the safety grade decay heat removal system under an extended station black out condition.

A robust scheme was worked out to close the AHX dampers of one system at a time when the sodium temperature at the outlet of AHX goes below 433 K to avoid sodium freezing,

Detailed transient multidimensional thermal hydraulic analysis of PAHR was carried out for PFBR.

Regeneration of PFBR cold trap is planned to be carried out by thermal decomposition of sodium hydride. A method based on monitoring the hydrogen released during the thermal decomposition of sodium hydride was adopted for the study. Thermal decomposition of sodium hydride in flowing argon was studied up to 700K.

Experiments were carried out as a function of heating rate and the extent of decomposition was estimated by quantifying the amount of hydrogen released. Experiments were also carried out with sodium mixed with sodium hydride. The peak temperature got shifted to 658K when sodium hydride is mixed with sodium. The extent of decomposition of sodium hydride was estimated from the amount of H_2 released and was found to be about 90%.

Twelve number of Control and Safety Rod Drive Mechanism (CSRDM) and three number of Diverse Safety Rod Drive Mechanism (DSRDM) were manufactured and functionally tested in manufacturer's shop floor.

A sodium pressure measurement device was developed to measure the static pressure of liquid sodium at high operating temperatures with high level leak tightness where the conventional pressure sensors are not suitable.



Scanner test setup

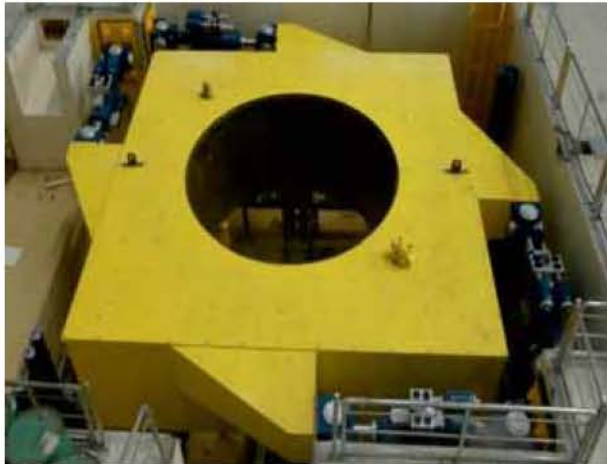
Transfer arm (TA) is the in vessel fuel handling machine of PFBR required to transfer core sub-assemblies (SA) within the reactor. In-sodium testing of transfer arm is being carried out in Test Vessel-5 of large components test rig.

An under sodium ultrasonic scanner has been developed for use in PFBR to ensure safe start-up of fuel handling operation. For qualifying the scanner to be used in the reactor, entire scanner along with the transducers, control and drive system of automation and 8-Channel ultrasonic imaging system were tested for under-water imaging at room temperature followed by under-sodium imaging at 180 °C. Functionality and the performance of the scanner in water and sodium imaging were found to be satisfactory. Images obtained in water were comparable with that of sodium.

A new test set-up simulating the fuel-blanket interface to measure the temperature fluctuations on the surface due to mixing of non-isothermal streams in sodium was commissioned in INSOT facility.

R&D for Future FBRs

A high capacity multi-axial shake table is commissioned at IGCAR. It is a 100 ton capacity table with 6x6 meter size. The table has a central hole of 3.5 meter diameter, to enable testing of large diameter vessels for directly inserting the largest possible size of reactor assembly models without any additional support structure.



100 t Shake table facility at IGCAR

The effects of impinging, flowing and stagnant sodium on limestone concrete surface were simulated by a series of experiments at 500°C. The sodium penetration depth into concrete, external and internal damage in the concrete, were assessed through elaborate instrumentations for monitoring the temperatures, aerosol concentrations and high speed imaging.

Design of permanent reactor assembly components was confirmed based on the detailed thermo-mechanical analyses and validation studies. To demonstrate manufacturability in all respects to comply with the nuclear quality and standards, it is proposed to manufacture one integrated reactor assembly, either at the project site or at the industry, ready for erection into the reactor pit during this plan period.

To enhance the reliability of core temperature monitoring system, core temperature probe housing three thermocouples was developed. As a part of import substitution, leak-tight electrical cable penetration assemblies for reactor containment building applications, mineral insulated thermocouples, heater cables and mineral insulated cables were developed indigenously.

An experiment was conducted to find out the quantity of sodium aerosols and quantitative information on chemical species present in the aerosols in a given sodium fire event. Hot sodium at 550 °C was discharged into a tray, allowed to burn and the emanating aerosols were discharged into



Top assembly of CFMM

atmosphere at a height of 10 m through a chimney. The aerosol concentration at various distances was measured and found to be within the limits.

RADAR level probes are planned to be deployed for level measurement in sodium facilities and in future FBRs. Sodium testing of two number of RADAR probes at various temperatures up to 550 °C was completed. Test results showed that there is no effect of temperature and aerosol formation on level measurement by RADAR probe.

A device named Core Flow Monitoring Mechanism (CFMM) was developed for measurement of sodium flow through individual subassemblies during reactor shutdown with Eddy Current Flow Meters (ECFM) as the sensor.

To prevent the circulation of active sodium outside the reactor vessel and to have an in-vessel purification system for the future FBRs an Integrated Cold Trap (ICT) was designed and fabricated.

Steam Generator Test Facility

Heat transfer experiments were conducted for assessing the heat transfer area margin of the

model SG of 5.5 MWt nominal heat transfer capacity. Initial experiments with fresh SG showed that a sodium temperature of 518.5°C at SG inlet was sufficient to produce steam at nominal conditions whereas the nominal temperature is 525°C. Reassessment of the area margin after about 10,000 hours of operation showed that a temperature of 518.5 °C is required to produce steam at nominal conditions. The increase in temperature is attributed to the reduction of heat transfer capability of SG due to the formation of stable magnetite layer inside the tubes.

To determine the stable steam generator start up conditions for PFBR, experiments were carried out simulating PFBR start-up conditions. Water admission into SG for start-up and power raising in PFBR is envisaged with sodium flow rated for the target power and 20 % of feed water flow rated for the nominal power. The experiment was repeated with orifices of 12.5 bar pressure drop.

Control systems & sensors

To reduce the design cycle and enhance the quality of design and development with respect to EMI/EMC requirements, test facilities for Conducted Emission (CE) and Conducted Susceptibility (CS) were established. Test equipment for conducted emission was installed as per CISPR standard. Test equipment for conducted susceptibility tests such as Electro Static Discharge (ESD), Electrical Fast Transient, Surge, Conducted Radio Frequency, Power frequency magnetic field, Pulse magnetic field, Voltage dips and Interruptions were installed and commissioned as per IEC standard. This in-house test facility was widely used and nearly fifty tests were performed on various electronic systems in deployment mode. It is also planned to augment the laboratory with additional test facilities.

Ten numbers of electrochemical hydrogen meters (ECHMs) were fabricated for installation in PFBR for steam leak detection. These sensors were assembled, calibrated and tested thoroughly in the laboratory. Currently, the long-term performance of the meters along with the associated electronics modules is being monitored in table-top sodium loops in the laboratory.



ECHMs undergoing long-term performance test in bench top sodium loops

Suitable stainless steel housings for the ECHMs were fabricated and delivered to BHAVINI for incorporation in the PFBR secondary sodium circuit. As part of IGCAR-CEA joint research project on fast reactor safety, one ECHM along with electronics modules was installed in SUPERFENNEC sodium loop in CEA-Cadarache for carrying out detailed experiments to evaluate the comparative performance of our ECHM with a conventional diffusion based sensor at CEA, France.

STUDIES ON MATERIALS FOR FBRs

Vacuum hot pressed annular hexagonal beryllium blocks for the three stacks of PFBR fabricated at BARC were delivered to PFBR.

Studies were carried out to improve the high temperature creep and low cycle fatigue properties of 316LN SS by increasing the nitrogen content above 0.08 wt% to increase design life of SFRs to 60 years (from 40 years). With these studies, nitrogen was optimized at 0.14wt% for enhanced mechanical properties.



Be blocks for PFBR stacks

Design of high temperature structural components of reactor assembly of SFRs is made according to RCC-MR fast reactor design code. Creep tests were carried out on 316LN SS containing 0.14 wt% nitrogen at 823, 873 and 923K at various stress levels in the range of 140–350 MPa. The creep data generated with a maximum rupture life of 33000 hours were analyzed according to RCC-MR nuclear code procedures in order to generate the creep design curves for the high nitrogen grade 316LN SS.

Fatigue and creep crack growth properties of 316L(N) stainless steel weld for Leak-Before-Break analysis of PFBR components were established.

Investigations were carried out to establish the sensitization behaviour of four heats of 316L SS. Time-temperature-sensitization diagrams were constructed and the critical cooling rate above which there is no risk of sensitization was found to be between 9 and 14K/h.

Detailed mechanical and microstructural investigations coupled with finite element analysis were carried out to identify the mechanism of type IV cracking.

An improved version of modified 9Cr-1Mo steel having higher type IV cracking resistance was developed by microalloying the steel with boron and reducing the nitrogen content. The addition of boron of the order of 100 ppm results in fine $M_{23}(C,B)_6$, which is resistant to coarsening, resulting in significant improvement of creep strength of the weld joints.

Fracture toughness was characterised for modified 9Cr-1Mo steel and 316(N) stainless steel welds for PFBR applications in advanced ageing conditions for end-of-life integrity assessment.

High temperature thermal stability and the sequence of phase changes up to melting and thermo-physical properties of Fe-0.28Mn-0.55Si-0.045C, magnetic iron alloy for the DSRDM electromagnet application were characterised by calorimetry and modelling.

To study the effects of sodium on mechanical properties of 316LN SS and modified 9Cr-1Mo steel, samples were exposed in a bimetallic sodium loop simulating the secondary systems of PFBR and after 40,000 hours of exposure at 798K microstructural examination and mechanical property evaluation were carried out. Based on the microstructural results and degradation parameters for 316LN SS, depth of carburization was estimated to be 200 and 225 μm , and overall thickness loss on both sides of Intermediate Heat exchanger (IHX) tubes would be 110 and 130 μm after 40 and 60 years, respectively. This data was provided to the designers for the estimation of life of IHX system of PFBR to estimate wall thickness of IHX system for future FBRs.

Pressurized capsule with attachment of thermocouple to the pressurised gas region by laser welding for use in creep-rupture experiments was successfully developed.

Laser welding was employed in fabricating ultrasonic transducer housing for under sodium scanner of PFBR and extended spark plug type leak detector.



Reduction of core diameter of wire in lathe and laser welded ESPLDs

FBR - FRONT END FUEL CYCLE

BARC supplied mixed carbide fuel pins for FBTR at Kalpakkam as per requirement. Fabrication of (U-Pu)O₂ mixed oxide (MOX) fuel pins for 500 MWe Prototype Fast Breeder Reactor (PFBR) of BHAVINI is continued. Third fabrication line has been commissioned to increase the production.

To recycle the Clean Reject Oxide (CRO) Microwave direct de-nitration and calcination technique (MWDDC) has been developed and adapted in fabrication line on production scale. Digital Radiography has been introduced in the production line for end plug welds to meet higher production targets. Fabrication of pin with uranium slug on a trial basis was carried out.

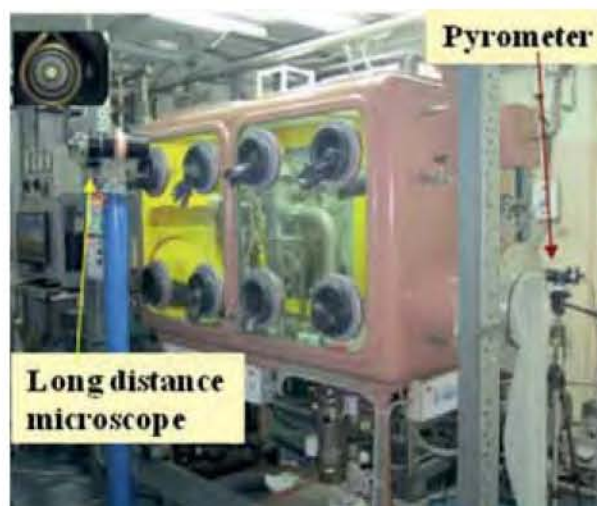
Development of (U-PuO₂) Cermet fuel was initiated. Heat Treatment of (U-20%PuO₂) was done and characterization studies were carried out.

To predict the life time of fuel pin inside the reactor, thermodynamic data on the stability of compounds of the fission product tellurium with clad constituents, viz., Fe, Cr, Ni etc. are required. In this context, the standard Gibbs energy of formation of various compounds in the systems Cr-Te-O, Fe-Te-O and Ni-Te-O were determined by thermogravimetry based transpiration techniques.

A high temperature quadrupole mass spectrometer (HTQMS) was commissioned inside an argon atmosphere glove box with a view to conduct vaporization studies on radioactive and air



HT-QMS facility for high temperature vapourisation studies



Equipment for solidus-liquidus temperature measurements using spot technique

sensitive samples. Burn-up measurements on MOX fuel pellets from the PFBR fuel assembly irradiated in FBTR were carried out by using TIMS. The effect of pulse width of Nd-YAG laser on the measurement of isotopic ratios of Li and lighter rare earths was studied using an in-house developed Laser Ionization Mass Spectrometer facility.

Towards development of sol-gel based fuel fabrication methods a reference test fuel pin containing uranium-plutonium mixed oxide annular pellets was fabricated and the pin was incorporated in a capsule along with the two sphere-pac test fuel pins fabricated last year using the fuel microspheres. The capsule was introduced in FBTR for irradiation.

The solidus temperature of a fuel is an important parameter from the design and safety aspect. The solidus temperature of Mark-I carbide fuel was measured using a novel spot technique using an experimental system built in-house. The solidus temperature of Mark-II carbide fuel of FBTR was also measured using this technique.

Studies were carried out on the extraction of elemental boron from boron carbide scrap through molten salt electrolysis. The physicochemical nature of boron obtained through this process was examined by characterizing its chemical purity, specific surface area, size distribution of particles and X-ray crystallite size. The microstructural characteristics of the extracted boron powder were analyzed by using scanning electron microscopy and

transmission electron microscopy. Raman spectroscopic examination of boron powder was also carried out to determine its crystalline form.

FBR- BACK END FUEL CYCLE

The development of pyroprocessing techniques for spent metallic fuels of FBRs is underway at IGCAR. Towards setting up of engineering scale facilities for demonstration of the process an Ambient Temperature Electrefiner (ATER) was erected. Electrefining of copper is also being carried out in this facility. The electro deposition of copper on Stainless Steel (SS) cathode was demonstrated. Hydrodynamic studies to find out suitable stirrer for electrefining operation were carried out. Power manipulator was erected in the facility and trial run is in progress. Cruciform anodes were fabricated and erected for electro deposition experiments.

A high temperature electrefiner with natural uranium electrefining is planned as a second stage towards setting up of engineering scale facilities of pyroprocessing. Various activities were in progress towards finalizing and setting up the facility. The design of the subsystems of the facility like the containment box, high temperature electrefiner, advanced cathode processor, salt handling and purification system, chlorination vessel, scrubber system, argon recirculation and purification system were completed and the specifications for all the systems were finalized. Detailed engineering drawings for various systems were prepared and procurement and fabrication of these systems is taken up. The construction of the Pyro engineering building to house the facility is also in progress.

Reprocessing of plutonium-rich spent fuel from Fast Breeder Test Reactor (FBTR) with a burnup of 155 GWd/Te is being carried out regularly in the Compact Reprocessing of Advanced fuel in Lead mini cell (CORAL) and it provided valuable inputs for the Demonstration Fast Reactor Fuel Reprocessing Plant (DFRP) and the PFBR reprocessing plant being built as part of fuel cycle facility. Several important milestones in terms of infrastructural development, improvement in the flowsheet, instrumentation, development of equipment, and



View of the dissolver and electrolyser along with the associated piping system

reduction in waste volumes were achieved in this complex technology, which is possessed by only a few countries.

U-Gd-Zr alloy slugs are being prepared for carrying out electrefining studies in the engineering scale demonstration facility. Electrochemical studies were carried out.

A computer code DIFAC (Diffusion of Actinides in Electrefiner) was developed as a part of modelling the electrefining process. Thermodynamic modelling of LiCl-KCl- UCl_3 system was carried out using the CALPHAD methodology.

In Demonstration Fast Reactor Fuel Reprocessing Plant (DFRP), an important milestone was reached with the installation of the dissolver. The installation of other important equipment and systems are nearing completion. It is planned to start the cold commissioning in December 2014.

Materials research for back end fuel cycle

Flux for Activated-TIG (A-TIG) welding of titanium, which is the material used for the dissolver vessel was developed and the procedure for A-TIG welding of 6 mm thick titanium plates was qualified as per ASME section IX.

Towards the development of SFRs with closed fuel cycle technology, metallic fuelled FBRs with co-located pyrochemical reprocessing plants were proposed and protective coatings such as

plasma sprayed partially stabilized zirconia coating were developed.

The corrosion behaviour of carbon materials under molten salt environment was investigated.

A pilot plant nitric acid loop with 400 litre capacity of 6N nitric acid was successfully operated for 10,000 hours to evaluate long term corrosion resistance and life estimation of reprocessing plant materials. An artificial neural network model for the corrosion process was developed using the large data bank obtained and life prediction values for components were computed.

A versatile monazite ceramic host for nuclear waste immobilization was prepared.

A single-cycle process was developed for extraction of Am and Cm and trivalent lanthanides from HLLW using an aqueous formulation of DTPA and citric acid.

Actinide extraction using Supercritical Fluid Extraction (SFE) technique for the recovery of uranium from the salt matrix was demonstrated.

R&D for Reprocessing

A novel method of treatment of solvent was designed and developed which will be tested in the CORAL facility for reducing the solvent waste volumes. This involves treatment of the used solvent with hydrazine carbonate. As the solvent gets damaged in the fast reactor spent fuel much more than that in the thermal reactor spent fuel reprocessing, this development would be of



System for assay of solid waste drums for fission products



Fuel cell service area piping

significant value addition.

A complete solid waste drum assaying system for accounting alpha as well as fission products was implemented in the CORAL facility. This has two sub-systems; one with ^3He detector based neutron monitors for assaying plutonium and other neutron emitting nuclides and the second one is with HPGe detector for assaying gamma emitting nuclides. With this setup, it was possible to completely assay the solid waste drums with surface dose of 2 mGy/h.

Sample handling (mobile) and capper-decapper (stationary) robots were provided for carrying out the sampling operation in a completely automatic fashion in the robot based sampling system. These robots are stepper motor controlled and are remotely operable. Both the robots operated in a preprogrammed sequence to accomplish the sampling task.

Fast Reactor Fuel Cycle Facility

The Fast Reactor Fuel Cycle Facility (FRFCF) is designed to meet the refuelling



Fast Reactor Fuel Cycle Facility Project Site

requirements of Prototype Fast Breeder Reactor (PFBR) currently under construction along with provisions in the design to expand the facility at a later date to cater to the reloading requirement of two more 500MWe FBRs. The financial sanction for the construction of project was accorded by Government of India and construction clearance from AERB was also received. Clearance from Ministry of Environments and Forests was obtained and clearance from Tamil Nadu Pollution Control Board is being received. Major civil tender packages were floated and a few of them are in the stage of awarding contract. Procurement action for long delivery items was initiated.

REPAIR & INSPECTION TECHNOLOGIES

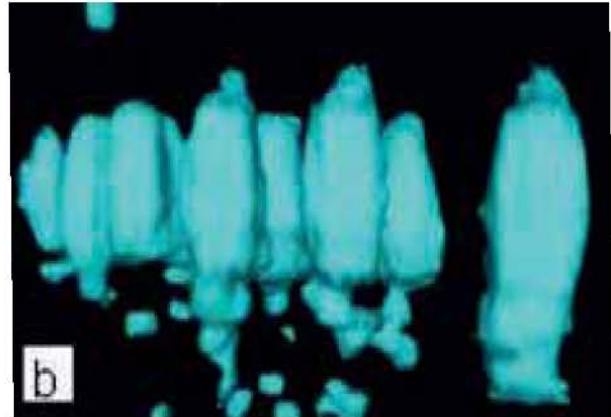
To reduce the inspection time with limited movement of transducers, guided wave based ultrasonic methodology was developed for ultrasonic inspection of main vessel welds. This technique can be used for quick inspection in thick stainless steel components.

For couplant-free high temperature ultrasonic examination, a spiral coil electromagnetic acoustic transducer (EMAT) capable of generating bulk wave modes was developed after 2-D hybrid finite element modelling. A plane polarised bulk wave spiral coil EMAT was developed. A stainless steel sample of 20 mm thick is used for examining the spiral coil EMATs.

A methodology with suitable software was developed for 2D/3D ultrasonic imaging as an alternative to the conventional XY raster scanning.



Elbows of different diameters

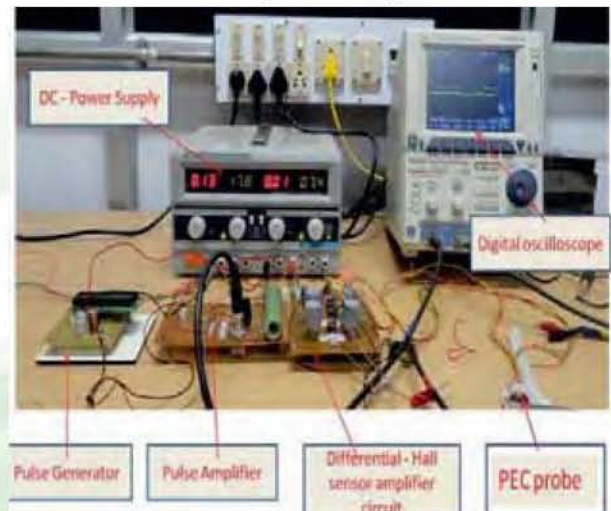


Under sodium ultrasonic 3D-image of a set of elbows of different diameters

GMR sensor based magnetic flux leakage technique was developed for non-destructive inspection of steam generator tubes.

Saturation based eddy current (EC) and magnetic Barkhausen emission (MBE) techniques were developed for electrochemical selective dissolution of mild steel patches from 9Cr ODS steel mother tubes.

For detection of sub-surface defects in thick stainless steel components, pulsed eddy current (PEC) technique was developed. A dedicated PEC instrument consisting of pulse generator, current driver circuit, probe, amplifier and display unit were also developed. The performance of the PEC technique to detect metal loss and defects in steel pipes covered with 8 mm thick non-conducting insulation has been experimentally verified.



PEC Instrument developed for detection of sub-surface notches

A digital X-ray radiography methodology was developed to assess the quality of friction stir welded (FSW) aluminium-zinc coated steel dissimilar lap joints. Digital frame integration and image processing with interpolation technique is used to improve the contrast sensitivity to sub-pixel resolution. Using this new approach, micro-pores and voids present in the FSW joint could be detected with good contrast and sensitivity.

For future FBRs, a reduced gap of about 200 mm between the stainless steel main vessel (MV) and ferritic steel safety vessel (SV) is planned to be used. In this context, experimental and simulation studies with proof-of-concept development were initiated to evolve a design of an in-service inspection vehicle for inspecting MV and SV from the reduced gap using the magnetic coupling principle. The magnetic field coupling with the ferritic steel SV could be effectively used to design a compact and novel vehicle to traverse the annular interspace. A four-wheeled vehicle was conceptualized and designed with the common rear-wheel traction. The simulation results and experimental studies carried out form the basis for the design of an inspection device for use in future FBRs.

HEALTH SAFETY & ENVIRONMENT

Reactor Safety

Seismic qualification tests were completed for several safety related systems and components. Notably, tests for long stem valves, VAT valves, gate valves for inclined fuel transfer machine and several instruments for shutdown systems were completed using 10 t shake table available at IGCAR. Prototype Diverse Safety Rod Drive Mechanism (DSRDM) along with Diverse Safety Rod (DSR) was tested and seismically qualified in water. Testing was done for both Operation Basis Earthquake (OBE) and Safe Shutdown Earthquake (SSE) conditions. Full insertion of DSR within the stipulated time and healthy functioning of DSRDM during and after earthquake have been demonstrated. Healthy functioning of DSRDM even after SSE indicated robustness of the design.



Diverse Safety Rod Drive Mechanism (DSRDM)

Radiological Safety

During the report period, the Radiological Safety Division provided efficient radiological surveillance and health physics services for the radioactive facilities of IGCAR (RCL, RDL, RML, FBTR). The Division has also been providing TLD personnel monitoring services covering 2000 occupational workers of IGCAR and BARC facilities, whole body counting - routine and special monitoring procedures for about 850 occupational workers belonging to various active labs of IGCAR and contract workers engaged in active facilities and bioassay services for over 200 occupational workers. In-situ testing of more than 50 HEPA filters was completed. Periodic updating of dose data in NODRS and personnel data along with the finger print and photograph of the radiation worker was also been completed. Accreditation for the TLD services was renewed by RPAD, BARC and Biodosimetry lab was accredited by AERB during this period. As part of increased radiological surveillance, six additional area gamma monitors were installed at various locations within the IGCAR campus and four autonomous gamma dose loggers and three gamma tracers were installed within the DAE complex at Kalpakkam.

As part of R&D in radiological safety, a set of site specific sodium aerosol release experiments in open environment were conducted and the physical /

chemical characteristics of sodium aerosol were analysed up to 1.0 km range. The results were analysed with dispersion codes for the impact assessment. For understanding the role of sodium aerosols in the cover gas region of fast reactor, sodium aerosol characteristics in the cover gas region of SILVERINA loop were carried out for various pool temperatures and at different levels. For the chemical exposure evaluation in the event of secondary sodium fire, chemical speciation of sodium aerosols were determined.

SF6 Tracer Dispersion Experiments were also conducted successfully to i) study the micro-scale dispersion around building complexes near BHAVINI site and ii) for studying the dispersion pattern and evaluation of site specific dispersion parameters, validation of Gaussian and particle models in open field.

As part of environmental and radiation emergency system, an extreme weather early warning system for Kalpakkam site was designed and installed for the prediction of cyclones and estimation of storm surge height near the site.

Apart from the above, counting and calibration facilities were also extended to various institutions involved in BRNS projects and industries in southern region. Irradiation of materials such as banana seeds from National Banana Research Center, Trichy and seeds from Annamalai University and fish samples from SRM University, Chennai were undertaken. Radiation awareness training programmes were conducted on periodic basis for the staff and also general public especially the students.

Environmental Safety

Studies on physiochemical, biological and geo-chemical characteristics of coastal environment (water, biota and sediment) were continued to meet Ministry of Environment & Forest (MoEF) regulation. Total trihalomethane (TTHM) formation studies at MAPS outfall indicated that the average TTHM content (50 ppb) was well within WHO limit.

Results of studies on bio-fouling organisms, phytoplanktons, zooplanktons and fish diversity in the coastal water indicated high diversity and high

density indicating the healthiness of the Kalpakkam coastal environment. Results of studies on dissolved heavy metal in Kalpakkam seawater indicated that the coastal water is not polluted with heavy metals. A new fish species to the world of fishery science has been identified and named as 'Scolopsis igcarensis', in recognition of IGCAR's contribution to marine diversity study.

Water quality studies on ground water samples from Kalpakkam region was carried out for fluoride and nitrate content. Ambient air quality monitoring at different places of IGCAR was continued to meet MoEF and AERB requirements.

Various industrial safety activities such as industrial safety training, first aid training, fire safety, road safety, contract workers training, occupational health survey of employees, training in height pass, introduction of safety induction card for contract workers, organization of safety promotional activities, submission of statutory reports to AERB, investigation and preparation of accident reports, maintenance of safety at construction sites, testing of material handling equipments were complied with as part of AERB requirement. Departmental employees and contract workers were trained in industrial safety to meet AERB statutory requirement. Portable fire extinguishers were maintained as per AERB regulations.



CHAPTER-3

NUCLEAR POWER PROGRAMME

STAGE-III





Test set-up for design qualification of graphite components

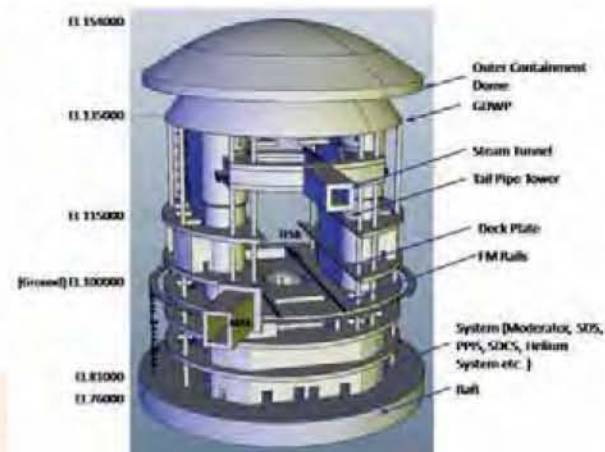
THORIUM BASED REACTORS

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

ADVANCED HEAVY WATER REACTOR

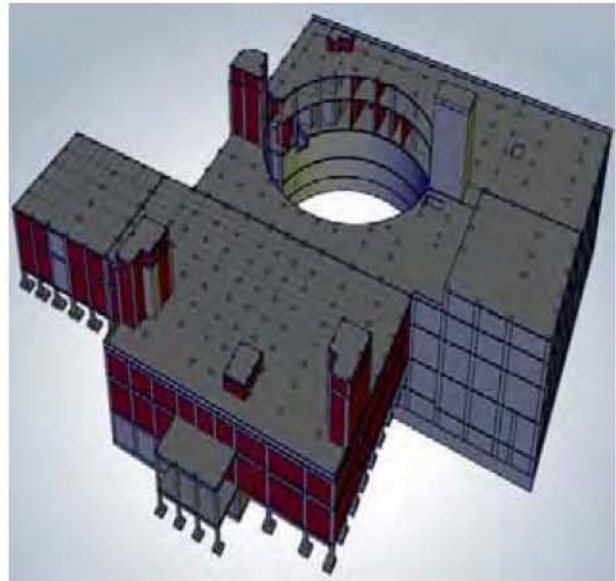
A major prerequisite for Advanced Heavy Water Reactors (AHWR) construction was achieved by way of compilation of Preliminary Safety Analysis Report (PSAR). Part-A of PSAR addressed the General Description of plant, Siting, Plant layout, Reactor System, Auxiliary Systems, Fuel & Fuel Handling, Turbine Generator (TG) & Electrical output system, Control & Instrumentation, Plant services, Radiation hazard control & radioactive Waste management, Reactor Physics & Shielding, Commissioning, Safety Management during operation, QA Programme, Decommissioning and end of life aspects and Nuclear Security. Part-B of PSAR addressed the transient and accident analyses.

3D CAD models of six major buildings were prepared using CATIA PDPLM software. Design

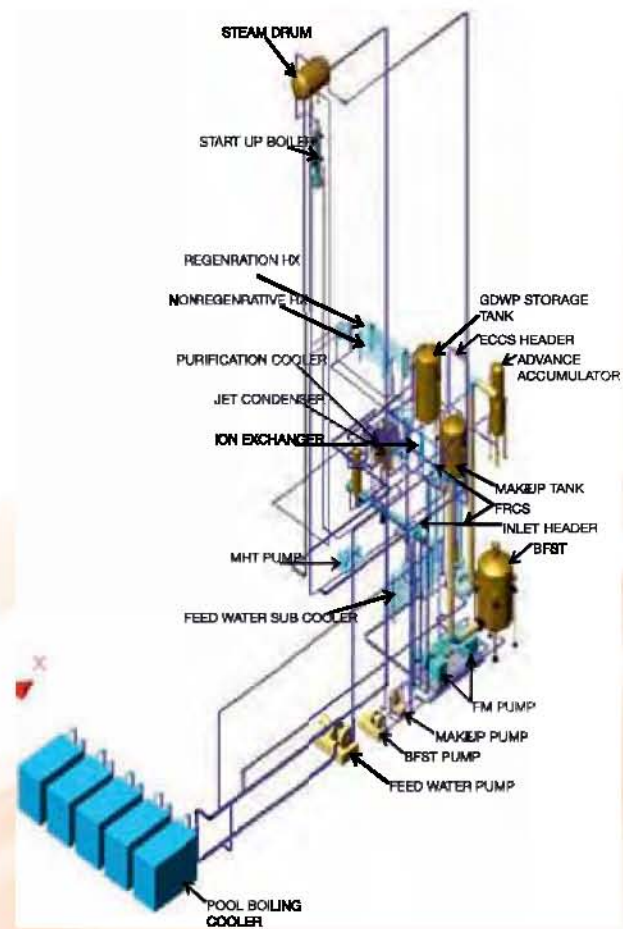


Reactor Building Model

Basis Reports, preliminary structural and seismic reports were prepared for each building.



Service Building Model



3-D Schematic of ATTF

AHWR Thermal Hydraulic Test Facility (ATTF) located in the facility PARTH: Facility for Proving Advanced Reactor Thermal Hydraulics jointly built by BARC & NPCIL at Tarapur fulfils the need to carry out experiments in a scaled facility simulating full length channels of AHWR.

ATTF is a scaled facility simulating the Main Heat Transport System, Emergency Core Cooling System (ECCS) and associated control of AHWR. ATTF simulates the same pressure and temperature conditions as in AHWR. The full height of AHWR as well as relative elevations of the Main Heat Transport System (MHTS) components such as fuel channels, steam drum and inlet header etc. are preserved in this facility. This ensures the natural circulation driving head in ATTF to be the same as that of AHWR.

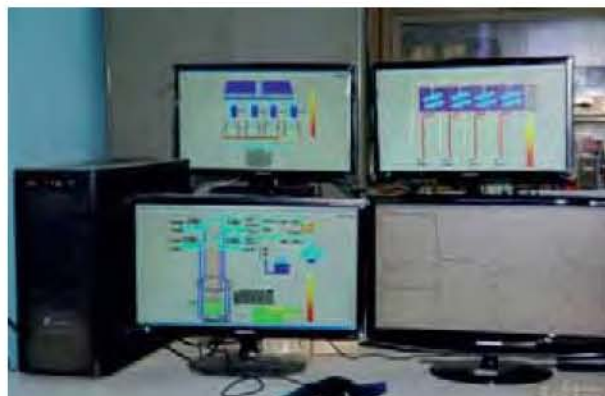
The Fuel Rod Cluster Simulators (FRCS) of ATTF, developed is highly instrumented and geometrically one-to-one replica of 54 fuel pin cluster of AHWR. The FRCS is electrically heated and can be individually powered up to 2.1 times the maximum channel power of AHWR (2.85 MW). Accident evaluations for scenarios like Loss of Coolant Accident (LOCA) involving in-bundle injection will also be performed in ATTF.

ATTF facility was inaugurated by the Hon. President of India and it has been commissioned.

To prove and establish the performance of critical components of the Fuel Transfer Equipment



1:4 Scale Model of AHWR Fuelling Machine for Seismic Testing



Plant analyser

located in Temporary Fuel Storage Bay (TFSB) of AHWR, a full scale prototype test setup was designed, manufactured, shop tested and commissioned at BARC.

A one - fourth scaled model of AHWR fuelling machine was designed and manufactured. Shake table testing of this model was carried out at Structural Engineering Research Centre (SERC), Chennai with simulated response spectrum of reactor site. Parameters important to seismic safety like toppling & skidding characteristics of FM, force transmitted to end fitting during clamped condition etc. were recorded during the test and addressed the uncertainties involved in analysis like non-linear friction characteristics at carriage & trolley wheel locations, behaviour of FM head while floating on the spring stack etc.

The plant analyser can handle operating transients as well as some important Design Basis Events such as Loss of Coolant Accident, Loss of Regulation Accident, loss of feed and failure of feed water temperature controller using on screen commands. An integrated console comprising of Main Heat Transport screen, Emergency Core Cooling System screen and Isolation Condenser screen were developed for AHWR.

Production trials with 1 kg batch of ThO_2 -13% UO_2 and ThO_2 -30% UO_2 pellets compositions were carried out for the development of fuel pellets for AHWR-LEU. Dissolution studies are being carried out to establish wet recycling of the fuel. Dry recycling route was developed.

Micro-XRF methodology using Synchrotron Radiation beam line at Indus-2 at RRCAT, Indore was used to assess the distribution of uranium and thorium in uranium-thorium oxide pellets.

Critical Facility for AHWR was operated on more than 60 occasions for various experiments which include measurement of level coefficient of reactivity. Reference core with 55 natural uranium fuel cluster assemblies had been extended to a core having 61 fuel assemblies by adding six natural U metal fuel cluster assemblies at peripheral lattice locations to augment the reactivity required for carrying out experiments with a cluster assembly consisting of thorium pellets. Criticality of the extended core was successfully achieved and observed moderator critical height matched fairly well with estimated critical height. Utilization of the facility was also continued for testing of fourteen nuclear detectors and irradiations of ten large volume samples for Neutron Activation Analysis (NAA).

A reversed phase (RP) High Pressure Liquid Chromatography (HPLC) based methodology was developed and employed for the separation and determination of Th, U and Pu in irradiated (Th,Pu)O₂ fuel using Mandelic acid as the eluent. Sample treatment conditions for conversion of all Pu to Pu(IV) and to minimize the loss of Th by hydrolysis were optimized.

A methodology for determination of boron in ThO₂ employing spectrophotometry with curcumin as a complexing agent was developed and validated employing Inter Laboratory Comparison Experiments (ILCE) standards of ThO₂ developed in BARC.

At IGCAR, irradiation of materials proposed to be used in Compact High Temperature Reactor (CHTR) being developed by BARC were completed to a neutron fluence of 10^{21} n/cm².

THORIUM FUEL CYCLE

Thorium metal powder has been produced for development of CERMET UO₂-Th fuel for AHWR. Th-3%U alloy, a prospective fuel for fast breeder reactors, was prepared using in-house produced uranium and thorium metals. Microstructure and

mechanical properties of the alloy were evaluated before and after ageing at elevated temperatures.

Kalpakkam MINI (KAMINI) Reactor

KAMINI reactor was in regular operation up to a maximum power of 30kW throughout, for neutron radiography of pyro-devices for VSSC / ISRO, calibration of neutron detectors from ECIL and activation analysis of samples from users. As part of Post-Irradiation-Examination (PIE), neutron radiography was carried out on the failed fuel subassembly of FBTR. Similarly neutron radiography was carried out on the fresh Pu-U-Zr sodium bonded metallic fuel pins to get pre irradiation data. A permanent set-up has been installed for high temperature testing of fission counters.

The pulse channels were replaced with electronic channels. Its performance is satisfactory. With this, all neutronic channels in KAMINI have been revamped with state-of-the-art channels and detectors. Installation and testing of Integrated Control and Instrumentation System developed by BARC and IGCAR is in the advanced stage of completion.

OTHER REACTOR SYSTEMS

The High Temperature Reactor HTR-10MW_{th} is being designed as a technology demonstrator of IHTR-600MW_{th} pebble bed reactor which is primarily being designed to produce heat at high temperature for the commercial hydrogen production. Analysis has been carried out to investigate the neutronic



Test set-up for design qualification of graphite components



ThC₄ microspheres prepared by sol-gel process

characteristics of cylindrical core pebble bed 10 MW_m HTR reactor design which is cooled by FLiBe, moderated and reflected by graphite. Parametric study shows that 17% and 19.5% enriched UO₂ fuel with 10% loading of TRISO fuel particles in pebble results in reasonably high burn-up, negative coolant void reactivity and low fissile inventory.

Graphite is proposed to be used as a structural material for in-core components of CHTR. Around 200 mechanical tests were carried out to generate the material database for design qualification of graphite components. The test data was used to arrive at the material reliability curve for 95% confidence level using the tensile test data. A computational code was developed to evaluate the probability of failure of graphite components. The outcome of this programme would lead to quantification of failure margins in graphite components under different modes of failure.

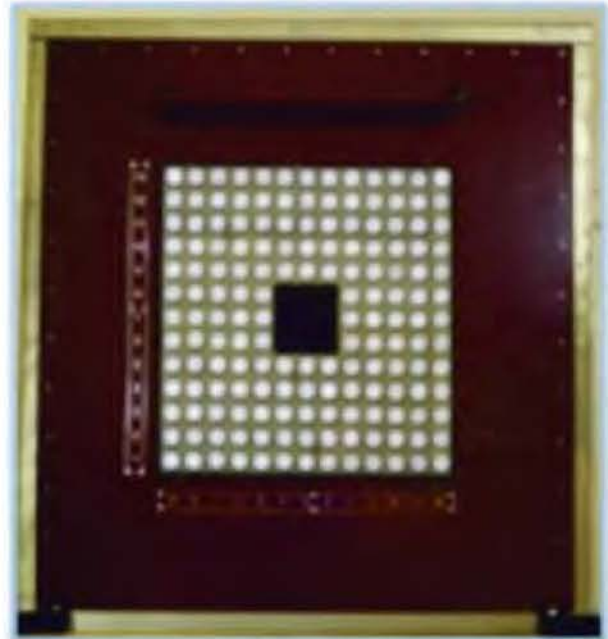
Sol-gel process was used for the fabrication of dense and high purity ceramic fuel ThC₂ in the form of microspheres. This process is safer compared to normal powder route since it eliminates handling of pyrophoric material. This contribution is important for CHTR programme.

Detailed project report for the XII Plan project 30 MW High Flux Research Reactor (HFRR) was prepared & design of various reactor systems is in progress. Work on overall layout of research reactors, fuel fabrication, reprocessing, waste management & other related facilities at Vizag progressed as per plan.

ACCELERATOR DRIVEN SUB CRITICAL SYSTEMS

A subcritical assembly driven by a D-D / D-T neutron generator was developed & commissioned at BARC for studying the dynamic characteristics of Accelerator Driven System. ADS Sub-critical core is coupled to the indigenously developed Purnima Neutron Generator.

In the field of neutron spectrometry, a new Monte Carlo based genetic algorithm has been developed to unfold both under-determined and over-determined problems. The advantage of this method is the independence of the final spectra from the initial guess spectra.



Subcritical core



Purnima Neutron Generator

The radiological safety aspects of proton irradiated Lead Bismuth Eutectic (LBE) were studied using the FLUKA Monte Carlo code. The results are expected to help the various ADS facilities using LBE as the spallation target.

MATERIALS

A control rod material, composite of $(Ti,Cr)B_2$ and 20wt.% $MoSi_2$ was successfully fabricated using $MoSi_2$ as the sinter additive for consolidation of $(Ti,Cr)B_2$. This material was qualified for control rod applications after successful in-pile tests. A consignment of 1200 of these special boron alloy pellets, segregated into 100 links was prepared, supplied and met all quality control parameters.

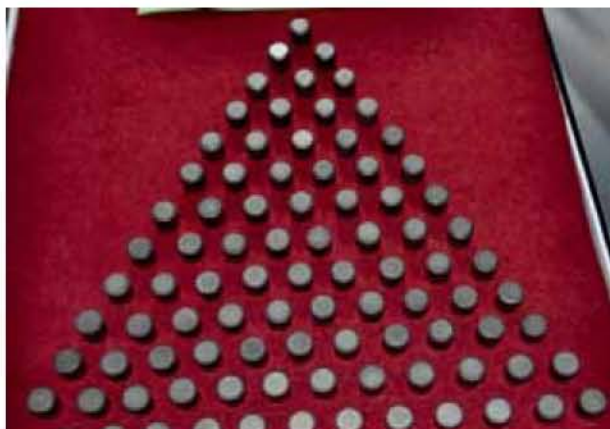
The supplied links were successfully tested and used at Emergency Protection Rods (EPR) setup of P-4 facility. Laser beam and electron beam welding of Nb-1Zr-0.1C alloy was carried out to standardize the fabrication techniques useful for CHTR components.

TRISO coated particle using natural uranium oxide as kernel in a single batch has been

developed. Initially, the experiments were conducted on surrogate zirconia and later extended to the uranium oxide kernel. The coating thickness as determined from simulations based on the coating kinetics matched well with that of the experimental results. Characterization of these TRISO coated particles is in progress to assess their suitability for CHTR application.

Graphite coupons were coated with silicon carbide at the lab scale using fluidized bed technique to demonstrate its feasibility and reproducibility.

A magnetic coupling based rotating disc corrosion test facility has been indigenously designed and fabricated in house for compatibility testing of various structural materials used for the fabrication of Indian Test Blanket Module with a liquid metal coolant Pb-17Li under various conditions of temperature and flow velocity. Compatibility of Indian Reduced Activation Ferritic Martensitic Steel (IN-RAFMS) and modified 9Cr-1Mo steel (P91) have been studied in this set up for up to 3000 h with Pb-



Boron Alloy Pellets



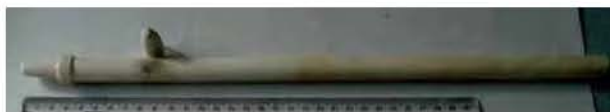
Cross-section of a TRISO coated fuel particle



3YSZ Components for use as end plugs in Heat Pipes (CHTR programme)



NiO-YSZ porous ceramic sleeves for use as liquid film breaking device



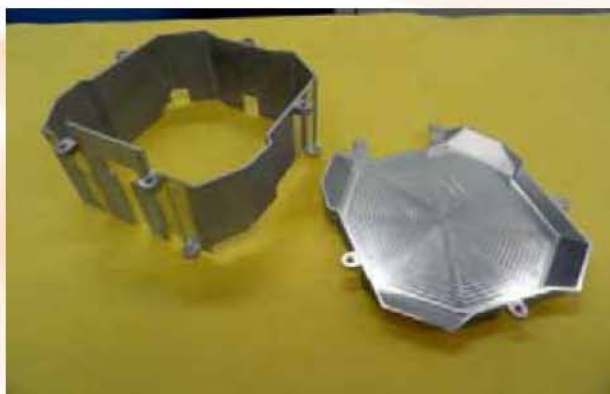
*8YSZ thimble (oxygen sensor) (left end)
joined with long alumina tube*

17Li eutectic at 823K. Under these conditions, an average corrosion rate of 0.022 mm/yr was observed for the IN-RAFMS disc sample rotating at 360 RPM.

Several ceramic components were fabricated in various shapes as per the user's requirement. About 800g of praseodymium metal with more than 99% purity was synthesised by fused salt electrolysis method. Lab scale success was obtained in preparing Nd-Fe and La-Ni master alloys by employing consumable cathode technique.

Polyethersulfone (PES) based beads impregnated with various solvents like Cyanex 923, D2EHPA, PC88A, TBP and Aliquat336 were prepared by phase inversion method and tested for rare earth separation from lean sources. Studies on separation of rare earths from various aqueous media such as chloride, nitrate, sulphate and phosphoric acid, employing various techniques such as ion-exchange, supported liquid membrane, emulsion liquid membrane and hollow fibre membrane were explored. Extraction of rare earths both by simple and functionalised multi walled carbon nano-tubes was investigated.

Preparation of intermediate product beryllium hydroxide for making beryllia ceramic continued with the standardized process and about 15 kg of hydroxide was prepared. A part of this intermediate has been converted into beryllia



Thermal Hood

ceramic intended for use in advanced APSARA reactor. Existing Rotating Electrode Process was automated for preparation of Be metal pebbles at a rate of 1.2 – 1.5 kg in a single shift using vacuum hot pressed Be as feed electrode.

A substantial quantity of beryllium scrap, generated during machining of beryllium components, was converted into useable beryllium by surface cleaning and the material was utilized for production of vacuum hot pressed beryllium

Thermal hoods are required to be used as heat extractor to control the temperature gradient inside the Laser operated Gyroscope of navigational and guidance system of space vehicle being developed at ISRO Inertial Systems Unit (IISU). Thiruvananthapuram. Twelve nos. of these complex-shaped components of special Al metal were fabricated and delivered.

HYDROGEN ENERGY

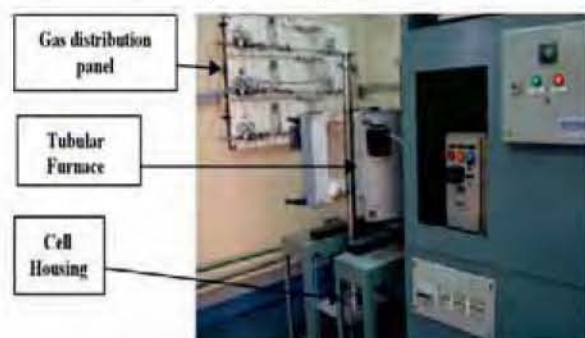
Pure and Yb-doped SrZrO₃ powders were prepared using glycine-nitrate combustion synthesis technique for potential applications in high temperature electrochemical cells, such as Solid Oxide Fuel Cell (SOFC) and oxygen sensors. The process parameters were optimized to achieve near theoretical density after sintering. The microstructure



High pressure SS reactive distillation setup



Compact electrolyser module



Testing facility for SOEC (Solid Oxide Electrolyser Cell)

and electrical property (conductivity) of sintered component under various operating atmosphere have been found to be stable over prolonged hours of test.

High pressure H_2 reactive distillation in SS system for hydrogen production by thermo-chemical water splitting is installed and mechanical testing completed. The system is designed to demonstrate process feasibility at real time system and subsequent High pressure tantalum lined system procurement is in the pipe line. Performance evaluation with surrogate material is initiated.

Fabrication and installation has been completed for compact electrolyser for on demand high purity oxygen production unit.

A test set up was developed for performance evaluation of tubular solid oxide electrolyser cell at high temperatures. A single cell (50 cm² active area) was tested at 950 °C in fuel cell mode and open circuit voltage was measured.

MATERIALS AND TECHNOLOGIES RELATED TO FUSION REACTOR

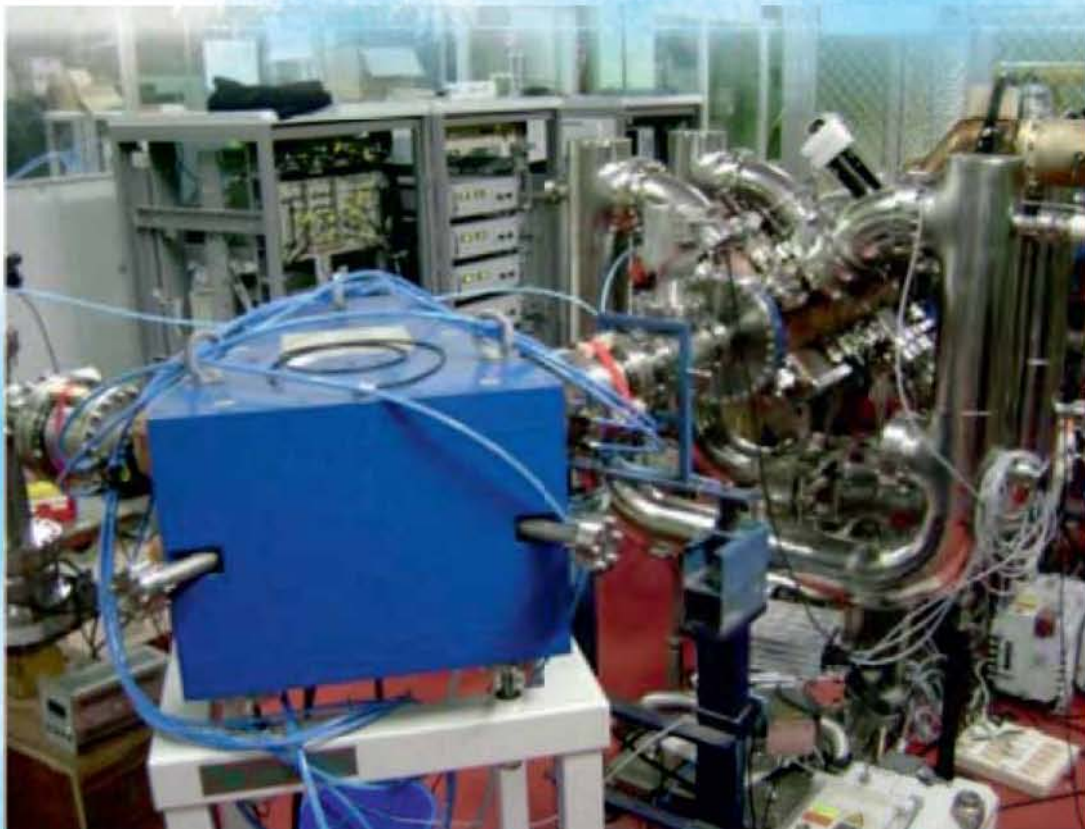
At IGCAR, effects of tungsten and tantalum contents on Impact, tensile, low cycle fatigue and creep properties of Reduced Activation Ferritic Martensitic (RAFM) steel were studied with a view to develop India-specific RAFM steel as a structural material for the Test Blanket Module (TBM) for testing in ITER. RAFM steel having 1.4 wt% tungsten and 0.06 wt% tantalum was found to possess optimum combination of impact, tensile, low cycle fatigue and creep properties and is considered for Indian fusion technology.

The transformation temperatures and kinetics of the ferrite austenite ferrite transformation was studied in the indigenously developed IN-RAFM steel. The variation of A_c and A_{c_2} , the austenite start and finish temperatures with heating and cooling rate were studied using Differential Scanning Calorimetry technique.

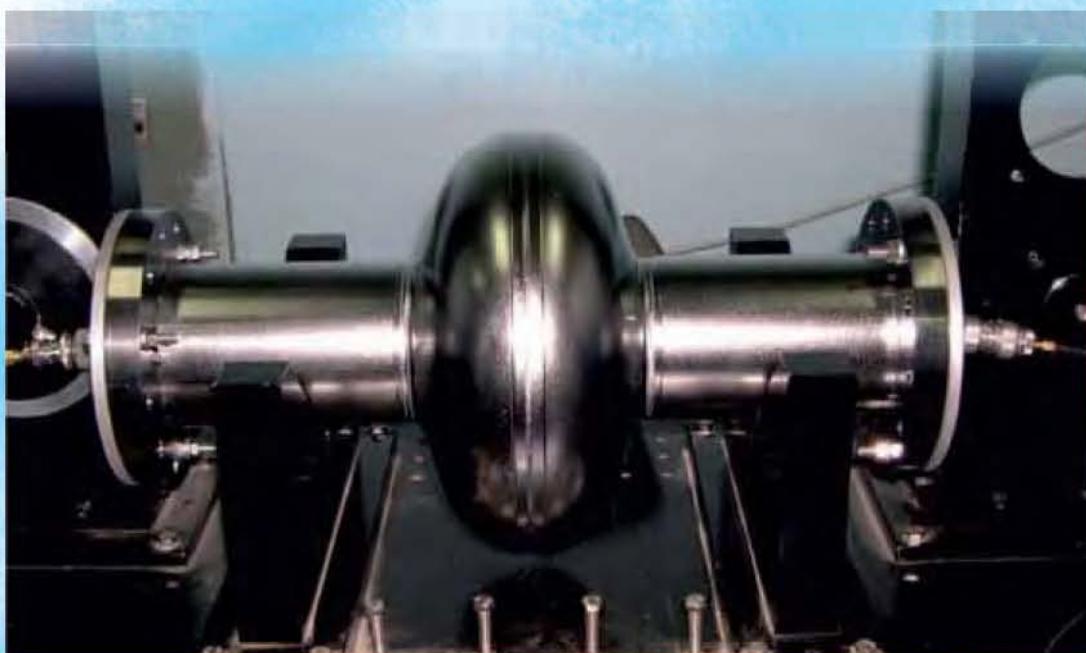


CHAPTER-4

ADVANCED TECHNOLOGIES AND RADIATION TECHNOLOGIES AND THEIR APPLICATIONS



A BARC designed & developed RFQ test line with analysing magnet



**World's first laser-welded single-cell 1.3 GHz niobium
SCRF cavity developed at RRCAT**

Advanced technologies and radiation technologies development and their applications, is one of the major programmes of the DAE's research organizations such as BARC, Mumbai, IGCAR, Kalpakkam, RRCAT, Indore, VECC, Kolkata and the industrial organization BRIT, Mumbai.

These organisations have developed a number of advanced technologies, hi-tech facilities and various sophisticated equipments over a period of time under this programme. 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.

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

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

RESEARCH REACTORS

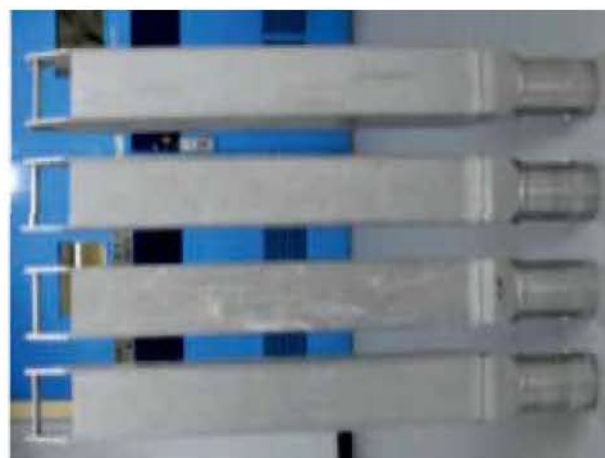
APSARA

Work on up-gradation of APSARA reactor to a 2 MW reactor progressed as planned. Safety Review of design basis reports & Preliminary safety Analysis Report is nearing completion. Procurement of various equipment and components was in progress.

A plate fuel development and fabrication laboratory was commissioned to cater to the fuel requirements of modified APSARA core and for the upcoming research and test reactors utilizing dispersion type plate fuel. The facility is in full operation and LEU (Low Enriched Uranium) is processed on a regular basis to fabricate U_3Si_2 dispersed in aluminium matrix and with Al-alloy clad plate type fuel elements. Till the time of preparing this



LEU fuel plates



Prototype fuel assembly

report, around 70% of the total fuel requirement for modified APSARA core has been accomplished.

The above mentioned plate fuel fabrication facility has also been utilized to prepare fuel plate elements with natural uranium based U_3Si_2 dispersed in aluminium matrix and with Al-alloy clad as part of technological demonstration for HFRR.

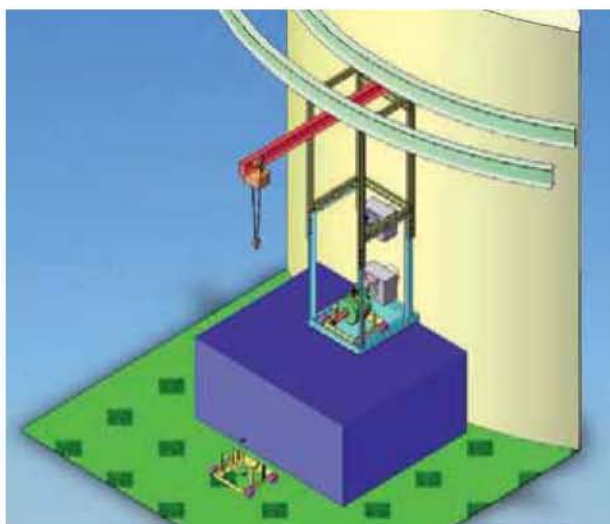
CIRUS

The reactor remained permanently shut down with de-fuelled core. Twelve irradiated Thoria rods were transferred for reprocessing. The whole moderator inventory was removed from the system and transferred to Dhruva for further utilization and for up-gradation. Reactor systems were maintained in preservation mode. Preparatory work towards planning of phase-wise decommissioning of reactor had been started.

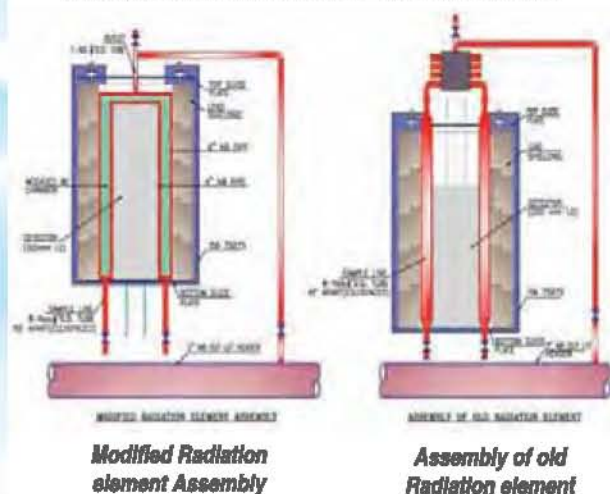
DHRUVA

DHRUVA continued to be the only facility for radioisotope production and national facility for neutron beam research. The reactor was operated at 50 MW_{th} till June. Subsequently reactor power was raised in steps up to 70 MW_{th} by August. Around one thousand samples were irradiated in tray rods for radioisotope production and fifty samples were irradiated in Pneumatic Carrier Facility as per the requirements of the users for neutron activation analysis. 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.

Two self-serve facilities were provided in Dhruva Reactor for irradiation of sample for a few



Hanging-Platform for handling sample receiving cask



Modified Radiation element Assembly

Assembly of old Radiation element

hours. A Hanging-Platform for handling the sample receiving cask was designed, fabricated and installed after design review and seismic evaluation. Sample receiving cask & sample discharge facility was modified to suit the site conditions. The facility was made available for use after successful trial operation using a dummy sample.

To improve the sensitivity for detection of fuel failure in Dhruva, one old radiation element was replaced with a modified element (annular type mixing chamber). Based on the feedback on performance, replacement of the existing chambers with the modified chambers in a phased manner was taken up. Eight chambers were replaced with new ones.

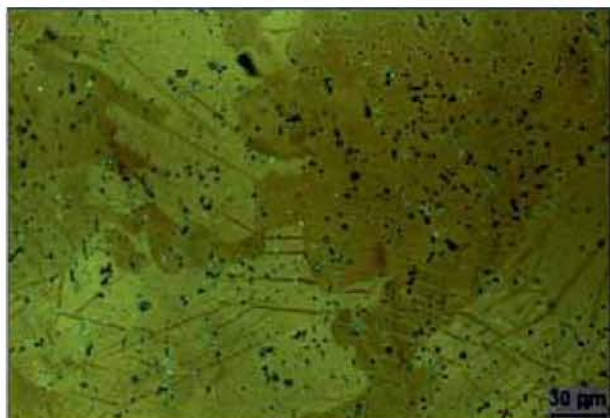
3-pitch long Inconel SPND (developed by NPCIL for 700 MWe PHWRs) with Inconel and Platinum clad Inconel as emitter was calibrated in beam hole-HS-3018 of Dhruva with periodic monitoring. Master Slave Manipulators of Dhruva were replaced as a part of Up-gradation process. Installation and testing of transmitters, switches and panels for "Supplementary Control Panel" was completed. Newly developed computer based (TPLC-32) Alarm Annunciation System was commissioned. The replacement of old heat exchangers with new heat exchangers was completed. The performance of the new heat exchangers was found to be satisfactory. Both the 20 kVA old inverters were replaced with new ones. One additional 20 kVA inverter was also commissioned to improve availability of class II power supply.

Post Irradiation Examination was carried out on Dhruva fuel Assembly C-4246 inside the hot cells. Gamma scanning was accomplished to analyze the burn-up profile. Microstructures were observed under microscope to see the effect of irradiation.

Metallographic samples were examined from irradiated fuel pin. Examination revealed an irregular surface of the fuel rod. Deformation twins and inclusions were observed in the uranium fuel. The fuel cross section and microstructure are shown below. The burn up of Dhruva fuel assembly was calculated using gamma activity emitted by Cs¹³⁴ and Cs¹³⁷. The non-destructive ratio method estimated the burnup to be 1800 MWD/TeU.



Dhruva fuel pin cross section U-rod and Al clad



Microstructure of irradiated Dhruva fuel

Development of a risk-informed methodology for identification, prioritization and assessment of safety significance of structures, systems and components (SSCs) in nuclear power plants was carried out to postulate the risk of an individual SSCs participating in an accident scenario.

Work on an IAEA project on writing of an IAEA Safety Report Series on 'Application of Probabilistic Approach to Research Reactors' was carried out. India was appointed as the lead country in this project and other contributors were Argentina, Brazil, and South Africa.

A nodal method based diffusion theory code has been developed and benchmarked with a number of benchmark problems related to square and hexagonal reactor cores. A good agreement

between the reported results and that of RPNES code was achieved. A Three Dimensional Gamma Shielding code based on point kernel method was developed for assessing shielding requirements against fast and thermal neutrons. Towards improving the operational flexibility and radioisotope production, feasibility study for installation of an Adjuster Rod assembly in engineering loop position G-19 of Dhruva reactor, was carried out.

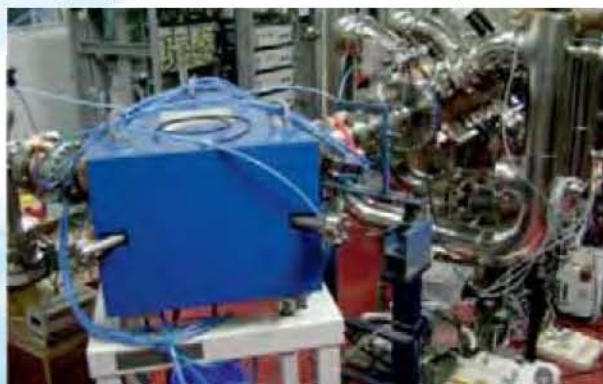
High Flux Research Reactor

Detailed project report for the XII Plan project 30 MW high flux research reactor was prepared & design of various reactor systems of HFRR is in progress. Work on planning the overall layout of Research reactors, fuel fabrication facilities, reprocessing facilities, waste management facilities & other related facilities in zone 3 of BARC facilities at Vizag recorded good progress.

ACCELERATORS

At BARC, the indigenously designed and developed 400 keV, 4 vane Radio Frequency Quadrupole (RFQ) was commissioned in pulsed mode by accelerating D^+ beams to 400keV with a transmission efficiency of about 95%, which is in agreement with simulations. Technologies such as RF power coupler and high-power RF system were developed indigenously and beams of protons (H^+) and H^{2+} were accelerated. Installation of LEHIPA sub-systems is in progress.

A 10 kW, 352.21 MHz RF solid state power amplifier for buncher cavity of LEHIPA MEBT was designed, developed and tested for its specifications.



RFQ test line with analysing magnet



A coaxial coupler developed & used upto 60 kW during beam acceleration from RFQ



Test setup of 325 MHz, 7 kW RF amplifier

Efficiency achieved was 65% and overall system gain was around 85 dB. Under Indian Institutes and Fermi Lab Collaboration (IIFC), a 7 kW RF amplifier at 325 MHz was designed, developed and tested up to its designed value of 7 kW. Efficiency achieved was 69% and overall system gain was around 90 dB. Design of 250 kW RF couplers for LEHIPA was completed.

DC electron accelerator was used for development of flue gas treatment process for pollution control in collaboration with BHEL Ranipet. The accelerator consists of an electron gun, a pressure vessel, high voltage column, scanning & beam extraction device and the control system. Electrons are emitted from the indirectly heated



3m tall accelerating column to generate electron beam of 3MeV energy



40 mm dia electron beam exits the high vacuum horn through titanium foil



Emittance meter connected to ion source

lanthanum hexaboride cathode by thermionic emission and get accelerated in a vacuum of 10^{-6} mbar to 1 MeV energy over 3 meter length. Electron

beam is then magnetically scanned and extracted from vacuum to atmosphere through a 50 micron thick titanium foil. Flue gas reactor also has a titanium foil window for entry of electron beam. In this dry process, electrons act as catalysts for oxidation of pollutants and their reaction with ammonia to form ammonium sulphate and ammonium nitrate.

Indigenous design and development of Kilo Ampere Linear Injector of 30 GW pulsed electron accelerator (KALI-30GW) having 1 MV bipolar charging Marx Generator followed by triaxial pulse forming line (Blumlein) was completed.

An in-house developed Relativistic Electron Beam (REB) gun was employed for High Power Microwave (HPM) generation for Intentional Electromagnetic interference (IEMI) investigations



1MV, 30kA, 80ns Pulsed e- Accelerator



100kV UWB source with antenna

and hardening of critical electronics circuitry and control systems. It is capable of producing hard Flash X-rays (FXR) of dose 2R@window for radiography of thick stainless steel, lead or tungsten which are opaque for soft X-rays and neutron radiography.

An Ultra Wideband System for EMI studies was developed. It consists of a MARX generator, a

pulse forming line and a radiating antenna. 30kV high voltage uni polar power supply is used for charging of the Marx generator. A wideband TEM horn antenna is used to radiate the pulse generated by the source. Antenna is designed to produce a gain of about 6dB at 200MHz frequency.

High Power Solid State RF Amplifiers for Indus-2

At RRCAT, the total installed RF power of in-house developed solid state RF amplifiers integrated with three RF stations on Indus-2 was increased to 225 kW. This is the highest power of solid state amplifiers operating at 500 MHz frequency operating in round-the-clock mode and has eliminated our dependence on imported klystrons.



High power solid state amplifier stations installed in Indus-2 RF area

Development of IOT based RF Amplifier System at 505.8 MHz

An IOT based 80 kW CW RF amplifier system operating at 505.8 MHz was developed for the Indus-2 RF system. It operates with a 36 kV, 24



505.8 MHz IOT amplifier



36 kV, 24 Amp DC power supply

Amp DC power supply. The amplifier was tested up to 60 kW RF power with wall plug efficiency greater than 55% and gain of 23 dB. This power supply was indigenously developed with series connection of IGBT based power modules each providing 500 V output. The outputs of these power modules were suitably staggered to minimize the ripple filter requirement avoiding the expensive crowbar for protecting the IOT amplifier.

Laser-Welded Superconducting RF Cavity

A new technology of laser-welding of niobium superconducting cavities was developed and successfully demonstrated. This technology, developed for the first time in the world, offers many practical advantages over the conventional electron beam welding technology especially as it permits welding in an inert gas atmosphere instead of vacuum. The first laser-welded single-cell 1.3 GHz niobium cavity was tested during this year and has achieved an excellent acceleration gradient of 31.6 MV/m with a high quality factor of 10^{10} at 2K.



World's first laser-welded single-cell 1.3 GHz niobium SCRF cavity



10 kW fiber coupled Nd:YAG laser

Commissioning of Vertical Test Stand (VTS) Facility for SCRF Cavity Qualification

A vertical test stand (VTS) facility for testing the performance and characterization of superconducting RF cavities at 2K was commissioned. Its cryostat has a liquid helium capacity of 2900 liters. The cryostat was successfully cooled down to a temperature of 1.86 K during commissioning and a single-cell 1.3 GHz SCRF cavity was tested using an in-house developed RF system. The VTS cryostat is designed to test superconducting cavities ranging from 325 MHz low beta spoke resonators to nine-cell 1.3 GHz cavities and five-cell 650 MHz medium and high beta cavities. The cryostat has an overall dimension of 1400 mm diameter and 5500 mm length with a clear testing aperture of 860 mm. A 200W 1.3 GHz RF system was indigenously developed to supply the required CW power for testing of the SCRF cavities in the VTS.



The VTS facility for characterization of SCRF cavities and RF instrumentation

Development and Testing of a Blade Tuner for SCRF Cavity

A blade tuner was designed and fabricated to study the issues related to the slow and fast tuning mechanism required for superconducting RF (SCRF) cavity. A prototype nine-cell 1.3 GHz normal conducting, dressed copper cavity was fabricated and integrated with tuner for testing the sensitivity, stiffness, hysteresis, resolution and precise control of the tuner. A tuning sensitivity of 320 kHz/mm and hysteresis of 35 μ m were measured during room temperature testing which matched closely to the design parameters. The tuner was also tested with piezo actuators which are required for fast tuning control of the cavity frequency.



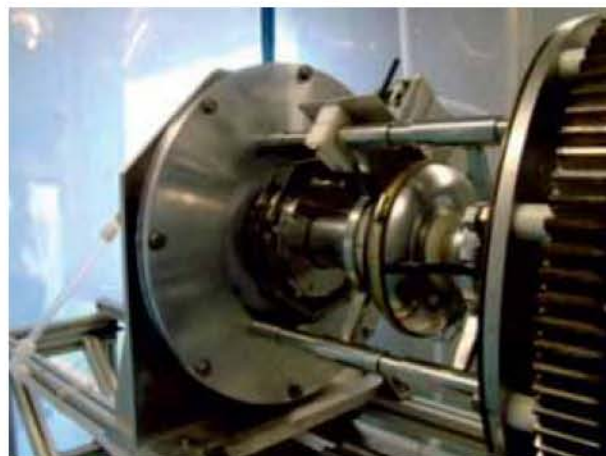
Blade tuner integrated with 1.3 GHz prototype dressed cavity

Polishing of 1.3 GHz Single Cell SCRF Cavity

A Centrifugal Barrel Polishing (CBP) machine, Electro-Polishing (EP) setup and High Pressure Rinsing (HPR) station have been set up. To develop the cavity processing recipe and generate required experience, a 1.3 GHz single-cell SRF cavity fabricated indigenously was polished using these facilities. As a first stage of processing, the cavity was mechanically polished for a maximum of



Cavity on CBP machine



Cavity on electro-polishing setup

105 micron using centrifugal barrel polishing (CBP) machine. The cavity was barrel polished for 100 hours with various media including 50 hours continuous polishing by a 0.04 micron colloidal silica solution. After the barrel polishing, the cavity was chemically polished by electro-polishing.

Development of Optical Inspection Bench for 1.3 GHz 9-cell cavity

A system was developed for optical inspection of the internal surface of 1.3 GHz superconducting RF cavities. The optical inspection bench comprises of two major sub-systems, Optical imaging system and Cavity positioning system. The system provides a resolution of 40 μ m. The system is being regularly used for the inspection of 1.3 GHz cavities. It serves as an import substitute for similar systems used in other international accelerator labs.



Niobium five-cell 1.3 GHz SCRF cavity being inspected on optical inspection bench



Plate-fin heat exchanger for indigenous helium liquefier

Development of plate-fin heat exchanger for indigenous helium liquefier

RRCAT had earlier developed the first indigenous helium liquefier in the country in August 2010. An aluminum plate-fin heat exchanger was developed indigenously with the rating of 64 kW. This will be used to enhance the liquefaction rate from 20 liter/hour to 50 liter/hour.

Development of 1 kW ferrite circulator for RF system of Accelerator

Bismuth doped calcium vanadium garnet (Bi-CVG) with an excellent temperature stability of magnetization, narrow resonance line width and high spin wave width combined with desired Curie temperature were developed. Various geometries of circulator were simulated for achieving the design parameter at desired frequency of 505.8 MHz. A coaxial stripline ferrite circulator was designed & fabricated with these discs and tested at 1 kW. A low insertion loss & high isolation at 505 MHz was achieved.



Indigenously developed ferrite resonator discs



Stripline ferrite 3-port circulator

Power Supplies for Fast Global Orbit Correction in Indus-2

Power supplies for energising 16 combined function corrector magnets in Indus-2, having two coils per magnet were made and installed. These power supplies are being used for global fast orbit correction in Indus-2 ring.



Power supplies for fast corrector magnets for Indus-2

Development of Power Supplies for IRFEL Beam Line Magnets

Power supplies for various magnets in the beam line of IRFEL project were developed. These are low power units rated for 13 A/ 15 V maximum with ± 100 ppm stability requirement of the output



Power supply for IRFEL beamline magnets

current. Power supply design was standardized on a standard 6U card with full-function feedback control and local-remote operation interface electronics on the same card. Five such power supplies are housed in one 6U, 19-inch rack.

Development of Travelling Wave Electron Linac

A travelling wave (TW) 10 MeV electron linac is being developed with the aim of having maximum indigenization of linac technology. The physics and engineering design as well as manufacturing, RF measurements and tuning of a prototype linac



Developed prototype 5 MeV TW electron linac

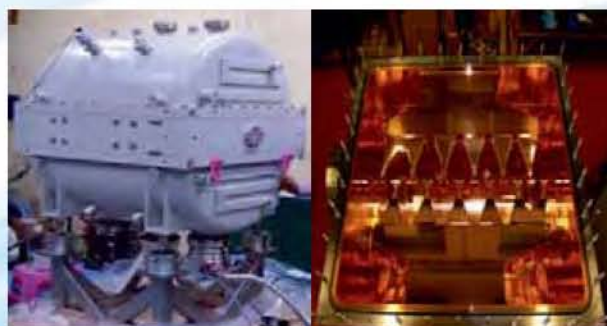
accelerating structure are completed in-house. All other sub-systems including RF, vacuum, controls and test vault are also developed and integrated with the linac. At the present stage, the developed accelerating structure accelerates the electron beam to 5 MeV energy, and more stages are being added to take it to the design energy.

Radioactive Ion Beam (RIB) of ^{111}In produced at VECC

Radioactive ion beam of ^{111}In (Indium-111) were recently produced at VECC RIB facility. Earlier, RIBs of ^{14}O (71 sec), ^{42}K (12.4 hrs), ^{49}K (22 hrs) and ^{41}Ar (1.8 hrs) were produced. Radioactive indium isotopes were first produced by bombarding natural silver target with 30 MeV, 400 nA alpha particle beam from the K-130 cyclotron. After radio-chemical separation, about 200 micro-curie ^{111}In chloride was deposited on an aluminum electrode and inserted in the plasma chamber of the 2.4 GHz ECR ion-source of the RIB facility. Indium ions produced by ion induced sputtering in the plasma were extracted from the ion-source, isotopically separated and a pure ^{111}In beam was measured at the focal plane of the separator.

High power test of fourth heavy-ion Linac cavity

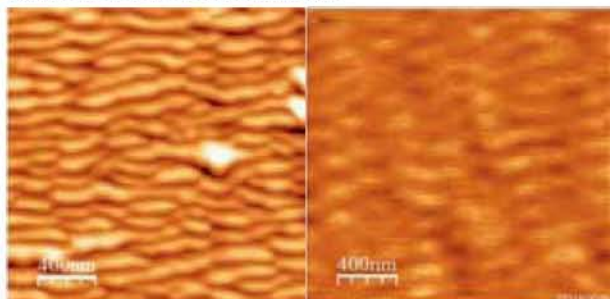
The beam energy in the RIB facility is 413.9 keV/u presently which is achieved using a RFQ linac and three heavy-ion Linac cavities. The fourth Linac cavity that will further accelerate the beam to 717.8 keV/u was recently commissioned and high power tests at 2 kW cw power have been successfully conducted. The Linac is designed for a resonant frequency of the 75.6 MHz.



The fourth IH cavity (left) and the details of the central rectangular frame (right) showing the two ridges and the drift tubes.

Material Science experiments using beams from RIB facility

Inducing ferromagnetic ordering at room temperature in wide-band gap semiconductors, particularly in ZnO and TiO₂ is very important from their potential application in opto-electronic and magneto-optic devices. Room temperature ferromagnetic ordering was induced in rutile TiO₂ polycrystalline sample after 4 MeV Ar⁸⁺ ion irradiation. The Ar⁸⁺ ions were produced in the Electron Cyclotron Resonance (ECR) ion-source and accelerated to 100 keV/u in the 3.2 meter long Radio Frequency Quadrupole (RFQ) Linac of the VECC-RIB facility. In another study, the role of carbon as target as well as projectile for nano-pattern formation on carbon film and Si (100) surfaces was studied by argon and carbon ion beams.



(Left) nano-ripple produced on carbon produced by 8 keV Ar⁸⁺ beam (Right) ripple on Silicon produced by 8 keV C⁶⁺ beam.

Superconducting electron linac development activities

The ANURIB (Advance National facility for Unstable and Rare Isotope Beams) project at VECC will be using a 50 MeV, 100 kW cw superconducting electron linac (e-Linac) as photo-fission driver for production of neutron-rich radioactive ion beams. A 10 MeV injector for the e-Linac is presently being developed in collaboration with TRIUMF Canada.

The ICM has been jointly designed by the VECC and TRIUMF team and is being fabricated in local industry in Vancouver area. Under the VECC-TRIUMF MoU two ICM cryo-modules will be made and tested at TRIUMF, one for each lab. The ICM for VECC is scheduled to arrive at VECC in middle of 2014. The niobium cavities for the ICM will be made jointly by TRIUMF. First batch of cavities have been made and passed rf benchmarking tests at TRIUMF

as well as at Fermilab. For testing of the two ICM cryo-modules at TRIUMF, a VECC e-Linac test area has been set-up.

LASER TECHNOLOGY

Development of a High Power OPCPA based Nd: Glass Laser

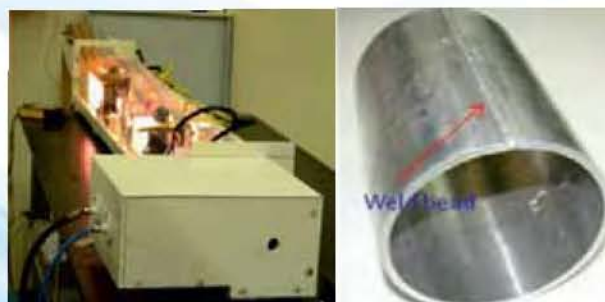
An OPCPA (optical parametric chirped pulse amplification) based Nd:glass laser system of 40 TW peak power was developed at RRCAT. An overall gain of the amplifiers in excess of 10¹⁰ was achieved. The laser system has a 100 fs laser oscillator, pulse stretcher, single pulse selector, multistage optical parametric amplifiers (OPAs), water cooled Nd:phosphate glass laser rods acting as power amplifiers in a linear geometry, spatial filter cum image relay cum beam expander systems, permanent and pulsed magnet Faraday isolators, beam optics, and finally a large aperture tiled pulse compressor.



Optical pulse compressor of 40 TW Nd:glass laser system

20 kW Peak Power (1 kW average power) Industrial Nd:YAG Laser

A prototype model of 20 kW peak power (1 kW average power) industrial Nd: YAG laser with dual-port fiber optic beam delivery was developed.



Prototype model of 20 kW peak power industrial Nd:YAG laser (left)
Laser welding of 4 mm thick aluminium tube (right)

Welding of titanium and aluminum up to a depth of 4 mm with good surface smoothness and drilling in hematite concrete up to a depth of 80 mm was demonstrated using this laser. The laser will have applications in the decommissioning of RCC walls of power reactors as well as in deep penetration welding.

Development of a 200W All-Fiber Laser

A 200 W rugged all-fiber single transverse mode Yb-doped CW fiber laser-amplifier system was developed. This has been used for cutting of 2.5 mm thick stainless steel with a kerf width of less than 100 μm .



200 W all-fiber Yb-doped CW fiber laser



Compact capillary discharge soft x-ray laser

Capillary Discharge based Compact Soft X-ray Laser

A compact soft x-ray laser based on a capillary discharge set up was developed. This laser is operated at 300 kV, 40 kA current with a current rise time of 27 ns. X-ray laser pulse energy of 3.4 μJ was measured at 46.9 nm wavelength.

Nd:YAG Laser for Defense Application

A prototype model of a Nd:YAG laser operating in cw mode was developed for indigenization of the laser radiator of missile firing system of T-90 tank. The laser was tested at Opto-Electronics Factory, Dehradun and it met the military standards.



Nd:YAG laser for missile firing system

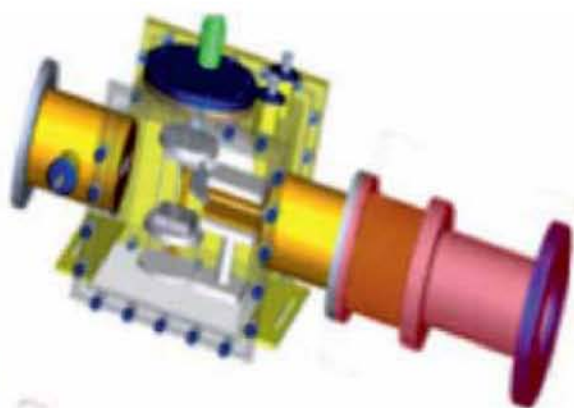


Computer controlled fiber bragg grating (FBG) inscription set-up

Computer Controlled Fiber Grating Inscription Set-up

A computer controlled fiber Bragg grating (FBG) Inscription set-up utilizing high repetition rate (5.5 kHz) 255 nm laser radiation generated from the second harmonic conversion of 510 nm radiation of copper vapour laser is developed.

At BARC, a high resolution and high dispersion Thomson parabola spectrometer (TPS) with time-of-flight unit was developed for characterization of ions produced in laser generated plasma and to calculate the hydrodynamic parameters. Energies of the C^{-1} to C^{-6} ions were measured from Thomson parabola in the energy range 300 keV to 3 keV and verified by time-of-flight measurement. A supersonic gas jet target assembly has been set up in a vacuum chamber with pressure in the range 10^{-6} torr. These gaseous targets will be used for laser plasma interaction experiments such as particle acceleration, incoherent x-ray generation and higher harmonic generation.



Schematic design of the TPS

Laser Applications

Laser-Driven Ion Acceleration

At RRCAT, experiments on ion acceleration were carried out using a 10 TW Ti: Sapphire laser focused to a particular intensity showed highly



Quasi-mono-energetic gold ions of different charge states (Au^{-1} to Au^{7+}) observed in ultra-intense laser plasma interaction.



Experimental setup for cooling and trapping of Kr atoms

repeatable, mono-energetic, multi-species gold ion emission from gold-carbon co-sputtered nano-composite samples on silicon substrate. Formation of high energy neutrals and negative ions in interaction of high intensity laser pulse interacting with solid targets was observed for the first time. In the case of thin foils, negative ions were observed both from the front as well as the rear surface.

A Magneto Optical Trap (MOT) for metastable Krypton

A Magneto Optical Trap (MOT) setup to cool and trap noble gas Krypton atoms in the metastable state was developed and made operational. This was the first successful demonstration of a noble gas (^{84}Kr) atom trap in the country. Nearly 105 atoms of Krypton at temperature of 300 μK were trapped in the MOT chamber using suitable configuration of laser beams and magnetic field.

Angle Independent Flow Velocity Measurement using Dual Beam based Fourier Domain Doppler Optical Coherence Tomography Setup

A single detector based phase resolved spectral domain Doppler Optical Coherence Tomography (DOCT) setup was developed to measure angle independent Doppler measurement of flow velocity.

Fabrication of Titanium Structures with Different Porosity using Laser Rapid Manufacturing

Ti-structures with different porosity and engineered mechanical properties were fabricated by the laser rapid manufacturing technique using a 2 kW fiber laser. These structures have potential



Fabrication of titanium structures with different porosity using the laser rapid manufacturing technique

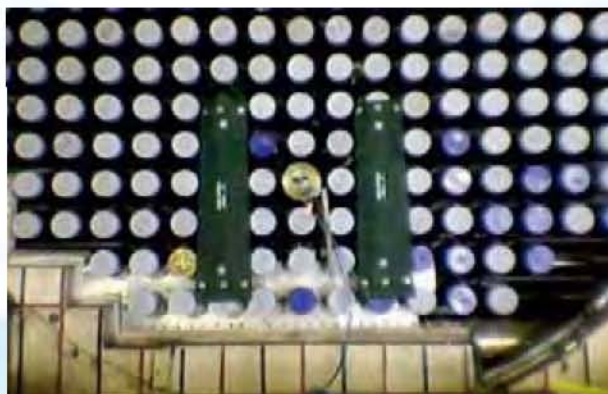
application in making customized prosthetic components.

Laser Shock Peening of Reactor Components for Improving Material Strength

Laser shock peening on ZrNb alloy was carried out using a pulsed Nd:YAG laser. The laser peening will reduce the probability of rupture of these tubes near the roll joint with the SS end fittings. Further work is in progress to carry out the laser peening on the inner surface of the zircalloy pressure tubes.

Development of Technology for In-situ Laser Cutting of Bellow Lip Weld Joint without Removal of Peripheral Obstacles

A new technique was developed and a new tool was designed for laser cutting of bellow lip joint without removing the yoke assemblies, yoke stud and the feeder pipes of the coolant channel as well as shock absorber assemblies of the neighboring coolant channels. The technology was used successfully in-situ at KAPS-2 to remove a single coolant channel in the central part of the manifold of coolant channels for post irradiation examination to assess the life of the pressure tubes with the new composition.



In-situ laser cutting of Q-10 coolant Channel at KAPS-2

Laser-assisted Surface Thermo-mechanical Treatment

Laser-assisted surface thermo-mechanical treatment approach of micro-structural engineering has been developed to enhance corrosion resistance of type 304 stainless steel. Surface thermo-mechanical treatment of type 304 stainless steel brought about significant improvement in its resistance against uniform and pitting corrosion. It was also found to be effective not only for enhancing material's inherent resistance against sensitization and inter-granular corrosion but also for reducing inter-granular corrosion susceptibility of pre-sensitized stainless steel.

SPECIAL MATERIALS

About 70 kg lithium titanate powder was synthesized by solid state reaction process. BARC delivered 15 kg Li_2TiO_3 powder of particle size $\sim 106 \mu\text{m}$ and 12 kg pebbles of 1.0 mm dia. to Institute for Plasma Research meeting specifications of ITER. Development of Li_4SiO_4 Powder and Pebbles continued. Experiments on the heat transfer in a packed fluidized bed with pebbles of different sizes were carried out.

Procurement and installation of equipments /pipings pertaining for augmentation of Lithium Metal Plant (Phase –II) continued. The special flooring work, installation & erection of bus bars in the plant area and commissioning of Power Control Centre (PCC) panel have also been completed. Laying of instrumentation & electrical cables is in progress.



Li_2TiO_3 pebbles of 1 mm size



At the Bhabha Atomic Research Centre (BARC) mock up gamma scanning experiment was carried out in AHWR critical facility to qualify integral gamma detector and data acquisition system. Computational tools to predict the gamma source



term were benchmarked. Results of this experiment will be useful in planning and carrying out the gamma scanning of fuel assemblies irradiated in light water reactor facility.

A 50 Te Fast response servo hydraulic linear actuator was developed for seismic shake tables and material testing applications. These actuators use special hydrostatic bearings to reduce friction to very low levels thereby increasing the precision. To obtain high bandwidth, an advance control algorithm was used. The performance improvement in actuator was experimentally proven in lab for small amplitudes.

A Micro Electro Mechanical System (MEMS) technology based acceleration sensor available in the market was upgraded for its limitation for long distance communication. Upgraded accelerometer was tested for its use in a shake table control experiment where it was mounted at distance of 20m away from the computer.

A Surface Replication Tool for pressure tubes of 220/ 540MWe PHWRs was developed. Replica tool is a surface characterization tool for obtaining replica from any surface flaw present on the inside surface of the pressure tubes.

PUF to be used for impact absorption and thermal insulation of transportation packages for radioactive materials was developed indigenously. Overpack made of PUF suitable to protect packages up to 100kg was developed, tested and qualified.



A tunable narrow bandwidth high power laser facility with remotely operated copper vapour laser and tunable dye lasers were installed to separate isotopes of different elements. Related technologies of electron beam evaporation condensation and liquid metal recycle in a high vacuum separator were developed for both radioactive & non-radioactive materials.

An all glass dye cell was designed by CFD analysis and fabricated for deployment in amplifier cell. Installation of remotely operated separator chamber with vacuum system fitted with an integrated electron beam vapour generating system and liquid metal recycle structure having corrosion resistant coating was completed. Experiments were conducted with full scale geometry to observe the phenomena of vapour condensation liquid metal recycle using bismuth.



CVL Lasers in encasement in clean-room tunnel



CVL Master Oscillator Power Amplifier



All Glass dye cell



Dye Oscillators commissioned

An All Metal Crucible assembly (AMC) with a charge of feed metal carrying capacity of 275kg was developed at BARC. Main hearth of AMC was



EB welding of Test coupons for parameter optimization and preparation WPS for the main crucible welding

manufactured out of forged Oxygen Free Electrolytic (OFE) copper block and was welded to the water headers by Electron Beam Welding (EBW). The data related to EBW of such a large block of copper was generated through several trials, development of the Weld Procedure Specification (WPS) and its qualification at BARC. The EBW was carried out with optimized parameters using an indigenously developed EBW machine.

A 50 fs, 800 nm 3 kHz laser with average pulse energy of 0.8 millijoule was commissioned to study ultrafast laser materials interaction process

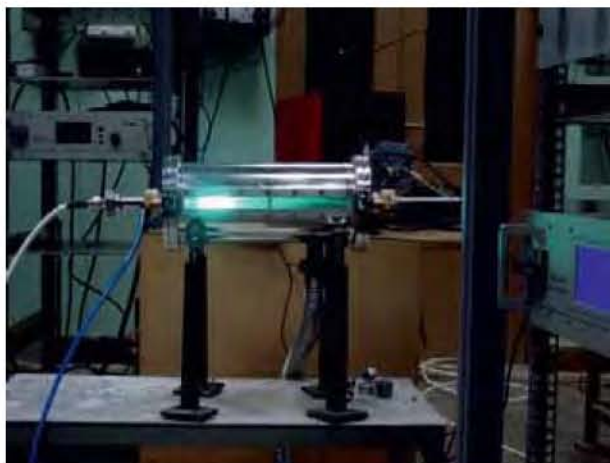


Femtosecond laser system

Laser processed microcones in S.S



RF Plasma CVD Facility for Deposition of Boron Carbide Coatings on inner walls of S.S. tube

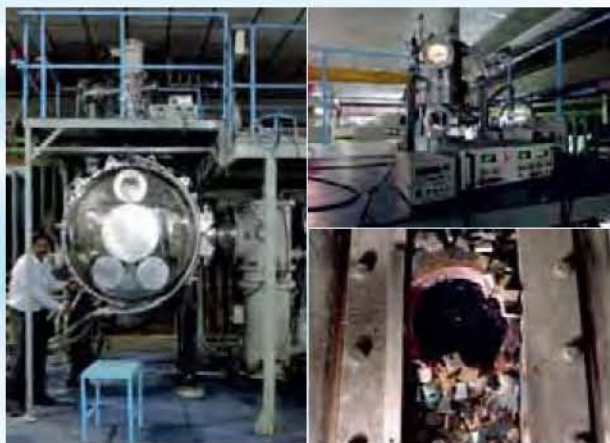


Microwave Excited APPJ with Ar-CF₄-O₂ gases

and laser assisted surface microstructuring. Femto second laser based surface micro-structuring leading to formation of self-assembled micro-cones, generation of self-aligned micro-tips on Stainless Steel electrodes resulting in field enhancement by over three orders of magnitude and improved field emission performance were demonstrated.

As a part of the program to develop Low Pressure Plasma Assisted CVD process for deposition of boron containing coatings for nuclear detector applications, a plasma assisted CVD process has been developed to get good quality deposition of higher (B₆C) boron containing coatings on both sides of stainless steel plates that are required for making a nuclear detector.

BARC's core competence in the field of high power electron beams was marshaled towards the development of a production scale, high power



Electron Gun Test Facility at BARC

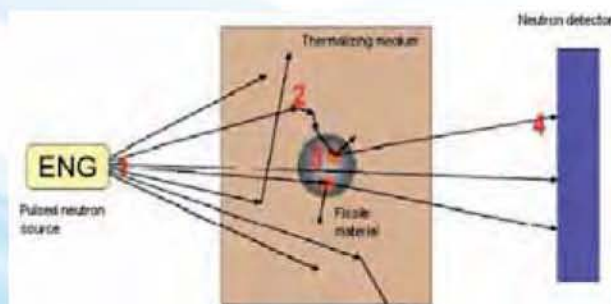
electron beam melting furnace powered with two 150 kW Electron guns. The efforts reached a stage of 75 kW melting operation with a single electron gun.

BARC demonstrated its capability in making industry ready 80 kV, 12 kW Electron beam welding (EBW) machine. Two EBW machines were designed, manufactured and installed at IIT Kharagpur (for welding research) and BARC-TIC (for job shop).



80 kV, 12 kW EB welding machine

Active neutron interrogation technique for detection of fissile material in bulk material using pulsed neutron generator was developed for improving sensitivity of fissile material detection for security as well as in nuclear industry for nuclear material accounting. It can detect very small quantities of fissile materials inside a shielded matrix directly even in presence of high neutron and gamma background and it is much more sensitive compared to passive techniques. This technique is based on differential die-away (DDA) analysis and works by exposing a medium to pulses of neutrons.



Schematic of Differential Die Away technique for fissile material detection



Experimental assembly showing bank of He-3 detectors surrounding the simulated hull vessel

An experimental facility comprising of a pulsed neutron source and a bank of He-3 detectors was set up to establish the DDA technique and quantify the detection limits using this approach especially for the case of leached hull-monitoring.

One of the most successful methods of detecting hydrogen in a nuclear reactor is by utilizing Ion Pumps. Ion pumps have high sensitivity for



Ion pump based hydrogen detection system

Hydrogen and operate at ultrahigh vacuum conditions. The present system is capable of detecting hydrogen from 50 ppb to 2000 ppb. Two such systems were delivered to FBTR, Kalpakkam and three more are undergoing testing and calibration.

BARC has developed inductively coupled plasma Mass Spectrometer (ICPMS) and transferred



ICPMS system developed at BARC

the technology to M/s Elico, Hyderabad. Two instruments were deployed at HWP, Manuguru and RMP, Mysore and one is ready for installation at ChED, BARC.

The multi-target DC/RF magnetron sputtering system was commissioned and process automated using a lab-view based process control software. The system has the capability to deposit several hundreds of nano-metric layers of metals, dielectrics, ceramics and composite materials with graded thickness on varieties of substrates to cater to the need of neutron and synchrotron beam transports. It is utilized to develop double-sided polarizing super-mirrors containing over 500 layer sequence of Co/Ti/Gd per side, for a neutron instrument of Institut Laue-Langevin, France.



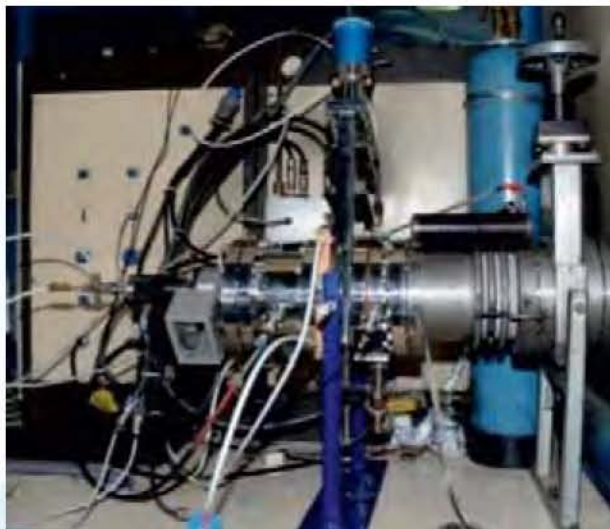
9-meter-long multi-cathode magnetron sputtering system

A hybrid detector telescope was developed for simultaneous detection of a wide range of

charged particles. Hybrid detector telescope is used for yield measurement of LCPs along the fragment direction from the coincidence measurement with the fission fragments produced in heavy ion induced fusion-fission reactions.

An indigenously developed MC-SNICS (Multi-Cathode Source of Negative Ions by Cesium Sputtering) source system is commissioned at Pelletron-Linac accelerator delivering negative ion beams across the periodic table with prolific intensity and better quality to diverse users. This state-of-the-art source is equipped with a precision remote controlled thirty six sample wheel, permitting rapid ion beam switching in situ without disrupting the accelerator operation ensuring high beam uptime of the accelerator.

An indigenously developed desktop Alpha Particle Irradiator, 'BARC BioAlpha' for in vitro radio biological studies for radiation risk assessment under



Multi-cathode Negative Ion Source Commissioned at Pelletron



BARC Bio-alpha

various radiation exposure conditions was developed & commissioned. The 'BARC BioAlpha' provides an alpha irradiation system with automation mechanism, which is novel and more user friendly for radiobiological experiments.

Indigenously developed Microbarometers and Calorimeters for the assay of special nuclear materials were delivered to the user divisions for field deployment.



Microbarometers



Calorimeter for assay of Special nuclear materials

A 2-D Position Sensitive Detector (PSD) for neutron beam imaging was developed. The 2D-PSD is useful for online monitoring of the neutron beam profile and alignment of neutron optics. This neutron imaging beam detector shows a better dynamic range of intensity and is faster than the traditionally used photographic method.

A tracking and stabilization system for the Seeker targeted for use in Brahmos missile was developed BARC and integrated with the rest of the Seeker at ECIL. Mono-pulse tracking chain is validated through outdoor tracking tests. A stabilized satellite tracking terminal for use in Airborne platform was developed for DRDO in collaboration with ECIL and is now under deployment.



BrahMos Seeker under demonstration at ECIL



Nuclear Instrumentation systems

Nuclear Instrumentation Systems consisting of Source Range Monitors and Intermediate Range Monitors employing Boron lined proportional counters and gamma compensated Ion chambers and High range gamma monitors (10mR/hr to 100R/hr) were developed and used for conducting experiments in P4- BPR & P4-Cold Facility.

A Tele Distress Alarm Device, named "Nirbhaya", was developed and the technology was transferred to ECIL for mass production. It is a small, rechargeable battery operated electronic device, used in any distress like fear of attack or medical emergency. Single-button, single-press activation device sends SMS alerts with GPS coordinates, through user's cell phone, to near and dear ones including police. Once activated, the device continues to send the message and latest GPS location every minute to the same phone numbers. The device operates on and pairs with user's cell phone via Bluetooth.

A 12-Channel battery operated portable ECG Machine was developed. A micro-SD card stores several ECGs locally and transfers to the PC using blue tooth connection. Also a low noise, low power, 12-channel analog ECG front end

ANUSPANDAN ASIC was designed for portable ECG instrument. This ASIC was tested successfully meeting its designed specifications.

A Windows based software package was developed for determination of Plutonium isotopic composition and the ^{241}Am content in solid Plutonium sample using high resolution gamma-ray spectrometry as non-destructive assay technique.

For fabrication of Low Temperature Superconducting multi-filamentary Nb_3Sn embedded cables in Oxygen free high thermal conductivity (OFHC) Copper matrix, machining process for deep hole drilling in OFHC Copper billets of 100mm diameter x 115mm length, having 97 through holes of diameter 4.90 mm was developed. This cable will be supplied to IPR, Ahmedabad.



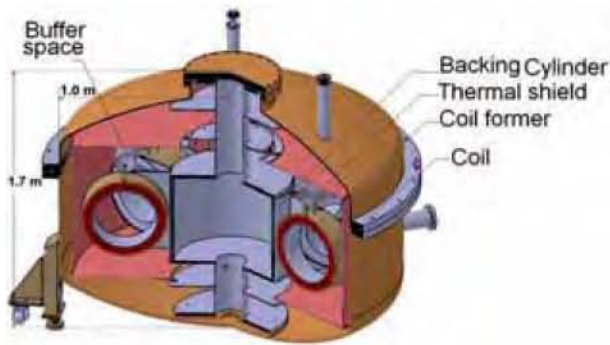
Finish Machined OFHC Copper Billets

0.6MJ Superconducting Magnetic Energy Storage (SMES)

In view of developing SMES technology to compensate voltage dip or sag problem of utility line for critical machines, VECC developed a 0.6 MJ SMES coil along with associated power converter system. DC-DC two-quadrant chopper and voltage source inverter (VSI) of the 1MJ System were tested individually and integration of all the subsystems was carried out.

4.5MJ Superconducting Magnetic Energy Storage (SMES)

Development of toroidal-type magnet of 4.5 MJ/1 MW capacity composed of modular solenoid coils connected in series and arranged in a toroidal symmetric fashion was started. VECC developed a custom-made Rutherford type NbTi based cable with sufficient critical current margin suitable for transient application.



Design concept (3D-CAD model) of the toroidal-type SMES system

The design criteria of the sectored toroidal-type SMES magnet was set with multi-objective optimisation of minimal superconducting material and magnet overall size to obtain required stored energy with the consideration of critical characteristics of superconducting cable, constraints of maximum electromagnetic stress induced by the Lorentz force in the sector coil, allowable fringe magnetic field outside cryostat, and maximum allowable operating current constraint from insulated gate bipolar transistor (IGBT) based power conditioning system is under development at VECC.

The whole toroidal coil system is supported through glass-fibre reinforced plastic (GRP) composite structure so that conduction heat load to the system is reduced. The entire toroidal-type coil assembly system is enclosed by thermal shield made of copper. Suitable support structure has been designed with detailed structural analysis for reliable operations under all possible scenarios. Coil winding with Rutherford cable is expected to commence shortly after the initial characterization of the cable.

FPGA Implementation of SMES based DVR controlled processor

SMES based DVR control processor was written in VerilogHDL, by creating suitable test bench control operations and functionality was verified. Fixed and floating point package was used in the place of real variables for synthesis into FPGA (Virtex 6) and it was verified in simulink by applying necessary input signal through NI-Multifunction DAQ (PCI6323).

Cryogenics

The high pressure turbo expander developed along with its aerostatic gas bearing system exhibited efficiency in excess of 72% during continuous test operation. This enabled the helium refrigeration unit to achieve its targeted refrigeration load capacity.

Four nos. of plate fin heat exchangers were developed for validation of in-house design codes for multi-stream plate fin heat exchangers. Various tests including helium mass spectrometer leak detection (MSLD) and pressure tests were performed on the heat exchangers.



Plate fin heat exchangers

Inter-stage blower

New cryogenic turboexpanders catering to 250W at 4.5K helium refrigerator were designed and fabrication drawings along with 3-D solid models were prepared. The relevant drawings and solid models were developed for fabrication.

In order to develop indigenous capability, an inter-stage blower specified to operate with 1.3 bar (abs) suction pressure, 3 bar (abs) discharge pressure and capacity varying from 200 to 500 l/hr was designed and developed. Inter-stage blowers were designed to transfer hydrogen gas from one cryogenic distillation column to another with built-in safety features.

Major piping for cryogenic systems was completed. Commissioning of a large air screw compressor (40Nm³/min, 400kW, 3.3 kV) was completed.



Major cryogenic system installation activities under progress at BARC

Robotics

Spot picker robot is an indigenous three-axis robotic system designed for precise spot excision to accurately pick spots from 2D gel electrophoresis (2DGE). This robotic system is a low cost biomedical system which demonstrates state-of-the-art technology in precise positioning and powerful imaging algorithm in the field of proteomics.



Spot Picker Robot

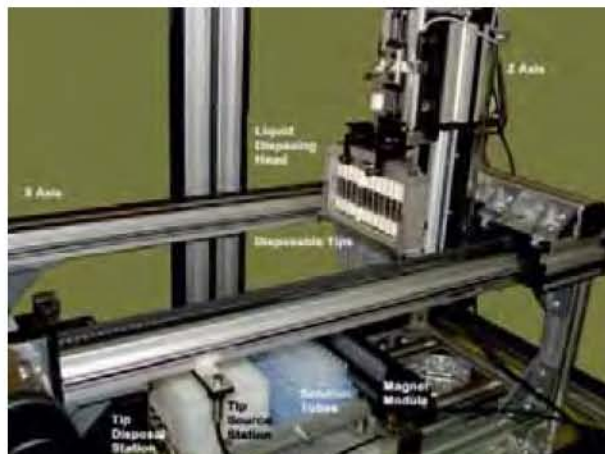


Protein Spot Cutting Tool

DORAbot (Detection Of Radiological Activity using a Robot) is a tracked mobile robot with cameras and radiation sensor packs to scout radioactive areas in and around nuclear installations in the event of a radiological emergency. It can drive autonomously towards the mission goal from its launch point along a specified path or an operator can tele-operate it in the mission site. The robot can conduct a survey mission to collect geo-tagged radiation measurements along planned path. An on-board gamma radiation monitor will record and transmit the value of radiological activity to the control centre. Obstacle detection, Obstacle avoidance and Waypoint navigation modules were developed.



DORAbot- An Outdoor radiation survey robot



Liquid Handling Robot System

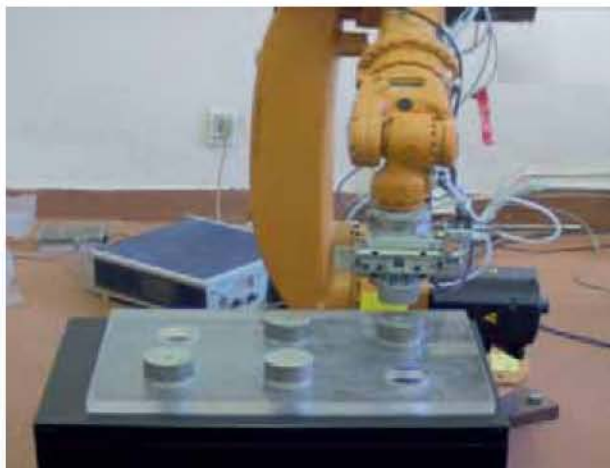
A parallel robot for conducting high precision neurosurgical procedure was developed. Assistive tools for conducting neuro-registration and neuro-navigation were also developed. Several experiments on neuro-navigation were conducted on a phantom. Algorithms for mirror manipulation for co-operation among two parallel manipulators in task space were implemented. Experiments on high precision path tracing, load sharing, surface generation and in-contact operations were conducted.

BARC also developed the Liquid Handling Robot for extracting DNA from different types of cells by magnetic bead separation method. This robot is capable of handling liquids in the range of 30 to 300 μ l in steps of 1 μ l. It has a repeatability of less than 5% in

the volume range 75 to 300 μ l and less than 10% in the volume range 30 to 50 μ l. A software interface allows the user to define reaction sequences using simple predefined steps.



Haptic Device for Master Slave Manipulation



Teleoperation of an Industrial Robot using Telepresence

A set-up for demonstration of Telepresence has been developed using Telerobotics with the existing LAN network available in BARC for transmission of video as well as control signals. The unit can be used to view the robot installed in one location from a remote location in 3D in HD resolution. The robot can also be operated in master-slave mode with force reflection. This technology will be useful in incident management to control the robot from anywhere if LAN connectivity is available.

ISOTOPE PROCESSING

The radioisotopes in India are produced in research reactors at Trombay, power reactors of NPCIL and accelerators at VECC. These

radioisotopes are processed by BARC, and a vast array of high quality radioisotope based products and equipment is commercially produced by BRIT. All these products and services have wide applications in the fields of medicine, agriculture, industry and research.

The activities and achievements of this programme segment of DAE during the report period, are listed below.

At BARC, a large number of reactor produced radioisotopes for medical, industrial, agricultural and research applications were produced and supplied to the end users. Radioisotopes for medical applications such as, ^{131}I , ^{99}Mo , ^{125}I , ^{153}Sm , ^{32}P and ^{61}Cr , were supplied to Radiopharmaceuticals Programme, BRIT for delivering to various nuclear medicine centers in the country. ^{177}Lu with specific activity more than 25 Ci/mg was produced and directly supplied to end users as per their requirements. Industrially important isotopes (^{203}Hg , ^{82}Br , ^{198}Au etc.,) were produced and supplied for their use in various industrial procedures and hydrology studies. Other miscellaneous radiochemicals were supplied directly to the different users of DAE family, national laboratories and universities through BRIT. A total of 3.7 KCi quantity of more than 50 different radioisotopes were produced and supplied.

The Regional Centre RAPPCOFF, Kota of BRIT continued excellent work in processing, production and transportation of Cobalt-60. A record 2 MCi of Cobalt-60 was processed during the period. Safe handling, transportation of adjuster rods from various reactors and processing of Cobalt-60 at RAPPCOF and subsequent transportation for fabrication of irradiator sources to Mumbai and the necessary decontamination of the facility were performed. Mobile hot cell was used to remove 16 numbers of Co-60 pencils as a test case. Decayed Cs-137 sources were removed and loaded in the transport flask at 4 customer centres. The centre was also involved in the source loading operations at Sri Lanka and SARC Delhi. Customized W-91 pencils for install and operate irradiator were prepared.

AGRICULTURE

Crop Improvement

In the area of mutation breeding for crop improvement, a high yielding yellow mosaic virus (YMV) resistant black gram variety TU-40 was released for commercial cultivation in south zone. Under the Breeder Seed Programme for Trombay groundnut varieties, 286 quintals of breeder seed of TAG-24, TG-37A, TG 38, TPG-41 and TG 51 was produced and distributed to the National Seed Corporations, State Farms Corporation of India, State Seed Corporations, State Agricultural Universities, KVK, IFFCO, Seed companies and farmers.

About 150 kg of breeder seed of pigeon pea (Trombay variety TT401) was produced and 600 single plant selections were made for maintenance breeding.

Black gram selection TU-18 has been promoted from initial varietal trial (IVT) to Advanced varietal trial (AVT-I) in All India Coordinated Research Project on Mungbean, Uradbean, Lentil, Lathyrus, Rajmash and Pea (MULLaRP). Three mung-bean genotypes, three black gram genotypes (TU339 for rabi and TU-26, TU10-12 for rice fallows) and one cowpea genotype (TC 901 for summer) were entered in IVT of All India Coordinated Research Project of Indian Council of Agricultural Research (ICAR). Five bruchid resistant selections black gram (TU-26, TU-40, TU-68, TU-72, TU-80) were entered into the third year entomology trials of MULLaRP.

Using ion beam radiation on TG26 and TG68 groundnut seeds, 19 promising lines were selected at M3. Gibberellin insensitive dominant dwarf groundnut mutant TGM, sub-orbicular leaflet mutant TGM 38 and funnel leaflet mutant TGM were registered with National Bureau of Plant Genetic Resources (NBPGR), New Delhi. Groundnut bruchid is an important storage pest that adversely affects quality and quantity of pods. A linkage map was constructed with 190 segregating markers using 164 recombinant inbred lines derived from the cross VG 9514 (bruchid resistant) X TAG 24 (bruchid susceptible).



*NISARGRUNA Plant of 3MT at Barbil (Odisha)
commissioned in July 2013*

A technology for a rapid, continuous and renewable method for production of the anti-cancer drug "Camptothecin" was developed. Purified binary proteins from the indigenous strain of *Bacillus sphaericus* ISPC-8 were found to be highly toxic to mosquito larvae. A rapid molecular method for detection of gliotoxin-producing strains of *Trichoderma virens* was developed. Several new terpene cyclase genes were identified in seven *Trichoderma* genomes using bioinformatics approach.

Studies on Cadmium and Arsenic bioaccumulation in heavy metal tolerant cultures of *Pseudomonas aeruginosa* (KDM-II) and *Providentia rettgeri*, using the Energy Filtered Transmission Electron Microscopy (EFTEM) revealed uniform distribution of arsenic and cadmium in the cytoplasm in both the cultures. Arsenic caused morphological changes in the cell wall while cadmium stress resulted in vacuole like structure in both the bacteria.

Twelve technology transfers of Nisargruna plants and two technology transfers of an inexpensive growth medium for mass production of the biofungicides *Trichoderma* spp. were processed. Sixteen Nisargruna plants were commissioned in 2013. More plants are under construction at Tihar Jail, New Delhi and Chennai Municipal Corporation and several MoUs are under discussion. Total number of Nisargruna plants now stands at 160.

FOOD PROCESSING

Research work in the area of radiation processing of food and agricultural commodities continued with emphasis on development of new products and applications at BARC. This included the use of radiation for extending the shelf life of ready to bake chappatis, minimally processed vegetables, Ready-To-Cook (RTC) potatoes, drumstick, cauliflower and cabbage as well as Ready-To-Eat (RTE) Apple, Methi Thepalas, Chicken Pulao and Jawla Tikki.

Gamma radiation was also found to enhance wine flavor quality, improve microbial quality of fresh sprouts, enhance functional properties of legumes such as kidney bean and cowpea and inhibit browning of shredded minimally processed cabbage during storage. Radiation processing aided in enhancing nutritional quality of cabbage and in the hygienization of high calorie blenderized food and protein powder prepared for immune-compromised patients. Technology demonstration and scale-up of litchi processing was achieved.



Radappertized Chicken Pulao



Minimally processed cabbage samples A. Control; B. Irradiated



200 kg capacity Solar Dryer

Improved mechanical and barrier properties of guar gum based nanocomposite films were achieved employing radiation processing. Process parameters were optimized for preparation of a honey based gel for clinical applications with improved stability up to three months at room temperature with a radiation dose of 15 kGy. Active zein composite films containing blend of PVA for improved mechanical properties and containing green tea and lime peel extracts as active ingredients were prepared.

New glass based dosimeters were developed for measurement of absorbed dose in the range of 250-1000 Gy and 1-10 kGy. The potential of a newly developed PVA (polyvinyl alcohol) based dyed film labels as a go/no-go indicator for use in commercial irradiation plant at doses above 6 kGy was demonstrated.

Trial runs for establishing efficacy of a 200 kg capacity solar dryer designed for dehydration of different food products were carried out.

The role of (Proline utilization A) PutA or proline oxidase in regulating stress induced programmed cell death (PCD) in *Xanthomonas* was established. Molecular mechanism of salt tolerance in food-borne pathogen *Salmonella typhimurium* was demonstrated due to significant up-regulation of *kdpA*, a gene involved in potassium transport in the stationary phase.

The RF electron linac facility at RRCAT was used for mutation breeding experiments by Nuclear



Irradiation of seeds by 7.5 MeV beam from electron linac

Agriculture & Biotechnology Division (NA&BTD), BARC. A large number of various seeds such as wheat, soya, lentils, beans, black gram, cowpea and chickpea seeds were irradiated using 7.5 MeV beam from electron linac.

A triode type electron gun with 50 kV, 1Amp peak capability was designed, developed and deployed for the 10 MeV electron linac. This linac will be used for irradiation of food items in the agricultural radiation processing facility of RRCAT.



Triode type electron gun for the 10 MeV electron linac

Radiation Processing Services

Radiation Processing Plant, Vashi

The Radiation Processing Plant at Vashi treated approx 42 MT of spices and other products during the financial year 2013-2014 and registered a growth of about 18 %. New products like lead impregnated rubber sheets and Corncob for animal

bedding were added for commercial processing. The facility re-qualified the certification audit for compliance to ISO-22000:2005 (Food Safety Management Systems) and surveillance audit for ISO-9001:2008 (Quality Management Systems) and excelled in meeting customer requirements.

New Radiation Processing Plants In Private Sector

Motivated by the successful commercial operation of private sector Radiation Processing facilities in the country, M/s Kumaka Industries Ltd., Vadodara signed a MoU with BRIT for setting up a radiation processing facility. The facility will come up at Sanand II, Gujarat for treatment of spices, chilled meat, poultry products, sea food etc.

HEALTH

Radioisotope based formulations, techniques and equipment are widely used in the diagnosis and treatment of various diseases. BARC, BRIT, RRCAT and VECC are major contributors in this field.

Radioisotopes are produced, processed and technologies are developed at Trombay for varied applications in the medical field. BARC's Radiation Medicine Centre, a premier centre in the field of radio-diagnosis and radiotherapy in Mumbai, is a regional referral centre of the World Health Organization (WHO) for South East Asia.

BRIT produces and supplies radio-pharmaceuticals for diagnosis and treatment of diseases, teletherapy and brachytherapy sources, radioisotope based kits, various instruments, and radio processing services. Jonaki Laboratory at Hyderabad produces and supplies P-32 labelled nucleotides for research in biology, biotechnology and drug discovery. Jonaki also markets S- 35 labelled amino acids produced by Labelled Compounds Programme at Vashi.

Radioisotopes for medical applications are also manufactured at VECC. The Regional Radiation Medicine Centre in Kolkata meets the radio-diagnostic and radiotherapy requirements of the eastern region of the country.

Radiopharmaceuticals

BRIT supplied over 30,000 consignments of ready to use radiopharmaceuticals of ^{131}I , ^{177}Lu , ^{32}P and ^{153}Sm containing nearly 1000 Ci to various Nuclear Medicine Centers for therapeutic and diagnostic purposes during the year.

A new facility for production and supply of ^{131}I – NaI high dosage therapeutic capsules for thyroid cancer was started after approval by AERB. The production capacity and frequency of supply of injectable ^{131}I MIBG improved considerably. MIBG is an important therapeutic and diagnostic product for treatment of neuroendocrine cancers. ^{131}I radiopharmaceuticals accounted for nearly 600 Ci radioactivity supplied in about 20,000 consignments. Rs 10 Crores revenue was generated from these radiopharmaceuticals.

Medical cyclotron facility at Parel supplied about 220 consignments of ^{18}F based PET radiopharmaceuticals to nuclear medicine centres with PET scanning facility in Mumbai which accounted for nearly 380 Ci of radioactivity generating a revenue of Rs. 6.5 Crores.

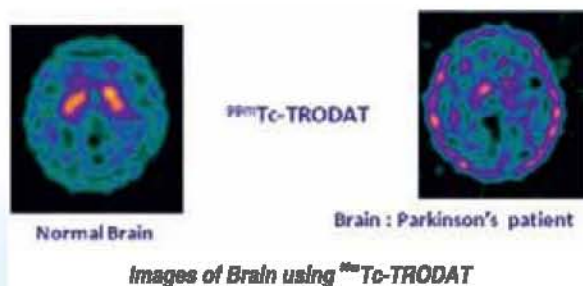
BRIT had earlier started a facility for production of ^{99}Mo - $^{99\text{m}}\text{Tc}$ Generator under the brand name 'COLTECH'. A new package for COLTECH generator was designed, developed and tested. Over 300 Ci of ^{99}Mo in the form of Sodium molybdate solution was supplied for solvent extraction generator and for ^{99}Mo - $^{99\text{m}}\text{Tc}$ Gel Generators and additionally

375 Ci of ^{99}Mo as alumina column generator (New product-COLTECH) were also supplied.

During the year 2013-2014, BRIT supplied 15 different Technetium cold kits for labelling and preparing $^{99\text{m}}\text{Tc}$ -radiopharmaceuticals which are used for diagnosis.

BRIT has started supplying four new TCK products. TRODAT kit for imaging of somatostatin receptors in tumour imaging, HYNICTOC kit for Dopamine receptors for studying neurological disorders, Tetrofosmin kit for myocardial perfusion imaging and HSA-nanocolloid kit for sentinel node detection. More than 15000 consignments of cold kits for labelling and preparation of $^{99\text{m}}\text{Tc}$ radiopharmaceuticals were supplied to various Nuclear Medicine centers during the year generating a revenue of around Rs. 4.5 Crores.

$^{99\text{m}}\text{Tc}$ -TRODAT is a radiopharmaceutical used for early detection and differential diagnosis of Parkinson's disease. Freeze-dried kits of TRODAT are produced at BARC on regular basis. Nearly 200 such kits were supplied to various nuclear medicine centers in hospitals. Preparation and use of $^{99\text{m}}\text{Tc}$ -HYNIC-TOC, $^{99\text{m}}\text{Tc}$ -TRODAT & $^{99\text{m}}\text{Tc}$ -TETROFOSMIN in human patients were demonstrated using the freeze-dried formulation prepared at BARC.



New AERB approved packing for Coltech Generator

First clinical use of ^{177}Lu -labeled HA particles in the treatment of rheumatoid arthritis, supply of 'BARC ^{125}I Ocuprosta seeds' for the treatment of ocular and prostate cancer, supply and evaluation of Ce-141 filled rechargeable phantoms for calibration of gamma cameras at Radiation Medicine Centre and Tata Memorial Hospital and bio-evaluation of 90Y Nafion membrane for skin cancers, have been carried out.

Preparation of patient doses of ^{177}Lu -DOTA-TATE using ^{177}Lu produced at BARC has been demonstrated in 9 hospital radiopharmacy units for treatment of more than 1000 patients suffering from neuroendocrine cancer. More than 200 Ci of $^{177}\text{LuCl}_3$ was produced and deployed to 8 nuclear medicine centres across the country.

^{177}Lu -EDTMP is a new therapeutic radiopharmaceutical for palliative care of bone pain due to metastasis. Six batches of ready-to-use ^{177}Lu -EDTMP suitable for administration into human patients were prepared and supplied to nuclear medicine clinics as per their requirement.

Radiation technology equipment

Bhabhatron machines

BARC manufactured 34 Bhabhatron machines. Twenty seven machines are in operation and remaining machines are under various stages of installation and commissioning.

Digital Radlotherapy Simulator

Indigenous development of Digital Radlotherapy Simulator is another milestone of BARC in the development of medical equipments in terms of quality treatment at affordable cost. The machine installed at Tata Memorial Centre was inaugurated by the Director General of IAEA during his recent visit to India. The technology was transferred to M/S Panacea Medical Technologies Pvt. Ltd., Bangalore.

Computer controlled multi source gamma calibration system

Computer controlled multi source gamma calibration system containing ^{137}Cs , ^{60}Co and ^{241}Am gamma sources was developed indigenously and



Irradiator and control console parts of gamma calibration system

used for the QA of country wide TLD personnel monitoring programme.

Neutron pocket dosimeter

A silicon diode based pocket dosimeter for neutron Dosimetry was developed at BARC. It can be used by the radiation workers working in nuclear power plants, fuel processing facilities and other industrial facilities involving neutron sources.



Neutron pocket dosimeter

Shadow shield whole body monitor

Design, development and manufacture of the shadow shield whole body monitor to measure Radionuclide accumulation in the human body was completed.

Research Irradiators

During the year eight Gamma Chamber-900 units, one PANBIT facility and one Gamma Shine 1000 units were decommissioned for the disposal of their decayed cobalt-60 source from different Institutions.



Install and Operate Irradiator

Install & Operate Irradiator

The cold commissioning of install and operate irradiator was completed. The cask was loaded with 45 kCi of Co-60 at HIRUP Hot Cell.

Blood Irradiators

Two Blood Irradiator 2000 units (BI 2000) and one Low dose Irradiator were supplied and installed at JIPMER, Pondicherry & ISM & SUM hospital, Bhubaneswar with nearly 2000 Ci of Cobalt-60 radioactivity. A 3 MCi multipurpose Irradiator has been set up at Colombo, Sri Lanka jointly with a private company and has been commissioned. BRIT had also carried out repatriation of 3 gamma chambers which were earlier exported to Sri Lanka from Colombo and Kandy on chargeable basis.



BLC 125 flask for exporting Cobalt-60 to Sri Lanka

Radiography Camera ROLI-I, II & III

BRIT supplied 90 new radiography exposure devices. Besides these under radiography services offered by BRIT around 500 ROLI cameras were serviced, 900 imported exposure devices were serviced & inspected and 1400 decayed sources were removed. A Medical Sterilizer cat II batch irradiator with a source strength of 100 kCi of Co-60 for sterilization of medical product for in-house application of hospitals was successfully designed and a scale & down model was fabricated. An X-Ray based low dose Irradiator was designed for Biological studies in cancer, biotechnology, stem cell research, small animal work etc. A 120 Ci Co-60 based Radiography Exposure Device for industrial application was designed and it is under fabrication.

Radio Diagnostic & Treatment Services

Radioimmunoassay (RIA) procedure for the measurement of insulin in rat serum was developed after modification of human insulin RIA kit. It served as a reliable tool for the measurement of relative rat insulin concentration in studies after more than 200 rat samples were analyzed for various research institutes.

A simple two-step RIA procedure for free T3 as per the guidelines of American Thyroid Association was developed. IRMA kit formulation for human C-peptide was completed. A trial batch of 25 kits were produced for the evaluation of its long term stability.

Around 4500 consignments of radioimmunoassay (RIA) and immunoradiometric assay (IRMA) kits were produced and the revenue earned by BRIT from the combined RIA and IRMA kits for the year 2013-14 was about Rs. 1.2 Crores. RIA Laboratory has received certification for ISO 9001:2008 and ISO 13485:2008 from United Kingdom Accreditation Services (UKAS).

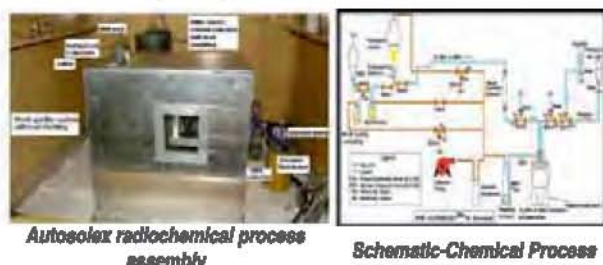
Regional Centre BRIT, Delhi supplied 900 consignments of ready to use Tc-99m Radiopharmaceuticals injections. Two thousand technetium cold kits were also supplied to nuclear medicine hospitals in Delhi and NCR Delhi. The revenue earned by RC Delhi was around Rs. 18 lakh.

Regional centre, Bengaluru supplied 300 consignments of ready to use ^{99m}Tc formulations. Around 600 TCK cold kits were sold through retail outlet for radiopharmaceuticals. 2500 Blood bags were irradiated using BI 2000. RC Bengaluru earned a revenue of around Rs. 26 lakh. Radioanalytical laboratory was inaugurated by Director, KMIO Hospital at regional Centre, Bengaluru for residual radionuclide determination and certification in domestic and export commodities.

The Regional Centre, Dibrugarh located at Assam Medical College & Hospital rendered the RIA and IRMA diagnostic services for the benefit of patients of the entire north-eastern region. More than 10,000 patients availed the services offered by this

centre for analysis of hormones like T_3 , T_4 , TSH, LH, FSH, PRL, beta- HCG, Ferritin and insulin. RC Dibrugarh earned a revenue of Rs. 15 lakh.

At regional Centre Kolkata civil work of DAE Medical Cyclotron is expected to be completed by March 2014. ^{99m}Tc produced by $^{100}\text{Mo}(p,2n)$ reaction was separated using Dowex-1 resin and HNO_3 . The purified ^{99m}Tc was found to be suitable for preparation of Tc-radiopharmaceuticals. In collaboration with VECC, Kolkata BRIT developed indigenously fully automated computer controlled $^{99}\text{Mo}/^{99m}\text{Tc}$ solvent extraction generator system. The generator is self-lead shielded. 1st clinical studies of ^{99m}Tc obtained from TCM-AUTOSOLEX module was performed at RPMC, VECC, Thakurpukur, Kolkata. More than 70 such clinical studies till December, 2013 were carried out there successfully. TCM-AUTOSOLEX generator gives enhanced radiological and pharmaceutical safety as well as enhanced capacity to handle a much larger quantity of Mo-99.



Direct production of ^{99m}Tc by irradiation of a natural molybdenum target was done at VECC under IAEA Coordinated Research Program.

A special target holder was designed and fabricated to irradiate Ga metal for the preparation of $^{68}\text{Ge}/^{68}\text{Ga}$ generator. Two irradiations were successfully carried out in this target holder using 3 μA proton beam. Separation of the ^{68}Ge produced from the Ga metal target was carried out by using a reported method. Overall recovery of ^{68}Ge at the end of separation was about 97%. A new SnO_2 based generator was prepared using the isolated ^{68}Ge .

Production of ^{109}Cd was done by reaction on natural silver target using 15 MeV proton beam. Chemical was carried out by using a reported method. Overall ^{109}Cd recovery was 100%.

Labelled Compounds and Diagnostic Kits

Labelled Compounds Programme of BRIT is involved in the synthesis & supply of a variety of ^{14}C , ^3H and ^{35}S -labelled products and production of Tritium Filled Self-luminous (TFS) sources for defence applications. BRIT supplied 42000 TFS sources and was involved in custom synthesis and supply of ^{14}C -radiolabelled Glyphosate and ^3H -labelled Folic acid. The revenue earned from nearly 1000 consignments containing a total activity of about 1 Ci during the year was about Rs.22 lakh.

Jonaki, Labelled Biomolecules Laboratory at The Regional Centre, Hyderabad is primarily involved in the production and supply of ^{32}P labelled nucleotides and also a few molecular Biology kits and enzymes. It supplied 1300 consignments. These comprised ^{32}P nucleotides, ^{32}P orthophosphoric acid, ^{35}S amino acids, LCK Kits, Taq Polymerase and PCR Product, radiopharmaceuticals cold kits (TCK products). It has planned a centralized radio pharmacy laboratory for supply of ^{99m}Tc as sodium pertechnetate. The laboratory is ready and will be functional for supply of radiopharmaceuticals after regulatory and quality clearance.

Approval for setting up a molecular diagnostic kits project under XII plan for Rs 332 lakh was sanctioned. The objective of the project is to develop Real time PCR based M tuberculosis detection kit using the patented FRET chemistry



Real Time PCR system at Jonaki Hyderabad

developed at Jonaki as a substitute for imported kits. Additional Real time PCR kits for determination of load of viruses like Hepatitis B and C, and HIV are in the process of development.

Radio Analysis

The Radioanalytical laboratory carried out the measurement and certification of residual radioactivity in various commodities such as food items for human & animal consumption, water samples, environmental samples, steel and other miscellaneous items. More than 8000 tests on export/domestic commodities and 1100 tests on water samples (gross alpha, gross beta ^{226}Ra & ^{228}Ra) were carried out during the year. About 3000 water samples received from Punjab State were analysed for the certification of uranium content. Five steel surveys were conducted for certification of surface radiation dose and 80 food samples imported from Japan were also analysed and certified.



Inauguration of Radioanalytical Laboratory at Bengaluru

Radioanalytical laboratory at BRIT Regional Centre, Bangalore obtained AERB accreditation and has started functioning.

Radiation Sterilization Plant for Medical Products (ISOMED)

The ISOMED facility engaged in contract gamma radiation processing services for terminal sterilization of the medical products processed 7400 m³ of product (about 90000 boxes of Medical products) during the financial year 2013-2014 earning a revenue of Rs. 300 lakhs. The average plant utilization factor was around 95%. The

certifications issued to ISOMED facility complying with the requirements of various International Standards facilitated the desired cutting edge to the facility in the radiation sterilization sector in the country.

New Projects

Indigenous HDR Brachytherapy Equipment (IHDR)

The objectives of the Project are to Establish the complete process and facilities for fabrication of Ir-192 HDR sources for regular production and to develop indigenous, remote operated high dose rate (HDR) brachytherapy equipment including necessary treatment.



Brachytherapy unit supplied to Tata Memorial Hospital

Facility for production of medical grade Fission Molybdenum

The objective of the Project is to set up a state-of-the art GMP compliant facility capable of producing 300Ci/week ^{99}Mo , utilizing LEU targets and



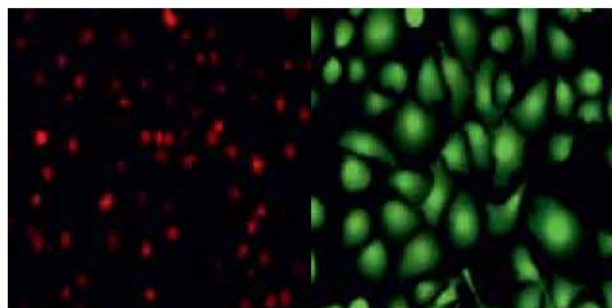
Civil construction for Fission Molybdenum Project

supply fully indigenous column generators to various diagnostic centres and hospitals in the country. After the site clearance by AERB, the design documents for the building were submitted to AERB. The work of construction of new RCC boundary wall for the complex and new security watch tower is over and the installation of new security and surveillance equipment is ongoing. The work on construction of laboratory building was nearing completion. The procurement of the production plant on turnkey basis is progressing.

Biomedical Applications

Photo-sensitizer for Photodynamic Therapy of Cancer

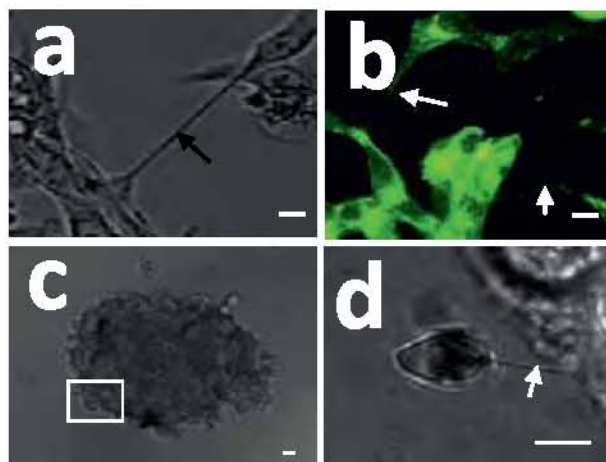
An x-ray activable copper-iodide complex of chlorin p6 (Cp6-COP) was synthesized for photodynamic therapy (PDT) of cancer and potential use in deep tumor treatment using x-ray radiation. The formation of the complex was confirmed by visible, infrared, ESR and XRF spectroscopy. Studies were also carried out to assess the phototoxicity of Cp6-COP in two human oral cancer cell lines.



*Cancer cells stained with cell death marker:
(a) Live cancer cells in un-treated sample (green)
(b) Cell death after PDT (red)*

Use of Optical Tweezers to Visualize Tunneling Nano-tubes (TNTs) in Tumor Spheroids and for Measurements of Elastic Parameters of TNTs

TNTs are ultrafine actin-based intercellular connections reported to be involved in transfer of various cellular components and are observed mainly in monolayer cultures of both primary and cancerous cell lines. Studies on TNTs in tumor spheroids are lacking due to the fact that TNTs are often buried under the close packing of the constituent cells. Optical tweezers were used to



*Visualization of TNTs: (a) Bright field image of monolayer,
(b) Fluorescence image of monolayer
(c) Tumor spheroid,
(d) Optically trapped cell.*

manipulate the cells at the surface of the spheroid to visualize the TNTs and also to determine the elastic force constant of TNTs by pulling the optically trapped cell.

Production of Oxygen-18 enriched water

Realizing the potential requirements of ^{18}O having application in nuclear medicine and biochemical research, HWB initiated technology development for enrichment of ^{18}O at HWP, Tuticorin. Doubly Labeled Water (DLW) having certain concentration of D_2^{18}O is used for measuring energy expenditure, total body water content, etc. ^{18}O finds use in Positron Emission Tomography (PET) for detection and staging of malignancies. An isotopic purity of 95% was already achieved in the prototype distillation column for ^{18}O water enrichment at HWP Tuticorin. This column can be used for recycling used O^{18} water received from RMC and other PET centres.

Indigenously designed and fabricated ^{18}O Enrichment Pilot Plant was successfully installed and commissioned at HWP, Tuticorin. The same is being operated for collection of engineering data for designing the full-fledged commercial plant which is coming up at HWP, Manuguru. The required data was collected and off grade ^{18}O water was upgraded to the required level of more than 95%. RMC, BARC and AIIMS & INMAS, Delhi have verified the purity and also used it.

Cancer Diagnostics and Treatment Services

The Tata Memorial Centre, comprising Tata Memorial Hospital (TMH), the Advanced Centre for Treatment, Research and Education in Cancer (ACTREC), and Centre for Cancer Epidemiology (CCE), continued its activities in diagnosis, treatment, research and education in cancer.

TMC has been carrying out research to evolve cost effective treatment for common cancers. The research for low cost screening and low cost care in cervical cancer and breast cancer respectively showed substantial reduction in mortality.

A state of the art Molecular Facility for Research and Service was commissioned at the Tata Memorial Centre (TMC) during the report period. Upgradation and procurement of several new equipments was done which included CT-DSA Miyabi system; Mammography; Anesthesia Delivery System; Minimal Invasive Surgery Instrument sets, Operating microscopes, Neurosurgical instruments with accessories, Endoscope Hopkins, Computer on wheels, Network computers, printers, Deep freezers, portable ECG Machine, Dental Ultra Sound Scalar, Night vision web camera, Floor cleaning machine and Linear accelerator.

Various lab equipments purchased during the year were Spectrophotometer, Deep Freezers, Ph Meter, Digital Dry Bath, Vertical Gel Electrophoresis Apparatus, Centrifuge Refrigerated Table Top Model Universal 320r, Thermal Cycler, Model, Laboratory Ice Flake Machine and Horizontal Gel Electrophoresis Apparatus. Other purchased equipments such as Steam Sterilizer, Cryostat Microme, Siemens Pre-Water Purification System, Blood Collection Monitor were in the process of installation.

Upgradation of systems and softwares in Radiation Oncology, Accounts, administration, pathology, Clinical information system and TO modules were completed.

The TMC initiated the establishment of "National Hadron Beam Facility & Cancer Centre for

Women & Children. The foundation stone for this facility was laid by Honorable Prime Minister of India Dr. Manmohan Singh on 10th January 2014.

DAE is planning to establish a cancer hospital in Andhra Pradesh and the land has been acquired and registered under the name of President of India. The tendering process has commenced. New cancer registries were established in – Pune, Nagpur, Ratnagiri, Kalpakam and Kudankulam. Cancer registries are already setup in Chandigarh, Sangrur and Mansa District of Punjab. The implementation of the Vizag Cancer Registry will take place very soon.

The Clinical Research Secretariat (CRS) along with the Department of Atomic Energy Clinical Trials Unit (DAE-CTC) are promoting research through support for clinical trials and promoting evidence based practices in cancer care. It provided support in the form of infrastructure, trained manpower, study design, statistical assistance, data management and analyses, data monitoring, informed consent translation etc. Fifteen new clinical trials were supported through DAE-CTC funds. It also facilitated several international collaborations. CRS/DAE-CTC conducted two courses namely, "Clinical Research Methodology Course" and "Good Clinical Practice Workshop".

Co-60 Teletherapy Sources:

BRIT supplied seven teletherapy sources to different hospital with total activity of about 70 kCi ranging from 60 and 180 RMM and another five sources were loaded in the flask for transportation to hospitals. Ten decayed sources were unloaded from the teletherapy units and stored for fabrication of irradiator source.

Brachytherapy Applications:

BRIT supplied 100 mCi of (Ir-192 + Pt Wire) and 500 mCi of Cs-137 for brachytherapy applications.

Cancer Awareness & Prevention

The health Awareness programme under the CHEST study covered 8 villages and screened a population of 2000 people. This included 948 people from 15 villages who were screened for oral cancer

and 9 persons were tested positive for oral cancer. About 950 people from 14 villages were screened using the Double Contrast Barium Swallow.

The baseline household survey of nine project clusters namely Trombay, Mandala, Shivneri Nagar, Mohite Patil Nagar, PMGP Colony, Lallubhai Compound, Deonar Colony Maharashtra Nagar I and Maharashtra Nagar II (SRA Buildings) and the survey of women for breast, uterine cervix and oral cavity cancers in 8th project clusters viz., Trombay, Mandala, Payalipada, Shivneri Nagar, Mohite Patil Nagar, PMGP Colony, Lallubhai Compound & Deonar Colony were completed. The Screening camps in the ninth project cluster viz Maharashtra Nagar II SRA buildings was initiated.

WATER

Desalination of water

An isotope hydrological investigation was carried out at 4 locations in Uttarakhand (Brahmkhal, Pipaya, Kakodakhal and Isala) and at 2 locations in Himachal Pradesh (Surla and Dhauli/Kandela) in collaboration with Himalayan Environmental Studies and Conservation Organisation (HESCO), Dehradun to rejuvenate the drying springs in the sub-Himalayan region by artificial recharge methods. Recharge areas of 47 springs were established using isotope techniques and geomorphology of the area and the recharge structures were constructed at these identified recharge areas.



Isotope hydrological investigation studies sites

Isotope hydrological investigation was also conducted at Tirumal Village, Madurai, in collaboration with DHAN (Development of Humane ActionN) Foundation, to demarcate the area of influence of recently renovated Urappareddy cascade of irrigation tanks (4 tanks) to quantify their contribution to the groundwater recharge. Water samples were collected from the irrigation tanks and downstream open wells and analysed for stable

isotopes such as ^{18}O and ^2H . It was found that the renovated tanks were effective in recharging the groundwater in these water scarce regions.

At the request of Sardar Sarovar Narmada Nigam Limited and M/s Kirloskar Brothers Limited, Pune, discharge rate measurements were carried out to assess pumping efficiency and energy conservation using radiotracer techniques at four Pumping Stations in Saurashtra branch canal, Gujarat.

A membrane based water purification plant for removal of iron contaminant from ground water was set up in remote location for community-use near Imphal (Manipur). The water purification unit does not require any electricity. It removes iron, bacteria and virus.



Membrane based water purification plant near Imphal



Membrane based unit for autoclaves in Hospitals

To alleviate the problem of turbidity present in the water used in autoclaves in hospitals, BARC designed and developed a membrane based system of capacity 300 liters/day for hospital use. The system uses membrane cartridges to get turbidity and pathogen free water for the autoclaves.

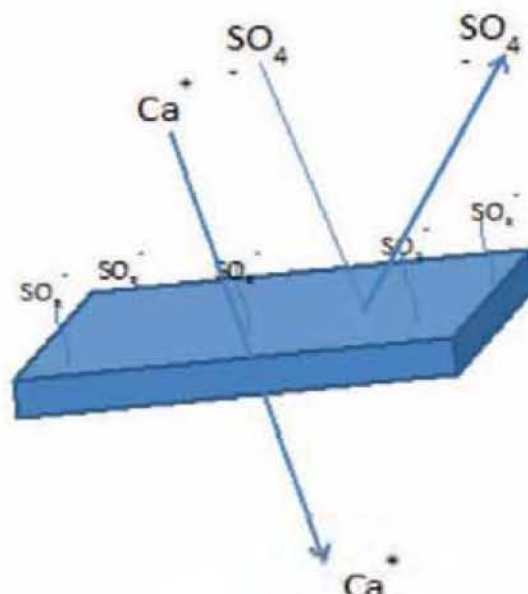
A solar water purification system was developed by BARC. After carrying out endurance test and performance evaluation, the know-how of high quality solar water purification system was transferred to entrepreneurs to make clean purified water accessible in remote locations.



Solar desalination & water purification system



Membrane based water purification unit



Mechanism of separation of negatively charged nanofiltration

A jumbo membrane based water purification unit developed by BARC was installed in one of the schools in Navi Mumbai for school children. Thin Film Composite Polyamide (TFC-PA) membranes for water desalination under Indian conditions were developed using BARC R&D efforts. These membranes are capable of removing 90% salinity from brackish water.



Recovery of valuable materials from reject seawater/brine effluent of desalination plant

Thin Film Composite (TFC) type negatively charged nanofiltration membranes containing fixed $-\text{SO}_3-\text{H}^+$ groups were developed by choosing appropriate chemical combinations of monomers. R&D work on nano-composite membrane resulted into development of high flux nano-silver impregnated UF membrane.

As a part of R&D efforts in the field of application of membrane process in front end of nuclear fuel cycle, field testing of indigenous membrane based technologies for treating wash liquor and weak liquor streams was carried out at UCIL, Tumalapalle. Encouraging results were obtained. The feasibility of recovering valuable materials from reject seawater/ brine effluent of desalination plant was demonstrated by grafting route as well as chemical route.

BARC is setting up a sea water desalination plant of 5 million liters per day based on hybrid Reverse Osmosis- Multi Effect Distillation technology for producing potable water for drinking and other uses as well as distilled water for high end industrial application. Action was initiated for the design and engineering of sea water desalination capacity at Orissa Sand Complex (OSCOM) in Chatrapur, Odisha.

Design Basis Report for the proposed nuclear desalination plant coupled to AHWR was finalized. Nuclear desalination plant consists of three units of 800 m³/d capacity Multi Effect Distillation-Thermal Vapor Compression plant using low pressure steam as energy source. A 250 m³/d low temperature evaporation desalination plant using waste heat was also considered.

Know-how of solar energy driven portable domestic brackish water reverse osmosis technology, stand-alone solar photovoltaic driven battery-less ultra-filtration system, arsenic removal from drinking water by physico-chemical process, preparation of composite polyamide reverse osmosis membrane for brackish water desalination and Low Temperature Technology of Fresh Water Generator utilizing waste heat for sea water desalination was transferred to private parties for wider deployment in a commercially viable manner.

INDUSTRIAL APPLICATIONS

Completely bio-degradable polymers based on polycaprolactone and partially bio-degradable linear low density polyethylene using radiation processed thermoplastic starch (RTPS) were developed at BARC. A completely biodegradable pure RTPS based transparent sheet of dimensions (1500 mm x 100 mm x 0.5 mm) were developed for testing. Formulations are ready for producing polymer films with tunable biodegradability at pilot scale.

SHRI Facility for hygeinisation of municipal sewage sludge at Vadodara continued to treat the sewage sludge in round the clock shifts. About 600 tons of dried hygeinised sludge was supplied to local farmers for use in agriculture. MoU with local farmer for large scale field trials of hygienized sludge and its formulations in agricultural practices was extended to explore more applications.

Upgradation work of electron beam machine at BRIT, Vashi complex to 5 MeV and 15 kW was undertaken to treat thicker materials for radiation sterilization, food preservation and research samples from industry and research institutes. Electron beam cross-linkable Polymer composite formulations were developed for High voltage insulation application and demonstrated to industry.

Hand-held Photon Counting based Uranium Analyzer

A hand-held version of the photon counting version of the uranium analyzer was developed at RRCAT for rapid measurement of trace uranium in



The hand held photon counting based uranium analyzer

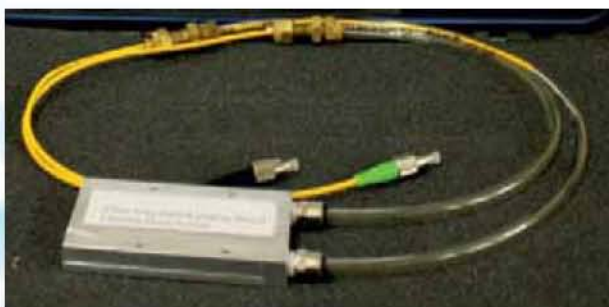
potable water. The FPGA and microcontroller based embedded interface for the instrument control and operation was also developed for this instrument. The technology for this instrument is being transferred to ECIL.

Fluorescence Lifetime Measurement Probe

Development of the handheld probe type fluorescence lifetime measurement system for characterization of Nd doped laser materials was completed. The developed system helped optimize the laser glass melt processing as it provides a quick measurement of the fluorescence lifetime without requiring any sample preparation during initial testing.



Fluorescence lifetime measurement probe for Nd doped laser materials



Packaged gamma dose sensor for integrated high level gamma dose monitoring

Fiber Grating based Fully Packaged Gamma Dose Sensor

Fiber optic sensors for high level dose above 50 kGy are not commercially available. Fully packaged long period grating (LPG) based optical

fiber sensors for high gamma doses was indigenously developed for field applications.

Radioisotope Sources supplied by BRIT

The various engineering products and services offered by BRIT included a supply of more than 2000 kCi of radioactivity in various forms and uses. The combined revenue for the engineering products and radiation processing services was close to about Rs 40 Crores.

Industrial Irradiator Sources

Irradiator sources with total activity of around 2000 kCi were supplied in eight consignments to various radiation processing plants in the country. A record single consignment of 882 kCi was supplied to NIPRO, Satara.

Radiography Sources

About 1400 radiography consignments of Ir-192 and Cobalt-60 sources with total activity of 60 kCi were supplied to various radiography camera customers in the country. Custom made Radiation Sources for Nucleonic Gauges and other uses were made with the two isotopes Co-60 and Cs-137 and total 5 Ci of radioactivity was supplied for reference and custom made sources during the year 2013-14.

Gamma Chambers

One Gamma Chamber of GC 5000 unit was loaded with 14 kCi of Co-60 radioactivity in 25 source pencils for the GC 5000 unit. Decayed source from one GC-900 was removed and stored in the storage flask. Radiometry of install and irradiate operator was done and it was decided to fabricate another set of pencils for further radiometry with 50 kCi of Cobalt-60. Refurbishment of one hot cell window was undertaken to improve the transmission efficiency. Cs-137 source used for oil logging at ONGC were recovered. The source rack and related equipments were inspected at SYMEC engineers, Navi Mumbai before shipment to Ethiopia.

Isotope Application Services

The Isotope Application Services Group of BRIT offered its valuable services during the year. The exact location of a stuck 'pig' in BPCL pipeline was scanned using gamma pipe scanner containing 5 mCi of Cs-137 developed by Isotope Application Services of BRIT saved downtime of the pipe and money.



*Gamma Pipe scanning at BPCL (left)
Location of underwater leak from the dam bed
using gold radioisotope (right)*

Gamma scanning of various process columns were carried out for a North India refinery using auto-column scanner. In collaboration with National Institute of Hydrology, Roorkee the Isotope Application Services group of BRIT detected the locations of leak of water from the dam bed in a dam near Chandigarh by using a radioisotope of Gold (^{198}Au).



CHAPTER-5

BASIC RESEARCH



A new supercomputer, "ANUPAM-Agra" developed by BARC



Protein crystallography facility at Indus-2 at RRCAT

The Department of Atomic Energy has contributed significantly towards strengthening basic research in India. The Department pursues basic research in its R&D centres that ranges from mathematics to computers, physics to astronomy and biology to cancer research. It also provides grants-in-aid to nine institutes of national eminence. Following were the major activities and achievements of DAE in basic research, during the period of report.

MATHEMATICS & COMPUTATIONAL SCIENCES

BARC developed a new supercomputer, "ANUPAM-Aggra" using parallel processing technology. This supercomputer is the largest and fastest in the ANUPAM series of supercomputers. The system consists of 8160 processor cores, 40960 Graphics Processing cores and 32 Terabytes of

memory. Peak performance of the system is 150 Teraflops and sustained performance measured using the High Performance LINPAC benchmark is 109 Teraflops.

A new projector based seamless tiled display was developed. This system consists of 9 LCD projectors arranged in a 3x3 tiled fashion projecting their images on a screen of 240 cm x 180 cm. The new display has the ability to display graphics content in 3-D using Active Stereoscopic glasses.

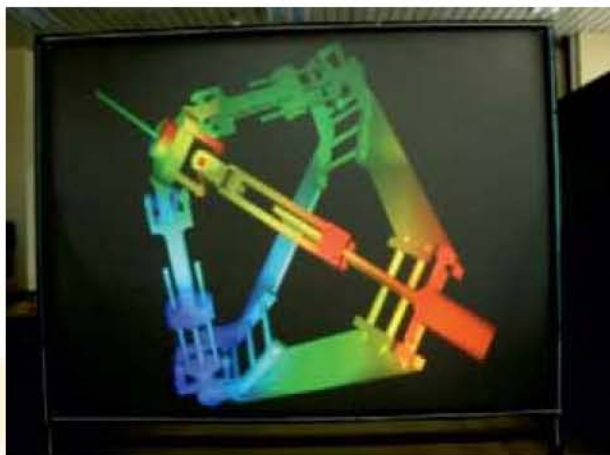
The computing facility of VECC was augmented by addition of blade system with 32 nodes in 2 chassis, 36 GB memory per node, Infiniband interconnect and 300 GB disk per node.

The School of Mathematics of TIFR proved some new results about pure extensions of commutative rings. "A product of terms taken from a set of successive terms in arithmetic progressions is a perfect square" was investigated. The Centre for Applicable Mathematics continued its research activity focusing on PDE, analysis and applications. Various properties of solutions of elliptic equations in Euclidean spaces and hyperbolic spaces were explored. The perturbed Q-Curvature problem in four dimensions was studied using the method of Lyapunov-Schmidt reduction. Regularizing effects of half-Laplacian in the Hamilton-Jacobi-Bellman equation were studied. A novel numerical scheme was developed for the Euler equations of compressible flows that conserves entropy and has kinetic energy consistent fluxes. New results on rates and communication requirements of secure communication/computation were obtained at the School of Technology and Computer Science. An online algorithm with 2-approximation for maximizing the throughput in communication system with arbitrary energy arrivals was found.

At SINP, the spectrum of the SU (m) spin Sutherland model associated with the BN root system was computed including the exact degeneracy of all energy levels. The combined effect of a conical topological defect and a Coulomb charge impurity on the dynamics of Dirac fermions in gapped graphene was studied.



Projection based Seamless Tiled Display



Display with geometry correction & blending

In Quantum Fields on Lattice, in the context of additive mass renormalization and chiral anomaly in Wilson lattice QCD it was shown that by appropriately averaging over suitably chosen branches one can reduce cut-off artifacts. It was found that the central branch among all the avatars of the Wilson fermion is the most suitable candidate for exploring near conformal lattice field theories. In Quantum Fields on Light-Front, in the area of polarized deep inelastic scattering, it was pointed out that the identifications of transverse boost and rotation operators in light-front theory were incorrect and the simple parton interpretation claimed was in fact for the transverse boost operator.

The Mathematics group of HRI contributed significantly in research and through vibrant outreach programmes. It rejuvenated mathematics learning at college and university levels. In Analysis and Geometry, extensive work was done on the analyticity of the Schrodinger operator on the Heisenberg group. Work was done on holomorphic Quillen determinant line bundles of integral compact Kahler manifolds. Specific non-special finite p-groups having Abelian automorphism groups were constructed in Group theory and Lie Algebra. Irreducible modules for the derivatives of the rational quantum torus were studied.

Extensive work was done on the evaluation of certain classes of convolution sums in Number Theory. Work was done on Liouville numbers and Schanuel's conjecture and also on the distribution of residues and prime roots. Monochromatic configurations for finite colourings of the plane were studied. Erdos-Ginzburg-Ziv theorem for finite commutative semi groups were investigated.

The Institute of Mathematical Sciences (IMSc) remained involved in the various projects with national and international institutes on Mathematical Sciences without Walls; Developing tools for dynamical modelling of C elegans neuronal network activity; Interplay of non-linearity with quantum effects and curved geometry - some applications; Computational Study of Functionalized Nanoparticles; INO Project; Algebraic Problems; Provably Efficient Re-processing Algorithms; National Initiative in Mathematics and Potential Theory on Infinite Networks and Trees.

The School of Mathematical Sciences at the National Institute of Science Education and Research (NISER) continued its teaching and research activities. In addition to formal courses and research, seminars were conducted regularly. A State-of-the-art Computing facility and a High Performance Computing Cluster for theoretical calculation was provided.

PHYSICS

At BARC, Surface-Enhanced Infrared Absorption (SEIRA) spectroscopic technique was developed for the study of organic and biologically important molecules. SEIRA substrates were fabricated and studies of taurine, sodium benzoate and uracil were carried out using attenuated total reflectance-Fourier transform infrared technique. The surface morphology of the gold nano-films was measured by AFM and morphology dependent SEIRA studies were carried out.

Investigations of the simplest alpha cluster nucleus, the dumbbell like nucleus ^8Be , crucial for the nucleo-synthesis of ^{12}C , the element essential to all living organisms, providing clues to the understanding of more complex alpha cluster structures in nuclei were carried out. The experiment involved measuring a very weak γ -decay branch from the $4+$ rotational state of 10^{-7} compared to the 2 -decay branch.

Three types of High Pressure Diamond anvil cell (DAC) used for interferometer based spectroscopic studies of material behavior at high pressure were manufactured and are being used to carry out experiments of radioactive samples at 100GPa pressure, to conduct high pressure (30 GPa) and sub-zero temperature application (10K).

Fabrication of Neutron Well Coincident Counter assemblies for determining the plutonium present in the form of fuel or alpha active waste for the nuclear material counting was completed.

The TACTIC telescope at Mt. Abu was deployed for TeV (10^{12} eV) gamma-ray observations of extragalactic objects. About 450 h of observation data was collected from Mrk421, Mrk501, 1ES1218+304 and 3C279.

For the MACE telescope being proof-assembled at ECIL Hyderabad, prior to its final erection at Hanle, Ladakh, the Telescope Control Servo system consisting of Telescope Control Unit and Telescope Drive Unit were installed at the proof-assembly at ECIL and initial drive tests for AZ axis was carried-out. A test panel with nine mirror panels with associated actuators is interfaced to the Active Mirror Control System for validating the actuator design.

The trial assembly of the 21m diameter MACE telescope is progressing at Hyderabad. The computerized azimuth drive system for pointing and tracking of the telescope was assembled and tested off-line. A prototype 64 channel camera was assembled and is undergoing elaborate qualification tests at BARC. About 1320 mirror facets were manufactured and qualified for deployment. The 240 KWp solar power plant required for the MACE telescope was installed and commissioned at Hanle. A 12 detector conventional Neutron Monitor with lead multiplier was set up at HARL, Gulmarg to augment the cosmic-ray modulation studies undertaken there with the lead free Neutron Monitor.



MACE Telescope components assembly

At TIFR, a new unambiguous and easy procedure to analyze event planes correlators data measured by the ATLAS collaboration at LHC was presented. Structure of the leptonic mixing matrix was discussed. Quantum Monte Carlo evidence was obtained for a direct continuous quantum phase transition between a Néel ordered antiferromagnetic ground state and a three-fold symmetry breaking Valence-Bond-Solid (VBS) ground state on the honeycomb lattice. Giant fluctuations and temporal intermittency were studied analytically in a stochastic one dimensional model with diffusion and

aggregation of masses in the bulk. Simple models with N grains at a single site in the Abelian sandpile models were shown to have proportionate growth with a striking resemblance to natural forms. An analytically tractable variation of the minority game in which rational agents use probabilistic strategies was proposed. A stochastic model of binary opinion dynamics was introduced.

In Astronomy and Astrophysics, the testing and calibration of CZTI and CPM packages for ASTROSAT were completed. The assembling and testing of CZTI flight models of payload are going on. The flight model of LAXPC payload of ASTROSAT is getting ready to be delivered to ISRO. The Soft X-ray Imaging Telescope (SXT) for ASTROSAT was delivered to ISRO. Lab model of Infrared Spectroscopic Imaging Survey (IRSIS) payload designs was ready for fabrication. Designs of indigenous balloon heliostats were ready for fabrication. A wide variety of problems related to supernovae and gamma-ray bursts were studied.

Several new and exotic pulsars were discovered by searching for pulsations associated with sources identified by the LAT instrument aboard the Fermi satellite at the National Centre for Radio Astrophysics. A highly unusual spiral host galaxy that has undergone multiple episodes of radio activity was discovered. The GMRT was used to make a sensitive all sky survey at a frequency of 150 MHz (TGSS). All required observations were taken and the 5th data release (DR5) was done.

In Condensed Matter Physics, rarely known multiglass phenomenon in $\text{Ca}_3\text{Co}_2\text{O}_7$ was investigated and evidence for a novel phase co-existence phenomenon due to magneto-electric coupling was found. The existence of magneto-electric coupling due to incipient spin-chain ordering was demonstrated. A variety of single crystals of strongly correlated electron systems were grown and their anisotropic physical properties were studied. Several patterns on the surface of GaAs were made and THz antenna was fabricated which showed 2 to 4 fold enhancement in its emitted power. Large exciton g-factors in anisotropically strained non-polar A-plane oriented GaN films using magneto-optical Kerr effect spectroscopy were measured and found.

In High Energy Physics, VHE gamma ray observations with HAGAR telescopes continued and the results from Blazar, Mkn 501 were finalized. Three-level laser cooling of Potassium (^{39}K) down to 12 micro-Kelvin was achieved for the first time.

The Nuclear and Atomic Physics study demonstrated, for the first time, the bond-selective fragmentation of a molecule using ultrashort, carrier-envelope-phase stabilized laser pulses. A pair of degenerate bands in ^{108}Ag was measured using Indian Nuclear Gamma Array (INGA). Directed emission of MeV neutral was observed in intense laser produced plasmas. Giant magnetic fields were probed at ultrahigh intensities. Experimental evidence of random lasing over gap states in one dimensional system was provided. Truncated Levy sums were proposed as a basis of intensity fluctuations in random lasers.

At SINP, the state of art of major capital equipments like cryogen free room temperature bore 9T for grain oriented, magnetocaloric effect studies, custom built UHV versatile thin film deposition set-up to fabricate high performance magnetic/nonmagnetic hybrid nano-structure, SQUID VSM for magnetic properties, thermal expansion, thermal transport experimental systems were installed. Research activities in Surface Physics encompassed the physical and chemical methods of growing low-dimensional structures with tunable morphology and mechanical /electrical /magnetic / optical properties, epitaxial growth of semiconductor quantum structures and their applications in micro-nano technology.

Research activities in Nuclear Physics included experimental study of nuclear structures and nuclear reaction mechanisms using different accelerator centres in India and a few abroad. The High Energy Nuclear and Particle Physics division was involved in two major experiments at the Large

Hadron Collider (LHC), CERN. The two experiments, ALICE and CMS collected data with a very high efficiency and SINP took an active part in the data collection, data analysis and extracting important physics results from these experiments.

SINP was involved in the development of the front-end electronics chip, fabrication of the second tracking station of the Muon Spectrometer and development of the di-muon high level trigger for ALICE. The institute made a strong presence in the Compact Muon Solenoid (CMS) experiment participating in the upgrade project of the hadron calorimeter and has successfully made part of the back end electronics of the future calorimeter system.

The area of research in Theoretical Physics at SINP included Particle Physics Phenomenology, Gravity, Cosmology, Strings, Nuclear Theory and QCD at Finite Temperature and Density. In Plasma Physics, theoretical studies of electromagnetic wave propagation in magnetized plasma were done. the selective excitation of low frequency drift mode was studied in detail for MaPLE (Magnetized Plasma Linear Experimental) in the experimental front.

At VECC, the Large Area Modular BaF_2 Detector Array (LAMBDA) was used for neutron measurement. The neutron detection efficiency of the spectrometer was shown to be comparable to that of the liquid scintillator based neutron detector (BC501A). The extracted efficiencies were compared with the GEANT4 simulation. The average interaction length of neutrons in the BaF_2 crystal was also estimated using the BaF_2 gamma multiplicity filter to determine the time-of-flight (TOF) energy resolution. Nuclear level density parameters obtained by the LAMBDA spectrometer were found to be consistent with those obtained by the BC501A neutron detector, indicating that the spectrometer can be efficiently used as a neutron detector to measure the NLD parameters.

A complete kinematical measurement of inelastic scattering of beam of 60 MeV from Variable Energy Cyclotron (VEC) machine on ^{12}C target was performed to study the various decay channels of Hoyle state with relatively higher in statistics compared to the previous measurements.



HTR card (left) and the test set up at SINP (middle) and at the industry (right)

Several studies were carried out both theoretically and experimentally to understand the functional dependence of nuclear level density on the key parameters, such as excitation energy, angular momentum and isospin. To independently verify the status of collective enhancement in the level density VECC carried out a new experiment. The experiment was performed using ^4He ion beam of energies from the cyclotron facility. Theoretical analysis of the experimental data was carried out using the statistical model.

The effects of the nuclear equation of state (EoS) & symmetry energy on the proton fraction in neutron stars and the location of the inner edge of their crusts and their core-crust transition density and pressure, were investigated thermodynamically in Theoretical Physics. The fusion cross sections for nuclear reactions of astrophysical interest were calculated. Transformation relations between statistical ensembles in the modelling of nuclear fragmentation were studied. The effect of particle fluctuation on isoscaling and isobaric yield ratio in nuclear fragmentation were investigated. The temperature of projectile like fragments in heavy ion collisions was determined using a microscopic approach. Spontaneous fission life times from the minimization of self-consistent collective action using density functional theory was estimated. The transport coefficients of heavy quarks propagating through quark gluon plasma were estimated and its implications on the equilibrium distribution were studied.

The research activities at HRI were carried out in five major areas of Physics and they were Astrophysics, High Energy Physics, String Theory, Condensed Matter Physics and Quantum Information. The recent focus of the astrophysics program in HRI was the study of analogue gravity in the area of accretion flows around massive objects like black holes.

In an internationally acclaimed work, HRI scientists carried out a multichannel global analysis of all data from ATLAS, CMS and the Tevatron experiment after the announcement that the Large Hadron Collider (LHC) has seen signature of the Higgs boson. One of the most important works pertaining to LHC physics which discusses higher

order corrections in the total cross section for Higgs Boson production in hadron collisions came from HRI.

Formal developments that originated in HRI included specific predictions about the leading correction term to the area law of black hole entropy, techniques to simplify calculation of scattering amplitudes in gauge theories, higher derivative corrections to string theory and a fresh look at gauge gravity duality through the stochastic quantization procedure. A duality between a class of two dimensional quantum field theories and generalized gravitational theories was initiated and carried forward in HRI. Application of formal string theory to practical issues in cosmology and hydrodynamics constitute vital contribution of HRI.

Discovery of magnetic superatoms is one of the more striking pieces of condensed matter research in the recent past which involved HRI theorists. Helical Edge states were studied in the context of topological insulators. Real space techniques for lattice systems were developed at HRI and they yielded significant result for frustrated Mott Insulators and disordered superconductors.

Scientists of HRI have been playing a pioneering role in understanding the flow of classical and quantum information in quantum many body systems. Work on quantum information aspects of non-equilibrium many body systems and resonating valence bond systems was an important contribution.

During the year 2013-2014, the Institute of Physics (IOP) undertook active research in various areas of theoretical and experimental physics. The high energy physics group remained actively involved in pursuing research in String theory, Cosmology and Particle physics. Some of the topics of recent interest were gauge / gravity duality, black hole Physics, anisotropic power law inflation, different aspects of relativistic heavy ion collisions, and dual superconductor model of Hadronization. Connection between phase transition in cosmology and Condensed matter system such as liquid crystal were investigated. In high energy phenomenology, cross section processes of one loop which are important for analysis of LHC data were studied.

Research areas in Condensed Matter Physics (CMP) theory included mesoscopic systems, statistical mechanics for non-equilibrium systems and biophysics. Some of the topics investigated were dynamic phase transition in DNA, fluctuation theorems, and phase transitions in driven lattice systems.

In nuclear Physics, research was focused on nuclear structure and nuclear reaction. The mechanism for the formation of superheavy elements in astrophysical objects, nucleus-nucleus reaction, study of cluster decay properties were pursued. Recently discovered superheavy nuclei and a new mode of fission decay for neutron-rich heavy nuclei was studied. In addition, studies on quantum information were also carried.

Major activities in experimental physics included studies on accelerator based materials science, surface and interface physics, and nano systems. Investigations in these areas were carried out by using the state-of-the-art facilities developed at the Institute. Some of the topics of current interest are ion beam-induced surface nanostructuring, pattern formation, epitaxial crystallization, and electronic structure studies of multiferroics, manganites etc.

The School of Physical Sciences of NISER continued to provide the five year integrated Master of Science programme and research programmes leading to doctorate in physics. The broad areas of research work in physics included subjects such as String theory, Lattice Quantum Chromodynamics, Experiments at Large Hadron Collider (LHC), Switzerland, Electronic structure of matter, Colloids, Soft-condensed matter and statistical mechanics, density functional theory, magnetism, superconductivity, low-temperature physics, semiconductors and nano-fabrication, spectroscopy, Ultra-cold atoms and Bose-Einstein condensation (experimental), Photonics–Nonlinear optics, Laser Physics and Nano-photonics.

The various facilities provided by the institute included the Scanning Electron Microscope and Lithography; Ultrafast Time-resolved Spectroscopy for quantum life measurements of molecular dynamics and Ultracold atoms and BEC facility using

atom trapping by lasers and Facility of Magnetic nanostructures and multilayers.

CHEMISTRY

Research work in the field of Chemistry in BARC has led to identification of a mono-triazinyl-phenanthroline and a sulphur-containing CYANEX 301 analog as two potential solvents for the separation of trivalent actinides and lanthanides from the high level nuclear wastes.

A new class of -amino-acetamide anion exchangers was synthesized and found to perform better than the commercial anion exchanger. A new host-entrapped PM597 formulation was developed and used as an aqueous dye laser system for round the clock operation.

Raman spectroscopic technique was developed and used to monitor the structural changes in the glass matrix of simulated waste and to understand the leaching behavior of the waste material under hot water treatment.

Nano-TiO₂ impregnated chitosan beads were developed for antimony decontamination. Electrochemical burner based process was developed for removal of stoichiometrically excess deuterium from moderator cover gas system during normal operation and primary heat transport system storage tank during dilute chemical decontamination. A process was developed for reducing the corrosion rate of carbon steel surface based on controlling particle size in the passive film to nano size domain.

An efficient and inexpensive iron oxide based catalyst (Fe_{1.8}Cr_{0.2}O₃) was developed for the sulphuric acid decomposition step of sulphur-iodine cycle (S-I cycle).

Good progress was achieved in the development of hydrogen storage materials based on carbon nanotubes, ionic liquids and metal organic frameworks.

Hybrid materials were developed for the decontamination of potable water from radioactive (U, Th, Pu & Am) and non-radioactive elements (fluoride and arsenic). A boron selective membrane was developed by functionalization of polypropylene membrane using N-methyl D-glucamine to provide

sorption capacity of 28 mg per gram. Sensor based on silver nanoparticles was developed for detection of mercury in industrial effluents.

A novel consortium consisting of sulphate reducing bacteria and green sulphur bacteria was developed for bioremediation of industrial effluents containing sulphate. A novel phototropic granular biomass was developed for denitrification of industrial effluents without having to supplement organic carbon. Two rare flavonoids ($C_{74}H_{74}O_{17}$ and $C_{24}H_{26}O_2$) of nutraceutical value were isolated from the weed, *Coronopus didymus*, by developing a rapid, novel and economical process.

A chemical approach was developed that selectively disrupts the function of Telomerase, thereby inhibiting the growth of cancer cells. This study demonstrated the use of a fluorogenic dye, Thioflavin T, to stabilize the telomeric DNA strand into a G-quadruplex structure under physiological salt conditions. This brings out a facile approach to inhibit telomerase activity, which leads to the arrest of cancer growth.

Iron oxide nano-particles were synthesized by chemical route and their surface was modified using amino acids and peptides to use them in cancer therapy and magnetic resonance imaging. These are used as nano-carriers for commonly used chemotherapy drug, doxorubicin (DOX). The surface charge of these nano-carriers is sensitive to the tumor environment which in turn releases the bound drug molecules to the tumor. These nano-carriers exhibit excellent T2 magnetic resonance contrast properties. The developed novel nano-carrier can serve as base material for diagnosis as well as therapy.

Perylene, tetracene and pentacene doped nano-aggregates of anthracene were developed and shown to exhibit white light emission with high efficiency, thus suitable candidates for making organic LEDs. A variety of single source molecular precursors were designed for the preparation of metal selenide and telluride nanocrystals and for deposition of thin films.

Studies on the speciation of uranyl-mandelic acid system were carried out by electrospray ionization mass spectrometer (ESIMS) using 10^{-6} M

$UO_2(NO_3)_2$ and 10^{-6} M mandelic acid in 1:1 methanol-water.

Microstructural characterization of Chitosan-NiO nanocomposite (CNC) and Polyvinyl Alcohol (PVA) based amino functionalized carbon nanotube composites was performed using positron annihilation spectroscopy (PAS) and SEM, XRD, SAXS to study polymer-nanoparticle interface in composites.

To understand the Ln^{3+}/An^{3+} separation behavior, lanthanide complexation studies were carried out using tridentate 'N' donor ligands such as 1,2,4-triazinylphenanthroline (TPhen), 1,2,4-triazinylbipyridine (TBipy) using UV-Vis spectrophotometric titrations and time resolved fluorescence spectroscopy.

Time resolved photoluminescence spectroscopic (TRPLS) technique was used to investigate the speciation of Eu^{3+} ion in alkali barium borosilicate glass having composition similar to the Trombay nuclear waste base glass used for fixing research reactor HLW.

To assess the retention behavior of actinides and long lived fission products in smectite rich clay, batch sorption measurements were performed at trace concentrations for the minor actinide elements Am(III) and Np(V) and for the long lived fission products, Cs(I), Sr(II), and Tc(VII) on purified and conditioned smectite rich clay at varying conditions of pH and ionic strength

A -hydroxy acetamide based extractant was synthesized and its extraction and complex chemistry with trivalent lanthanide and actinide ions was studied.

The significance of low-frequency ring deformation modes in driving ultrafast ET reaction with anthraquinone acceptors was unraveled at TIFR. Sensors for biologically relevant small molecules and metal ions were developed. Site specific hydroxylation of mono-unsaturated fatty acids by mutation of thermostable cytochrome P450 enzyme which may have potential implication in fatty acid metabolism in biology was achieved.

The School of Chemical Sciences at NISER imparted high quality undergraduate and

postgraduate level of knowledge to students coupled with cutting edge research activity. In addition to traditional organic, inorganic, physical and theoretical chemistry areas, the school embarked on teaching and research activity in the interface areas of Biology, Material Sciences and Medicine. GC Mass and ESI Mass Spectrometers, State-of-the-art NMR Spectrometer for 1D and 2D Experiments and Time-Resolved Fluorescence Spectrometers were the facilities that were provided by the school.

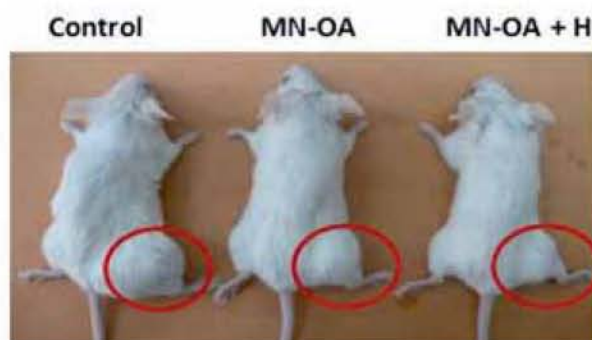
BIOLOGY

In *D. radiodurans* 110 proteins differentially expressed in response to radiation were identified to be metabolic enzymes, DNA/RNA metabolism/modification related proteins and Protein translation/folding/turnover related proteins.

A novel mechanism of N-terminal processing of the 30 kDa MnSOD was revealed in the stress tolerant cyanobacterium *Anabaena* 7120. Studies in Rice revealed the predicted three splice variants (SVs) of Os06g05110 Fe-SOD gene. Their response to salinity stress was dependant on genotype's salt tolerance and was not responsive to Methyl Viologen (MV) stress.

Applied research for environmental monitoring and clean-up using recombinant DNA technology was actively pursued at BARC. A biosensor for detection of ppt levels of the pesticide lindane was designed, constructed and its specificity, efficacy and stability were demonstrated.

Under the collaborative work between DAE and Government of Kerala, more than 5000 newborns were screened from two hospital units at Kerala namely, Victoria Hospital, Kollam and Taluk Head Quarter Hospital, Karunagappally. No change in frequency of congenital malformations between High Level Natural Radiation Areas (HLNRA) and Normal Level Natural Radiation Areas (NLNRA) was observed. The cytogenetic studies showed that there was no significant difference in frequency of micronuclei, chromosomal aberrations, spontaneous frequency of DNA strand breaks and oxidative damage between HLNRA and NLNRA populations. A Next Generation Sequencer (Illumina HiSeq-1500) was installed at ACTREC, Kharghar, Navi Mumbai.



Demonstration of efficacy of magnetic nanoparticles in hyperthermia treatment of cancer.

Radiation-induced bystander effect was established both at the cellular and histological level using an in vivo fibrosarcoma tumor model in BALB/c mice.

Combinatorial therapy of fibrosarcoma bearing mice with MN-OA (magnetic-oleic acid) nanoparticles and hyperthermia showed significant regression in the tumor, indicating efficacy of nanoparticles in hyperthermia therapy.

Radioprotective and immunomodulatory effect of several natural molecules was studied. Radioprotection studies in mice with concanavalin A showed that it could offer complete protection against whole body irradiation (WBI) induced mortality at a dose as high as 10 Gy and this effect was mediated through activated T-cells.

Under the Animal House Facility of the BioScience Group around 4500 mice and 478 rats were supplied for research to various divisions of BARC and BRIT under various research projects.

An experimental setup was made available for studying biological effects in cells at 3 MeV proton beam using Folded Tandem Ion Accelerator at BARC. The setup facilitated precision irradiation of cultured mammalian cells to known doses for quantifying the damage due to proton charged particles on model biological systems. Various biological endpoints such as micronucleus induction, survival, chromosomal aberration and apoptosis were studied.

TIFR developed an in vitro assay to study the biogenesis of lipid droplets in liver which allows to understand how metabolic stimuli regulate the



Titanium window for proton beam irradiation of biological samples

formation, storage and use of lipids in liver. A new model system using phagosomes isolated from dictyostellium was developed. Roles for tension and geometry in directing cytoskeletal dynamics and mediating transition in cell behaviour were identified and a novel role for oxidative stress signaling in cytoskeletal remodeling in a morphogenetic movement that resembles wound healing was uncovered.

A key role of an enhanced 5-HT₂ receptor signalling in mediating the paradoxical anxiogenic and depressive behavioral effects caused by early life treatment with the antidepressant Prozac was identified. A role for key epigenetic machinery in programming long lasting behavioral effects of early Prozac treatment was demonstrated.

Host response to malarial parasite infection in mice and humans was studied using ¹H NMR-based metabolomics. Tryptophan metabolism in various organs of mice infected with malarial parasite was investigated in relation to kynurenine metabolism.

Genes contributing to sporulation efficiency in 34 genetically and environmentally diverse yeast strains using genome-wide association mapping were mapped. The role of Wnt signaling in laminin synthesis were unraveled. Sirt4 in the mitochondria regulate energy homeostasis via ATP generation in mammals was demonstrated. Tissue-specific developmental phenotypes associated with Rad51 and BRCA2 null mutant flies were characterized. Molecular basis of Rad52-mediated positive regulation of HR was uncovered in BRCA2-minus

mammalian cells. Changes in mitotic spindle architecture, cell sizes and cell fate specification in haploid embryos compared to normal diploid zebrafish embryos were identified.

The National Centre for Biological Sciences, Bangalore discovered new nucleic acid motifs based on both DNA and RNA and their potential use in creation of nano devices as sensors for bio-imaging and cell specific delivery. To understand the molecular mechanisms of Notch signaling and human cancer stem like cells efforts for development of a translational initiative programme was undertaken.

Studies on insect flight as a system to understand how sensory modalities evolve novel solutions to solve the problems of fast sensory acquisition and how the motor system optimizes speed and accuracy of response in different situations were established. Genetic screens for identifying G-protein coupled receptors (GPCRs) were carried out.

At SINP, in the areas of chemical and structural biology, studies on the recognition of multiple stranded DNA (Quadruplex) and putative anticancer agents from plant source showed that one such agent, ellipticine binds to DNA with a 3:2 stoichiometry in terms of ellipticine: DNA.

A two color single molecule FRET Imaging set up for real time monitoring of complex macromolecular systems was developed. Modes of interactions of a cyanine dye with proteins were investigated using spectroscopy, crystallography and theoretical docking study.

Research in the area of Disease Biology focusing on hematological and neurological disorders was continued. The widely prevalent disease of Eastern India, HbE-thalassemia, along with sickle cell anemia and leukemia were studied as model for hematological disorders while Alzheimer's, Huntington's and the Prion diseases were studied for the neurodegenerative diseases.

The School of Biological Sciences at NISER continued its research and teaching with harmonious synthesis of classical and modern biology. The

various facilities for research and teaching provided included Confocal Microscope Facility, DNA sequencing and Surface Plasmon Resonance Facility and Micro-array facilities for Genomics.

CANCER

The Advanced Centre for Treatment, Research and Education in Cancer (ACTREC) at Kharghar continued to take rapid strides forward particularly in its patient care and research programs and has more than 200 on-going research projects.

The Clinical Research Centre (CRC) at ACTREC initiated many new procedures like the use of state-of-the-art Intraoperative Image-guided surgery techniques, specifically navigable 3D ultrasound based surgery and fluorescence guided-resections of malignant gliomas by the neurosurgery service.

Established programs of Cancer Research Institute (CRI) and several Principal Investigator-led laboratories continued to focus on cancers that are a major cause for concern in the Indian context at the chromosomal, DNA, RNA and protein level. The present research focused on identification of genomic alterations in oral cancers; molecular basis of oral and cervical tumorigenesis; genome wide expression studies & validation of differential miRNA expression in medulloblastoma, a common brain tumor in children; Screening of myeloid cells from chronic myeloid leukemia; identification and delineation of the mechanism of action of chemo preventive agents from curcumin, tea and grapes against chemical induced carcinogenesis, and various topics related to chemotherapy and molecular changes in early detection were also studied.

SYNCHROTRONS & THEIR UTILISATION

During the year at RRCAT, both the synchrotron radiation sources, Indus-1 at 450 MeV energy, 100 mA current and Indus-2 at 2.5 GeV energy and up to 150 mA current were operated in the round-the-clock-mode. Indus-2 synchrotron radiation source is the largest size and also the highest energy accelerator built in the country.

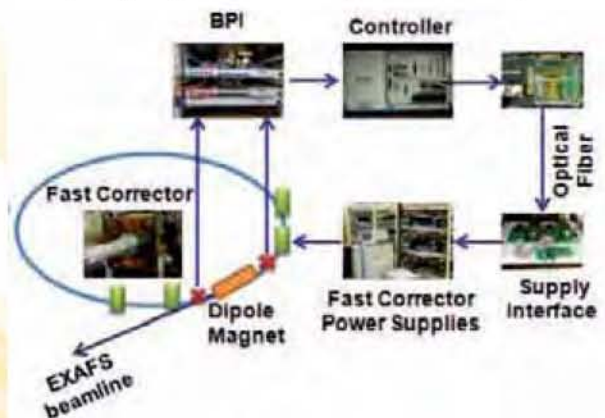
Various subsystems of Indus-2 were upgraded. The output power of the solid state RF amplifiers was increased to 225 kW. The Indus-2 current was increased to more than 180 mA at 2.5 GeV energy.

To counter the rise in temperature during operation of the ring at higher currents, the end plates were fitted with OFC copper plates to cool the end plates of the chambers. With this cooling arrangement, the highest temperature observed was around 60 °C at 130 mA beam current in routine operation of Indus-2 at 2.5 GeV. A local fast orbit feedback system was developed to take care of high frequency beam perturbations. Beam positions in both vertical and horizontal planes were corrected.

Beam dynamics and magnetic lattice computations were done to evolve and finalize the specifications for these insertion devices at Indus-2. Two planar undulators are under fabrication and will be installed in the Indus-2 ring towards the end of this year.



Cooling arrangement in Indus-2 dipole chamber's end plate



Local fast orbit feedback system developed for Indus-2



Beamline optics and experimental station on the X-ray imaging beamline

During the report period, four more beamlines such as Scanning EXAFS beamline, X-ray Diagnostic beamline, Soft X-ray Absorption beamline and X-ray Imaging beamline were commissioned on Indus-2. In total twelve beamlines on Indus-2 are now operational. The X-ray Imaging beamline will facilitate absorption and phase contrast imaging of advanced composites biomaterials, industrial products etc.

The existing X-ray micro-focus beamline was upgraded with the total external reflection x-ray fluorescence facility. X-ray lithography beamline was used for fabrication of compound x-ray refractive lenses. Micro-fluidic channels were made in SU-8 photo-resist for an ultra-sensitive glucose sensor using the x-ray lithography beamline. Low and high temperature and high pressure experiments were performed using the angle dispersive x-ray diffraction beamline. Several materials systems were synthesized and studied at Indus beamlines. Lab based synthesis facilities like arc melting furnace and high temperature box furnace were set up. Studies of strategic interest such as composition mapping in mixed uranium-thorium fuel pellets for Advanced Heavy Water Reactors were also done.

A new laboratory was set up to investigate protein crystals starting from gene cloning to



Total external reflection x-ray fluorescence facility at X-ray micro-focus beamline



*Protein crystallography facility at Indus-2
(a) Cell growth and centrifuge lab. (b) Protein purification lab*

elucidating protein structure using the protein crystallography beamline. Structure of several proteins were solved.

An x-ray diagnostics beamline was commissioned on Indus-2 storage ring to measure transverse beam parameters of electron beam such as beam size, beam emittance and beam position by employing pinhole array imaging. A tungsten pinhole array is used for x-ray imaging of Indus-2 electron beam. Imaging is carried out on a phosphor screen with optimum magnification factor. The energy selection for imaging is carried out using remotely controlled metal filter assembly. Wire beam profile monitor with tungsten wire were developed to find the position and profile of synchrotron radiation before the pinhole array.



X-ray diagnostic beamline installed at Indus-2 (left) and filters and phosphor screen assembly installed in the hutch (right)

An IR (Infra-red) beamline was installed on Indus-1. The total number of beamlines on Indus-1 reached to six. An electron-ion spectrometer was set up on the soft x-ray reflectivity beamline of Indus-1 for studying problems like complete kinetics of molecular dissociation.

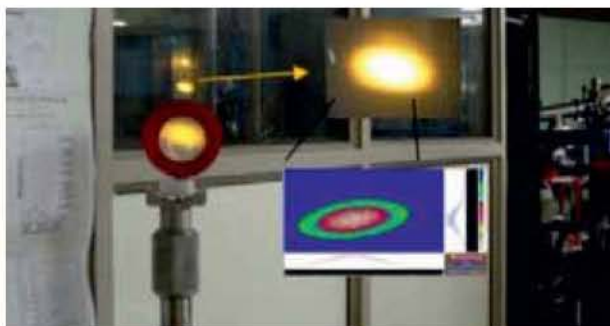


*Gas-cell payload for the Mangalyaan mission (left)
The electron-ion spectrometer set up on the reflectivity beamline on Indus-1 (right)*

VUV absorption spectra of sulphur dioxide and acetone at low temperatures in matrix isolated phase and ice phase were recorded using low temperature experimental facility on photo-physics beamline at 10K. Several experiments were carried out on the Angle Integrated Photoelectron Spectroscopy (AIPES) beamline, band offset measurements in ZnO/Ge and ZnO/GaP systems.

Protein crystallography (PX) beamline was augmented with an auxiliary biochemical laboratory and cold rooms. Using this facility the single crystals of five novel proteins were grown and subsequently used for diffraction studies on PX beamline. The researchers from various centers utilized the PX beamline and associated facility for their diffraction experiments.

As a part of infrared beamline development, alignment of the front end and transport optics connected to the front end of the infrared beamline coupled to the Indus-1 synchrotron source was carried out.



First beam observed at the IR experimental station at Indus-1

X-ray Absorption Fine Structure Spectroscopy (XAFS) at BL-08 and BL-09 beamline at RRCAT have been utilized to correlate the structure of the ayurvedic drug Rasa-sindura with toxicity.

The HRVUV (High Resolution Vacuum Ultraviolet) beamline at Indus-1 SRS was utilized for characterization of the specialized gas cells used in the Lyman Alpha Photometer (LAP) payload on the Mars Orbiter Mission launched by ISRO.

The combination of an intense VUV source along with a good spectral resolution essential for these experiments is provided by the HRVUV beamline at the Indus-1 synchrotron radiation

source, which is the only facility of its kind available in India.

Beam line Stopper Assemblies for various Synchrotron Beamline required for various beam lines at Indus-2 synchrotron radiation facility at RRCAT, Indore to stop the beam coming from the storage ring when beam line is not required for experimentation were designed, developed & manufactured.

Assembly of Experimental station for SAXS / WAXS beam line for studying small Angle and Wide Angle X-ray scattering of synchrotron radiation when passed through different types of substrates consisting of (i) Platform sub-assembly (ii) Base structure sub assy (iii) Support structure sub-assembly (iv) Beam stop sub-assembly and (v) Sample holder sub-assembly was designed.

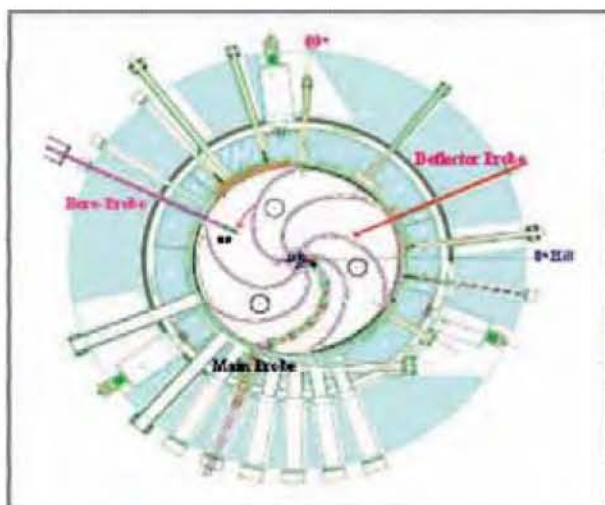


Beam Line Stopper Assembly

Various instruments such as Compact X-ray slit assembly without cooling with 1 micron accuracy, Enhanced Water Cooled Compact Slit Assembly and Plane Grating Monochromator for PEEM/ARPES Beam line of Indus-2 were designed and developed.

CYCLOTRONS & THEIR UTILISATION

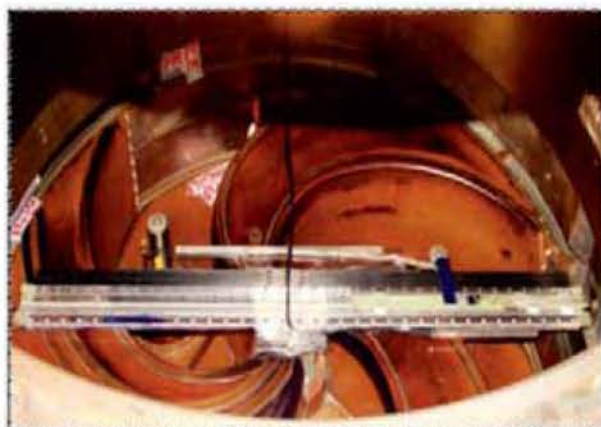
Significant progress was achieved at VECC towards extraction of the beam in the superconducting cyclotron. Several investigations were performed to understand the properties of the accelerated ion beam in SCC accurately. The orbit centering was measured using three probes installed about 120° apart. With this arrangement beam centering was measured applying 'beam shadowing' technique.



Median plane view of the superconducting cyclotron installed with three beam probes

A novel technique was used to measure the phase of the circulating beam with respect to RF voltage. A detailed mapping of the magnetic field was carried out in the superconducting cyclotron using a search coil set-up for quantitative measurement of the field imperfections and to eliminate the same.

Various field maps were taken at different excitations of main coils on a polar grid of 2.54 mm radial step and 1° azimuthal step. Magnetic field data was then processed and analyzed. A gross deviation in average magnetic field up to 120 mm radius was found. A large first harmonic magnetic field with peak value of 45 Gauss was also found at 650 mm.



Search coil on the radial zig mounted on a Shaft installed at the central-plug hole

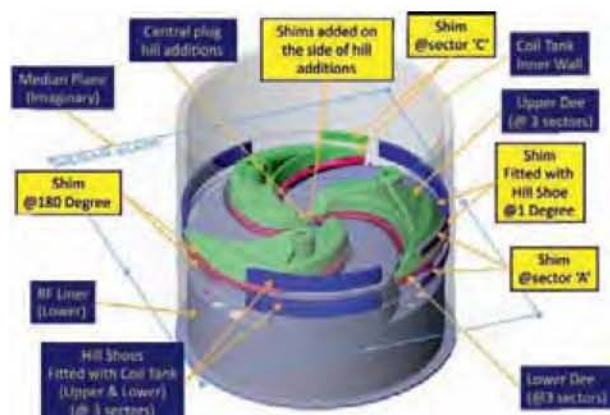


NMR probes kept at the center and on the hill for the calibration of the search coil

To correct the field errors a few shims were put in appropriate places inside cyclotron and central region iron geometry was also modified. To confirm the corrections magnetic fields were re-measured at several excitations. To accommodate these modifications the central RF cover and coil tank liners were also modified. The magnetic field was mapped at different stages of iron-shimming procedure.

Development of New Compact Field Mapping Jig

A magnetic field mapping jig was designed to fit in the narrow gap of the RF liner. Carbon fiber composite having high weight to strength ratio was chosen as the structural material to keep the jig straight throughout the 1.2 meter length of the jig. The jig was assembled in the cyclotron along with a NMR and the errors were measured accurately. The deflection of the total assembly in the vertical direction was measured and found to be less than



Shim locations



Central plug.

Modified hill-addition.

Different stages of iron-shimming

0.25 mm and the jittering movement about a straight line was less than 50 micron in the median plane.

K130 Variable Energy Cyclotron (VEC)

The K130 variable energy cyclotron is presently accelerating alpha, proton beams using an internal PIG ion source. The K130 cyclotron is generally operated in fundamental mode and has been delivering light ion beams in the range of 6.5–18 MeV per nucleon. Recently a low energy light ion beam (1-2 MeV per nucleon) was developed. Singly charged helium beam of 3.33 MeV to 7.77 MeV was developed in third harmonic mode of operation. Helium beam of 5.55 MeV and 7.77 MeV were transported to target to perform an experiment in scattering chamber of channel#2. Such low energy light ion beam was transported to target for the first time in this K130 cyclotron.

Proton beam of 2.0 MeV was also developed in third harmonic mode of operation. Single charged helium of 1.2 MeV and 2.8 MeV (less than 1.0 MeV/n) was developed in fifth harmonic mode of operation. Such beam acceleration in fifth harmonic mode was performed for the first time in this K130 cyclotron.

Deuteron beam of 15 to 25 MeV was developed and an experiment was also carried out in channel#2 with 25 MeV deuteron beam.

The cyclotron operated for more than 3000 hours in terms of new beam development and delivered beam on target for conducting experiments in various fields of research mainly in nuclear physics, radio-chemistry, material science and producing of Rare Ion Beams (RIBs) etc.

Improvement of K130 cyclotron beam chamber vacuum system

Improvement of the K130 cyclotron beam chamber vacuum system was carried out by repairing resonator tank – Dee tank interface air leak. The work involved disassembly of most of the cyclotron mechanical components except the main



Side flanges of the cyclotron disassembled



New corner post

magnet. A new concept was used to replace the corner post vacuum sealing. All the four side flanges of the accelerating chamber were taken out. The resonator tank was separated from Dee tank by about 100 mm towards south side of vault. New corner post and "H" construction O-ring were used and the cyclotron was re-assembled. The interface air leak repair work has greatly improved cyclotron functioning and reduced cyclotron downtime considerably.

Design and development of bending magnet with high rigidity and homogeneity

Two high rigidity and homogeneity bending magnets were designed to transport high energy beam from the K-500 superconducting cyclotron to different experimental stations. These magnets weighed around 12 Ton and 16 Ton respectively. The maximum field that can be produced in the pole gap is 16 kG with better than 3×10^{-4} field homogeneity at all excitations. Both the magnets were designed for maximum beam rigidity of 3.3 T-mtrs to cover all the operating species of K-500 superconducting cyclotron. These magnets were made from AISI 1010 steel and the precision machining was carried out in CNC machining centre to achieve the desired Rogawski profile. Pole gap and individual pole profile was maintained within 40 micron accuracy and symmetry of the two poles was maintained within 100 micron. Magnetic field was also measured with different current.



Magnetic field measurement with hall probe and repeatability check of dimensions after disassembly and assembly of switching magnets

Precision Phase Control for the RF system of K500 superconducting cyclotron

The radio frequency (RF) system of K500 Superconducting Cyclotron was commissioned with the stringent requirement of various RF parameters and a remarkable achievement was made. The three-phase RF system of Superconducting cyclotron was

developed in the frequency range 9–27 MHz with amplitude and phase stability of 100 ppm and ± 0.10 respectively. The phase control system has the option to change the relative phase difference between any two RF cavities and maintain the phase stability within ± 0.10 during round-the-clock cyclotron operation. The said precision phase loop consists of both analog In-phase/Quadrature (I/Q) modulator to achieve faster response and also Direct Digital Synthesis (DDS) based phase shifter to achieve wide dynamic range as well.

Development of True Bipolar switch-mode power supply for x-y steering magnet

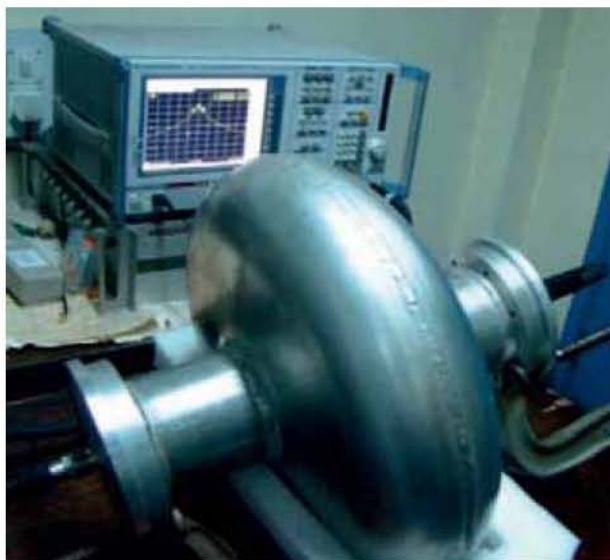
A novel topology of high performance smooth-varying dc current regulation based on "Pulse Width Modulation with Unipolar Voltage Switching" was adopted for the development of these prototype steering magnet power supplies.



Bipolar switch-mode power supply

650 MHz, $\beta=0.61$, Superconducting RF linac cavity

R&D on the design and development of 650 MHz, $\beta=0.61$ Superconducting RF linac cavity was going on under Indian Institute Fermilab Collaboration (IIFC). The RF design for the said cavity was carried out using 2D SUPERFISH code and 3D CST Microwave Studio code and Ansoft HFSS code. The multipacting analysis was carried out extensively by using 2D MultiPac code and 3D CST Particle Studio code. The 3D analysis for the same cavity was carried out extensively for further investigation using CST Particle Studio code that



VNA Measurement of single cell cavity

took into account Furman Model for three types of secondary electron emission, true secondary, back scattered and rediffused electrons. The half cells of the prototype aluminium cavity were fabricated after the design and development of the necessary die-punch assembly. The inside dimensions of the half-cell was measured using Laser Faro Coordinate measuring machine (CMM) and the maximum deviation of the order of 0.4 mm was found and further improvement is being tried.

PLASMA & FUSION TECHNOLOGIES

In the Steady-state Superconducting Tokamak-1 (SST-1), the first plasma was successfully obtained after an elaborate and extensive engineering validations on June 20, 2013. With this achievement, now India has joined the elite club of countries (after Russia, France, Japan, Korea and China) having superconducting Tokamaks capable of conducting steady state experiments. Integration of other sub-systems and advanced diagnostics systems is on full swing, along with installations planning for first wall components.

In the Aditya tokamak, a total of 863 APPS discharges and 234 Capacitor bank discharges were carried out. A new technique for avoiding disruptions was successfully demonstrated in ADITYA tokamak through stabilization of Magneto-Hydrodynamic

(MHD) modes. Contributions were made to the disruption data base of the International Tokamak Physics Activity (ITPA) group.

The auxiliary heating systems consisting of Electron Cyclotron Resonance Heating (ECRH), Ion Cyclotron Resonance Heating (ICRH) and Lower Hybrid Current Drive (LHCD) are getting ready for operations and efforts are on to use them in SST-1. After operating the positive Neutral Beam Source in the test stand, it is now being readied to integrate to the SST-1 machine along with all the necessary beam-line components.

The development of fusion technologies relevant to the fusion reactor advanced very well. For magnet technology, long length Niobium-Titanium (Nb_3Ti) based cable-in-conduit-conductors (CICC) superconductors were indigenously developed. A High Heat Flux Test Facility with 200 kW power in steady-state operation mode, for testing and characterizing materials for divertor modules, was made operational.

For the Cryo-pump development, designs were made for cryo-panels, radiation shields, baffles etc. Different experimental systems for characterizing adsorbents for the cryo-pump were setup and some developed sorbents are being tested.

The notable achievements of Facilitation Center for Industrial Plasma Technology (FCIPT) included installation of plasmapyrolysis system for hospital waste disposal in Srinagar Medical College, Srinagar; Plasma Nitriding system at Central Tool Room, Ludhiana and Plasma Activation system at M/S Triton Valves, Mysore. Works on development of low temperature atmospheric pressure plasma which can be used for infected human skin treatment and for modification of properties of seeds are also in advanced stages.

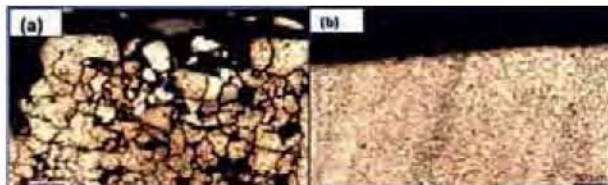
At the Center for Plasma Physics, Guwahati the experiments like double-plasma experiment, dusty plasma experiment and the pulsed power experiment are all progressing well. The thermal plasma laboratory is developing a segmented plasma torch assisted Divertor Simulator system.

An innovative space saving online fabrication facility was set up for the fabrication of long length Cable-In-Conduit-Conductor (CICC) in the existing facility. 100m long 30kA Nb₃Sn based superconducting CICC of 30x30mm cross section was fabricated and delivered to IPR, Gandhinagar using online fabrication facility. Towards fabrication of 200m long Nb-Ti based superconducting CICC, required length of 1st and 2nd stage cabling was completed.

MATERIALS SCIENCE

Studies on nickel aluminide diffusion barrier coating formed on superalloy 690 in a low Al-containing pack continued and advanced microstructural characterisation was carried out.

Alloy 600 outer sheathing of Self Powered Neutron Detectors (SPNDs) used in PHWRs showed failures recently. Thermal treatments of this alloy, as well as a thermo mechanical processing to increase the special boundaries to more than 85%, were carried out for increasing the alloy's resistance to sensitization and intergranular corrosion, which are the principal causes of failure for this alloy. After corrosion tests, these treatments were found to have a beneficial effect.



Intergranular corrosion of Alloy 600 shown in (a) is replaced by uniform corrosion in (b) after thermo mechanical processing

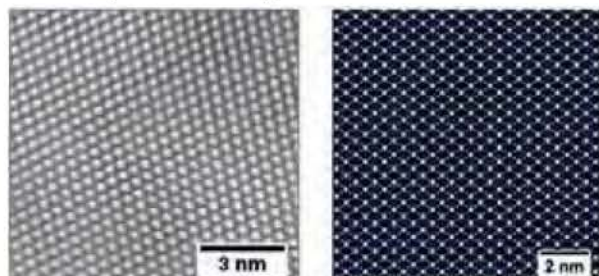
Dislocation dynamics modelling and in-situ X-ray diffraction studies were carried out on zirconium alloys for understanding deformation mechanisms in these alloys. Proton irradiation studies were carried out to understand the irradiation damage in Zr-1%Nb alloy.

Zr and Hf -based bulk metallic glasses were synthesized using rapid solidification techniques and characterized using advanced techniques.

Phase evolution studies were completed for U-10wt% Zr metallic simfuel corroborating to 10 atom% burn up.

In a collaborative India-UK project with Open University, UK, the Ga- assisted diffusion bonding method was developed to join stainless steel to titanium to form joints without any defects such as cracks, discontinuities and pores between the two materials. The interfaces of the joints were characterized at different length scales using various microscopic and microanalysis techniques to establish the mechanism of bonding.

At IGCAR, thermodynamic calculations were carried out for V-Ti-Cr alloy system using Miedema model taking into account the chemical, structural and elastic contributions to enthalpy. An alloy with composition 7V-38Ti-55Cr was prepared by vacuum arc melting on a laboratory scale and studied by TEM techniques.



Lattice image of 7V-38Ti-55Cr alloy along with corresponding simulated image

Ti-5Ta-2Nb, alloy, a candidate material for the electrolytic dissolver was joined to 304L austenitic stainless steel, the structural material for rest of the plant by explosive cladding process. A simple sensor for detection of cations in ppm levels was developed using magnetically polarisable nano-emulsions.

UHV based magnetic transport system consisting of various mechanical/electrical RF components was designed completely in-house and fabricated in India. The commissioning of low energy positron beam was accomplished by recording the 511 keV annihilation gamma ray i.e., slow positron signals, at the target. RF pulsing electronics and necessary components are incorporated in the beam line and fine tuning of electronics for optimizing the pulse width of bunched positrons is in progress.

In the quest for transition metal based superhard materials, a novel phase of Osmium Carbide (OS₂C) was synthesized by laser heating

pure Os and C at 8 GPa and T~ 2000K using Laser Heated Diamond Anvil Cell (LHDAC) facility.

Low (ppb) level gas detection in dynamic state using semiconductor nanostructures was demonstrated.

Investigations on tribiological properties of plasma chemistry dependent ultrananocrystalline diamond (UNCD) films deposited by Microwave Plasma Enhanced Chemical Vapour Deposition (MPECVD) system were carried out on silicon substrate.

High temperature Hall measurement facility was used for in-situ probing of the mechanism of gas sensing by metal oxides.

Successful research activities in Condensed Matter Physics and Materials at VECC included the development and physical studies of nanostructured multifunctional materials like multiferroic and conducting polymer based super capacitors with application in energy cells; Irradiation induced growth of nanostructures like nanoripples; Perovskite & Double perovskite materials used as ferroelectric relaxors; Radiation damage studies of mechanical & crystal structure properties of alloys employed as nuclear structural materials in power reactors and Studies of Dislocation dynamics In materials.



Nanorods protruding out of nanopores by cross sectional SEM (left)
Single nanorod protruding 5 μ m from pores (middle)
TEM images of PEDOT-NiFe₂O₄ nanotube having diameter less than 20nm (right)

The current research highlights included development & studies on Bismuth Ferrite nanorods; Synthesis of single phase nano BiFeO₃ particles and its irradiation studies; Nanotube Poly-NiFe₂O₄ nanocomposite and its performance as a electrode material for super capacitor; Magnetic Behavior of Template Grown 2-D Array of Cobalt Nanowire; Ion Irradiation on ZnO thin films; Irradiation induced growth of nanostructures; Structural and impedance spectroscopy of perovskite barium substituted lead zinc niobate; The design of the chamber for achieving



Indigenously developed Nd phosphates glass rods and slab.

high dpa and high temperature during irradiation of Zr-2.5% Nb in Variable Energy cyclotron; Irradiation with 7 MeV proton as well as characterisation of Zr-1%Nb alloy the cladding material for 1000 MWe VVER type pressurized water reactors and Irradiation studies of Al alloys and Ti- alloys candidate structural materials of support structures using 4MeV proton to study the effect of induced activity during their lifetime operation in the superconducting cyclotron.

Large size Nd:glass laser rods were Indigenously developed under a collaborative activity between CGCRI and RRCAT, and tested for their lasing performance.

The electrical and magnetic properties of the superconducting Ti-V alloys were studied as materials alternative to niobium in a high neutron-irradiation environment. Attempts were made to grow single crystals of large diameter congruent lithium tantalate (LiTaO₃) single crystals by Czochralski technique in Iridium crucible inside an inert (Ar) atmosphere growth chamber. Calcined lanthanum (La) modified Nd:Y₂O₃ powder was compacted in form of disks using uniaxial and cold isostatic press (CIP). High surface area Carbon Aerogel (CA) with surface area of 2000 m²/g was developed. The material was used for preparation of industrially suitable platinum loaded carbon aerogel based catalysts to provide tritium separation or deuterium enrichment. Radiation hard fully packaged GaAs pin detectors with an amplifier stage having a spectral response in the range 300 to 800 nm were developed using the MOVPE growth techniques.

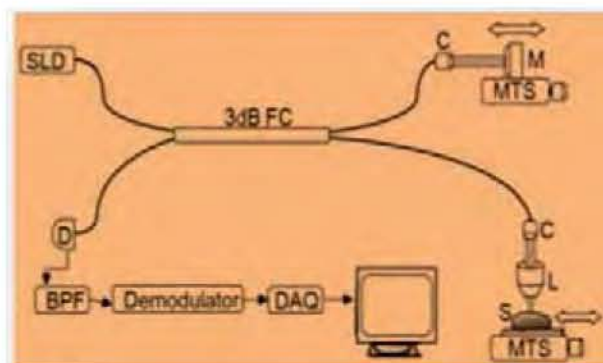


LiTaO₃, single crystal; 42 mm dia. and 50 mm length

Studies in material science at TIFR observed multiferroicity in any element for the first time. Ferromagnetism and ferroelectricity were found to coexist in elemental, single crystalline Se microtubes below 40K. Plasmonic quasicrystals for broadband, polarization and launch angle independent excitation of plasmons were designed and demonstrated. GaAs was grown on graphene. Growth of semi-polar oriented AlInN was demonstrated. A simple and robust method to produce large 2-dimensional and quasi-3-dimensional arrays of tunable liquid microlenses using a time varying external electric field as the only control parameter was demonstrated. Self assembling single amino acid fibers were formed and evaluated. Aligned nanofibers of TiO₂ were formed directly on FTO for dye-sensitized solar cell applications.

INTERDISCIPLINARY AREAS

A time-domain based low-coherence fiber-optic interferometer was indigenously developed for depth-resolved tomography imaging of scattering samples for material science research. The setup consists of a Bandpass Filter (BPF), Collimator (C), Photodetector (D) Fiber Coupler (FC); Lens (L); Mirror (M), Motorized Translation Stage (MTS) a Super Luminescent Diode (SLD). The system was optimised for high S/N sensitivity and was able to



Schematic of time-domain OCT system



Schematic of spray dried powder with silica

probe highly scattering samples including biological ones, up to a depth of 1 mm with a resolution of 10 micrometers.

Spray dried powder granules consisting correlated silica nanoparticles were synthesized from dilute colloidal dispersions. It was demonstrated that incorporation of such powder granules enhances the water permeability of polymeric ultra-filtration polysulfone membrane, almost by two times, without sacrificing for the rejection performances. The potential of bacteria template micro-granules in removal of uranium was also evaluated.

The oxalate (ox) and phenanthroline (phen) ligands based one dimensional single chain molecular magnets were designed and synthesized. A giant coercivity of 3.2 Tesla was observed. The observation of both one-dimensional nature and higher coercivity of molecular origin in single-molecule magnets is considered one of the most relevant achievements in molecular magnetism.

The basic biophysical studies on mosquito-larvicidal proteins led to design and synthesis of a novel protein complex that is more toxic than any combination of Binary toxins known so far.

At the Centre for Interdisciplinary Sciences, TIFR, the theory of the actin cortex of the living cell was proposed as an example of a wetting phenomena in a system with actively driven stresses and currents. Heteronuclear metal complexes containing 3d and 4f metal ions were investigated. Pulse schemes were designed for the selective manipulation of proton resonances in solid-state NMR. A new optimal structure dominating the instability of a laminar shear flow with a temperature gradient was found. Non-equilibrium transition from localized to diffusive state in sheared amorphous solids was demonstrated. A system of self-assembling nano-rods which spontaneously form chains was characterized.

For the Indian Lattice Gauge Theory Initiative, QCD with two light dynamical staggered flavours of mass was simulated on lattices to estimate the radius of convergence for baryonic susceptibility. The ground and excited state spectra of singly, doubly and triply-charmed baryons were determined by using dynamical lattice QCD.

As a part of ongoing effort for development of NTD Ge sensors for mK thermometry, fast neutron induced damage in irradiated Ge samples was studied using PALS and channelling technique for Neutrinoless Double Beta decay Experiment.

At Pelletron Linac Facility, Pelletron and LINAC were operated for user cycles and it delivered a variety of beams as per user requirement. Lighter beams like Li and B beams were accelerated through LINAC for user experiments. Indigenously developed Multicathode SNICS source was tested with Pelletron.

For the Inter-Institutional Centre for High Energy Physics (IICHEP), the fencing work and boundary wall construction at INO site was started. Design and final schematic for the RPCDAQ module was completed.

For the Gravitational Wave Prototype Detector a single massive binary system treated as a gravitational atom was shown to produce Coherent states of radiation even while restricted to single graviton emission. It was asserted that quantum gravitational optics is an exact anchoring constraint for quantum gravity because all states of radiation are fundamentally quantum.

INTERNATIONAL RESEARCH COLLABORATION

India is a scientific member country of Institut Laue-Langevin (ILL), France through an MOU with BARC. Under this MOU, BARC is making in-kind contribution to ILL by providing overall mechanical engineering support in fabrication, assembly, testing and supply of aluminium and steel housings for neutron guides and Lead shields. All the housings were leak tested for a vacuum leak rate of 7×10^{-10} Torr-Lit/Sec. About six Aluminium housings and four steel housings were fabricated and dispatched to ILL. 75 nos. of Lead plates weighing 733 kg each were manufactured and dispatched to ILL. Manufacturing of 70 Nos. of 1.5 Ton lead plates is in progress.



Al Housing for neutron guides



Steel Housing for neutron guides



Lead Shields for ILL

Design, development and fabrication of precision alignment table for neutron beam lines was completed.

BARC provided an overall mechanical engineering support to the work of Resistive Plate Chamber (RPC) Upscope (RE4), CERN, Geneva, Switzerland. The work involved fabrication of 200 Nos. of Copper cooling systems for RPCs, their leak testing at 20 bar of Argon pressures, packaging and dispatch to CERN. All the Copper cooling systems for RE4/2 & RE4/3 were dispatched to CERN. A few cooling rings were integrated and assembled on RPC super modules at CERN and were installed on CMS.



Copper cooling systems



(a) & (b): Assembly of RPC Super-module at CERN

Under the project entitled "A comparative study of individual monitoring techniques for Radon and Thoron and their decay products for dose estimates in different indoor environments" between BARC and Institute of Radiation Physics (ISS), Germany, intercomparison exercises of the instruments developed in BARC and in ISS in an experimental test-house and chamber available in the German institute were carried out.

The spatial distribution studies of thoron and thoron progeny using passive pinhole gas dosimeters and progeny sensors were carried out in thoron test house coupled with wall exhalation

studies. Additionally, field intercomparisons in real indoor environments in Germany and in India are on way.

As part of collaborative work between BARC and CALCE University of Maryland, USA, R&D work on development of prognostics and health management (PHM) of electronics component was continued. A broad framework to implement PHM as part of risk-based application for nuclear plant was developed.

In collaboration with International Atomic Energy Agency a RCA midterm project review and coordination meeting on "Supporting Nuclear and Isotopic Techniques to Assess Climate Change Impact for Sustainable Marine Ecosystem Management" IAEA/RAS/07/24 was held during December 2-5, 2013 at Goa. It was attended by 13 international participants and 4 national team members.

IGCAR participated in the Coordinated Research Program on Control Rod Withdrawal and another on Sodium Natural Circulation Tests performed during the PHENIX End-of-Life Experiments along with ANL from the USA, CEA and IRSN from France, IPPE from the Russian Federation, JAEA from Japan, KIT from Germany and PSI from Switzerland. Prediction from IGCAR was very close to the measured values and close to other participants.

RRCAT set up the infrastructure for SCRF cavity fabrication, processing and testing. A number of single-cell prototype cavities at 1.3 GHz had been earlier developed and tested under the framework of Indian Institutions Fermilab Collaboration (IIFC). The first 650 MHz single-cell niobium cavity was fabricated by RRCAT and IUAC and tested at Fermilab. A 500 W solid state amplifier at 650 MHz



500 W solid state amplifier module at 650 MHz

was designed and developed under the Indian Institutions- Fermilab Collaboration (IIFC).

TIFR continued to actively participate in the data harvesting phase for the Belle Experiment. TIFR shall be building the silicon micro-vertex detector (SVD) of the upcoming Belle II experiment, in particular the 4th layer (L4). For the CMS experiment, half of HO detectors were fitted with Silicon photo multipliers, while from the rest half the older photo detectors were removed.

At the International Centre for Theoretical Sciences a pipeline for searching for gravitational waves for spinning black hole binaries was demonstrated. The structure of the posterior distribution for Burgers equation was investigated and it was related to the problem of observability. In the area of heat conduction in low-dimensional systems, large-scale simulations were performed to clarify the question of universality and to verify recent predictions on the hydrodynamic description of anomalous heat transport. A novel resolution to recent formulations of the information paradox, by constructing operators that describe the interior of the black-hole in the AdS/CFT correspondence was found. The effects of purely elastic collisions on the dynamics of heavy inertial particles in a three-dimensional random incompressible flow was studied and it was shown that a shell-model version of the three-dimensional Hall-magnetohydrodynamic (3D Hall-MHD) equations provides a natural theoretical model for investigating the multiscaling behaviors of velocity and magnetic structure functions. The Chern-Simons theories coupled to matter that describe novel excitations called anyons which interpolate between bosons and fermions was investigated.

The Indo-German collaboration between SINP and Deutsches Elektronen-Synchrotron (DESY), Hamburg in Synchrotron research was successfully going on. International Collaboration with CERN in ALLICE and CMS experiments and International Collaboration with SNOLab in PICASSO experiment were continued.

At IPR, the fabrication of Resonant Magnetic Perturbation (RMP) coils for Joint European Torus (JET) was started by interacting closely with experts

from Culham Center for Fusion Energy (CCFE), United Kingdom. In the other collaborative work, the JET neutron yield calibration was done by direct measurements using a calibrated ^{252}Cf neutron source deployed inside the JET vacuum vessel. An agreement was signed to cooperate on tokamak WEST project (Tore Supra Upgrade) at CEA, France.

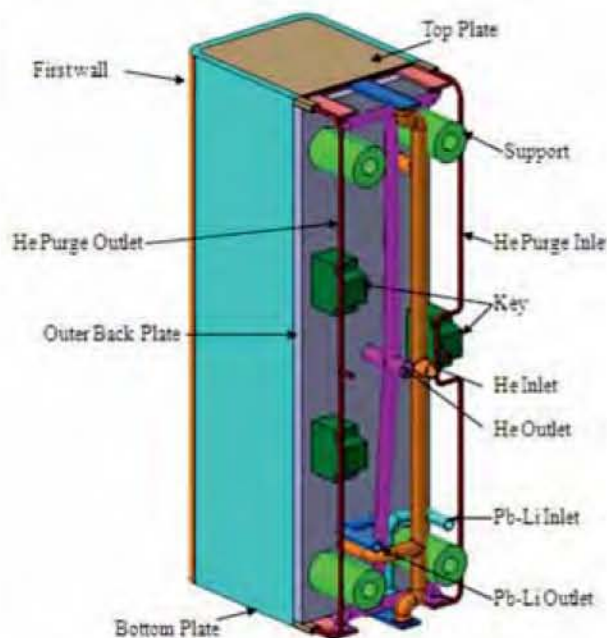
Joint projects of IMSc with other international institutes included Indo-Austrian Joint Research Project on Parameterized Complexity of Local Search; CEFIPRA: Arithmetic circuits computing polynomials with University of Paris; Indo-German research grant of the Humboldt Foundation for research on the graph isomorphism problem; British Royal Society project on above guarantee kernelization with University of London; LIA-Informel Project on Concurrency and Automata theory with University of Bordeaux and ENS-Cachan; INRIA-Indo-French-Singapore project on Logic, Games and Control theory; India-EU programme on mathematics for health and disease; ITRA - Media Lab Asia project on decongesting India's transportation networks using mobile devices.

International Thermonuclear Experimental Reactor (ITER)

During the year, for the ITER project 14 Procurement Arrangements (PA) were signed. Three major contracts for the manufacturing of ITER components were also signed. Indian contractor assigned to build the largest vacuum chamber made substantial progress in full scale mock-up production/ process qualification at factory and erecting the workshop at French site. Identification of vendors for other procurements is in progress. In the meantime project management, quality assurance and control, safety etc. are being implemented to the required international levels.

IPR, BARC and IGCAR are involved in the design, material development, thermo fluid MHD analysis and various aspects of Lead Lithium cooled Ceramic Breeder (LLCB) Test Blanket Module (TBM) for ITER.

BARC completed a full scale 3-D MHD numerical simulation of the Indian TBM. The computation domain consisted of 2.7 million volume



Schematic of Indian Test Blanket Module

elements with adequately resolved boundary layers of $12\ \mu\text{m}$ thickness. The flow distribution in each channels, velocity profiles, electric potential distribution, currents, effect of electrical coupling and pressure drop were obtained. Recirculation zones in the flow field, which may give rise to hot spots or tritium trapping regions, were also identified. Based on this analysis, the performance of the TBM in extracting thermal loads arising from the neutrons is presently being studied.

India is developing Lead-Lithium cooled Ceramic Breeder (LLCB) Test Blanket Module (TBM) for testing in the ITER. All the advanced technologies for material and material processing involved in the construction of the TBM are being developed and are being digested indigenously with collaborations from national and international institutions. Under Large Cryogenic systems development, conceptual design of various sub-systems and components was completed and testing of prototypes in smaller scales were started. Under the fundamental plasma sciences, various physics based small basic experiments are being conducted.

Design and detailed engineering of scale down (1:10) system of critical equipments outside the domain of open literature of laboratory scale experiment for Tritium Extraction System (TES) of



Test setup for Performance of De-Oxo bed

test blanket module (TBM) for ITER were completed at BARC. Hydrogen permeation membrane, and a system for studying hydrogen solubility in PbLi under TES conditions was designed, fabricated and installed. Laboratory scale material/component testing of De-Oxo bed was completed.

Experiments were conducted on De-Oxo bed at different temperatures and feed compositions to generate design data. Developed theoretical model was validated using experimental data.

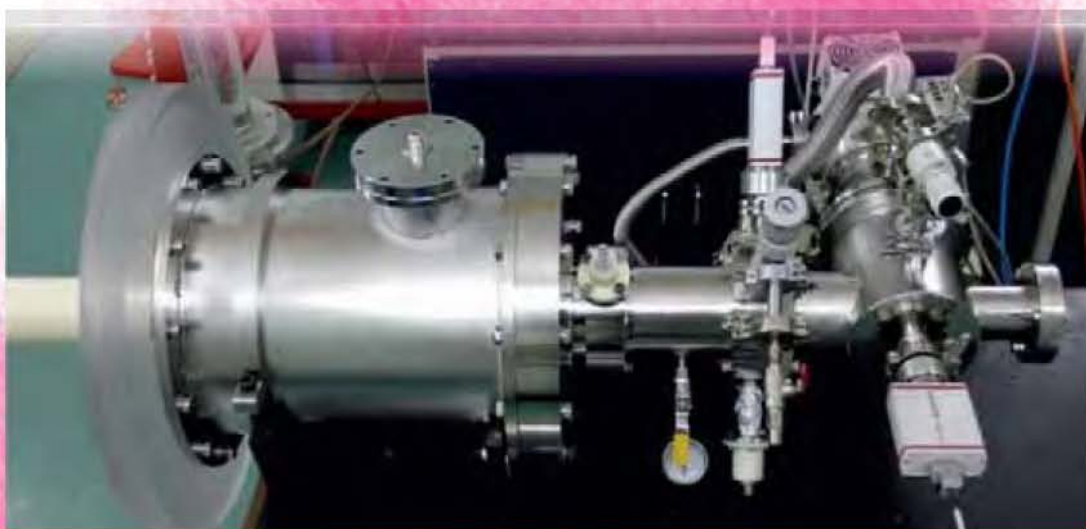


CHAPTER-6

RESEARCH EDUCATION LINKAGES



Electron Gun Test Facility at BARC



Compact capillary discharge soft x-ray laser developed by RRCAT

The Department of Atomic Energy supports the research education linkages mainly through grants-in-aid to institutes of national eminence, funding of extra-mural research, DAE-UGC consortium for scientific research and others.

The human resource and knowledge management is developed through Homi Bhabha National Institute (HBNI), Training School and the Administrative Training Institute.

The Board of Research in Nuclear Sciences (BRNS) an advisory body of the Department of Atomic Energy (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.

The National Board for Higher Mathematics (NBHM) established under the aegis of DAE promotes excellence in higher mathematics education and research in the country.

HUMAN RESOURCE DEVELOPMENT AND KNOWLEDGE MANAGEMENT

Homi Bhabha National Institute

Homi Bhabha National Institute (HBNI) completed seven years of its existence and continued to grow smoothly steadily. It has seven Boards of Studies which are Chemical Sciences, Engineering Sciences, Health Sciences, Life Sciences, Mathematical Sciences, Physical Sciences and Strategic Studies. Degrees and

diplomas awarded under these different disciplines include Ph.D, MSc (Engg.), M Phil, M.Tech, PG Diploma, M.Sc., Diploma in Radiation Protection (DRP), Diploma in radiation medicine (DRM), Diploma in Medical Radioisotope Technology (DMRIT), DM, MD, MCh etc. More than 3250 students were on roll under HBNI as on March 31, 2014. HBNI awarded 321 Ph.D, 586 M.Tech, 8 M.Phil, 111 M.Sc. 23 M.Sc. (Engg), 157 diplomas in radiation protection, 42 diplomas in medical radioisotope technology, 36 diploma in radiation medicine and 106 post graduate medical degrees.

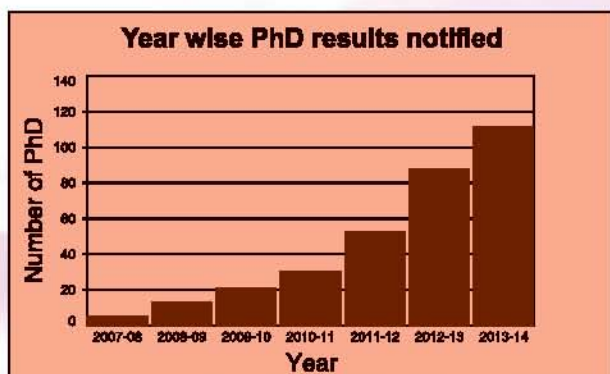
HBNI continued to strengthen its linkages with premier research and academic institutes in the country and abroad. It has MoU with various institutes such as Institute of Chemical Technology, Mumbai; Indian Institute of Science, Bangalore; Indian Institute of Technology, Bombay; Indian Institute of Technology, Madras; Indian Statistical Institute, Calcutta; Jadavpur University, Kolkata; Indian Institute of Technology, Kanpur; Tata Institute of Fundamental Research, Mumbai; The University of Virginia; The Commissariat a l'energie atomique et aux energies alternatives, France; University of North Texas, USA.

Training School

The academic programme of the 56th batch of BARC were continued and screening test for 57th was organized. To popularize the atomic energy and to encourage the eligible students in the north-east, BARC teams visited the engineering colleges in Assam.

Total 372 candidates were selected for OCES/DGFS 2013. Based on the technical performance in the selection interview and preference of the training school, a total of 194 candidates were offered BARCTS, Mumbai. The 57th OCES batch of BARCTS was inaugurated by Director BARC as Chief Guest on August 1, 2013.

Hundred and nineteen TSOs from the BARC OCES-2012 (56th batch) after successful completion of the training, were placed in various units of DAE. Plans to visit as many colleges and universities as possible were in progress to promote DAE activities and thereby attract best talent to our fold.



Upon successful completion of the 1-year academic course work in their respective BARC Training Schools, the TSO's enrolled for M.Tech with HBNI, continued their M.Tech course in the different Divisions/Units of DAE and were allotted with the M.Tech project work in consultation with the respective Head of Division/Unit. The allotment of M.Tech Projects to all the eligible fresh officers from OCES 2012 was completed.

During the period of report, three advanced courses under 6th set of QUEST which commenced in August, 2012 were continued and completed. Infrastructural facilities such as Library, Computer labs, Nuclear Physics (RDM) and process control labs etc. were updated and well maintained for the benefit of the TSO's.

At AMD, activities related to Human Resource Development were continued with in-house and external institute training programme for staff and officers. BARC Training School AMD Campus, Hyderabad continued its activity in the fourth year with Geology and Geophysics Trainee Scientific Officers (TSO).

At IGCAR, the seventh batch of 52 trainee scientific officers completed their training in six disciplines and were placed in various units of DAE. In the present academic year, 54 Trainee Scientific



PhD / M.Tech students working on project works related to Indus accelerators and beamlines utilization.

Officers are undergoing training at the Training School. Nineteen Research Scholars were inducted to pursue their doctoral programmes in the frontier areas of engineering and basic sciences and employees who are pursuing higher studies under the aegis of Homi Bhabha National Institute (HBNI) were also undergoing coursework at the Training School.

RRCAT extended the available research facilities for training of university students in the areas of accelerators, lasers and their applications. Total 130 such students pursued their project work at RRCAT during 2013.

The National Centre for Radio Astrophysics, TIFR organized two major student training programs Pulsar Observing for Students (POS-2013) and Radio Astronomy Winter School for College students (RAWSC-2013)

In NPCIL the Human Resource initiatives are directed towards fulfilling the NPCIL's mission and vision by providing guidance, support and advice on the effective implementation of the strategy, policies, procedures and tools for recruitment and retention of talent. About 200 trainee engineers were taken for NPCIL Batch-20 during the year as a part of annual program for induction of young talent into the Organization. Training and Development initiatives covered competency development for fresh as well as experienced manpower across hierarchy. Further, well developed internal training programs, customized management development programs with the involvement of professional training institutes and experts were also organized for higher levels. More than 3400 man-days of training were imparted during the year.

A structured on line grievances mechanism which is sensitive and attentive to employee grievances at all levels is smoothly functioning and has minimized the grievances of employees at NPCIL. Performance Linked Incentive Scheme (PLIS) linked to various production targets and construction milestones finalized by way of tripartite settlement between Management, Employees and Conciliation Officers has been proved very successful and instrumental in improving the production by boosting morale of employees and executives.

Total 758 High Performers were felicitated under NPCIL (High Performers Annual Award) Scheme during 2012-2013. The HRM initiatives of NPCIL were also recognized by Institute of Public Enterprises (IPE) and World HRD Congress (WHC) by conferring "Global HR Excellence Award for Talent Management" jointly in February 2013.

UCIL in association with International Atomic Energy Agency (IAEA) organized an Interregional training course at Jamshedpur (Jharkhand) on "Uranium exploration strategy, mining and processing techniques" during April, 2013. Thirty nine participants from twenty three IAEA member countries participated in this event. Experts from IAEA, Canada and India (UCIL, AMD, DAE, BARC, NFC, Forest Research Institute, Jadavpur University) imparted training on various aspects of uranium industry.

The Institute of Physics (IOP) contributed in a significant way towards quality human resource development in the form of a one year pre-doctoral course followed by the Ph.D. program. Ten post-doctoral fellows joined the Institute in the year 2013-14. Further this year, eight doctoral scholars received their Ph.D. degrees, while eleven scholars joined the pre-doctoral programme. The Institute actively promoted interactions with colleges, universities, academic institutions, and other national laboratories by means of visitor programmes, workshops, symposia, and other academic events.

The Institute organized the 3rd International Conference on Physics at Surfaces and Interfaces (PSI-2014) during February 24–28, 2014, International School and Conference on Quantum Information (IPQI-2014) during February 17–28, 2014, Discussion Meeting on Radioactive Corrections (DMRC) during March 3–5, 2014, and co-organized Workshop on High Energy Physics (WHEP-2013) during December 12–21, 2013 as well as National String Meeting during December 2013.

IMSc provided an intensive teaching programme with a high level quality. Students were selected at the graduate and postgraduate level each year through an all India joint entrance screening test followed by an interview. They underwent two years of rigorous course-work, and after successful completion they joined the doctoral thesis work under the supervision of a faculty member. The qualified thesis work was submitted to the Homi Bhabha National Institute, which is a deemed University of which IMSc is a part, for award of PhD degrees. Apart from this regular activity, IMSc also offered the opportunity of learning for a few students during the summer vacation period. These students spent up to

6 weeks doing projects with faculty members. The faculty also supervised short-term projects during other periods. Several students visited the institute for a semester working on short-time research projects.

The Institute provided an excellent scientific library and computing environment with dedicated high speed network. Adequate infrastructure to host several national and international conferences, workshops and instructional schools were also met.

To nurture world class scientists for the country who will take up challenging research and teaching assignments in universities, R & D laboratories and various industries, the exemplary teaching and research attributes of the faculty of National Institute of Science Education and Research (NISER) inspired the motivated bright young students to dedicate their lives for scientific research. With over 300 students, NISER operated five batches of students admitted to the flagship MSc programme through NEST in Biology, Chemistry, Physics and Mathematics and Doctoral Programme in all Basic Sciences.

Administrative Training Institute

The Administrative Training Institute (ATI) of DAE completed more than five years of its functioning. ATI continued to arrange wide range of training programmes for the professional development of officials of the Department of Atomic Energy. More than 480 programmes covering over 13,500 employees were organized by ATI till now.

Efforts were made to meet the current need of the training and tuning the delivery to cover topics of relevance using blend of methodologies appropriate to the audience.

The programmes catered to a wide spectrum starting from the Head of Units to the grass root level. These included the induction programmes for the newly recruited UDCs, stenographers, purchase/stores clerks; refresher programmes; management development programmes; soft skills; task specific workshops; computer applications and experience sharing workshops.

The training programmes were finalized in consultation with the officer in-charge of the respective cadres. The resource persons were sourced for within the department, other government departments and professional agencies.

More than hundred programmes were organized during the year 2013-14. The additional programmes were conducted to meet the specific requirements. Director/Deputy Secretary level officers were nominated for the workshop on preparation of notes for the Cabinet/Cabinet Committees. Officers working in DAE were also sponsored for the long term and short term courses under the Domestic Funding of Foreign Training scheme of The Department of Personnel and Training.

To align with the National Training Policy – “Training for All” a number of steps were taken. The strategy of “Training at doorstep” on various subjects like RTI and Records Management, Ethics and Values in Administration, Works Procedure, Building Blocks for Professional Excellence, Workshop on Communication and Presentation Skills, Workshop on creativity for Innovation and Excellence, Workshop on Administrative Vigilance and Role IO/PO, Security Awareness programme, etc. were continued. The programmes were arranged at different localities like Kolkatta, Kalpakkam, Hyderabad, Bhuabneswar, Bangalore, Kota, Pazhakalyal, Mysore, Tuticorin, Shillong, etc. Large number of officers participated in the programmes.

Post retirement life management programmes were organised for employees due for retirement. The highlights of some of the other programmes conducted were Induction training programme for the newly recruited administrative staff; Capacity building Workshop for Prospective Deputationists to International Projects; Workshop on Assessing and Reviewing APAR; Training Programmes for Scientific and Administrative Officers on Project Management at IIT, Bombay, Mumbai and IIM, Kozhikode; Workshop on Procurement – CVC Guidelines, procurement procedure for scientific officers and Senior Administrative and Purchase Officers; Workshops on Soft Skills for various target groups; Programmes for Union / Association representatives on soft skills,

computer applications, Reservation in Services, RTI etc.; Seminar on Staff and Industrial Relations for members of Union and Admn. Heads Scientific and Technical Officers; Management Developments Programmes for Group A and B Officers including Scientific and Technical Officers as also empanelled APO/AAO at Administrative Training Institute, Mysore and Mahatma Gandhi State Institute of Public Administration, Punjab; Training Programme on MS Project for Scientific and Technical Officers.

SPONSORED RESEARCH

Board of Research in Nuclear Sciences (BRNS)

BRNS played a proactive role in tapping some of the highly talented young scientists and technologists by offering K.S. Krishnan Research Associateship (KSKRA). DAE Graduate Fellowship Scheme (DGFS) of BRNS is meant to identify and encourage Graduate Level students doing M.Tech. at IITs and NITs to initiate them in a career to pursue scientific research. Selected young scientists are awarded fellowship under DGFS to work on research projects in any one of the DAE units, simultaneously pursuing Ph.D. degree though Homi Bhabha National institute (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 Science Education (HBCSE).

During the year 2013-14, 264 new research projects were sanctioned by BRNS till December 2013. In addition, six new MOU's were formulated for collaborative research work with various academic institutes and creation of facilities at academic institutes. These are: (a) Development, production and supply of ultra-low loss micro-wave substrate for high power solid state amplifier to RRCAT by C-MET, Thrissur (Rs. 1.70 Crore for five years) (b) Augmentation of National Facility for Analytical Electron Microscope (NFAEM) at IISc., Bangalore (₹ 1.44 Crore for three years) (c) Setting up Low energy (3 MeV) Particle accelerator at Gurughasidas Univ., Bilaspur, Chhattisgarh, (₹ 9 Cr. for three years) (d) Extension of Programme on the design and

development of aerogel supercapacitors" C-MET, Thrissur (₹. 3.70 Crore for five years) (e) General purpose computer code for optics calculations of solar thermal power plants to be used for design and optimization of reflectors & receivers at Institute of Chemical Technology, Mumbai (₹. 1 Crore for three years) (f) Establishing a Regional Nuclear Agricultural Centre at Bidhan Chandra Krishi Viswavidyalaya (BCKV), Kalyani, West Bengal (₹. 7 Crore for five years).

Two new and nine ongoing prospective research fellowships (PRF) amounting to ₹.7 Crores were granted this year. Under DAE Graduate Fellowship Scheme (DGFS), 25 M.Tech. in seven different IIT's & NIIT's and 5 Ph.D. students were offered/awarded fellowships.

Financial support to the tune of 2.5 Cr. was extended for funding 230 seminars, which were conducted by professional organizations on various topics of relevance to DAE. Out of this 14 symposia were solely organized by the DAE fraternity and they were fully funded by BRNS. Thirty-eight fellowships were offered/awarded under the Raja Ramanna Fellowship Scheme (Senior Scientists Scheme) & Homi Bhabha Chair.

Promotion of Mathematics

NBHM with the help of the Homi Bhabha Centre for Science Education (HBCSE) conducted the Mathematics Olympiad activity for talented young students at higher secondary level. The six-member Indian team secured 2 Silver medals and 3 Bronze medals at the 54th International Mathematical Olympiad held at Santa Marta, Colombia.

NBHM conducting Madhava Mathematical Competition for the undergraduate students. NBHM provided grants to various mathematical centers engaged in activities of promoting higher mathematics. The Chennai Mathematical Institute that runs a high quality undergraduate programme in mathematics is a regular recipient of grants from NBHM. The Kerala School of Mathematics, Calicut the Institute of Mathematics and Applications, Bhubaneswar and the Bhaskaracharya Pratishthana, Pune are the other institutes getting

grants from NBHM based on various programme proposals.

The board provided scholarships and fellowships to the students, selected through nationwide competitive tests to pursue studies at masters and Ph.D. levels.

During the summer vacation, active training programmes called Mathematics Training and Talent Search were also organized outside the regular educational framework at the undergraduate level. Supplementary training activities were undertaken for selected students at postgraduate level in a coordinated fashion under the Advanced Training in Mathematics (ATM) programme.

The Board also provided grants for promotion of activities in pure and applied mathematics, under several schemes, including support to research projects, travel grants for participation in workshops, conferences and undertaking collaborative research, funds for organizing conferences etc.

NBHM provided grants to mathematics libraries around the country to purchase the latest books and journals in mathematics. Around 96 of 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.

Financial support was provided to 92 national and international conferences held in India and 14 Instructional Schools for advanced training in mathematics and 44 research projects. Travel grants were provided to 101 mathematicians to enable them to participate in conferences held in India and abroad. Four 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 60 researchers for the period of 3 years.

New web-based interactive system for communication, evaluation of proposals was in advanced stage of completion to help researchers obtain the prompt response from NBHM on their applications for grants.

GRANTS-IN-AID

Grants to Aided Institutions

The aided institutions of the Department of Atomic Energy are an integral part of the Department in as much as there is a growing synergy between these institutions and the Research and Development Units of the Department. Several joint projects were undertaken between the Units and Aided Institutions and there is frequent interaction between the academicians of the aided Institutions and the Scientists of the R&D Units.

The Department has nine aided institutions fully funded in terms of their recurring and nonrecurring expenditure. The funds (Plan & Non-Plan) allocated to these Aided Institutions by the Department of Atomic Energy during the financial year 2013-14 were Tata Institute of Fundamental Research (TIFR), Mumbai (655.75 crores); Tata Memorial Centre (TMC), Mumbai (746.04 crores); Saha Institute of Nuclear Physics (SINP), Kolkata (153.37 crores); Institute of Physics (IOP), Bhubaneswar (33.11 crores); Institute of Mathematical Sciences (IMS), Chennai (49.59 crores); Harish-Chandra Research Institute (HCRI), Allahabad (44.96 crores); Institute for Plasma Research (IPR), Gandhinagar (671.80 crores); Atomic Energy Education Society (AEES), Mumbai (53.40 crores); National Institute of Science Education and Research (NISER), Bhubaneswar (220.00 crores)

Grants to Cancer Hospitals

The Department of Atomic Energy (DAE) is releasing grant to Dr. B. Barooah Cancer Institute (BBCI), Guwahati through Tripartite Agreement (signed among DAE, the North-Eastern Council (NEC) and the Government of Assam). This hospital is a Regional Cancer Centre (RCC) for cancer treatment and control in the North-Eastern Region (NER). The Department's total share as per the 4th Tripartite agreement upto the year 2013-14 is approximately ₹. 3941.60 lakh for revitalization of the BBCI which includes the cost of construction for expansion of the hospital as well as the procurement of major radiation related equipment. During the year 2012-13, an amount of ₹. 4.02 crore was released by the department.

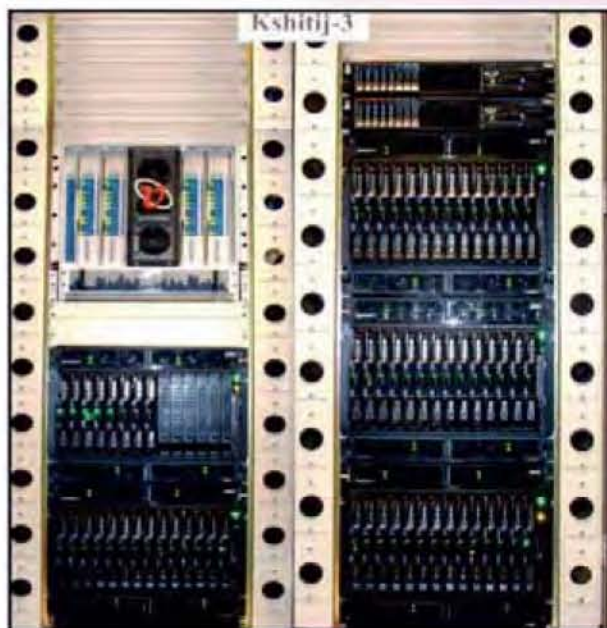
The Department also extended financial assistance to Cancer hospitals located in other parts of the country. The budget provision for the year 2013-14 for such partial financial assistance was to the tune of ₹.20.25 crore. An increasing need was felt to use the expertise available in the DAE funded Tata Memorial Hospital for creating a better network between cancer institutions all over the country. An Apex Committee was formed under the Chairpersonship of Director, TMC, for this purpose. The Apex Committee met on 18 times and deliberated on indigenous development and manufacturing of the equipment related to radiation oncology such as Cobalt 60 Teletherapy, Low Energy Linear Accelerator, High Energy Linear Accelerator, simulator development, Brachytherapy.

Olympiad Programme

During the year, nine exposure and orientation camps were conducted by HBCSE for Olympiad, NIUS and STEM students and teachers. Testing and standardisation of equipment was completed for the 10th International Junior Science Olympiad held in December 2013. Laboratory upgrades were carried out in physics and chemistry. Outline of project-based learning at school level is being prepared.

INFORMATION TECHNOLOGY APPLICATION DEVELOPMENT

At IGCAR, a prototype development and implementation of a Knowledge Management Portal was undertaken and it was integrated with many work processes. The portal is expected to streamline the work processes, act as repository of knowledge and thus enabling knowledge preservation, enhance the knowledge sharing culture and hence improving the overall performance of the division. The portal facilitates the document management and information management. The developed modules were Document Management, Expertise Management, Monthly reports, Discussion forum, VEC (Computers & Networks), indents/work order module, Annual Maintenance contracts (AMC), Expenditure statement, Gate pass module, PRIS-G projects module, Research scholars/project student's module, Divisional Quarterly Progress



High Performance Computing Cluster Kshitij-3

Reports, divisional meetings MOMs and Motivational documents. The details of CD vision committee and CD Knowledge Module task force are also provided in the portal. The portal is used by employees of IGCAR with more than 1000 usages per month.

A 64 Tera-byte storage capacity for storing scientific data has been commissioned and integrated with centralized computing facility. Next, RRCAT campus network - RRCATNet - was expanded from 3000 nodes to 3450 nodes. A digital archive of electronic theses, dissertations and



User interface for Reading Neutron Count



User interface for Setting Instrument Parameters

conference papers of RRCAT has been setup in Scientific Information Resource Centre. The aggregated computing power of computing clusters now stands at 13.28 TeraFlops with integration of High Performance Computing Cluster (HPCC) Kshitij-3.

A web-based facility for online submission of Immovable Property Return (IPR) for Group-A gazetted officers of VECC was developed at VECC.

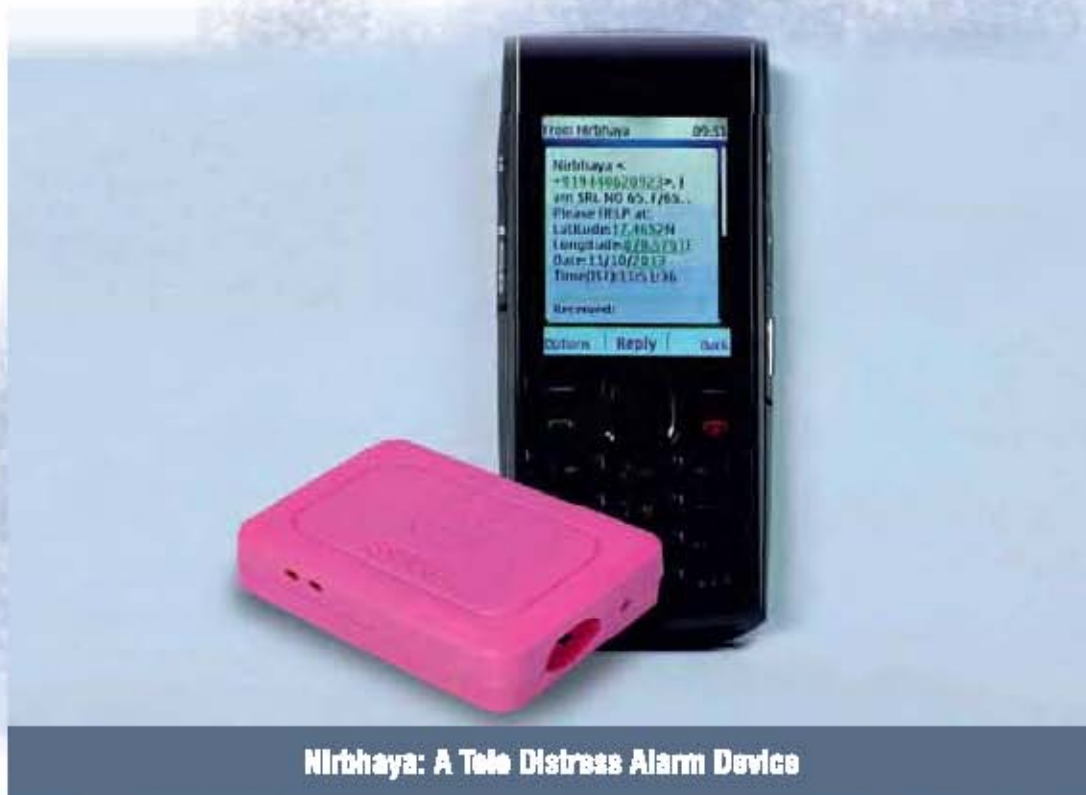
A PC based software was designed and developed at VECC for interfacing a Pulse Link Extended Range Neutron Area Monitor that can measure neutrons of energy from thermal to 1 GeV. The software provides a suitable user interface to set/adjust various parameters of the instrument and read the neutron count from it for the specified time interval as decided by the user.

A "RFID-based Automatic Key Management System" was designed to allow or restrict the employees of an organization to access room keys by using their RFID based identity card and also record all key transactions. The system consists of RFID Card reader, touch-screen based panel-PC for operation and data logging, key module controller board and key module with multiple key slots with locking arrangements. Basic technique of operation of the system has already been established. A MoU was signed with Webel Mediatronics Ltd., Kolkata for developing a production grade version of the system.



CHAPTER-7

TECHNOLOGY TRANSFER AND COLLABORATIVE PROGRAMMES



Nirbhaya: A Tele Distress Alarm Device



MoU signed with M/s Kumaka Industries Ltd., Vadodara for setting up a Radiation Processing Plant at Sanand in Gujarat.

The spin-off technologies generated out of the core programmes of the Research and Development organizations of DAE were developed and transferred to industries for commercial exploitation. Over a period of time, a number of technologies were transferred to industries.

DAE organizations also entered into scientific collaborations with public and private sector organizations. This interaction had given beneficiary organizations a technological edge.

TECHNOLOGY TRANSFER

The various new technologies introduced by BARC into public domain were Smart Radon Monitor Technology; Preparation of Thin Film Composite (TFC) Charged Nanofiltration (NF) Membranes; Mass Multiplication medium of biofungicide *Trichoderma* Spp; Insitu Testing of HEPA Filter Installation; *Trichoderma* Chitinase Gene Construct for Plant Transformation; Production of Intumescent Rigid Polyurethane Foam; Portable Radio Isotope Detection and Identifier (PRID); Process for retaining pericarp colour and extending shelf life of litchi; Technology of "Distress alarm device- Nirbhaya" was transferred to ECIL for commercialization.

Total number of technologies transferred by BARC during the year 2013-14 were 47. Licenses for 10 different technologies were renewed after expiry of the license period on receipt of appropriate license renewal fee.

Two agreements were signed during the report period taking the total tally to twenty seven. These agreements provided number of perpetual licenses for exclusive rural deployment of the technologies like Soil organic carbon detection and testing kit, Foldable solar dryer, Nisargruna, Vibrothermal disinfector, Domestic Water Purifier, Solar BWRO, Dip N drink membrane Pouch and Litchi preservation.

COLLABORATIVE PROGRAMMES

Six MoUs from various divisions of BARC were signed for collaborative developmental work. BARC Centre for Incubation of Technologies (BARCIT) activities were initiated with signing of five

MoUs for incubation in the field of "water", "wound dressing", "Nano Particles of Lithium Titanate", "Neutraceuticals" and "Projectile Velocity Measurement".

M/s Kumaka Industries Ltd., Vadodara has signed a MoU with BRIT for setting up a radiation processing facility. The facility will come up at Sanand II, Gujarat for treatment of spices, chilled meat, poultry products, sea food etc.

SOCIETAL INITIATIVES

DAE Out Reach Centre (DAE-ORC) was set up in Pandharpur in collaboration with SVERI to spread AKRUTI Programme in and around Pandharpur. Created Wi-Fi connected NKN enabled rural education infrastructure and created tablet based access for rural children in 5 schools near DAE-ORC at 5-15 km distance. BARC set up technologies such as Environmental Radiation Monitors-IERMON installation, Nisargruna, Soil Organic Carbon Detection & Testing kit, Vibrothermal Disinfector as a training facility in Rural Human & Resource Development Facility. BARC initiated new seed variety multiplication (TG-51) with more than 15 farmers. Four new AKRUTIs were set up in surrounding villages around DAE-ORC.

INTELLECTUAL PROPERTY RIGHTS

DAE-IPR Cell constituted by the Department, works as a nodal agency for all Intellectual Property Rights (IPR) related matters including filing of patents within India and abroad for all the Units including Public Sector Undertakings and Autonomous Institutions under DAE. During the financial year 2013-14, two regular DAE-IPR cell meetings and one special meeting to discuss other issues were held. Eight new inventions were reviewed for the patentability. DAE filed fifteen new patent applications including eleven in India and four in USA.

During the year 2013-14, eight of the previously filed patents were granted to the Department. Six out of the eight patents were in foreign countries, five in European Union and one in USA.

1. Non-ionic, porous, solid resin with chemically bonded crown ether – (IGCAR)
2. Calcium Potassium Ferric amide prophylactic mixture comprising this compound and the use thereof for decorporation of Radio-caesium in subjects affected by nuclear radiation – (BARC-BRNS)
3. Dialkyldiaza-tetraalkylacetone diamide derivatives useful for the separation of Trivalent actinide from lanthanide and process for the preparation thereof – BARC
4. Fluorescence correlation microscope with real time alignment readout – TIFR
5. A flexible magnetic membrane based actuation system and devices involving the same - BARC
6. A method of qualifying Niobium and/or other super conducting materials for reliable fabrication of Superconducting Radio Frequency (SCRF) Cavities – RRCAT

During the year, 104 patent applications were referred to the Department by the Controller General of Patent, Intellectual Property (IP) India to screen for the applicability of section 20 (1) of Atomic Energy Act, 1962, i.e., whether the application is related to or useful for atomic energy and give its opinion. Directions of the Department were communicated to the Controller of Patents in India.

CHAPTER-8

INFRASTRUCTURE



**Nuclear Employees Sports & Cultural Organisation (NESCO)
building at Anupuram, Kalpakkam**



Fire station building constructed by DCSEM at VECC Kolkata

CONSTRUCTION, SERVICES & ESTATE MANAGEMENT

Directorate of Construction, Services & Estate Management (DCSEM) is responsible to provide infrastructure support to various Units of Department of Atomic Energy (DAE) including its aided institutions. DCSEM is involved in planning, design & execution of various construction works for Housing, Schools, Hospitals, Laboratories, Institutional Buildings & infrastructural facilities to support Scientific & Technological programmes of DAE. 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 construction of Pre Engineered Multipurpose Hall at Rajarhat, Kolkata for VECC and fire station & Anunet building at VECC Kolkata were completed. DCSEM also completed construction of 56 type B Quarters (stilt+7 upper floors) in two separate blocks for IIT-B Powai, Mumbai.

Prequalification of agencies for construction and design work of SNSS (School of Nuclear Security & Studies) and Guest House for Global Centre for Nuclear Energy Partnership (GCNEP), Bahadurgarh at Haryana for Phase I and submission



Pre Engineered Multipurpose Hall at Rajarhat, Kolkata for VECC



Anunet building at VECC Kolkata

of documents required for MoEF clearance was completed. Prequalification of agencies for construction of Hostel, Bio Science Laboratory and Community Centre for TIFR at Colaba, Mumbai; Hostel for trainees of BARC/HBNI Phase- II and 100 bedded hospital and Ancillary building for TMC at Vishakhapatnam were also completed.

Various works of DCSEM at Anushaktinagar, Mumbai which were under progress were Convention Centre / Sr. Officers Guest House and Administrative Training Institute Complex; Residential Quarters for CISF personnel; Restoration / Renovation of Old Houses more than 20 years old Phase-I; Creche Facility; Up gradation of services under 12th plan; Construction of 356 residential quarters; Hostel for trainees of BARC/HBNI Phase- I; Construction of Extension of V.S.Bhavan and Up gradation of substation works.

Major construction works of other units/ autonomous units under progress were First Research and Technical (FRt) Block for TIFR, Hyderabad; Medical Cyclotron building, Chakgoria, VECC, Kolkata; Computer & Information Centre Building at VECC, Kolkata; RIB (Radioactive Ion Beam) laboratory for VECC; Core Library, Training school with Hostel, staff quarters for Atomic Mineral Directorate (AMD) at Cherlapally, Hyderabad; UG water tank of 100 KL capacity with pump house and RCC ESR of 75 KL capacity at AMD Cherlapally, Hyderabad; Academic Block and residential quarters along with infrastructure facility for ICTS (International Centre for Theoretical Sciences) of TIFR, Hessarghatta, Bengaluru; Academic Township, Sports complex & Residential Township for NISER, at Bhubaneswar and Building for Fission based ⁹⁹MO Production facility for BRIT adjacent to ISOMED in BARC.

Major work orders issued by DCSEM during the report period were for Construction of Facilities for Research in experimental Nuclear Astrophysics (FRENA) laboratories for SINP, at Bidhannagar Kolkata; Construction of UG water tank with dry well pump and pump house for VECC at Rajarhat, Kolkata; Renovation of houses for internal finishes at Anushaktinagar, Mumbai; Blower building for Medical Cyclotron Project VECC Kolkata and Approach road for Convention Centre, Anushaktinagar, Mumbai.

Engineering Services Division of DCSEM maintained 9821 residential flats and public buildings of the Department in Mumbai including execution of up-gradation works required for the buildings. DCSEM also fulfilled the responsibility for the operation & maintenance as well as up-gradation of electrical power distribution, lifts, water supply, sewer lines, sewage treatment plant, fire fighting system, rain water harvesting system and energy conservation of the services in the large township at Anushaktinagar, Mumbai.

The Estate Management Section of the Directorate continued to manage the estate of DAE and allotment of residential flats, shops including public buildings and the security for the DAE Estate in Mumbai.

During the year of report schemes worth ₹ 290 Crores were executed for various DAE units and other departments including projects for DCSEM worth ₹ 108 Crores.

PURCHASE & STORES

The primary goal of the Directorate of Purchase and Stores (DPS) is to procure right material at right price from right source, storing the same and issue to various constituent Units of Department of Atomic Energy. DPS caters to material management needs not only of Research and Development units of DAE but also of its industrial units i.e. Heavy Water Board, Nuclear Fuel Complex and Board of Radiation and Isotope Technology. DPS has taken initiative for utilizing Information technology to meet new challenges of increasing departmental needs with no corresponding increase in manpower. DPS also

concludes various service contracts such as transportation contracts, import / export clearance contracts, Marine Insurance Contracts, etc.

Following works were carried out by DPS during the year 2013-14:

Enhancement of IT Infrastructure

Steps for creating infrastructure for implementation of end-to-end e-procurement were initiated as a systematic approach without compromising on Security aspects of data and activities of DAE. Internal Workflow Automation application was in the final stage of development. For better handling of IT related activities, action for entering into an agreement with ECIL for providing support was on hand. A fully integrated solution which will be available 24 x 7 instead of facilities available for general shift is being planned.

Procurement of Equipment from Domestic Manufacturers

Majority of users requirements were met from domestic manufacturers. Requirements above the value of ₹ 25 lakhs were processed by floating Public Tenders giving wide publicity in important newspapers across India and by publishing in Indian Trade Journal in addition to uploading on DPS web site as well as on Central Public Procurement portal. Import substitution activities were also considered to reduce dependence on import.

A policy for providing preference to domestically manufactured electronics goods in government procurement and due to security consideration as notified by the Department of Electronics & Information Technology, Ministry of Communications & Information Technology, Government of India was put in force.

Procurement of Equipment from Foreign Suppliers

Equipments not available locally were sourced from foreign countries by floating global tenders as well as limited tenders depending on the value.

Uranium Fuel Imports

With the opening of nuclear trade to civil nuclear facilities, the procurement of Uranium Fuel with the objective of deriving maximum advantage in meeting the department's goals through leveraging experience of DPS has become pertinent. During the year, a contract was entered into for importing 2000 MT of Uranium ore concentrates. In addition to above, negotiations were held for alternative sources for import of uranium fuel. DPS received 295 MT of fuel pellets of natural uranium dioxide during the period.

Heavy Water Exports

During the financial year 18.60 MT of Heavy Water worth ₹ 3690.88 lakhs was exported to France and USA.

GENERAL SERVICES ORGANISATION

General Services Organisation, Kalpakkam takes care of the common facilities such as Housing, Medical services, Office transport services, Water supply, Solid waste collection and disposal and all maintenance activities in the Atomic Energy Townships at Kalpakkam and Anupuram which cater to the needs of various DAE Organisations located at Kalpakkam Viz. IGCAR, MAPS, BARCF and BHAVINI. GSO also provides administrative support to various common advisory committees constituted by Kalpakkam Management Committee (KMC).

GSO provides infrastructural facilities and administrative support to Kendriya Vidyalayas, Atomic Energy Central Schools and Atomic Energy Central Higher Secondary School. Infrastructure support was provided to Nuclear Employees Sports and Cultural Organization. All Departmental administrative work relating to Kalpakkam Nuclear Installation Local Authority (KNILA) was carried out by GSO.

The Civil Engineering Division of GSO took care of the construction and maintenance of the residential quarters for the employees and office buildings. Its other activities included maintenance of roads, water treatment plant, sewage treatment plant and horticulture. The Electrical and

Telecommunication Section provided and maintained uninterrupted power supply to all the quarters and buildings. It also carried out the operation and maintenance of the electronic Telephone Exchange. The Mechanical Section handled the two Water Treatment Plants and two Sewage Treatment Plants, one each at the two townships and also looked after industrial safety, fire safety, air conditioning and Autoshop activities. Computerisation of activities and providing hardware, software and networking support to offices and public buildings were done by the Computer Section.

Medical needs of DAE, NPCIL, BHAVINI and AEESF employees and their family members covered under Contributory Health Service Scheme were looked after by the DAE Hospital at GSO, Kalpakkam. New medical equipments such as Monitors, Ventilator, Wall mounted light, Doppler Ultrasound Scanner, Dental Chair, Impedance Audiometer etc. were procured during the period 2013-2014.

Some of the significant achievements during the year 2013-14 are as under:

Construction

Construction of the following buildings were completed NESCO (Nuclear Employees Sports & Cultural Organisation) Building at Anupuram; II B & IV D Quarters at Anupuram and Kindergarten School at Kalpakkam.



II B Quarters at Anupuram



KG School at Kalpakkam

Electrical & Telecommunication

Following works were completed during the year 2013-14:

Two new substations namely SS8 & SS9 were commissioned at Kalpakkam township and electrical loads were redistributed in order to reduce the loads on overloaded substations; The old Tsunami affected substation MSS1A at Kalpakkam Township was decommissioned. All the loads were transferred to other substations; Augmentation of Intercom telephone exchanges at Kalpakkam and Anupuram Township was carried out with new battery bank and chargers; Design of Electrical and Telecommunication systems for the High rise Buildings at Anupuram was done and incorporated in the composite tenders of civil construction; Fire detection Alarm Systems were installed for the Telephone Exchange and Substations; Trespasser Alarm System was designed and implemented in all the Substation and Telephone Exchange at Kalpakkam; Ten old depleted Feeder Pillars were replaced with state of the art Feeder Pillars; Rewiring of twenty old residential buildings was completed and Revamping of SS4 substation was completed.

The following works were under progress:

Action was initiated to revamp the old substations MSS2, SS6, SS7 and SS1 at Kalpakkam Township; LED Street lights was introduced at Kalpakkam Township; Solar Power Panels of 10 kW rating were introduced at Kalpakkam Township; Two new substations namely MSS2 and RMS5 at Anupuram Township were in advanced stage of erection, testing and commissioning and Telephone cable network were augmented both in Kalpakkam & Anupuram.



Electrical Substation – Kalpakkam

Computerisation

During the report period, Wide Area Network Connectivity was established between Kalpakkam & Anupuram. This connectivity is expected to facilitate transfer of data between offices in the two townships. The biometric attendance system was fully functional and in-house developed software was used for retrieval of data and monitoring the system. Computerisation of service book records, transport & airline bookings, leave records management & APAR preparation was completed.

GSO Technology Day

National Technology Day was celebrated on 18th May 2013. A one day seminar was organized. Over two hundred participants including thirty three delegates participated in the seminar. The event provided a platform to showcase their activities and promoted a sense of dignity in their work.



Autoshop Model at GSO Technology Day Seminar

Quality circle

The third GSO quality circle annual meet (QCAM) was held on 25th June 2013. Twenty six quality circles participated in the event. For the first time quality circles from transport, administration and estate management presented their case studies. Five trophies namely Visveswaraya, James watt, Edsion, Chanakya and Sushrutha were won by SKY QC–Civil Construction, KTS; SAKTHI QC–Auto shop, BEST QC–Electrical Construction, ATS; SHELTER QC–Estate Management and SUSHRUTHA QC–Dispensary respectively.

The SAKTHI QC and BEST QC represented the Unit at the Regional Meet and were awarded the

GOLD and SILVER trophy respectively. The SAKTHI QC was nominated for the National Meet at Kolkata and was adjudged as "EXCELLENT".

Societal Initiatives

Under the auspices of Indian Women Scientists Association a talk by Commandant CISF, Ms. Rekha Namblar was arranged specially for ladies and girl children. A booklet on Personal Security Tips for Women was released. One thousand copies of the booklet were distributed to participants and school students.



Release of Booklet On Personal Security for Women



CHAPTER-9

PUBLIC SECTOR UNDERTAKINGS (FINANCIAL PERFORMANCE)





Control Room at the Kudankulam Nuclear Power Project

Financial performance statistics of DAE's public sector undertakings (PSUs) namely, the Nuclear Power Corporation of India Ltd., Uranium Corporation of India Ltd., Indian Rare Earths Ltd. and Electronics Corporation of India Ltd. are given below. (BHAVINI is yet to commence commercial operations)

Operational highlights of these public sector undertakings, except ECIL, have been covered under the relevant major programme heads. A gist of the operational performance of PSUs is given here.

NUCLEAR POWER CORPORATION OF INDIA LTD.

The provisional net profit after tax (PAT) for the year 2013-14 was ₹ 2117 Crores. The net profit after tax for previous FY 2012-13 was ₹ 2101 Crores. The NPCIL bonds continued to be rated at AAA (Highest Safety) by CRISIL and CARE.

URANIUM CORPORATION OF INDIA LTD.

The overall performance of the Company in terms of MoU signed with DAE was rated as "Very Good" for the year 2012-13. The total income of the Company during the year 2012-13 was ₹ 855.12 Crores as against ₹ 707.28 Crores in the previous year. The Company is consistently making profit year after year and the profit before tax during the year 2012-13 was ₹ 144.17 Crores as against ₹ 86.26 Crores in the previous year and registered an increase of 67%. On the basis of compliance with guidelines on Corporate Governance, The Department of Public Enterprises awarded "Excellent" grading to UCIL for the year 2012-13.

INDIAN RARE EARTHS LTD.

During the year 2013-14, the Sales Turnover was ₹416.22 Crores (provisional) and the Profit before tax in 2013-14 was ₹36.31 Crores (provisional). As against this, for the financial year 2012-13 the Sales Turnover and PBT were ₹533.48 Crores and ₹237.43 Crores respectively. The fall in revenue for 2013-14 was mainly on account of the extensive damage to OSCOM Plant due to cyclone Phailin which resulted in production losses and

deferment of shipments which were effected from Vizag Port in place of Gopalpur Port.

ELECTRONICS CORPORATION OF INDIA LIMITED

Electronics Corporation of India Limited (ECIL) is engaged in the design, development, manufacture, supply, installation and commissioning of a wide variety of electronic equipment for Atomic Energy, Defence, Aerospace, Security, Information Technology and e-Governance verticals. The company is a key player in the strategic electronics space in the country and has unique multi-disciplinary competencies. ECIL has been consistently registering growth in its turnover over the past few years and is poised to leverage the large growth in strategic electronics.

ECIL has built a strong technological base by associating with prestigious R&D institutions and academic institutions. ECIL has emerged as a major player in providing integrated security solutions to vital installations of the country. ECIL is also a key partner in the implementation of the National Population Register (NPR) project of the Government of India. The company also played an important role in the recent General Elections with the EVM Mark-V and the Voter Verifiable Paper Audit Trail (VVPAT) printers.

Performance

Against the target of ₹1800 Crores each for production and sales, the company achieved a production of ₹1406 Crores and a net sales of ₹ 1430 Crores for the financial year 2013-14 as compared to ₹1678 Crores and ₹1600 Crores respectively for production and net sales for the year 2012-13. The significant achievements during the report period were as follows:

I) Atomic Energy Sector

- Main plant control and instrumentation works at Kundankulam Nuclear Power Project
- Control and instrumentation works for Bhavini's 500MWe PFBR
- Prototype control systems, test simulators etc. for 700MWe PHWR
- Radiation Detection Equipment for seaports



PFBR Control Room

II) Defence Sector

- Combat Command Control Centre and Mobile System for Missile Checkout for Akash missile program
- Command, Control, Communication, Computer, Intelligence system for BrahMos missile program



Mobile System for Missile Checkout

III) Space Sector

- 21 metre telescope for MACE
- Ground Station for Earth Observation Satellite at Antarctica
- Antennas and associated equipment, Cockpit Voice Recorders and Inertial Sensors and actuators

IV) Security Sector

- Mobile Container Scanners for the Department of Logistics, Ministry of Finance
- Surveillance Systems for Delhi Police and Courts
- Encryption Systems

V) Other Sectors

- Electronic Voting Machines and Voter

Verifiable Paper Audit Trail printers for the Election Commission of India and State Election Commissions

- National Population Register
- Socio Economic Caster Census
- Sales Tax e-Governance Project for Maharashtra
- Automation of land registration records of Karnataka Government
- SCADA and Control and Instrumentation equipment for Oil Pipelines

Research & Development

The in-house R&D programme is guided and supported by the Technology Development Council (TDC). Work on the following projects was under progress:

- Radio Frequency Seekers for missile programme
- Intelligent Area Radiation Monitor
- 32G FLOPS Multicore Digital Signal Processing (DSP) system
- Virtual Panel Control for Power Plant Simulators
- Explosive Detectors and Micro PLC system

The RF seeker technology for missiles has been integrated and demonstrated.

New Products Introduced

- Electronic Voting Machine Mark V
- Laundry monitor (for monitoring contamination on protective clothing)
- Plastic Scintillator based Portal Monitoring System
- Combat Command and Control Centre and Mobile System for Missile Checkout for the army version of Akash missile program
- 1.8m and 0.73m antenna systems and Submarine SATCOM Terminal

Certification of the applicable Quality Management Systems

- External audit for recertification for Safety, Health and Environment (SHE) was completed

Tie-ups and Agreements

- The company has entered into a Memorandum of Understanding with NIT Warangal for joint research for communication systems.
- The company has entered into a Memorandum of Understanding with Elbit Systems EW and Sigint – Elisra Ltd., Israel to address the market for Radar Systems.

Outlook for 2014-15

The Company is aiming to achieve the following for the year 2014-15:

I) Atomic Energy Sector

- Radiation Monitoring Systems for 700 MWe, KAPP 3&4 and RAPP 7&8
- Sensors for Compact LWR project
- High Voltage Power Converters for ITER program
- Control and Instrumentation systems for ATPV



High Voltage Power Supply system for ITER

II) Defence Sector

- Military Communication Systems Including HF, VHF and UHF radios
- Communication Jammers for State Police and Prisons
- C4I systems for Missile Programmes
- Electronic fuzes for the Indian Army

III) Space Sector

- Weather and Surveillance Radars
- Ship-borne SATCOM Terminals
- Cockpit Voice Recorders
- Inertial sensors

IV) Security Sector

- Integrated Security System for Delhi Police Phase IV
- Information Security appliances like Secure Network Access System (SNAS) and Integrated Threat Management System (ITMA)
- Encryption Systems
- Surveillance Systems for vital installations of the nation



Integrated Threat Management Appliance

V) Others Sectors

- National Population Register
- Automation of Maharashtra Sales Tax Department Operations
- Electronic Voting Machines for Madhya Pradesh State Election Commission
- SCADA systems to Oil Pipelines

VI) Research and Development

- Embedded Linux based PLC System
- IF Digitiser for Electronic Warfare Systems
- Radar target echo simulator
- RF seekers for missile, testing and flight trials



CHAPTER-10

OTHER ACTIVITIES



Visitors attending the Public Outreach Programme organised by GCNEP at Bahadurgarh, Haryana



Eye Camp for Cataract Operation at Narora

NATIONAL SECURITY

BARC continued implementation of the necessary research and development as well as manufacturing activities required for national security. The reload core for Aриhant went critical and a major milestone in national security was achieved. The vessel presently is undergoing harbour trials.

CRISIS MANAGEMENT

The Crisis Management Group (CMG), a standing Committee of the Department of Atomic Energy (DAE) is responsible for coordinating the Department's response to any radiation emergency in the public domain. 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. A response system is in place to tackle emergency situations by mobilizing the expertise of the DAE in the field of radiation measurement and protection and medical treatment of radiation injuries with an objective to make these specialized technical support facilities available to public officials who would be handling various types of emergencies related to radiation / radioactive materials in the public domain. The CMG also provides its expertise in various forums in the field of disaster management at both National and International levels.

The Crisis Management Group formally meets to review the crisis management plans at different facilities, to discuss issues related to radiological incidents 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 incidents.

The Emergency Response System of DAE is also available to respond to any request from public officials in the event of a reported presence or suspected presence of radioactive material. For this purpose, guidelines have been circulated to all State Governments and Union Territories.

A significant component of the emergency response system of DAE is the availability of two

emergency communication rooms at Mumbai which are manned on a round-the-clock basis throughout the year. These have multiple modes of communication and are in constant contact with various nuclear facilities in the country as well as with the International Atomic Energy Agency (IAEA) in Vienna.

During the report period, India not only ensured its participation in all IAEA conducted International exercises (popularly known as ConvEx exercises) but also met all the convention requirements identified under the Early Notification and Assistance Conventions (ENAC). India's participation was facilitated by Crisis Management Group (CMG) of DAE and its Emergency Communication Room (ECR) which is also the national contact point for nuclear and radiological emergency.

A few of the achievements were as follows:

- IAEA's IEC (Incident and Emergency Centre) Newsletter No. 44, Second Quarter 2013, specifically mentions India's prompt response during ConvEx-1a Exercise conducted on 19th March 2013.
- During ConvEx-2a (2013) exercise conducted on 23rd Oct, 2013, India could successfully meet all the requirements of IAEA's Convention on Early Notification.
- In ConvEx-2b (2013) exercise conducted during 11-12 June, 2013, India offered its assistance in real time to the affected country Slovenia and when Medical Assistance was asked for, all arrangements could be completed within the stipulated time-period (which was appreciated by IAEA) and India's medical team found a place in IAEA's Assistance Mission to Slovenia.
- India participated in the International Exercise ConvEx-3 (2013) conducted by IAEA during 20-21 November 2013. This is the largest exercise in the field of nuclear and radiological emergency which is conducted by IAEA once in 3-5 years. Total 57 States and 10 international organizations registered their participation for the exercise. India, though participating for the very first time in this large scale exercise, was among those few countries which opted for the highest level (Level-B) of participation.

Response of various states was continually monitored and assessed by IAEA, both for the content as well as for promptness. Based on the evaluation of responses of the states, towards the end of the exercise, Final Assistance Action Plan was prepared by IAEA. In this final document, only three countries could find a place; out of them, one assistance offer each of Turkey and Mexico were selected and India could achieve the status as the only country which was selected by IAEA to offer assistance in the four areas of expertise.

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. The numbers of exercises carried out during the year were: Communication Exercises-402; Fire Emergency Exercises-62; Plant Emergency Exercises-47; On-Site Emergency Exercises-12 and Off-Site Emergency Exercises-7 nos.

Off-Site Emergency Exercises were carried out in the public domain in the vicinity of nuclear power stations at MAPS, Kalpakkam in August 2013; at KAPS, RAPS & NAPS in October 2013 and TAPS, Kaiga and HWP, Manuguru in December 2013. These Off-Site Exercises were conducted by the concerned district officials (the District Magistrate or Collector) and information flows were established to the CMG as well as to the National Crisis Management Committee of the Union Government.

During the year, "National Mitigation Plan for Nuclear Radiological (N/R) Emergencies" was finalized by CMG and submitted to Ministry of Home Affairs (MHA).

BARC-SAFETY COUNCIL

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

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

BARC. It addresses the requirements for new radiation installations in BARC.

SCIENCE RESEARCH COUNCIL

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

INTERNATIONAL RELATIONS

India, a designated member of the Board of Governors (BoG) of the International Atomic Energy Agency (IAEA) since its inception, continued to take active part in policy management and programmes of the Agency. India was represented on a number of committees of IAEA on safety, safeguards, nuclear radiation, nuclear engineering and application, nuclear law etc. India hosted several IAEA Workshops, Technical Meetings etc., and offered the services of its experts under the IAEA Technical Cooperation Scheme in a number of fields. India also made an extra-budgetary contribution of USD 50,000 to the Innovative Nuclear Reactors and Fuel Cycles (INPRO) of the IAEA. Various activities funded out of India's contribution of USD 1 million to the IAEA's Nuclear Security Fund (NSF) were also undertaken in cooperation with the IAEA.

In addition to participation in the Annual General Conference of the IAEA in September, 2013, India was represented at both the International Ministerial Conference on Nuclear Power in the 21st Century (St. Petersburg, June, 2013) and the International Ministerial Conference on Nuclear Security (Vienna, July, 2013). India also remained involved with nuclear security issues within the Nuclear Security Summit process and the Global Initiative to Combating Nuclear Terrorism.

The foundation plaque for Global Centre for Nuclear Energy Partnership (GCNEP) was unveiled by the then Prime Minister Dr. Manmohan Singh at Jhajjar in Haryana on January 3, 2014. Thirteen training/public outreach programmes were conducted by GCNEP during January 2013 to March 2014.



The then Prime Minister Dr. Manmohan Singh unveiling the foundation plaque for GCNEP at Jhajjar, Haryana

Cooperation at the multilateral level in regard to the peaceful uses of nuclear energy was also maintained through the European Organisation for Nuclear Research (CERN), the International Thermonuclear Experimental Reactor (ITER), and the Nuclear Energy Agency of OECD.

Intensive discussions under the existing bilateral Inter Governmental Agreements on cooperation in the peaceful uses of nuclear energy took place with the major partner countries. Discussions were held on conclusion of IGAs with Japan and Australia.

The 5th meeting of the India-US Civil Nuclear Working Group (CNWG) was held in Mumbai on 17-18 July, 2013. Discussions on collaboration under the MoU concerning cooperation with the Global Center for Nuclear Energy Partnership were held on the margins of the CNWG meeting. The Arrangement for the Exchange of Technical Information and Cooperation in Nuclear Safety Matters between the Atomic Energy Regulatory Board and the United States Nuclear Regulatory Commission was signed on 9 October 2013.

The 11th India-France Joint Committee meeting on Civil Nuclear Cooperation was held at Cadarache during 4-5th November 2013.

DAE delegations visited Kazakhstan and the Republic of Korea during the year. DAE was also part of the delegation led by Ministry of External Affairs to the Nuclear Security Summit (NSS) at the Hague, Netherlands.

The appropriate arrangement between the Department of Atomic Energy and the Canadian Nuclear Safety Commission, pursuant to the agreement between the Government of the India and the Government of Canada for Cooperation in Peaceful Uses of Nuclear Energy was signed in March 2013 and it entered into force on 20 September 2013. The first meeting of the joint committee under the agreement took place in Mumbai on 29 November 2013. A delegation of the Canadian nuclear industry participated in the India Nuclear Summit 2013.

Follow-up mission of IAEA's Operational Safety Review Team (OSART) visited RAPS 3&4 during February 3-7, 2014. The results of the follow-up mission were considered to be excellent by the OSART.

MANAGEMENT SERVICES

The Management Services Group (MSG) of DAE continued to provide Information Technology services to DAE headquarters. Information Technology infrastructure in DAE Secretariat was continuously upgraded by providing adequate redundancies in systems and network facilities.

During the year, MSG coordinated DAE's Integrated Management Information System Project. This project will act as a decision support mechanism for the top management. It will cover critical management areas of human resource management, project management, finance and security. It will also create an information bank on achievements, important reports and documents created across various units of DAE. The project is being executed with the help of a Task Force and overseen by an Apex Committee comprising various Heads of Units.

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. During the year it finalised the preparation of a Crisis Management Plan to counter cyber-attacks in accordance with guidelines issued by the government and integrated it into DAE's Crisis Management Plan. MSG got quarterly internal IT security audits done by all units of DAE. It also ensured compliance of the IT security guidelines issued by CISAG.

DAE's web site (<http://www.dae.gov.in>), a repository of parliament questions and answers, press releases, acts, rules, agreements, orders, publications, achievements of the department, and provides downloadable forms for the benefit of the public and acts as a window to the public to communicate its activities was maintained by MSG. The site is well connected and linked to all the constituent units of DAE.

MSG also managed various applications relating to administration and accounts activities in DAE Secretariat. MSG operated a helpdesk in DAE Secretariat that enabled delivery of all IT services to the users.

VIGILANCE

The Chief Vigilance Officer (CVO) holds the overall responsibility of vigilance activities of DAE. To facilitate proper functioning of the vigilance machinery and to establish effective co-ordination amongst the Organisations, a senior officer in each of the Constituent Units and Aided Institutions of the Department has been designated as Vigilance Officer to carry out the vigilance functions effectively. Fulltime CVOs are co-ordinating vigilance activities in the Public Sector Undertakings of DAE.

Vigilance functions include timely submission of various vigilance returns to the Central Bureau of Investigation (CBI), Department of Personnel and Training (DoPT), Central Vigilance Commission (CVC); issuance of sanction for prosecution; processing of vigilance and disciplinary cases; monitoring of the progress of inquiry proceedings, investigation of complaints and others.

During the year, a one day workshop on CVC guidelines on tendering process was organised by DAE to sensitize various guidelines issued by CVC.

"Vigilance Awareness Week 2013" was observed in the Department of Atomic Energy, Mumbai from 28/10/2013 to 02/11/2013. Competitions such as Slogan Competition, Poster Competition, Essay writing competition etc. were held during this week. Vigilance Awareness Week was also observed in the Constituent Units/ Public Sector Undertakings and Aided Institutions of the Department.

OFFICIAL LANGUAGE IMPLEMENTATION

DAE and its constituent units, PSUs and aided institutions continued to carry out their activities to promote the use of Rajbhasha (Hindi) in various disciplines of Nuclear Science and Technology. Some of the efforts made in this direction are highlighted below:

DAE conducted 15th All India Rajbhasha Sammelan on 16th and 17th January, 2014 at Institute of Mathematical Sciences and various lectures and programmes were organized during the course of the Sammelan. The souvenir in Hindi on the proceedings of the Sammelan was also published.

IRE, Chavara and IPR, Gujarat were notified under Official Language Rule 10(4). So far, 35 offices were notified under the said rule.

The Parliamentary Committee on Official Language inspected AMD (Northern Region) New Delhi; ECIL, Chennai; RRCAT, Indore and ECIL, Bengaluru.

DAE inspected IMS, Chennai; Bhavini, Kalpakkam; NIZER, Bhubaneswar; AMD, Hyderabad; NFC, Hyderabad; ECIL, Hyderabad; TMC, Mumbai; TIFR, Mumbai; AMD (North-Eastern Region), Shillong; IOP, Bhubaneswar; Seismology Division, Delhi Seismic Unit (BARC), New Delhi and ECIL, New Delhi. In addition to this, various Units/PSUs/Aided Institutions namely BARC, RRCAT, NFC, AMD, IGCAR, VECC, HWB, GSO, DCS& EM, AERB, NPCIL, IRE, ECIL, UCIL, Bhavini, TIFR, TMC, IPR, HRI and IOP inspected their subordinate offices and sections.

About fifty three seminars and forty four talks in Hindi on diverse subjects, mostly related to Nuclear Science were organized and the souvenirs in Hindi on the proceedings of the seminars/talks were also brought out.

All the Gazette Notifications, Cabinet Notes, Annual Reports and other documents furnished to the various Committees of the Parliament, and the Agreements and MOUs were prepared bilingually.

More than 2150 officers and employees were imparted training in Hindi, noting and drafting in Hindi workshops. About 883 officers and employees under the incentive scheme for doing original noting and drafting in Hindi, 89 Typists under the incentive scheme for Hindi Typing and 48 Stenographers under the incentive scheme for Hindi Stenography were awarded.

Around 434 Officials, 18 Typists and 51 Stenographers were imparted training in Hindi, Hindi Typing and Hindi Stenography respectively. 480 Officials, 46 Typists and 40 Stenographers were undergoing training in Hindi, Hindi Typing and Hindi Stenography respectively. 379 Officials, 10 Typists and 11 Stenographers were given cash awards and other incentives for successfully passing Hindi, Hindi Typing and Hindi Stenography examinations.

Hindi books worth Rs. 7,60,087/- were purchased. Quarterly meetings of OLICs were held regularly and the progress of implementation of Hindi was monitored regularly through Departmental OLIC meetings. The quarterly progress reports and minutes of the meetings of OLICs of all Units/PSUs/Aided Institutions were also reviewed regularly.

DAE and its 22 establishments have their websites in bilingual form and these were updated regularly. Presently, there are 22,220 bilingual computers in the Department.

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.

About 42 house magazines and 5 newsletters were brought out by various

establishments of DAE. The total strength of Hindi staff in DAE and its constituent Units, PSUs, and Aided Institutions was 130.

SCIENTIFIC INFORMATION RESOURCE MANAGEMENT

The Scientific Information Resource Centre (SIRC) of Department of Atomic Energy continued to procure new books, periodicals and other reading materials. User services such as Circulation, News Clippings, Reference & Information, Reprography, etc. were provided uninterruptedly. Printed publications for departmental as well as for public use were published by the Publications Unit of DAE. These included publications relating to statutory documents such as Annual Report and Outcome Budget; internal publications such as DAE diary and Accounts at a glance and public awareness materials such as DAE perspective, brochures, leaflets and booklets etc.

Scientific Information Resource facilities of BARC was continuously upgraded/equipped with the state-of art facilities and technology infrastructure to provide seamless access to information to BARC scientists and engineers in their day-today R & D activities and it also extended its facilities to other DAE institutions.

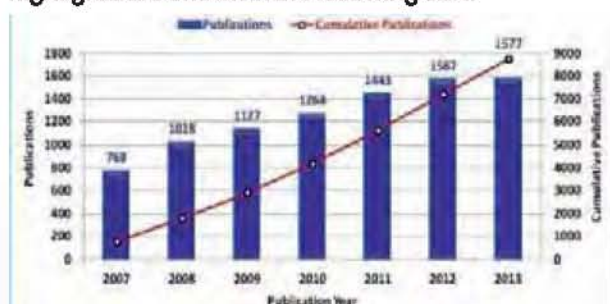
Around 950 books, various standards, codes, patents and complete sets of standards were procured during the report period. More than 2600 scientific and technical reports and about 1550 bound periodicals were added to the collection. BARC currently subscribes to about 1400 periodicals and 9 Databases. Access was provided for more than 3500 online journals through Lakshya, the Online Information Gateway. A mirror site of Online Information Gateway Lakshya facility was setup at BARC. The digital portal Saraswati was upgraded for higher speed and volume for accessing digital resources from web browser interface at the users desktop. Open source based digital repository E-Sangrahaay now holds more than 7500 journal articles.

For efficient Book Circulation, management and Inventory Tracking, ISO based RFID Library Management Solution has been implemented and

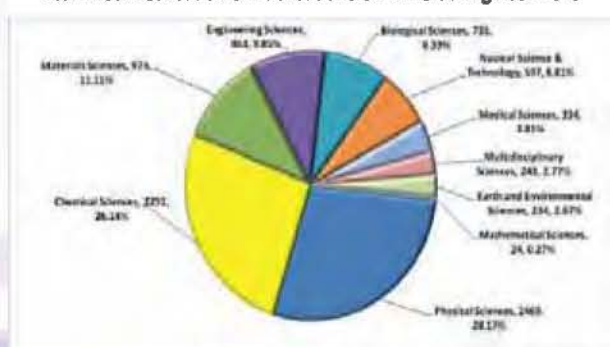
made operational at BARC. The Library circulations unit continued to provide user friendly services to scientists and engineers of BARC and other DAE units. Interaction with other National and International organizations continued.

The full text of publications of BARC scientists and engineers were made available on SARASWATI-the Library Intranet. BARC central library extended the Remote Access of more than 1800 Science Direct online journals to more than 700 Scientist and Engineers of BARC.

Research activities in Library & Information Science and Scientometrics on various topics related to nuclear science and technology and other major thrust areas were continued. A total of 8764 publications were published during 2007-2013. The highlights are shown in the following cart.



Year-wise Distribution of Publications of BARC during 2007-2013



Subject-wise Distribution of Publications of BARC during 2007-2013

BARC External and Internal Reports, issues of the BARC Newsletter, Scientific Information Resource Bulletin, Pulse and various brochures for the National Technology Day, including Atoms in the Service of the Nation, printed material for the Graduation Day Function, HBNI Annual Report, invitation cards for various events, Pocket Diaries, Pocket Calendars and other material for various Divisions of BARC were produced.

Printing and Binding Unit continued to provide printing of restricted reports, reprints, invitation cards, visiting cards etc., by using offset and screen printing processes. Binding of collected scientific publications of various Divisions, reprints, tender documents, restricted reports etc., was carried out.

Photography and video recording services were provided to scientists and engineers of BARC. Events like national and international conferences, public lectures as well as VIP visits were covered. Digitization of photographs of archival value was initiated. Audio Visual films were developed in-house with local voice over for inauguration of advance facility developed by BARC.

At IGCAR, Redhat Linux Virtualization high performance server and IP SAN (Internet Protocol Storage Area Network) based advanced digital library infrastructure was commissioned to host various applications and e-resources of SIRD.

Patron information was integrated into the RFID (Radio Frequency Identification) based employee identity card which enabled library transactions through the same card. Compact shelving system to accommodate hard copy of technical reports and back volumes was installed.

PUBLIC AWARENESS

The Department of Atomic Energy (DAE) carried out a gamut of public outreach programmes on a mission mode to alleviate unwarranted fears and misconceptions, to address apprehensions harboured against nuclear energy and to keep the public abreast with the contributions of atomic energy towards societal welfare. DAE participated in and organised a host of events comprising exhibitions, seminars, workshops, essay and quiz contests in different regions of the country which were well received by the target audiences.

The 101st Indian Science Congress was held at Jammu University, Jammu during February 3 – 7, 2014. The theme of the exhibition was India Vision 2020, with focal theme as "Innovations in Science & Technology for Inclusive Development". DAE participated in the exhibition displaying all its activities.



Students taking keen interest in the exhibition at the DAE pavilion during the 101st Indian Science Congress

DAE participated in INNAVIAZONE'13 organised by the GH Patel College of Engineering and Technology (GCET), at Anand, Gujarat during August 16-17, 2013. The event was a platform for encouraging young students to solve real world challenges by applying science and technology.



Students at the DAE exhibition during INNAVIAZONE'13

The 17th National Exhibition with the theme, "India Advancing towards a World Power" was held at the Visvabharati University, Shantiniketan, West Bengal during September 6 – 10, 2013. DAE participated in this event and exhibited all the peaceful uses of atomic energy. DAE units SINP and VECC, Kolkata also participated and exhibited their R&D activities.



Students being briefed during Mahakoshal Vigyan Parishad Jabalpur

'Jigyasa', a three day exhibition with focal theme "Growing Surge for New Technologies: are we ready to satisfy the expectations" was organised by the Mahakoshal Vigyan Parishad Jabalpur, M.P during September 19-21, 2013. Members of the general public, students at the high school, college level and academicians benefited from this event.

A two day public awareness and outreach programme on DAE Technologies was held at the MM PG College, Fatehabad, Haryana during October 3-4, 2013. Various DAE technologies were exhibited and it proved to be a very useful exercise, especially in the wake of the proposed nuclear power project in this area.



Visitors being briefed on DAE Technologies at MM PG College, Fatehabad, Haryana

The 25th All India Essay Contest on Nuclear Science and Technology was held in October 2013. About 500 essays were received out of which the authors of thirty three were selected for making an oral presentation at Mumbai. The selected participants visited various DAE facilities. Prizes, in cash were awarded on Founder's Day, October 30, 2013.

The 33rd India International Trade Fair 2013 organised by the ITPO, was held at the Pragati Maidan, New Delhi during November 14-27, 2013. DAE exhibited all its activities.

The International Agricultural Trade Fair and Conference- KRISHI 2013 was organised by the Human Service Foundation, Nasik during November 15-19, 2013. DAE provided information about its contributions in the areas of agriculture and food processing. Several farmers, members of the rural public, scientists and private entrepreneurs visited the exhibition.



Visitors attending the Public Outreach Programme organised by GCNEP at Bahadurgarh, Haryana

A two day Public Outreach Programme on DAE Technologies for Rural India was organised by the Global Centre for Nuclear Energy Partnership (GCNEP) at its site at Bahadurgarh, Haryana, during November 21-22, 2013. The event was held at the PDM Group of Institutions. DAE exhibited all its technologies contributing to the development of the rural sector. The event was very well received by the local, general and rural public.

DAE organised the 5th International Exhibition and Conference, India Nuclear Energy 2013 at the Nehru Centre, Mumbai during November 28-30, 2013. National and International professionals in the Nuclear Power Industry participated in this event. In a concerted effort, DAE along with its other constituent units exhibited its activities specifically in the area of nuclear power and also various applications of radioisotopes, advanced technologies etc. International participation included France, Russia, Canada and Korea.

The 8th National Seminar on the Peaceful uses of Atomic Energy was organised by the United Schools Organisation (USO), New Delhi during December 5-6, 2013. Science teachers and educators from various regions of India attended this Seminar and found it immensely useful and informative. Experts of DAE addressed the participants on the peaceful applications of atomic energy contributing to societal welfare.

Radiation Medicine Centre (RMC) as a part of its Golden Jubilee Celebrations held the 45th Annual Conference of Society of Nuclear Medicine, India (SNMICON 2013) at the Nehru Centre, Mumbai during December 12-15, 2013. Professionals in the

area of nuclear medicine, physicians, technologists and radiation safety officers from all over India participated in the event. DAE provided information on all its activities with emphasis on its contributions in the area of nuclear medicine and healthcare.

The 7th International Food Convention (IFCON) was organised by Central Food & Technological Research Institute (CFTRI), Mysore during December 18-21, 2013. DAE's contributions in the area of agriculture and food processing were exhibited and the visitors were addressed by DAE experts.

DAE participated in the Garhwal Science & Technology Fair at Srinagar, Pauri, Garhwal during December 18-20, 2013. The theme of the exhibition was "Application of S&T for Disaster Mitigation and Management". School and college students from in and around the area, members of the general and rural public visited the exhibition.



Shri. Nitin Gadkari at the DAE pavilion during AGROVISION at Nagpur.

AGROVISION with theme as "Building Sustainable Livelihoods & Increasing Farmers 'Income'" was held at Nagpur during December 26-29, 2013. The department's achievements and contributions in the area of nuclear agriculture especially for the benefit of farmers and applications in food processing were exhibited. A large number of farmers and other scientific professionals benefitted from this event.

DAE participated in 'Anu Week – 2014' at Nagercoil (close to Kudankulam), Tamil Nadu during January 21 – 25, 2014. The event comprised an exhibition, a seminar for high school/college teachers on the 'Societal Applications of Atomic Energy', quiz contest for school students etc. The event also included a visit of the plant by all the participants in the seminar. The visit proved immensely fruitful in

removing baseless misconceptions about the plant. The exhibition was a concerted effort by BARC, NFC, Palayakayal Unit, Heavy Water Plant, Tuticorin and KKNPP, NPCIL.

The Bangalore India Bio 2014 organised by the Government of Karnataka, was held at Bangalore during February 10 – 12, 2014. DAE exhibited its achievements in the area of healthcare, biotechnology, agriculture and food. Jonaki Laboratory, BRIT, Hyderabad also participated in the event. Several technologists, farmers and scientists visited the DAE pavilion.

In addition to all these events, several public awareness lectures/workshops on atomic energy were conducted in different regions of the country throughout the year. Many of these were in the vernacular medium also.

With an objective to further strengthen the Department's public outreach activities, several advertisement films showcasing the major contributions of DAE were produced and telecast on National and regional channels of Doordarshan. These films, developed with the help of Prasar Bharati, highlighted the areas of nuclear power generation, food security, healthcare management, research & education among others. Dubbed versions of these films in selected regional languages were also developed. Department of Audio-Visual Publicity (DAVP) was engaged for the production of further thematic advertisement films to convey the DAE roles and contributions more effectively. Conventional methods of public awareness such as lectures and seminar in schools and colleges, public awareness events, participation in science fairs and exhibitions etc. are also continuing.

To enhance the visibility and recognition of the Department and its constituent units, a new logo was developed. It was unveiled in Mumbai by the Hon'ble Prime Minister of India on January 10, 2014. In order to further expand the coverage across a wider cross-section of people, a multi-pronged approach involving permanent exhibition centres, media workshops etc. are planned under the recently approved XII Five Year plan project on "Expansion of DAE Outreach and Perception Management".

Nuclear Power Corporation of India Limited (NPCIL) carried out a gamut of public outreach activities conveying the facts on nuclear power in a simple transparent and credible manner addressing apprehensions and concerns of the people.

During the year about 12,60,000 persons were reached out through the multi-pronged initiatives. About 8000 students from Mumbai Municipal Corporation and Atomic Energy Education Society schools visited the Hall of Nuclear Power at Nehru Science Centre developed by NPCIL in collaboration with Nehru Science Centre. NPCIL participated in more than 60 exhibitions across the country to make around 9.25 lakh people aware, reaching out to around 47,000 students and teachers, educationalists, environmentalists and media persons through lectures and seminars. Two scientific meets on radiation and cancer were organized for the doctors and site visits of around 63,000 people were carried out.

Several innovative public awareness programmes were conceived and implemented for communities around the Indian nuclear power plant sites as well as at several other locations across the nation. Use of TV commercials, advertisements, digital cinema, radio jingles, single-sheet print publications, innovative comic books and animated films, etc. in vernacular languages, enhanced interaction with press and media, e-public awareness campaigns, rallies in support of nuclear power are a few among many modules that were adopted to supplement the scaled up outreach activities. NPCIL has entered into partnership with several special agencies like Vigyan Prasar of the Department of Science & Technology.

Following innovative moves in Public Outreach Activities were undertaken by NPCIL:

Farmers Integration Programme (FIP)

Farmers Integration Programme (FIP) is specially designed for the farmers for driving away the prevailing myths and apprehensions related to radiation and to develop the positives understanding of nuclear energy especially to improve their agricultural yields, food irradiation technology, improvement of shelf life of crops by sprout inhibition, early ripening of fruits and prevention from

*Farmers Integration Programme*

insecticides etc. Under this programme, first interactive workshop was organised for farmers in collaboration with Amity University, Noida and Krishi Vigyan Kendra (Under ICAR, Govt. of India), Bhivani, Haryana on November 16, 2013. The workshop was attended by more than 80 farmers,

Promotion of Nuclear Power through an Innovative Medium: Street Plays

Sixty street shows were carried out in Fatehabad, Haryana, a city near Gorakhpur Haryana Anu Vidyut Pariyojana and around Narora Atomic power Station. The aim of these Street Plays is to educate, inform and share the need of electricity, various forms of electricity sources available for us in India, their various merits and demerits, why Nuclear Energy is one of the important sources of electricity generation.

*Newspaper in Education (NIE) Programme with Times of India**Media Students Adaptation Programme (M-SAP)*

Exhibition on wheels

To increase the coverage of public outreach activities and to reach more people in remote areas, a mobile bus was deployed at Chutka, Madhya Pradesh and Mahi Banswara, Rajasthan by Nuclear Power Corporation of India Limited (NPCIL). The bus was fabricated with informative displays/models/posters etc. on nuclear energy to make people aware about the various aspects of nuclear energy.

Nuclear Awareness through EduSat

A new project "Nuclear Awareness through EduSat" has been launched to create awareness on nuclear power among the students and academicians. For this, NPCIL has joined hands with the Educational Multimedia Research Centre (EMMRC) wing of Anna University, Chennai.

Newspaper in Education (NIE) Programme with Times of India

To employ the brain of young children by educating them about the various aspects of nuclear energy under the "Newspaper in Education (NIE)" campaign has been launched recently in collaboration with Times of India (TOI) newspaper. Under the student connect programme, various activities like 48 creative workshops on nuclear energy, distribution of comics, publications, single sheets and CDs are being organised in a year time in various schools and colleges across the country with the massive coverage.

Media Students Adaptation Programme (M-SAP)

As a special initiative, NPCIL has decided to nurture the young journo from leading mass communication institutes and universities by arranging their visit to our nuclear power plants to have first-hand experience as a course assignment under the very unique programme M-SAP. So far three visits of media students from Amity University, UP, Mumbai University and Makhan Lal Chaturvedi University, Noida have been organised.

Comic books & Animation Films

An animated film exclusively on radiation and its benefits to the mankind "A Friend- forever" has been made in four Indian languages dispels the unfounded fear of a common man about radiation. Besides, others comics and animated films have been developed and produced in 7 languages like Hindi, English, Marathi, Gujarati, Tamil, Telugu and Kannada. Over 3 lakhs copies of the comic books have been distributed. About 200 short and animated films have been developed in nine languages.

Capacity-building for outreach

120 resource-persons of NPCIL were trained by the expert faculty during the various training programmes in Media Communication and Public Communication at its Sites. In addition, Orientation training programmes were organized for 60 resource-persons selected from various sites and H.O for conducting awareness in villages around Mithi Viridi (Guj) and Chutka (M.P) sites prior to the public hearing at these sites.

Development of Books and Films on Nuclear Energy by Vigyan Prasar

Apart from organising the workshops and seminars on nuclear energy across the country, Vigyan Prasar, Dept. of Science & Technology, Govt, of India has produced a series of documentaries films, books and radio jingles on various aspects of nuclear energy, in a very simple, interesting and lucid way, covering all the topics related to it. These films and books have been created by eminent and experienced authors and film makers.

Kendriya Vidyalaya Teacher Adoption Programme

Zonal Institute of Education and Training (ZIET), Mumbai has been offering regular opportunities to NPCIL to extend its awareness campaign to teachers and Principals of Kendriya Vidyalayas from all over India who are deputed for in-service training at the Institute. Four awareness seminars were conducted by NPCIL at the Institute.

Web based Public Awareness

NPCIL web site has been provided a link for public for seeking information; visit to a nuclear power station.



Students visit to BARC

BARC conducted several public awareness programmes for the benefit of students, teachers and farmers across the country. Twenty seven public awareness programmes were conducted during the period. Media coverage to the various events organized at BARC were also arranged.

Two awareness programmes at Chiplun, Maharashtra and Mangalore, Karnataka were held by BARC for University students, teachers and farmers. Senior scientists from BARC, NPCIL and TMC addressed the audience about various issues related to peaceful uses of nuclear energy. Similarly, more than five different visits to BARC and/or Biogas plant at Anushakti Nagar were organized for school and college students, staff and farmers from rural Maharashtra.

BARC presented technologies in "Vendor Development and Technology Show" held at Bangalore International Exhibition Centre, Bangalore during 6-8 June, 2013.

SOCIAL WELFARE

Corporate Social Responsibility

NPCIL aims to function as responsible corporate entity while discharging its social responsibilities towards all stakeholders including consumers, employees, local communities and



Aids and Appliances distributed to differently-abled people near Kalpakkam



Construction of Motorable Bridge at Govar village near Kalga



Drinking water Scheme near Kalpakkam



Patients at Rural Dispensary near Kakrapar

society at large. The three major areas in which CSR work was done were education, healthcare, and infrastructure development. Skill development projects were also initiated under education area.

The number of CSR projects taken-up has increased from 116 to 306 and total annual monetary allocation has increased from ₹ 21.5 Crore to ₹ 55

Crore. Moreover, an additional CSR fund of ₹ 125 Crore to be utilized during 2012-14 was sanctioned on account of Silver Jubilee year of the company for initiating major CSR projects especially in the area of education and infrastructures. Using this fund, the CSR projects worth about ₹ 50 Crore have been planned and being implemented.

During the report period, total eighty projects were taken up which included thirty projects in education and skill development, fifteen projects in health and twenty six projects in infrastructure category. Sustainable development projects were planned and implemented during the year and ₹.2.75 Crore was allocated for sustainable development activities.

EMPLOYEES' WELFARE

Employee's Health Care

Contributory Health Service Scheme (CHSS) was introduced in the Department in the year 1962, with an object to provide specialised and personalised health care to its employees and the members of their family, even after retirement. The Revised CHS scheme came into effect from 01/02/1998. The Department reviewed the scheme from time to time and the orders amending/substituting or inserting new rules in the scheme were issued.

The CHS scheme was framed particularly for Mumbai but the same has been extended to other places such as Tarapur, Indore, Kota, Talcher, Manuguru, Kalpakkam, Chennai, Baroda, Kolkata, Tuticorin, Mysore and Hyderabad. In addition to DAE employees, the scheme also covered the staff of some of the PSUs & Aided Institutions among DAE family.

DAE extended the CHSS facility for the staff and their family members at Greater Visakhapatnam and engaged the services of a medical officer on contract basis for providing treatment to the employees and their family members at AMD, NER, Shillong under CS(MA) Rules, 1944.

Children's Education

The Atomic Energy Education Society (AEES) with an objective to meet the educational needs of the children of the employees of the Department of Atomic Energy and its constituent units working at different centers in the country achieved significant results in its pursuit of excellence in academic as well as non-academic fields. During the year, AEES launched several long-term key projects such as Application of Science and Technology for Educational Reforms (ASTER).

Over 2400 students had appeared in the Class-X, CBSE board examination in March, 2013 and the pass percentage was 100 as compared to 99.91 last year. 24% of the students secured A1 Grade (91-100%) and another 24% secured A2 Grade (81-90%). More than 1850 students had appeared in the Class XII board examination in March, 2013 and the pass percentage was 87.80. The pass percentage at Atomic Energy Central School (AECS)-3, Tarapur was 100%.

Twenty two students secured admission into IIT, 41 students secured good ranks in AIEEE and more than 344 students got admission in engineering courses through the state level examinations and 28 students secured admission into medical stream.

Four students were awarded the National Talent Search Scholarships for the NTSE conducted by National Council of Educational Research and Training (NCERT).

In the 55th Annual All India UN Information Test 67 students secured good ranks in all India level. Among them one student secured second position in pre-senior category and another student got 4th position in senior category of All India level.

One Student of AECS-2, Mumbai qualified in the Regional Mathematics Olympiad (RMO) Exam conducted by Homi Bhabha Centre for Science Education (HBCSE), Department of Atomic Energy (DAE) and appeared for Indian National Mathematics Olympiad (INMO) conducted by HBCSE.

One student of AECS, Indore was awarded 3rd prize in quiz competition along with cash prize and a commendation Medal and another student of AECS-2, Kalpakkam was awarded commendation Medal.

Two Students of AECS, Turamdih secured first position in national level of "Hindi Vigyan Prashna Manch", conducted by HBCSE.

In National Level Olympiad in Physics, Chemistry and Astronomy conducted by Indian Association of Physics Teachers, one student of AECS, Indore was qualified in the first phase of Physics, Chemistry and Astronomy Olympiad and secured National Top 1% certificate in all the subjects and two more students got top 1% certificate in State level.

In the National Level Science and Mathematics Olympiads, 38 students of AECS-2, Rawatbhata scored more than 90% in School level and were awarded Medals. Eleven students of AECS-2, Jaduguda, got Gold Medals in Mathematics Olympiad conducted by Council of Elementary Education, New Delhi and one Student of AECS, Mysore got 1st prize in Quiz Competition in All India AEES Junior Science and Mathematics Olympiad. One Student of AECS, Oscom scored 100 out of 100 in National Mathematics Olympiad conducted by All India Mathematics Teachers Association.

One student of AECS-2, Kalpakkam got Best Student Award alongwith cash prize in the Inspire Internship Camp organized by Department of Science and Technology, Govt. of India. One Student each of AECS-4, Mumbai, AECS, Kakrapar and AECS, Indore qualified for KVPY Fellowship Award instituted by Indian Institute of Science, Bangalore.

Fifty eight students of Class IX of various AEC Schools participated in AEES Junior Science and Mathematics Olympiad (in collaboration with HBCSE) at AECS-2, Mumbai along with fifteen mentor teachers.

About 336 students from AEC schools of Mumbai and Tarapur got qualified in the elementary level and 199 students got qualified in the Intermediate Level Drawing Gradation Examination conducted by Directorate of Art, Maharashtra State Board.

In 45th All India Competition in Music and Dance, one student of AECS, Manuguru, was awarded 1st prize in Junior Group and another student got 2nd prize in State (Karnataka) level vocal competition in sub-junior group.

All India Inter AECS Athletic Meet & Table-Tennis Tournaments were held at AECS-2, Kalpakkam and AECS-Kaiga respectively in 2013.

Atomic Energy Education Society in collaboration with the Department of Atomic Energy Sports and Cultural Council organized Summer Sports Coaching Camp for school children in various games such as Football, Volleyball, Basketball, Lawn Tennis, Table Tennis, Badminton and Athletics.

Orientation programmes were organized by AEES for the PGTs with a view to empower them to plan and execute the various classroom activities to be used for better evaluation. Another programme was organized for PRTs in Physical Education at AECS-2, Tarapur and AECS-1, Hyderabad.

The Rolling Trophies for the best performers in various fields were awarded to Atomic Energy Central Schools and Junior Colleges on the occasion of the occasion of Republic Day celebrations 2014.

DAE SPORTS & CULTURAL ACTIVITIES

The DAE Sports and Cultural Council (DAE S&CC) facilitated promotion of sports, physical fitness, yoga and also promoted capacity building in various sports, adventure and cultural activities across DAE units and their residential colonies by holding competitive sports and game events at DAE level, encouraging positive health initiatives like Yoga camps and fitness centres, organising adventure treks and nature camps for employees and their families, conducting summer sports camps for DAE AEES school children, organising inter DAE sports-cultural meets and finally facilitating DAE teams in participating in National level tournaments.

The Council scheduled the XXIX Inter DAE sports & Cultural Meet with eleven different sports and cultural events spread over ten units of DAE. Sports infrastructure at various units have been upgraded for conducting these meets. The Council procured and provided suitable mementoes as tokens of the department's appreciation and to all participants and volunteers who contributed to the success of this meet. Teams to participate in National events like ball badminton, kabaddi, football, bridge,

Table Tennis, Badminton etc. were selected during the meet.

More than 150 children were benefited through the summer camps conducted at AEES schools at Mumbai, Anupuram, Kaiga, Kalpakkam, Turamdih etc. DAE Sports and Cultural Council through its demonstration Community Centre at Mumbai conducted a number of sports camps, training and tournaments in Badminton, Table Tennis, Chess, Cricket and regular coaching for children of DAE family residing at Anushaktinagar.

The Annual Anushaktinagar Festival SPLASH -2013 was a Mega Event and about 11 events were organised. Under Nature and adventure related activities, the fifth DAE S & CC Nature and Adventure Camp for the children of DAE employees was organized at Van Vihar, Ambivali village near Karjat, Raigad district during 8-10 November 2013.



Dr. C. B. Venkataramana, Additional Secretary DAE and President DAE S&CC addressing the gathering at the opening ceremony of SPLASH 2013

Girisanchar, the annual trekking programme organized by DAE Sports and Cultural Council entered its 25th year in 2014. To commemorate the Silver Jubilee year, for the first time DAE S&CC organised 25 self-financed treks to nearby locations of a number of DAE units on October 20, 2013.

Significant efforts were made by the council towards promoting health and fitness activities for the employees and their family members through subsidising fitness centres at DAE units and facilitating regular yoga activities through yoga camps, nominating employees and yoga volunteers to major conferences, provision of yoga literature to AEES schools, regular practice and organisation of DAE Yoga Conference.



Workshop on Yoga for Self Realisation at NFC, Hyderabad



Ladies Fitness Camp at NCC, DAE S&CC

A high point during the year was the organisation of the second national yoga workshop on "Yoga for Self Realisation" during April 6-7, 2013 at the Nuclear Fuel Complex, Hyderabad. The workshop included theme based talks from internationally renowned yoga exponents and community yoga practice for the participants. Two new fitness centres, one at RRCAT, Indore and one for senior scientists at Anushaktinagar was established during the year.

As a part of infrastructural development and promotional activities, DAE S&CC supported the organization of various sports and cultural equipment and activities in many of the residential colonies of the Department.

RTI COMPLIANCE

The Right to Information Act of Government of India which came into force on 12th October 2005 has been implemented at DAE and all its constituent units.

During the year, IGCAR received 108 applications under RTI Act of which 5 applications were transferred to other PIOs and for all the remaining applicants, information was provided. RTI

related issues were dealt efficiently at AMD. Total 116 RTI applications were received during the year out of which 98 were replied, 5 were transferred and 13 were returned in original (RIO). Out of 19 first appeals, 19 were replied and 4 CIC hearing appeals were attended. At NPCIL, the mandatory information required under the RTI act was posted on its website. Out of 240 RTI appeals received 230 appeals were replied. IREL received 152 RTI queries and all were replied. UCIL received and replied 74 RTI queries during the report period and replies to 3 queries were under process. The no of RTI queries received in SINP was 45 and 37 queries were replied. DCSEM received 166 RTI queries out of that 157 were replied and replies to the remaining 9 queries was in process. NBHM received 4 RTI queries and these were answered during the period.

AWARDS & PRIZES

The units of Nuclear Power Corporation of India Limited received several awards during the year for performance in safety, environment protection and other areas. TAPS-3&4, RAPS 1&2, RAPS-3&4, KAPP-3&4 and KGS-1&2 bagged National Safety Council of India's various Safety Awards for the year 2012 and KGS-3&4 for the year 2013. AERB's Safety awards for the year 2012 for industrial safety and fire safety were bagged by TAPS-1&2, TAPS-3&4, KAPP 3&4 and KAPS 1&2 respectively. NAPS-1&2 won the Golden Peacock Award for Environment and for Training functions. KAPS-1&2 received Gujarat State Safety Award-2011 for outstanding safety performance. KGS-3&4 received Safety award from Ministry of labour & Employment for the year 2011 for accident free year.

UCIL was awarded with "Greentech HR Silver Award" by Greentech Foundation in "Training Excellence" for the year 2013. It also bagged "BT Star PSU Excellence Award" for excellence and best practices in PSU business by Bureaucracy Today and Greentech Foundation. For "The Underground Remote Asset Tracking System" project UCIL won "Engineering Excellence Award" as an Engineering Marvel of India under people's choice category in the magazine "Engineering Watch".

The awards received by ECIL during the year were the SCOPE Gold Trophy Award for Excellence



Shri P Sudhakar, CMD, ECIL receiving the SCOPE Award for R&D, Technology Development & Innovation for the year 2011-12 from the Hon'ble President of India.



Chief Executive BRIT receives the INS Industrial Excellence Award from Shri Ratan Tata

in R&D, Technology Development & Innovation; the ELCINA Research and Development Award and the DAE environment award from AERB. ECIL won the "Rajbhasha Trophy" for implementation of official language from Town Official Language Implementation Committee (TOLIC). ECIL's quality circles received the "Par Excellence" and "Excellence" awards for their solutions at national level competition.

The Board of Radiation and Isotope Technology (BRIT) received the INS Industrial Excellence Award.

HWP, Kota won Rajasthan Energy Conservation Award-2012: First position in Chemical Sector, consecutively 2nd time and also Certificate of Appreciation by National Safety Council of India, Safety Awards-2011 in Manufacturing Sector. HWP, Kota won AERB's Fire Safety Award in Category-I for the Year 2012. HWP, Hazira received National Safety Award-2011 for outstanding performance in Industrial Safety from Ministry of Labour & Employment. It also obtained IS: 18001

recertification from M/s BIS. Atomic Energy Regulatory Board conferred "Industrial Safety Award-2012" on HWP, Thal. The plant was also awarded Rajiv Gandhi Environment Management Award. RCF Thal complex including HWP-Thal bagged Greentech Safety Excellence Award-2012 from Greentech Foundation, New Delhi for outstanding achievement in Safety management. Quality Circle (Astiva) of HWP Instrument Section received 3 stars (Top most rating) at 'International Quality Circle Convention' held in October 2012 at Kula Lumpur, Malaysia.

Prof Rajesh Gopakumar of HRI was awarded the TWAS physics prize in October 2013 and he also won the G D Birla prize in physical sciences for the year 2013. Prof Aditi Sen De received the Buti foundation award of the Indian Physics Association for the year 2013. Prof Raj Gandhi was awarded the "Fermilab Intensity Fellowship".

Dr. Tejen Basu, fellow of Institute of Plasma Research, Gandhinagar was awarded Indira Gandhi Award (third) by Hon'ble president for writing scientific book in Hindi.

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.

For the purpose of DAE Annual Report 2013-2014 (PWD Report - I & II merged)

ANNUAL STATEMENT SHOWING THE REPRESENTATION OF PERSONS WITH DISABILITIES AS ON 01.01.2014 AND NUMBER OF APPOINTMENTS MADE DURING THE PRECEDING CALENDAR YEAR 2013 IN RESPECT OF CONSTITUENT UNITS

Group	Number of Employees					Direct Recruitment						By Promotion					
	Total	VH	HH	OH		No. of vacancies reserved			No. of appointment made			No. of vacancies reserved			No. of appointment made		
(1)	(2)	(3)	(4)	(5)		VH	HH	OH	Total	VH	HH	OH	Total	VH	HH	OH	
Group A	7808	0	1	41	0	0	0	1	231	0	0	10	38	0	0	1	
Group B	10316	7	7	62	1	2	2	2	75	0	1	20	94	0	0	0	
Group C	11226	14	25	107	7	9	11	11	511	0	3	19	141	1	0	0	
TOTAL	28350	21	33	210	8	11	14	14	817	0	4	49	273	1	0	1	

Note 1 : (i) VH stands for Visually Handicapped (persons suffering from blindness or low visions)

(ii) HH stands for Hearing Handicapped (persons suffering from hearing impairment)

(iii) OH stands for Orthopaedically Handicapped (persons suffering from locomotor disability or cerebral palsy)

(iv) There is no reservation for persons with disabilities in case of promotion to Group A and B posts. However, persons with disabilities can be promoted to such posts, provided the concerned post is identified suitable for persons with disabilities provided the concerned post is identified suitable for persons with disabilities.

Note 2 : Column No. 9 and 16 show the sum total appointments made in the Department by way of Direct Recruitment and Promotion

For the purpose of DAE Annual Report 2013-2014 (PWD Report - I & II merged)

ANNUAL STATEMENT SHOWING THE REPRESENTATION OF PERSONS WITH DISABILITIES AS ON 01.01.2014 AND NUMBER OF APPOINTMENTS MADE DURING THE PRECEDING CALENDAR YEAR 2013 IN RESPECT OF AIDED INSTITUTIONS

Group	Number of Employees					Direct Recruitment					By Promotion				
						No. of vacancies reserved					No. of appointment made				
	Total	VH	HH	OH		VH	HH	OH	Total		VH	HH	OH	Total	
(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)		(10)	(11)	(12)	(13)	(14)
Group A	1175	4	4	8		1	1	2	0		0	0	1	NIL	NIL
Group B	2935	7	1	21		1	2	2	1		1	0	1	NIL	NIL
Group C	2657	6	12	32		2	3	4	4		0	0	4	1	1
TOTAL	6767	17	17	61		4	6	8	5		1	0	6	1	1

Note 1 : (i) VH stands for Visually Handicapped (persons suffering from blindness or low visions)

(ii) HH stands for Hearing Handicapped (persons suffering from hearing impairment)

(iii) OH stands for Orthopaedically Handicapped (persons suffering from locomotor disability or cerebral palsy)

(iv) There is no reservation for persons with disabilities in case of promotion to Group A and B posts. However, persons with disabilities can be promoted to such posts, provided the concerned post is identified suitable for persons with disabilities provided the concerned post is identified suitable for persons with disabilities.

Note 2 : Column No. 9 and 16 show the sum total appointments made in the Department by way of Direct Recruitment and Promotion

ANNUAL STATEMENT SHOWING THE REPRESENTATION OF PERSONS WITH DISABILITIES AS ON 01.01.2014 AND NUMBER OF APPOINTMENTS MADE DURING THE PRECEDING CALENDAR YEAR 2013 IN RESPECT OF PUBLIC SECTOR UNDERTAKINGS

Group	Number of Employees				Direct Recruitment								By Promotion							
					No. of vacancies reserved				No. of appointment made				No. of vacancies reserved				No. of appointment made			
	Total	VH	HH	OH	VH	HH	OH	Total	VH	HH	OH	VH	HH	OH	Total	VH	HH	OH		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)		
Group A	7054	6	4	40	2	4	1	319	0	1	0	NIL	NIL	NIL	28	0	0	0		
Group B	6013	11	3	56	0	2	2	41	0	0	0	NIL	NIL	NIL	9	0	0	0		
Group C	9092	9	8	57	3	5	3	113	0	0	0	0	0	0	99	0	0	0		
TOTAL	22159	26	15	153	5	11	6	473	0	1	0	0	0	0	136	0	0	0		

Note 1 : (i) VH stands for Visually Handicapped (persons suffering from blindness or low visions)

(ii) HH stands for Hearing Handicapped (persons suffering from hearing impairment)

(iii) OH stands for Orthopaedically Handicapped (persons suffering from locomotor disability or cerebral palsy)

(iv) There is no reservation for persons with disabilities in case of promotion to Group A and B posts. However, persons with disabilities can be promoted to such posts, provided the concerned post is identified suitable for persons with disabilities provided the concerned post is identified suitable for persons with disabilities.

Note 2 : Column No. 9 and 16 show the sum total appointments made in the Department by way of Direct Recruitment and Promotion

CHAPTER -12

CITIZEN'S CHARTER





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
Role of Nuclear Power as Primary Energy Source in the years to come.

VI) WHOM TO CONTACT**I. Public Grievance and complaints**

Dr. C.B.S. Venkataramana,
Additional Secretary,
Public Grievances Officer & Chief Vigilance Officer,
Department of Atomic Energy,
Anushakti Bhavan, C.S.M. Marg,
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YOU CAN ALSO COMPLAINTO:

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NEW DELHI - 110 023.

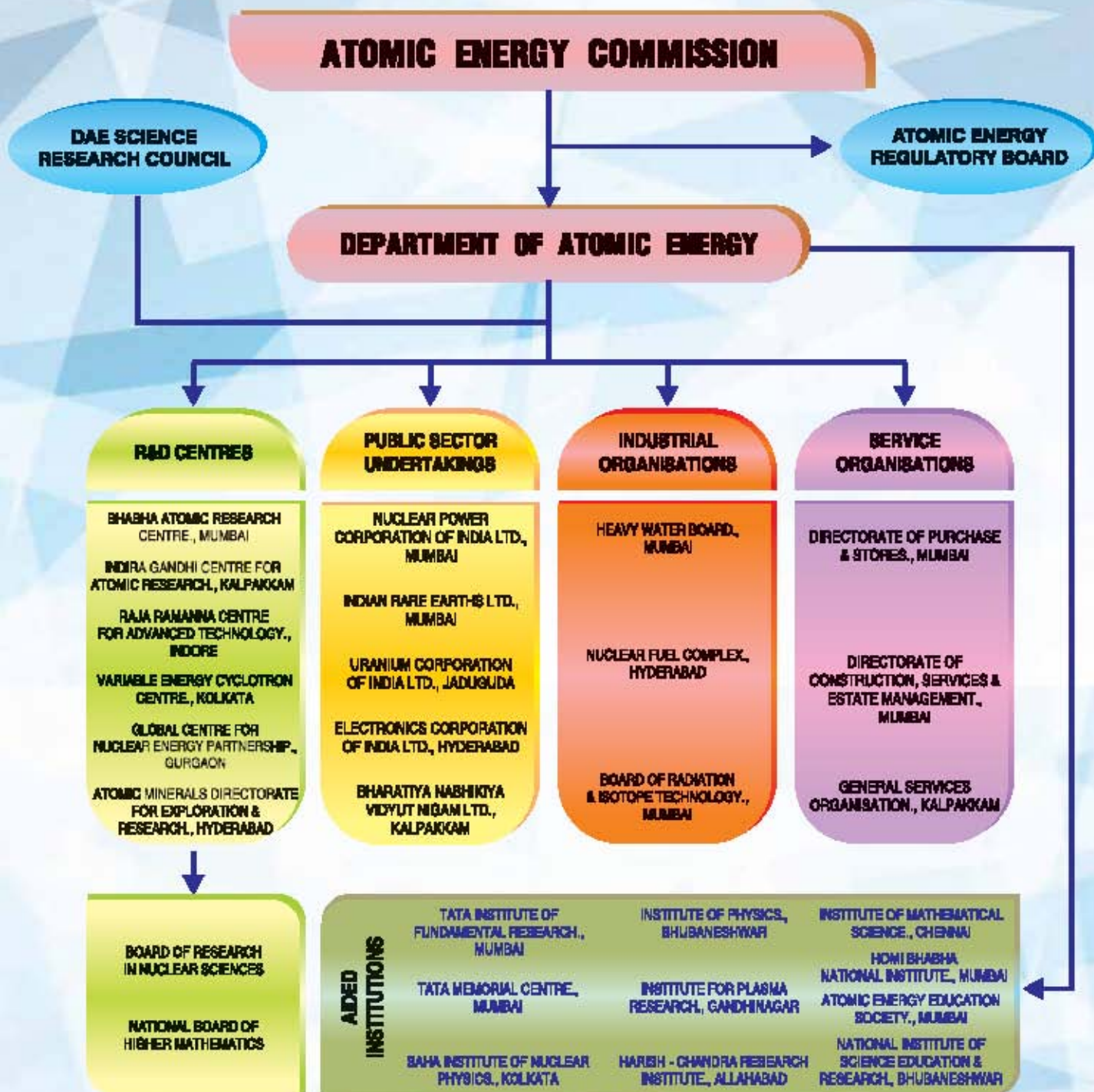
ANNEX-I

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.

An integrated group of organizations, the Department comprises six 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 nine 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.



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	Perspective 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	Waste Management	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 programmes 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

REPLIES TO AUDIT OBSERVATIONS

THE REPORT NO. 22 OF 2013- THE REPORT COVERING THE ONE YEAR PERIOD 2011-12, CONTAINS SIGNIFICANT RESULTS ARISING FROM TEST AUDIT OF TRANSACTIONS OF SCIENTIFIC AND ENVIRONMENTAL MINISTRIES / DEPARTMENTS OF THE UNION GOVERNMENT, AUTONOMOUS BODIES FUNDED BY THESE MINISTRIES / DEPARTMENTS AND OTHER SCIENTIFIC INSTITUTIONS ENGAGED IN RESEARCH AND DEVELOPMENT AND SCIENTIFIC PURSUIT.

The observations of the Audit are as follows:

Para No: 2.1 Avoidable expenditure on compensation due to breach of Agreement

Nuclear Fuel Complex (NFC) entered into an agreement for procurement of a minimum quantity of magnesium granules from a private firm for a period of seven years. No clause to cover deviations in the procurement quantity was included in the agreement. In the meantime the requirement shifted to magnesium chips from magnesium granules. NFC could not revise the agreement and also failed to document the proceedings of an important meeting with the firm on the issue, resulting in avoidable payment of ₹ 1.43 crore towards compensation due to breach of agreement.

Nuclear Fuel Complex (NFC) is a major industrial unit of the Department of Atomic Energy (DAE) and is responsible for the supply of nuclear fuel bundles and reactor core components for all the nuclear power reactors operating in India.

During the course of its research activities NFC designed, developed and qualified prototype/process for production of magnesium granules. The technology was transferred to private parties for commercial production of magnesium granules on non-exclusive basis for a period of seven years. NFC further decided to give an undertaking to the firms for purchasing a minimum of 10 MT per annum during the seven year period of the agreement.

Accordingly NFC entered into an agreement with Yashoda Metals, Hyderabad (firm) for transfer of the technology and grant of license for seven years for manufacture of the magnesium granules against payment of a lump sum amount of ₹3.50 lakh as a non-refundable technology transfer fee. The agreement stipulated supply of a minimum of 10 MT of magnesium granules per year for seven years for which NFC would place purchase orders accordingly. The agreement also allowed NFC to inspect and test the product manufactured by the firm and in case it failed to meet the specifications as per the agreement, the former had the right to revoke the licence. Audit observed that NFC did not include a safety clause in the agreement to protect itself from possible deviations in the procurement of magnesium granules from the firm. Audit also found that no inspection was carried out by NFC though the firm did not install manufacturing facility as per the terms of agreement.

The users changed their preference from magnesium granules to magnesium chips and floated an open tender for the procurement of magnesium chips. Thereafter, the firm filed a petition against this in the Hon'ble High Court of Andhra Pradesh, as a result of which the tender notice was withdrawn and the petition was dismissed.

Later on the firm requested NFC to revise the agreement for supply of magnesium granules into magnesium chips and referred to an earlier meeting, in which it was requested to stop the implementation of the project. The firm also claimed that it was asked during the meeting whether it could supply magnesium chips, as there was no demand for magnesium granules. NFC neither documented the minutes of the said meeting nor revised the agreement. Audit observed that although NFC was aware of the change in preference of the user to magnesium chips, it did not take adequate measures to re-negotiate the contract and safeguard its interests.

Against the 70 MT of magnesium granules stipulated in the agreement, NFC procured only 15 MT from the firm. Due to lack of response, the firm issued a legal notice to NFC for loss on account of breach of contract committed by NFC. The matter was ultimately referred to the Sole Arbitrator, who decided in favour of the firm. NFC challenged the award before Hon'ble City Civil Court, Hyderabad but lost the case and eventually paid ₹ 1.43 crore to the firm towards full and final settlement of the above case.

Failure to protect its interest by not satisfactorily pursuing the issue with the firm nor documenting discussions of important meetings resulted in avoidable expenditure of ₹ 1.43 crore as compensation for breach of agreement.

In reply NFC denied that the Department had advised the firm to unilaterally suspend production of magnesium granules and manufacture magnesium chips. NFC further stated that the requirement of magnesium granules still existed. In the same reply, they stated that the firm never furnished any status report on production as the required unit was not installed by them.

The reply of NFC needs to be viewed in the context of its failure to document important proceedings in the execution of the agreement. They failed to carry out any inspection of the unit though as per the agreement they had right to do so. Further NFC committed to buy 10 MT per year of the magnesium granules from the firm for a period of seven years without including safety provision for possible deviations in the procurement. Also in spite of being aware that the user had changed their preference to magnesium chips instead of granules, NFC took no action to revise the agreement or to document the meetings held with the firm on the issue.

Thus failure to carry out inspection of the unit as also to record adequate precaution by NFC in the execution of the agreement resulted in avoidable expenditure towards payment of compensation of ₹ 1.43 crore.

Action Taken

M/s Yashoda Metals, the transferee have not fulfilled the contractual obligations as they have not installed the equipment for production of magnesium granules at any stage. However, both the arbitration award and judgment of the court went against the Department not because of any breach of the contractual obligation by the Department but due to technicalities involved.

A per clause 5.2.1 of the agreement, M/s Yashoda Metals were required to furnish quarterly status of production and the sale of the product. But they have never furnished any report on the status of production and have not supplied any magnesium in the form of granules to DAE.

Even though, NFC is ready to procure magnesium granules from M/s Yashoda Metals, they have made an objection to the issuing of tender notice by the users by filing a writ petition in the Honourable High Court of Andhra Pradesh against the NIT. Then they approached the Department/NFC on their own and expressed their willingness in the meeting said to be held on 21.04.1993 for which no official record is available to set up the equipment for supply of magnesium chips (not granules). But the Department had not advised them unilaterally to suspend the production of magnesium granules and manufacture magnesium chips. Subsequently, the department has accepted for the supply of magnesium chips from the party as the requirement for the chips also existed.

As regards extension of the agreement under clause 13, it may be stated that given their non-performance in the initial period of the agreement itself, the Department did not consider for extension.

As per clause 5.2.1 of the agreement, the transferee is required to intimate details of setting up of the plant and machinery and also to get the necessary approval of NFC for the said plant and machinery, so as to ensure that they conform to the standards and specifications laid down to meet the requirements of the technical know-how document. This is necessary due to advanced technical issues involved in the production of magnesium granules. It is reiterated that, they have never submitted any report as required above and reason for not initiating necessary action, legal or otherwise, could not be traced from the records available. Likewise, no minutes or notings are made or available for the meeting said to be held on 21/04/1993 to prove the veracity of the allegation of the transferee that NFC had instructed them to suspend the production of 'Magnesium Granules' and manufacture 'Magnesium Chips'. Taking Legal advantage of lack of proof of the said meeting on 21/04/1993 and by mix up of the interpretation of the technical word 'chips' and 'granules' in the court they have got the benefit of doubt both from the arbitrator and the honourable court and the Department was ordered to pay the compensation of ₹ 1.43 crore paid to M/s. Yashoda Metals in compliance of the orders of the Hon'ble High Court of Andhra Pradesh for no fault whatsoever of the Department.

Para No: 2.2 Hasty procurement of equipment without creating Infrastructure facilities for Installation

Saha Institute of Nuclear Physics, Kolkata (SINP) could not install equipment of ₹ 38.90 crore for want of required infrastructure.

The Saha Institute of Nuclear Physics (SINP), Kolkata is an Institute of basic scientific research working under Department of Atomic Energy (DAE). SINP formulated a proposal to set up a national Facility for Research in Experimental Nuclear Astrophysics (FRENA) in February 2007. The project comprised of procurement of a three MV (high current) tandem and a 500KV accelerator system along with other accessories at an estimated cost of ₹ 35 crore. To install these pieces of equipment, major works including construction of accelerator hall and laboratory buildings, electrical and air conditioning, liquid nitrogen plant, computers and networking, etc., were to be completed at an estimated cost of ₹ 24.46 crore at the institute's new campus at Rajarhat, Kolkata. The proposed facility was to provide opportunities of research in the field of low energy nuclear astrophysics for first time in India.

In June 2007, SINP sought the approval for procurement of the equipment for the FRENA project from DAE for which DAE sanctioned ₹ 35 crore in March 2008. Before the memorandum conveying sanction was received, it floated (November 2007) a global tender for the equipment allowing the bidders, 35 days to respond as against 90 days as stipulated in the Purchase Manual of DAE. A single bid received from a foreign firm was opened on 7 December 2007 and supply order for two items (Switching magnet, Type 'A' including accessories and 900 deflection magnet including accessories) was placed with the firm on 31 December 2007.

Subsequently, SINP revised supply orders twice, first in March 2008 and again in August 2008, to include remaining 24 pieces of equipment and issued to the same firm. The total value of orders was Euro 57,81,084 and delivery period was 24 to 26 months from the placement of confirmed orders. The institute placed orders for procurement of equipment without prior approval of the DAE and the concurrence of Member (Finance), Atomic Energy Commission (AEC) as required under Delegation of Financial Powers Rules. The equipment was received in December 2010 and expenditure of ₹ 38.90 crore had been incurred on the same.

As stated above, SINP had planned to construct the accelerator hall and laboratory building at the proposed new campus at Rajarhat and the works were scheduled to be completed by September 2009. But, it engaged a consultancy firm for the preparation of a Master Plan for its Rajarhat campus only in September 2008. In December 2009, it decided to construct the FRENA laboratory building in existing Salt Lake campus, citing

procedural delays in getting the approval of the Master Plan for the Rajarhat Campus. Meanwhile the equipment was delivered in December 2010. The tenders for construction of laboratory building had not been finalised as of October 2012, despite lapse of 22 months from the date of delivery of equipment. As 22 month period was stipulated for completion of building works in prequalification tender documents and, therefore, the building infrastructure is not expected to be ready before August 2014. This indicated lack of planning coupled with delayed action for construction of infrastructure for costly equipment. Thus undue haste in placing order for equipment resulted in following:

- (a) Equipment worth ₹ 38.90 crore was lying uninstalled and extra expenditure of ₹ 15.03 lakh has been incurred since December 2010. The temporary arrangement in place for last 18 months is likely to continue at least for another 18 months, as construction of the laboratory building was yet to start (June 2012).
- (b) The project cost was revised to ₹ 45.24 crore to cover escalation in equipment cost, exchange rate variation and custom duty etc., the approval of DAE for the revised project cost was still awaited (June 2012).
- (c) No testing for the equipment was done and the warranty period for the equipment was over in March 2012. Rectification of any major fault, if discovered during installation in future will have additional cost implications.

SINP stated (June 2012) that Directorate of Constructions, Services and Estate Management (DCSEM) of DAE had shortlisted the interested agencies for construction of the accelerator hall and laboratory building. Tender papers for the same were being prepared and construction of the building was expected to commence later this year. SINP subsequently stated (October 2012) that AERB had given approval in September 2012 and they were in process of placing the work order for construction of the building. The fact remains that SINP showed undue haste in procurement of equipment and did not show the same level of diligence in creating supporting infrastructure which led to idling of costly equipment.

Action Taken

SINP has clarified that it follows its bye-laws and its purchase procedure which are generally in line with General Financial Rules (GFR) and it has also clarified that it has not violated provisions of GFR. However, DAE is issuing suitable instructions to SINP to strictly adhere to the Delegation of Financial Powers extended to it.

As regards the revision in the cost of the project from ₹ 35 crore to ₹ 45.24 crore to cover the escalation in equipment cost, the proposal is being sent to Member (Finance) for obtaining post facto concurrence.

As regards delay in development of related infrastructure, SINP has been advised to take immediate steps in consultation with DCS&EM to increase the pace of construction activities so that equipment can be commissioned without further delay.

REPRESENTATION OF SCs, STs AND OBCs

ANNUAL STATEMENT SHOWING THE REPRESENTATION OF SCs, STs AND OBCs AS ON 01.01.2014 AND NUMBER OF APPOINTMENTS MADE DURING THE PRECEDING CALENDAR YEAR 2013 IN RESPECT OF CONSTITUENT UNITS

Groups	Representation of ST/ST/OBC (as on 01.01.2014)				Number of appointments made during the calendar year 2013									
					By Direct Recruitment				By Promotion			By Deputation		
	Total Emp	SC	ST	OBC	Total	SC	ST	OBC	Total	SC	ST	Total	SC	ST
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Group A	7808	560	109	568	251	2	1	28	380	31	8	2	0	0
Group B	10316	1921	617	1719	103	12	8	34	408	73	29	9	1	0
Group C	11226	2334	1246	2639	843	104	51	228	259	89	21	3	0	1
TOTAL	29350	4815	1972	4926	997	118	60	288	1047	173	58	14	1	1

ANNUAL STATEMENT SHOWING THE REPRESENTATION OF SCs, STs AND OBCs AS ON 01.01.2014 AND NUMBER OF APPOINTMENTS MADE DURING THE PRECEDING CALENDAR YEAR 2013 IN RESPECT OF AIDED INSTITUTIONS

Groups	Representation of ST/ST/OBC (as on 01.01.2014)				Number of appointments made during the calendar year 2013									
					By Direct Recruitment				By Promotion			By Deputation		
	Total Emp	SC	ST	OBC	Total	SC	ST	OBC	Total	SC	ST	Total	SC	ST
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Group A	1175	51	7	81	33	2	1	5	11	0	1	0	0	0
Group B	2935	408	87	378	79	12	5	33	13	2	0	0	0	0
Group C	2657	753	142	388	85	11	8	16	4	1	1	2	0	0
TOTAL	6767	1212	236	847	177	25	14	54	28	3	2	2	0	0

ABBREVIATIONS

ACTREC	Advanced Centre for Treatment, Research and Education in Cancer	FBTR	Fast Breeder Test Reactor
ACF	Automated Charging Facility	FCIPT	Facilitation Center for Industrial Plasma Technology
AEC	Atomic Energy Commission	FDIR	Fluorescence Detected Infra Red
AEES	Atomic Energy Educational Society	FDNPS	Fukushima Daiichi Nuclear Power Station
AERB	Atomic Energy Regulatory Board	FPC	First Pour of Concrete
AHWR	Advanced Heavy Water Reactor	FRCS	Fuel Rod Cluster Simulators
AIPES	Angle Integrated Photoelectron Spectroscopy	FTC	Fuel Transfer Cell
ALARA	As Low as Reasonably Achievable	GCNEP	Global Centre for Nuclear Energy Partnership
AMD	Atomic Minerals Directorate for Exploration & Research	GHAVP	Gorakhpur Anu Vidyut Pariyojana
ANURIB	Advance National facility for Unstable and Rare Isotope Beams	GPCB	Gujarat Pollution Control Board
ASDF	Actinide Separation Demonstration Facility	GSO	General Services Organisation
ASFSF	Additional Spent Fuel Storage Facility	HBCSE	Homi Bhabha Centre for Science Education
ASTER	Application of Science and Technology for Educational Reforms	HBNI	Homi Bhabha National Institute
ATI	Administrative Training Institute	HCRI	Harish-Chandra Research Institute
ATTF	AHWR Thermal Hydraulic Test Facility	HESCO	Himalayan Environmental Studies and Conservation Organisation
AWTF	Additional Waste Tank Farm	HFRR	High Flux Research Reactor
BARC	Bhabha Atomic Research Centre	HLW	High Level Liquid Waste
BARCIT	BARC Centre for Incubation of Technologies	HLNRA	High Level Natural Radiation Areas
BCKV	Bidhan Chandra Krishi Viswavidyalaya	HPLC	High Pressure Liquid Chromatography
BHAVINI	Bhartiya Nabhikiya Vidyut Nigam Limited	HPM	High Power Microwave
BRIT	Board of Radiation & Isotope Technology	HRVUV	High Resolution Vacuum Ultraviolet
BRNS	Board of Research in Nuclear Sciences	HWB	Heavy Water Board
BWR	Boiling Water Reactor	IAEA	International Atomic Energy Agency
CB	Central Bureau of Investigation	ICAR	Indian Council of Agricultural Research
CCFE	Culham Center for Fusion Energy	ICP-MS	Inductively Coupled Plasma-Mass Spectrometry
CERN	European Organisation for Nuclear Research	ICRH	Ion Cyclotron Resonance Heating
CHTR	Compact High Temperature Reactor	ICTS	International Centre for Theoretical Sciences
CICC	Cable-in-conduit-conductors	IEMI	Intentional Electromagnetic Interference
CISAG	Computer and Information Security Advisory Group	IERNON	Indian Environmental Radiation Monitoring Network
CMM	Coordinate Measuring Machine	IFTM	Inclined Fuel Transfer Machine
CMS	Compact Muon Solenoid	IGCAR	Indira Gandhi Centre for Atomic Research
CNWG	Civil Nuclear Working Group	ICHEP	Inter-Institutional Centre for High Energy Physics
CORAL	Compact Reprocessing facility for Advanced fuels of Lead cells	IIFC	Indian Institute Fermilab Collaboration
GRC	Clinical Research Centre	IISU	ISRO Inertial Systems Unit
CRI	Cancer Research Institute	ILCE	Inter Laboratory Comparison Experiments
CRZ	Costal Regulation Zone	ILL	Institut Laue-Langevin
CTM	Cell Transfer Machine	ILRT	Integrated Leak Rate Test
CVC	Central Vigilance Commission	ILW	Intermediate Liquid Waste
CVO	Chief Vigilance Officer	IMO	International Mathematics Olympiad
DAE	Department of Atomic Energy	IMSo	Institute of Mathematical Science
DCSEM	Directorate of Construction Services & Estate Management	INGA	Indian Nuclear Gamma Array
DDA	Differential Dis-Away	INRP	Integrated Nuclear Recycle Plant
DESY	Deutsches Elektronen-Synchrotron	IOP	Institute of Physics
DFRP	Demonstration Fast reactor fuel Reprocessing Plant	IPR	Institute for Plasma Research
DGA	Di-Glycolamide	IPWR	Indian Pressurised Water Reactor
DGFS	DAE Graduate Fellowship Scheme	IREL	Indian Rare Earths Limited
DHAN	Development of Humane Action	IRSIS	Infrared Spectroscopic Imaging Survey
DHOA	Di-hexyl octanamide	ITER	International Thermonuclear Experimental Reactor
DIFAC	Diffusion of Actinides in Electrowinner	ITPA	International Tokamak Physics Activity
DoPT	Department of Personnel and Training	JET	Joint European Torus
DORAbot	Detection Of Radiological Activity using a Robot	JNPP	Jaitapur Nuclear Power Project
DPS	Directorate of Purchase & Stores	KAMINI	Kalpakkam MINI Reactor
EBW	Electron Beam Welding	KAPP	Kakrapar Atomic Power Project
ECCS	Emergency Core Cooling System	KARP	Kalpakkam Reprocessing Plant
ECIL	Electronic Corporation of India Limited	KKNPP	Kudankulam Nuclear Power Project
ECR	Electron Cyclotron Resonance	KSKRA	K.S. Krishnan Research Associateship
ECRH	Electron Cyclotron Resonance Heating	LAMBDA	Large Area Modular BaF2 Detector Array
EMS	Environmental Management System	LBNE	Long Baseline Neutrino Experiments
EoS	Equation of State	LEU	Low Enriched Uranium
EPR	Evolutionary Pressurized Water Reactor	LHC	Large Hadron Collider
ERM	Environmental Radiation Monitors	LHDAC	Laser Heated Diamond Anvil Cell
EVM	Electronic Voting Machine	LLCB	Lead-Lithium Cooled Ceramic Breeder
		LOCA	Loss of Coolant Accident
		MACE	Major Atmospheric Gerasimov Experiment
		MAPDPS	Material Accounting and Production Data Processing System
		MaPLE	Magnetized Plasma Linear Experimental

ABBREVIATIONS

MAPO	Mixed Alkyl Phosphine Oxide	STME	Science, Technology and Mathematics Education
MC-SNICS	Multi-Cathode Source of Negative Ions by Caesium Sputtering	SVD	Silicon micro-Vertex Detector
MEE	Multiple Effect Evaporator	SXT	Soft X-ray Imaging Telescope
MEMS	Micro Electro Mechanical System	TBM	Test Blanket Module
MHD	Magneto-Hydrodynamic	TBP	Tributyl Phosphate
MHTS	Main Heat Transport System	TDP	Technology Demonstration Plant
MoEF	Ministry of Environment and Forest	TE8	Tritium Extraction System
MPECVD	Microwave Plasma Enhanced Chemical Vapour Deposition	TF8B	Temporary Fuel Storage Bay
MSAPO	Mixed Substituted Alkyl Phosphine Oxide	THM	Total Heavy Mineral
MSG	Management Services Group	TIFR	Tata Institute of Fundamental Research
NAA	Neutron Activation Analysis	TMC	Tata Memorial Centre
NBHM	National Board of Higher Mathematics	TOF	Time-of-Flight
NBPGR	National Bureau of Plant Genetic Resources	TP8	Thomson Parabola Spectrometer
NCRA	National Centre for Radio Astrophysics	TRIUMF	TRI University Meson Factory
NFC	Nuclear Fuel Complex	UCIL	Uranium Corporation of India Limited
NIGER	National Institute of Science Education & Research	UNCD	Ultrananocrystalline Diamond
NIUS	National Initiative in Undergraduate Science	VBS	Valence-Bond-Solid
NLNRA	Normal Level Natural Radiation Areas	VECC	Variable Energy Cyclotron Centre
NPCL	Nuclear Power Corporation of India Limited	VFD	Variable Frequency Drive
NSG	Nuclear Security Summit	VSSP	Versatile Solvent Synthesis Pilot Plant
NTPF	Niobium Thermit Production Facility	VVPAT	Voter Verifiable Paper Audit Trail Printers
OHSMMS	Occupational Health and Safety Management System	WIP	Waste Immobilization Plant
OLW	Organic Liquid Waste	XAFS	X-ray Absorption Fine Structure Spectroscopy
OPCPA	Optical Parametric Chirped Pulse Amplification		
OSART	Operational Safety Review Team		
OSCOM	Orissa Sand Complex		
OTMS	Online Thoron Mitigation System		
PA	Procurement Arrangements		
PARTH	Facility for Proving Advanced Reactor Thermal Hydraulics		
PFBR	Prototype Fast Breeder Reactor		
PHWR	Pressurised Heavy Water Reactors		
PLF	Plant Load Factor		
PLS	Performance Linked Incentive Scheme		
PREFRE	Power Reactor Fuel Reprocessing Plant		
PRF	Prospective Research Fellowships		
PRL	Prefabricated Ring Liner		
PRTRF	Power Reactor Thorium Reprocessing Facility		
PSAR	Preliminary Safety Analysis Report		
QARMS	Quad-rotor based Aerial Radiation Monitoring System		
RAFMS	Reduced Activation Ferritic Martensitic Steel		
RAPP	Rajasthan Atomic Power Project		
RDD	Radiological Dispersal Device		
REB	Relativistic Electron Beam		
RFID	Radio Frequency Identification		
RFQ	Radio Frequency Quadrupole		
RIA	Radioimmunoassay		
RIB	Radioactive Ion Beam		
RIP	Resin-In-Pulp		
RMC	Radiation Medicine Centre		
RMP	Resonant Magnetic Perturbation		
RPPO	Renewable Power Purchase Obligation		
RRCAT	Raja Ramanna Centre for Advanced Technology		
SBO	Station Blackout		
SCC	Super Conducting Cyclotron		
SCDA	Severe Core Damage Accident		
SCRIF	Super Conducting Radio Frequency		
SEIRA	Surface-Enhanced Infrared Absorption		
SEIRC	Structural Engineering Research Centre		
SFC	Spent Fuel Chopper		
SFSF	Spent Fuel Storage Facility		
SINP	Saha Institute of Nuclear Physics		
SMES	Superconducting Magnetic Energy Storage		
SNSS	School of Nuclear Security & Studies		
SOFC	Solid Oxide Fuel Cell		
SST	Steady-state Superconducting Tokamak		



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