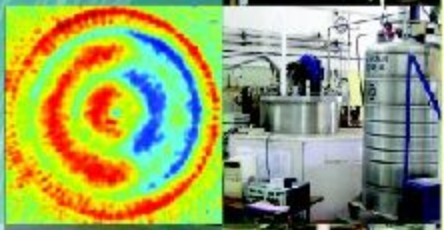
ANNUAL REPORT 2010-11




पऊवि
DAE

DEPARTMENT OF ATOMIC ENERGY • GOVERNMENT OF INDIA

Late Dr. H .N. Sethna
(24th August 1923 - 5th September 2010)

.....the use of science as a strategy of development must be imbused with aesthetic sensitivity. Human life can be enriched not by bread alone but by an ability and opportunity to appreciate creativity. Then only scientific knowledge can be responsive to human needs…...

I foresee exciting developments in the strategy of science and technology for development: its use to alter the power balance in the society, its potential to integrate art and science and the possibility that science will liberate the human soul and enable man to fulfill his potential.

(Dr. H.N. Sethna, former Chairman, Atomic Energy Commission, at the first Dr. A.L. Mudaliar Memorial Lecture at the Indian Institute of Technology, Madras, on January 31, 1975 Science and Technology in India: Strategy of Development)

EXECUTIVE SUMMARY

Nuclear Energy has a crucial role to play in achieving the objectives of sustainable economic growth of India that needs several fold increase in installed electricity generating capacity ensuring food security and providing healthcare and potable water to the masses. Nuclear energy for power generation, use of the nuclear tools and techniques in industry, applications of nuclear energy in diagnosis and treatment of diseases, nuclear technologies for crop improvement, food preservation, and water treatment, and many of its other applications, establish it as an indispensable resource for the nation.

The Nuclear Energy Programme of the Department of Atomic Energy (DAE), focuses on the use of water cooled reactors, fast breeder reactors and thorium based reactors for power generation, and development and deployment of advanced technologies and radiation technologies for various applications in industry, agriculture, healthcare and research. The basic research being done by the research & development organizations of DAE, contributes to the expanding domains of knowledge. The Department is also engaged in enriching the knowledge and skills of its human resource. The vision, activities and mandate on which its programmes are based, are outlined in the Citizen's Charter in this Report.

During the year of report, the Programme of the Department has registered many impressive achievements alongwith accelerated growth in all its segments, as detailed below.

NUCLEAR POWER PROGRAMME : STAGE - 1

PRESSURISED HEAVY WATER REACTORS

The Nuclear Power Corporation of India Ltd. (NPCIL), a public sector undertaking of DAE, is responsible for the design, construction, commissioning and operation of nuclear power reactors.

With 20 operating reactors (2 boiling water reactors and 18 pressurised heavy water reactors), the total installed nuclear power generating capacity in the country is now 4780 MWe. Currently, a capacity of 3400 MWe is under construction and construction of 1400 MWe will soon commence with the first pour of concrete in RAPP-7&8.

During the year of report, NPCIL registered significant achievements in generation, capacity addition, Renovation & Modernisation (R&M), progress in projects and pre-project activities at new sites, and posted improved financial performance.

Power generation

NPCIL achieved power generation of 23,272 million units - the highest ever, in the year 2010. This was an increase of 37% over the power generation in the previous year. For the current financial year 2010-11, the power generation upto December 31, 2010 was 18,012 million units.

NPCIL set yet another record of generating about 98 million units in a day. The 540 MWe TAPS-3 attained full power level of operation for the first time in January 2011. NPCIL's operating reactors MAPS-2 and TAPS-2 recorded continuous operation of more than a year without outage. During the year 2010, thirteen of the seventeen operating units achieved availability factor of more than 85%. The overall availability factor for the year was 88%. For the calendar year 2010, the Capacity Factor increased to 66% as against 56% in the year 2009. The operating reactors have registered over 322 reactors years of safe operation so far.

Capacity Addition

With the completion of three reactors viz.

RAPS-5&6 and Kaiga-4, each of 220MWe, NPCIL added 660 MWe to its power generation capacity raising the installed capacity to 4780 MWe.

Projects Under construction & New Projects

Both the reactor units of Kudankulam Nuclear Power Project-1&2 (2x1000 MWe), being set up in technical collaboration with Russian Federation, reached an advanced stage of commissioning. Unit-1 is expected to be in operation by March 2011, with Unit-2 following closely.

NPCIL also launched four new 700 MWe indigenous pressurized heavy water reactors -- two each at Kakrapar, Gujarat (KAPP-3&4) and Rawatbhata, Rajasthan (RAPP-7&8). At KAPP-3&4, first pour of concrete was carried out, and at RAPP-7&8 excavation work reached an advanced stage of completion. With the first pour of concrete at RAPP-7&8, the capacity under construction will be raised to 4800 MWe.

For Kudankulam Nuclear Power Project-3&4 (2x1000 MWe), early-works and various pre-project activities made progress.

The Ministry of Environment and Forest gave environmental clearance for the Jaitapur Nuclear Power Project-1&2 (2x1650 MWe). NPCIL also initiated action in respect of bio-diversity conservation plan for the site. For this Project, the early-works-agreement was signed with M/s AREVA, France.

Pre-project activities commenced at the four green field sites namely Gorakhpur (Haryana) and Chutka (Madhya Pradesh) for indigenous 700 MWe PHWRs, and Kovvada (Andhra Pradesh) and Chhaya Mithi-virdi (Gujarat) for 1000 MWe or larger capacity light water reactors under international cooperation. All these are steps

A view of Kudankulam Nuclear Power Project -1&2

First Pour of Concrete in progress at KAPP-3&4

towards reaching installed nuclear power capacity of about 60 GWe by 2032.

Renovation & Modernisation

NPCIL carried out renovation & modernization, and in-core repairs using in house-developed tools and techniques. En-masse Coolant Channel Replacement (EMCCR), En-masse Feeder Replacement (EMFR) & up-gradation jobs of reactors were successfully completed at the Unit-2 of Narora Atomic Power Station and Unit-1 of Kakrapar Atomic Power Station.

Partnership & Diversification

During the report period, NPCIL signed following MoUs for setting up:

- Nuclear Power Plants in India, with NTPC, Indian Oil Corporation, National Aluminium Corporation, Korea Electric Power Corporation and others.
- An Integrated Facility at Hazira for the manufacture of special exotic steels and large size forgings, with Larsen & Toubro, and
- A 600 MWe hydroelectric plant at Malshej Ghat with Tehri Hydro-electric Power Corporation

FRONT END FUEL CYCLE

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

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

Heavy Water Production

The Heavy Water Board is responsible for production of heavy water for the Indian PHWRs. It is also engaged on the development and demonstration of technological feasibility of various processes for the products required for the Front and Back End operations of the Nuclear Fuel Cycle.

The performance of the operating Heavy Water Plants was very satisfactory during the report

Solar Evaporator for steam generation at the Heavy Water Plant, Kota

EXECUTIVE SUMMARY

Boron Exchange Distillation Plant at Heavy Water Plant, Talcher

period, and the capacity utilization of the plants exceeded 100%. The Board bagged the sixteenth export order for supply of 11 metric tonnes of heavy water to KHNP, South Korea.

In the first quarter of this period, the Plants at Manuguru and Kota had faced constrained operations of their cooling towers. However, the revamping work was carried out successfully, that resulted in improvement in production and specific energy consumption (Gj/kg) at these plants.

The Manuguru Plant achieved a cumulative percentage target production of 98.3%. Also, subsequent to commissioning of the Distributed Control System (DCS), the Kota Plant operated smoothly and achieved a cumulative percentage target production of 96.5%. Both these plants are expected to achieve their target production. An excellent performance was registered by the Hazira Plant by achieving a cumulative percentage target production of over 106%, the Thal Plant recorded a very good performance by achieving around 89.3% of its targeted production, and the Baroda Plant continued to produce heavy water satisfactorily.

As a part of its energy conservation endeavour, the Heavy Water Board implemented various energy saving schemes. As a result of the energy conservation measures taken, and due to stabilization of the captive power plant, the surplus of the power generated at Manuguru Plant, was regularly exported to APTRANSCO. The energy conservation efforts at the Kota Plant included erection of 4 solar dishes of solar based steam generation system and installation of VFDs (Variable Frequency Drives). Installation of an Auxiliary Turbo-generator to generate 2 MWe power by recovering energy from throttling of steam, was in progress here. At the Thal Plant, the measures taken resulted in increasing the gas throughput.

As a part of the diversification programme of the Heavy Water Board, a Solvent Extraction Test Facility was set up at Talcher for testing various

solvents. The Industrial Facility set up here to produce enriched Boron for fast breeder reactors, and detector grade Boron, continued to provide enriched KBF_4 to the Elemental Boron Plant at Manuguru, and detector grade enriched Boron in the form of CaF_2-BF_3 complex, to BARC and ECIL.

Efforts to establish various synthesis routes for production of organo phosphorous solvents continued at the Tuticorin Plant. The Bench scale solvent synthesis set up here continued to produce high purity chemical DHOA and successfully synthesized TOPO for bench scale solvent extraction plant. Setting up of a Versatile Solvent Synthesis Pilot plant for production of solvents Tri Iso Amyl Phosphate (TIAP), Diethyl Hexyl Phosphonic acid Mono Diethyl Hexyl Ester(D2EHPA-II) and Dihexyl Octanamide (DHOA) continued at the Tuticorin Plant. Scaled-up Tri Butyl Phosphate Plant (130MT/ year capacity) at Baroda was under final stages of commissioning.

Heavy Water Upgrading

Production of more than 15 ton/yr of nuclear grade upgraded heavy water was achieved at Trombay

Mineral Exploration and Mining

During the field season 2009-10, the Atomic Minerals Directorate for Exploration and Research (AMD) accelerated the pace of its exploration activities with focused approach to meet the XI Plan targets. The major achievements were as as follows :

Uranium Investigations by AMD established 22,466 tonnes (U_3O_8) of additional uranium resources at Tummalapalle and Chitrial (both in Andhra Pradesh), Rohil (Rajasthan), and Umthongkut (Meghalaya). With this India's uranium resources now stand updated to 1,62,762 tonnes of U_3O_8.

Drilling of over 217,500 m was carried out to establish additional uranium resources in the known occurrences and subsurface continuity of mineralisation in the new promising areas.

Significant mineralised intercepts / bands were identified in boreholes drilled at Tummalapalle and adjoining blocks, Chitrial and Koppunuru (Andhra Pradesh); Deshnur and Gogi-Darshnapur (Karnataka); Rohil and its extensions (Rajasthan) ; Wahkut and Umthongkut (Meghalaya).

Exploratory mining at Gogi, Gulburga district, Karnataka was initiated on 18 June, 2007 by UCIL on behalf of AMD. A progress of 181m in shaft sinking, including 59 m of current field season, was achieved.

The Uranium Corporation of India Limited (UCIL) mines and processes uranium ore for pressurized heavy water reactors.

UCIL operates five underground mines at Jaduguda, Bhatin, Narwapahar, Turamdih & Bagjata; one open cast mine at Banduhurang, and two processing plants at Jaduguda and Turamdih, all in Jharkhand state.

To meet the increased demand of uranium, the corporation took up construction of Mohuldih Uranium Mining Project in the Saraikela-Kharsawan district of Jharkhand. Turamdih processing plant was also under expansion. Construction work of Tummalapalle Uranium Mining & Milling Project in Andhra Pradesh was approaching completion. Expansion of Tummalapalle uranium project and a new uranium mining and milling project at Gogi in Karnataka, were at pre-project stage.

UCIL has also proposed to take up Uranium ore mining and milling project at Lambapur in Andhra Pradesh and Uranium ore mining and milling project at Kylleng Pyndengsohiong, Mawthabah in Meghalaya for which pre-project activities were continued. The project construction will start after due approval from the Government of India.

Fuel Fabrication

The Nuclear Fuel Complex fabricated and supplied fuel bundles for pressurised heavy water reactors and boiling water reactors of NPCIL. It completed processing of imported uranium material

Nuclear Fuel Complex : Dispatch of fuel to KAIGA-4

to meet the fuel requirements of KAPS-1&2, and processed Magnesium Di-Uranate (MDU) received from UCIL to supply fuel for NAPS-1 & KAIGA-4.

Also, NFC achieved highest ever production of PHWR fuel bundles, zirconium sponge, PHWR fuel tubes & niobium metal.

Indigenously developed pilger mill

At NFC, manufacturing of critical components for various sub-assemblies, to meet the commissioning schedules of 500 MWe PFBR, progressed. With the commissioning of indigenously developed pilger mills, production of fuel tubes was enhanced.

For production of reactor grade zirconium sponge, NFC commissioned a new Zirconium Complex .

NFC presented the data generated during trial production at Zirconium Complex, Pazhayakayal to AERB for obtaining operation consent.

NFC successfully executed an order received from IAEA against global competition for the manufacture, supply, erection and commissioning of fuel element end-cap welding unit for Turkish Atomic Energy Authority.

Fuel for Research Reactors

At Trombay, production of uranium metal ingots

for research reactor Dhruva and Purnima Sub-critical facility continued. Low density burnable poison rod (BPR) materials were produced using different processes.

BACK END FUEL CYCLE

Fuel Reprocessing and Waste Management

Plutonium Plant, Trombay and KARP, Kalpakkam were regularly operated.

A new reprocessing plant called ROP (Revamping of PREFRE) was constructed at Tarapur for carrying out the reprocessing of power reactor fuel. To reprocess spent fuel from research reactors operation of Plutonium Plant, Trombay was continued.

Storage of spent fuel from MAPS in Spent Fuel Storage Facility (SFSF) at Kalpakkam and its processing at KARP facility, were continued.

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

The recycling and optimal utilization of uranium is essential to meet India's current and future energy security needs. Towards this end, a significant milestone in the country's three-stage nuclear energy programme was achieved with the commissioning of the second Power Reactor Reprocessing Plant by BARC at Tarapur.

Recently, work on setting up of an Integrated Nuclear Recycle Plant with facilities for both reprocessing of spent fuel and waste management, also commenced at Kalpakkam.

At the Waste Immobilisation Plant, Kalpakkam, the trials on second ceramic melter were started.

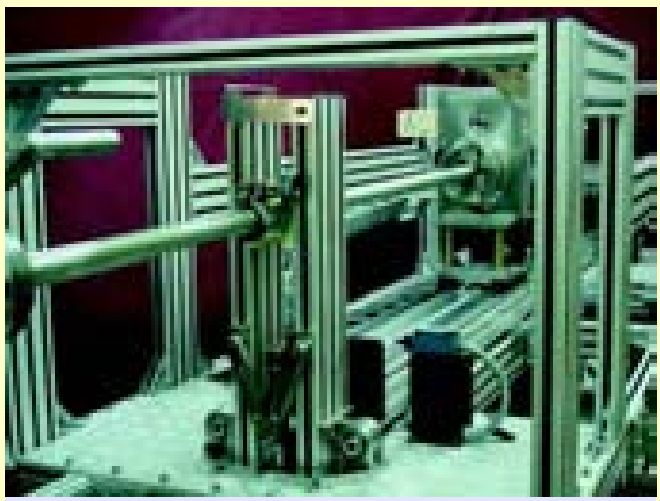
R&D SUPPORT TO POWER SECTOR

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

BARC successfully developed a tool for remote in-situ pressure tube inside diameter measurements using existing Fuelling Machines. For in-service inspection of coolant channels, the Centre also delivered 6 Channel Inspection System (BARCIS) units to NPCIL. Now every 220 MWe PHWR site is equipped with one BARCIS unit.

A scaled up version of a prototype Electro-Chemical Filter was designed at Trombay to remove Iron and Silica turbidity in secondary cooling water at PHWR power plants. Commissioning of the pin-by-pin core diffusion code HEXPIN was an

The Prime Minister, Dr. Manmohan Singh unveiling the plaque to inaugurate the Power Reactor Fuel Reprocessing Plant-2 at Tarapur, in Maharashtra on January 07, 2011



BARCIS 540 Drive Mechanism

important development.

BARC provided its technical and analytical support for the ageing management activities, to NPCIL.

HEALTH SAFETY & ENVIRONMENT

Personal monitoring services for external radiation were provided to about 23,000 radiation workers working in DAE through the BARC Laboratories at Trombay, Tarapur and Hyderabad.

To meet the growing demand of Radon and Thoron monitoring in nuclear fuel cycle facility and the environment, different types of application specific online Radon and Thoron monitors were developed at BARC.

BARC developed an optically stimulated luminescence (OSL) phosphor. Based on this, a new four element OSL dosimeter badge and a prototype OSL dosimeter badge reader were developed. These badges were given to various facilities for trial.

BARC has developed solar-powered Environmental Radiation Monitor for open field installation. Fifty such monitors have been installed at different places in the country.

IERMON:Complete system with solar panel, GM tube and battery

BARC carried out studies to assess the impact of the oil spill that occurred on August 7, 2010 on Mumbai bay. Continuous analysis of oil & grease in sea water samples collected was carried out and the data was submitted to the Maharashtra Pollution Control Board.

Bench-top and portable continuous radon monitors were developed. These indigenous instruments are based on electrostatic collection and scintillation cell principles, and are more efficient and cost competitive.

The nodal Emergency Response Centre (ERC) at BARC responded quickly to the radiological incident that occurred at Mayapuri, Delhi. The response team was also assisted by ERC Delhi, Narora, National Disaster Response Force and AERB in identifying and locating the Co-60 source and safely securing and transporting them in the shielded flasks to Narora.

During the report period, ECIL supplied equipment worth over Rs. 230 crore to Commonwealth Games. A large number of personnel from various security agencies in the country were trained on detection of any radiation sources and mitigation of any radiation emergency. In addition, during the games, a team of radiation scientists was deputed at the venue for radiation surveillance.

NUCLEAR POWER PROGRAMME : STAGE-2

FAST BREEDER REACTORS

The second stage of the nuclear power generation programme aims at setting up of fast reactors. These reactors produce more fuel than they consume.

For the design and development of liquid sodium cooled fast breeder reactors, along with the development of the associated fuel cycle technologies, the responsibility lies with the Indira Gandhi Centre for Atomic Research (IGCAR). The

fast breeder reactor programme being pursued by the Centre, is supported by research and development in a variety of disciplines including reactor engineering, chemistry, metallurgy, material science, safety, control and instrumentation. The Fast Breeder Test Reactor at Kalpakkam, also caters to technology development related to fast reactors.

The Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI) has been constructing the 500MWe Prototype Fast Breeder Reactor (PFBR) at Kalpakkam. This reactor is based on the fast breeder reactor technology developed at IGCAR.

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

The PFBR has reached an advanced stage of construction.

PFBR's entire civil structural works of Electrical Building-1&2, Control Building, Radioactive Waste Building, Fuel Building, Steam Generator Building-1&2 were completed. The roof of Reactor Containment Building was completed partially. The Peripheral Buildings surrounding NICB (Nuclear Island Connected Buildings) were also completed.

Subsequent to the erection of safety vessel in reactor vault, the main vessel along with core catcher and core support structure was erected inside, suspended on vertical tie rods. Thermal baffle was lowered inside main vessel and welded to main vessel. Grid plate along with primary pipe and inner vessel was installed.

The Balance of Plant (BOP) civil construction progressed. The construction of indoor Gas Insulated Switchyard was completed & pre-commissioning works were under progress.

PFBR Project : Overall view of Power Island

PFBR Grid Plate

For PFBR, the manufacture of inner vessel, roof slab, large & small rotatable plugs, two steam generators, four intermediate heat exchangers, one secondary sodium pump and additional primary ramp and primary tilting mechanism of inclined fuel transfer machine, were completed.

The project achieved an overall physical progress of 63% at the end of November-2010.

Fast Breeder Test Reactor

The Fast Breeder Test Reactor (FBTR) at Kalpakkam completed 25 years of operation in October, 2010. During the period of report, the 16th irradiation campaign was completed and the reactor operated at 18 MWt with the turbogenerator synchronized to the grid, generating 3.2 MWe. Steam temperatures, as high as 733 K could be realized.

As part of the fuel development programme, test irradiation continued on high plutonia mixed oxide (44%).

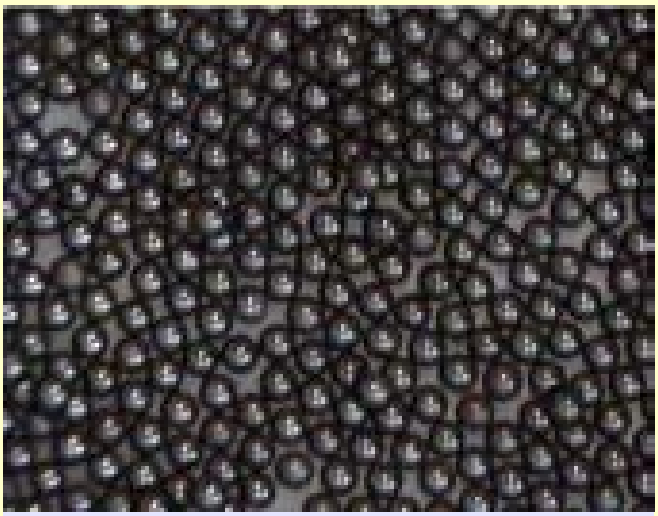
FBR Fuels

Plutonium bearing fuels for the Fast Reactor Programme are supplied by BARC. The experimental (U-30%Pu) MOX fuel for PFBR enriched with Uranium-233 exceeded the designed burn-up of 100,000 MWd/t. Experimental conditions were optimised to prepare mixed $(U,Pu)O_2$ microspheres by sol-gel process. Oxide

Pilot plant facility for sodium cleaning

Uranium metal deposited on a solid cathode (IGCAR)

New fabrication line of Advanced Fuel Fabrication Facility for PFBR (BARC)



$(U_{0.47}, Pu_{0.53})O_2$ microspheres sintered at 1450°C (BARC)

dispersion strengthened ferritic martensitic steel tubes were developed for fuel clad-tube application.

Fast Reactor Fuel Reprocessing

Successful campaigns of FBTR spent fuel reprocessing in CORAL facility at Kalpakkam, provided valuable information on the operation and maintenance of centrifugal extractor and centrifuge. Detailed Project Report for FRFCF (Fast Reactor Fuel Cycle Facility) was submitted for obtaining financial sanction.

The spent mixed carbide fuel from the Fast Breeder Test Reactor (FBTR) with a burn-up of 155 GWd/t, was reprocessed in the CORAL facility. The fissile material was re-fabricated as fuel and loaded back into the reactor. This marked the successful closing of the fast reactor fuel cycle.

FBR Related Technologies

To ensure the manufacturing feasibility of innovative components, manufacturing technology development exercises were undertaken for thick plate narrow gap welding and welded grid plate.

At Trombay, the major components of the Inclined Fuel Transfer Machine for PFBR were manufactured.

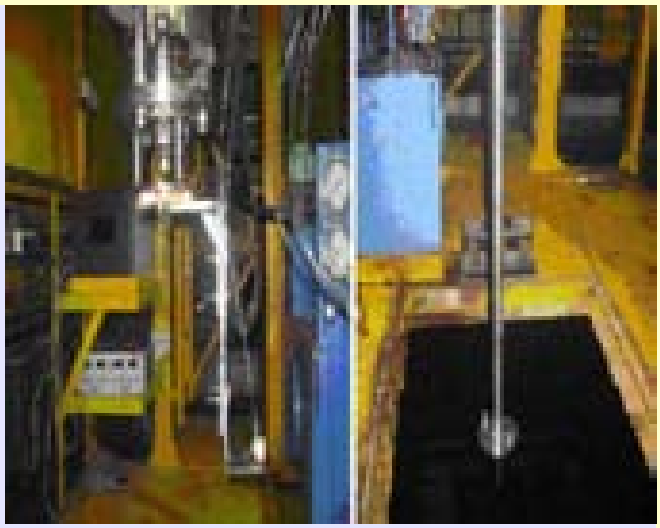
Development of oil-less active magnetic bearings for centrifugal sodium pumps, ultrasonic waveguide for high temperature applications, ultrasonic technique for detection of sub-assembly protrusion in PFBR were completed at Kalpakkam.

SADHANA - a sodium loop for testing of PFBR safety grade decay heat removal in sodium was commissioned and experiments qualified the component and system design.

Development of single board data acquisition, remote terminal and distributed digital control system for PFBR, were the major activities towards electronics and instrumentation.

As a part of an IAEA international collaborative

Active Magnetic Bearings. Use of these bearings eliminates chances of accidental spillage of oil into sodium circuit



Ultrasonic technique for detection of Sub-Assembly protrusion

project for the design of future fast breeder reactors, reactor assembly design concepts were completed at IGCAR.

To visualize the models of fast breeder reactors and associated fuel cycle facilities, an advanced visualization centre, a world-class fully immersive system was commissioned at IGCAR.

NUCLEAR POWER PROGRAMME : STAGE - 3

THORIUM BASED REACTORS

BARC is developing a 300 MWe Advanced Heavy Water Reactor (AHWR), that is a thorium fuelled reactor with several advanced passive safety features. Other advanced reactor systems such as Compact High Temperature Reactor, Accelerator Driven Subcritical System are also under development at this Centre.

The major developments carried out in this programme domain, were the following :

Advanced Heavy Water Reactor

The full scale Integral Test Loop for the Advanced Heavy Water Reactor (AHWR) was augmented with an additional 3 MW instrumented fuel rod cluster simulator developed inhouse. This facility will serve as a test bed for validation of many new techniques.

A semitransparent 1/6th linear scaled experimental setup of AHWR calandria was designed, fabricated and installed for moderator flow distribution studies.

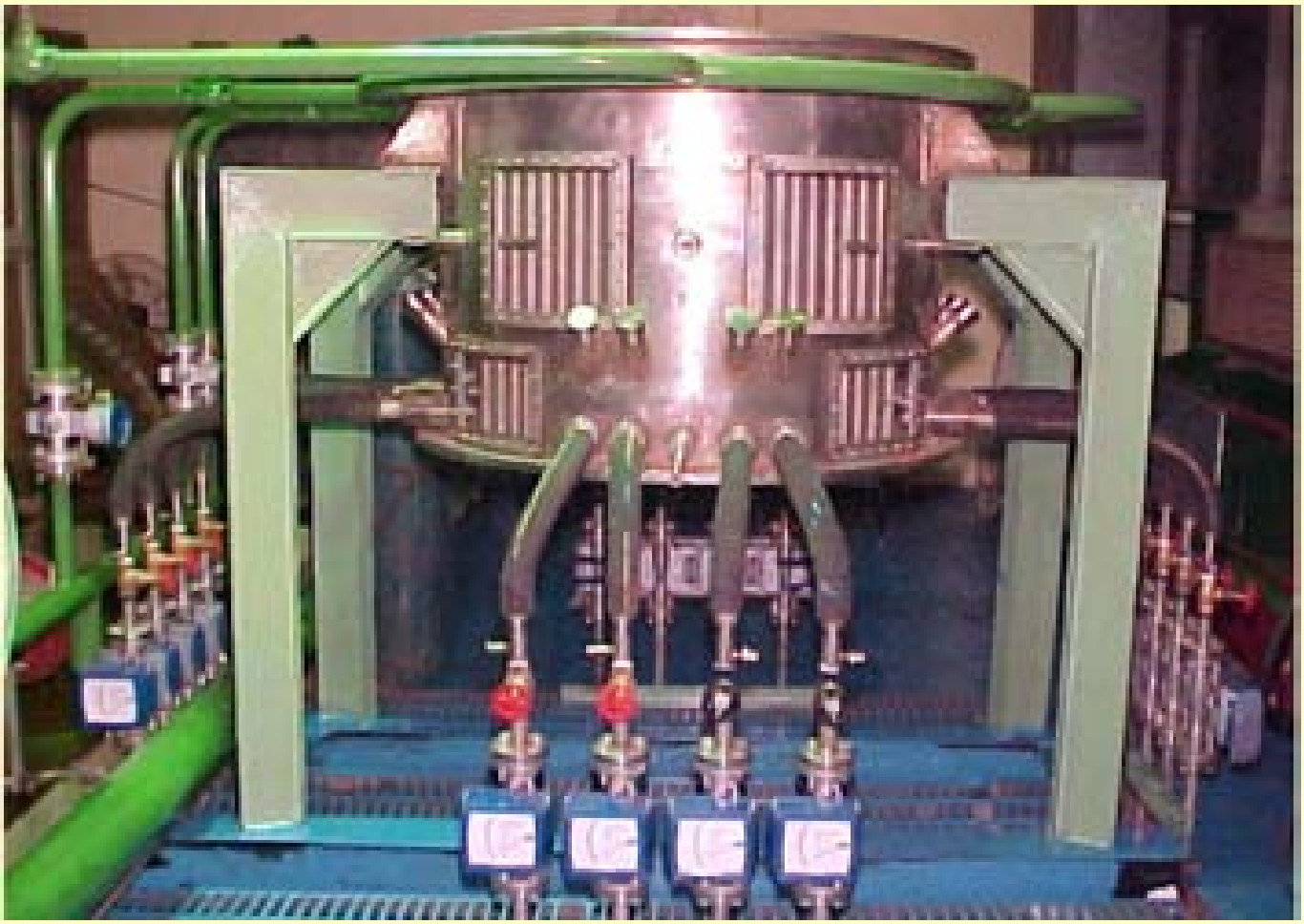
The design of the equilibrium core of AHWR was finalised.

Critical Facility for Advanced Heavy Water Reactor (AHWR) and 540 MWe PHWR was operated for various experiments.

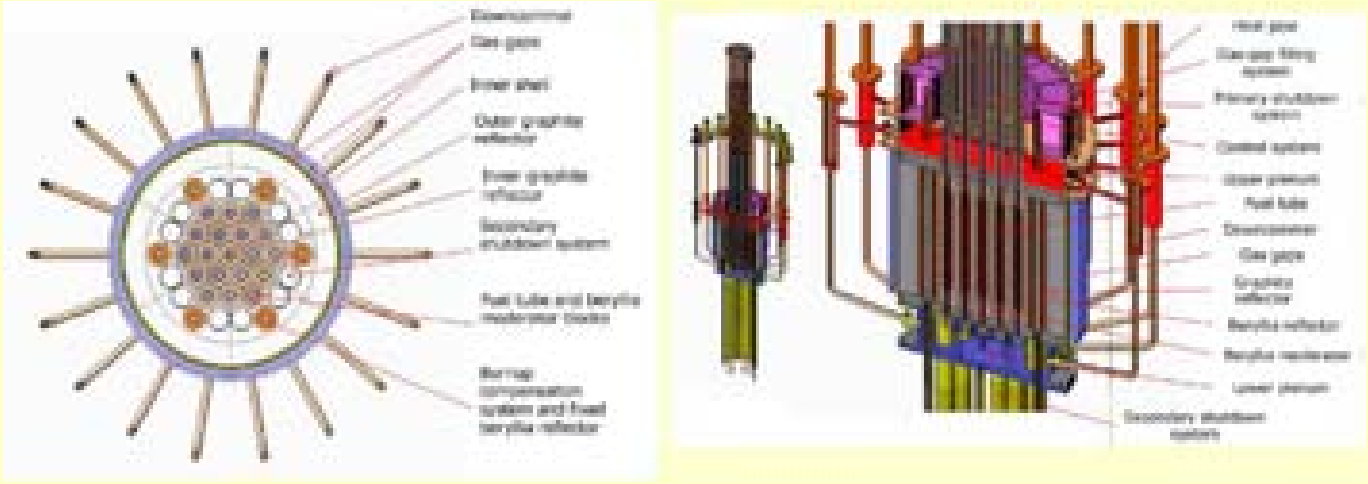
The Passive Poison Injection System in AHWR, that fulfills the shutdown function in the event of failure of wired shutdown systems, was designed, developed and tested under simulated conditions.

Impregnated Agglomeration Process was developed at BARC for the fabrication of (Th-U)O_2 fuel for AHWR. Thoria fuel clusters were also fabricated for carrying out experiments in AHWR-Critical Facility.

Setting up of AHWR Thermal-Hydraulic Test Facility continued at the R&D Center, Tarapur,



Test facility for moderator flow and liquid poison distribution studies



Schematic of Compact High Temperature Reactor (CHTR)

Other Reactor Systems

High Temperature Reactor Programme

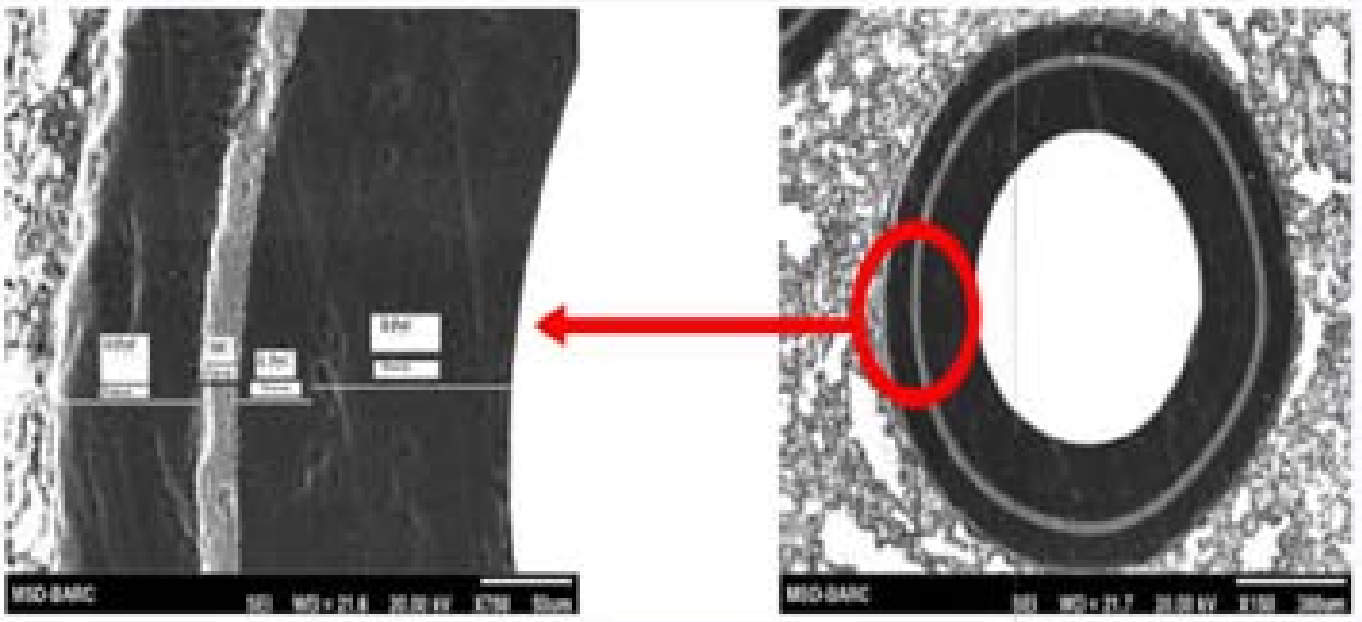
Prototype of fuel tube of CHTR made of high density graphite

At BARC, Compact High Temperature Reactor (CHTR) physics design simulations were performed with new design modifications.

Development of fuel tubes of CHTR using ceramic matrix composites was taken up.

As a part of the Accelerator Driven Subcritical Systems (ADS), an Electron Cyclotron Resonance Microwave Ion Source is under development at BARC. During the report period, mechanical designs of its critical systems were completed. The first trial assembly of the Ion Source was also done.

A 600 mm long Prototype of Radiofrequency Quadrupole (RFQ) fabricated and characterized for its RF parameters. This is a part of high power accelerator developmental for ADS programme at BARC.



SEM image of the TRISO-coated particle produced in the spouted bed reactor

ADVANCED TECHNOLOGIES

Research Reactors

New Electronic Differential Pressure Indicating Switches (EDPIS) gauge of Dhruva

The research reactors Dhruva and CIRUS completed 25 years and 50 years of their operations respectively. These reactors have been extensively used for isotope production, basic research, material testing and human resource development.

During the report period, CIRUS reactor was generally operated at 20 MWt. Power was raised to higher levels as and when required, for sample irradiation and experiments. The reactor has been shut down permanently.

Research reactor Dhruva continued to operate with availability factor of more than 72%. As a part of the XI plan project, all the 144 coolant channel flow monitoring differential pressure gauges in Dhruva were replaced with Electronic Differential Pressure Indicating Switches (EDPIS).

Apsara reactor was de-commissioned to make way for its new and upgraded version. The new version of APSARA will have several advanced features and core capability to deliver 2MWth power.

The Critical Facility for AHWR and 540 MWe PHWR was extensively used for various experiments. At BARC, various core configurations for the proposed High Flux Research Reactor were worked out for optimum design.

Accelerators

The Superconducting Cyclotron at the Variable Energy Cyclotron Centre (VECC) successfully accelerated several internal beams up to the extraction radius. The Cyclotron along with the other subsystems, was getting ready to deliver beam for experiments.

The rejuvenated Room Temperature Cyclotron continued to provide high quality stable alpha and proton beams for nuclear physics and material science experiments. The machine is the primary accelerator for the upcoming Radioactive Ion Beam (RIB) Facility at VECC.

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

A Low Energy Heavy Ion Irradiation / Implantation facility was developed at Trombay for materials science and atomic physics research.

For the understanding of the physics of short-lived atomic nuclei, advanced accelerators such as Radio Frequency Quadrupole and IH Linacs, were developed at VECC. With the availability of alpha beam from the upgraded, K-130 cyclotron, various experimental programmes were taken up at VECC.

Industrial Computed Tomography set up at BARC

Superconducting Cyclotron at Variable Energy Cyclotron Centre

For energizing superconducting cavities of Proton Linac, a 30 kW (CW), 650 MHz solid state amplifier was under development at RRCAT. The Centre also developed a Centrifugal Barrel Polishing Machine for smoothening the inside surface of superconducting radio frequency cavities to achieve high accelerating gradients.

For upgradation of the dipole magnets of the 700 MeV Booster ring, two pre-prototype laminated, sector type dipole magnets were developed, and Septum magnets for Indus-2 storage ring, were assembled with alumina coated coils.

A new technology of electron beam cured polymer sheets that can be moulded at high temperature, was developed and demonstrated by BARC. This Centre also established an Industrial Computed Tomography (ICT) unit that provides vital image details such as defect sizing, location, 2D and 3D imaging. At the BARC's Electron Beam Centre, Navi Mumbai, accelerator beam was employed for demonstrating industrial applications such as cross-linking of poly-ethylene, diamond colouration, Teflon degradation and production of photo-neutrons. Material irradiation studies were also conducted.

Laser Technology Development and Applications

RRCAT developed a number of lasers for industrial applications during the report period. For drilling of holes, metal cutting and welding a 10 kW peak power pulsed industrial Nd:YAG laser with 500 W average power, and for surface cleaning applications a short pulse duration Nd:YAG laser for surface cleaning applications were developed. Successful development of a Copper-HyBrID laser with average laser power of 110 W

Undoped $Li_6Gd(BO_3)_3$ crystal

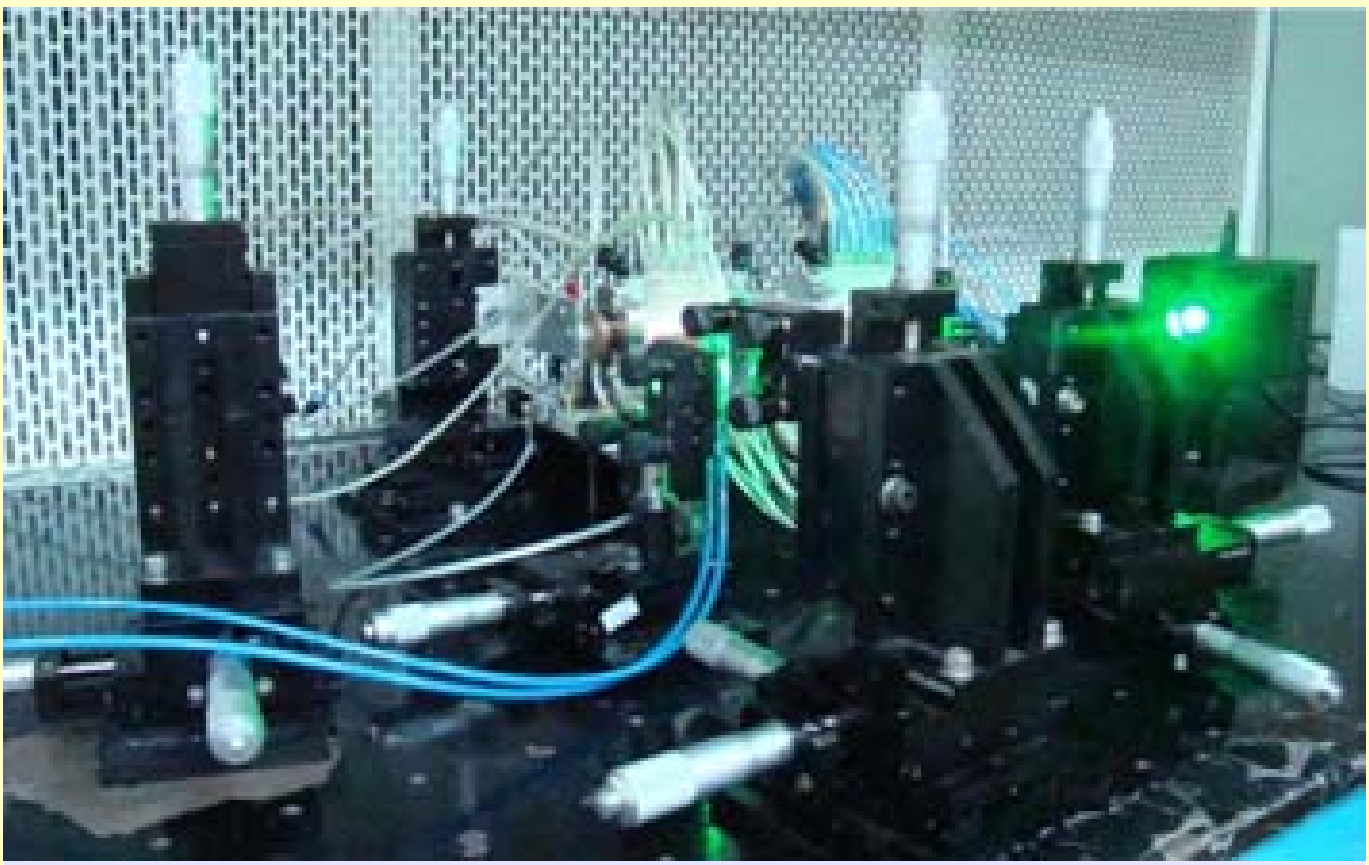
was also achieved.

A 80 W continuous wave green beam generation Nd:YAG/KTP based laser was successfully demonstrated. Another 455 mW/Facet continuous wave semiconductor laser emitted 980 nm light. Terahertz spontaneous emission was observed in the Compact Ultrafast Terahertz Free Electron Laser (CUTE-FEL) being built at RRCAT.

Good quality transparent single crystals of lithium gadolinium borate and sodium yttrium tungstet were grown at BARC.

Robotics

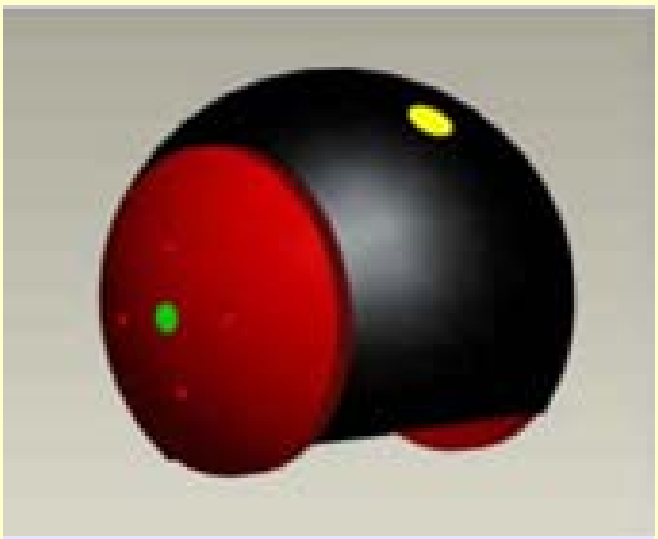
A high precision Servo Hydraulic Motor was developed by BARC. This motor has potential use in low speed precise position control applications such as high payload robotic manipulators. Also, to control many rotary/linear hydraulic actuators, multi-axis Digital Servo-Controller Cards were



80 W Continuous Wave Green Laser in a Z-cavity

Multi Axis Servo Control Card for robotic applications

Slave and Master Arms of the Telerobot developed at BARC



A remote Fire Surveillance Robot developed at Trombay

developed and successfully deployed. These cards are a good substitute for the imported ones.

For surveillance of a location under fire, an inexpensive Surveillance Robot was developed at BARC. With a transmission limit of 100 metres, this device gives the fire brigade team a general idea of the intensity of the fire, its origin and how to search out victims.

At VECC, a Mobile Robot in the K-130 Room Temperature Cyclotron vault and experimental caves was deployed to map the dose-profile of the various regions around the main machine.

Cryogenics & Recovery of Helium

At RRCAT, a major success was of Helium liquefaction that was achieved with the fully indigenous Helium Liquefier. A pool type liquid Helium Cryostat, for operating down to 2 Kelvin (-271 deg C) temperature, was also designed and developed at the Centre, and superconducting RF cavities were tested at this temperature.

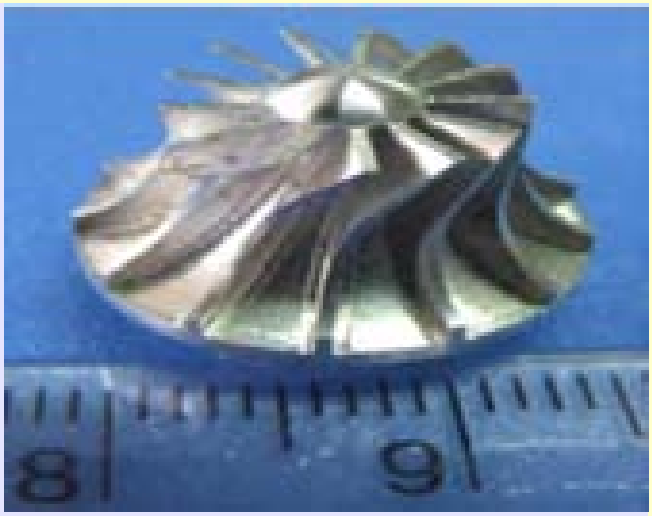
At VECC, the major achievements in the field of cryogenics included the Development of 2-stage pulse tube Cryocooler for cryogenic applications; Integration of a new Helium Liquefier, and Commissioning of a novel cryosorption based Helium Purifier. The Centre also undertook a 3-stage programme of developing Superconducting Magnetic Energy Storage system.

A cryogenic turbine impeller (size 16 mm, service speed 2,64,000 rpm) was designed and developed at Trombay. Indigenously developed micro cryo-cooler unit was integrated with hand held thermal imager meant for night vision device.

RADIATION TECHNOLOGY AND THEIR APPLICATIONS

Today, Radiation Technology, through its various applications, is hugely benefiting the areas

Helium Liquefaction system developed at RRCAT



16 mm cryogenic turbine impeller

of healthcare, agriculture and water-purification, and industry. BARC, VECC and RRCAT are engaged in the development and applications of such technologies.

Radioisotopes are produced in the research reactors at Trombay, accelerator at Kolkata and the various nuclear power plants of NPCIL. The Board of Radiation and Isotope Technology (BRIT) produces and supplies a wide range of radioisotope products, and radiation technology equipment for medical and industrial uses. The Board operates plants for radiation sterilization of medical products and radiation processing of spices and allied products. It also offers facility for detection of radioactivity in products benefitting exporters and importers.

Radioisotopes

At BARC, a wide variety of radioisotopes for medical, industrial and research applications were produced and supplied. Radioisotopes were produced for medical applications as well as for industrial and research applications.

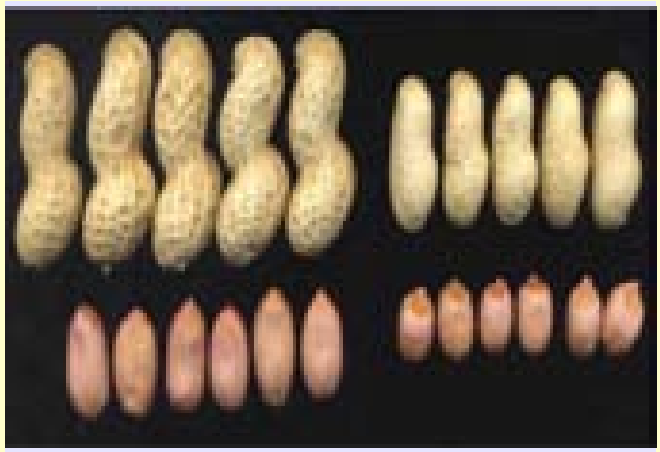
During the report period,more than 53,000 consignments of various radioisotope based products and radiation processing services were provided by BRIT to customers in India and abroad, bringing a sales turnover of Rs.55 crore.

Agriculture

Groundnut variety Trombay Dharwad Groundnut-39 (TDG-39) was released and notified by the Government of India for commercial cultivation. This is a confectionary grade large seed groundnut variety developed by BARC in collaboration with University of Agricultural Sciences, Dharwad. Two new mutant lentil varieties (Pairy mung and Trombay Jawahar Tur) were also notified for commercial cultivation. The total number of mutant crop varieties developed by BARC using nuclear techniques, stand at 39.

The Kombucha tea obtained by fermenting black tea with the Kombucha culture, showed excellent healing activity against gastric ulceration in mice.

Fifty Nisargaruna solid waste treatment plants were established at various places by BARC.



Trombay groundnut variety, TDG 39

Trombay mungbean variety, TM-2000-2

Food Technology

Electron Beam Irradiation of Seeds at RRCAT

KRUSHAK Food Irradiation Facility at Lasalgaon, near Nashik, Maharashtra is commercially operated by the Maharashtra State Agricultural Marketing Board (MSAMB), under a tripartite MoU signed by BARC, BRIT and MSAMB.

Radiation processing at a dose of 7.5 kGy was found to extend shelf life of an antidiabetic herbal formulation upto 18 months without affecting its microbial, biochemical, antioxidant capacity and organoleptic quality, when stored at ambient temperature.

RRCAT and the National Bureau of Plant Genetic Resources, pursued seed irradiation studies using the 750 keV DC accelerator, to explore the potential of electron beam irradiation as quarantine disinfestation treatment against insects and pests in seed.

At Trombay, biodegradable and antimicrobial Packaging Material was prepared and in-vitro experiments done at BARC on a microbial system, exhibited anti-mutagenic and radio-protective properties of honey.

Sludge Hygienization Research Irradiator (SHRI) facility at Vadodara was operated on round-the-clock basis to hygienise sewage and produce enriched manure for use at local farms.

Nuclear Medicine and Healthcare

Under the Labelled Compounds Programme, BRIT supplied a wide variety of ^{14}C, ^{3}H and ^{35}S-labelled products, oligonucleotides (DNA primers) and ready-to-use non-radioactive (cold) kits used for labeling nucleic acid with ^{32}P-labelled nucleotides.

Various types of Tritium Filled light Sources were prepared and supplied for defence applications. An export order received from Germany for radiolabelling of isosorbide with Carbon-14 was executed.

JONAKI Laboratory at Hyderabad developed an improved multiplex PCR based M. Tuberculosis detection kit.

BRIT also introduced two new kits for the preparation of injections for renal imaging and myocardial perfusion imaging. It successfully completed the contract work for labelling of

^{99}Mo-^{99m}Tc Column Generator Plant

monoclonal antibody (ch TNT 1/B) with ^{131}I for a US firm. Another order from the company is expected.

More than 58,000 cold kits for formulation of ^{99m}Tc, 410 Ci of ^{99}Mo (TCM-2) for extraction of ^{99m}Tc, and approx. 15,000 consignments of ready to use radiopharmaceuticals of ^{131}I , ^{32}P, ^{51}Cr and ^{153}Sm were supplied by BRIT to various nuclear medicine centres.

Fifty one batches of Geltech generators were processed and supplied to nuclear medicine hospitals across India. Over 800 generators were supplied to the users, reflecting a growth of about 48% over the previous year.

Over 9000 radioimmunoassay (RIA) and immunoradiometric assay (IRMA) kits were produced and supplied to about 300 immunoassay laboratories throughout the country. LH IRMA kit was also introduced in the market.

Major components of the ^{99}Mo-^{99m}Tc Column Generator Plant arrived from the Gamma Services, Leipzig, Germany and installation of the Plant was completed. The plant will be commissioned shortly.

At the BRIT's Regional Centre, Kolkata, significant progress was made in the Medical Cyclotron Project. A new project of setting up of medical use Mo-99 Production Facility for medical use, was sanctioned.

Six hospitals in India started therapy of neuro-endocrine tumours using ^{177}Lu-DOTA-TATE produced at Trombay.

BARC successfully developed Radiotherapy Simulator technology and installed first radiotherapy simulator at the Indian Red Cross Society Hospital, Nellore, Andhra Pradesh.

BARC supplied ^{55}Fe , ^{57}Co and ^{63}Ni sources for research work to DRDO, ISRO and IGCAR. Many of these sources are far less expensive than the imported sources.

RRCAT helped to build a production version of the laser that will be used in the treatment of tuberculosis of the lung and the lymph node.

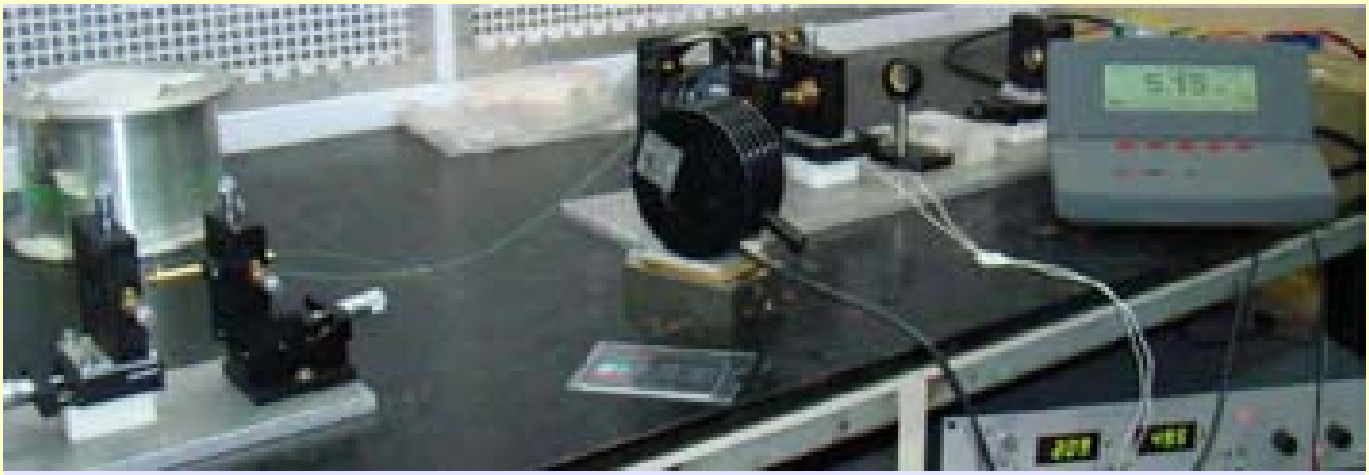
A 5W single-transverse mode Erbium - Ytterbium (Er :Yb) co-doped fibre laser was developed at RRCAT. This laser will be useful in optical coherence tomography, microsurgery, skin resurfacing and nonlinear frequency conversion.

In BARC's Radiation Medicine Centre, the development of synthesis protocols, radiochemical evaluation and commercial production was carried out for two Flourine-18 (F-18) containing diagnostic agents for cancer.

The Regional Radiation Medicine Centre (RRMC) at Kolkata continued to provide nuclear diagnostics service and radio nuclide therapy to patients. Imaging technologies for early detection of breast cancer were taken up by VECC.

Cancer Diagnostic & Treatment services

The Tata Memorial Hospital (TMH) and Advanced Centre for Treatment, Research and



5 W Erbium -Ytterbium co-doped CW fiber laser at 1564 nm

Education in Cancer (ACTREC) continued with their activities in diagnosis, treatment, research and education in cancer.

As part of the Cancer Prevention Programme, screening services for common cancers were provided and a model for Cancer Control Programmes for the country was created. The Urban Outreach Programme in the slums of Mumbai and Rural Outreach Programme in the districts of Ratnagiri and Sindhudurg, of Maharashtra, continued. For early detection of oral, breast and uterine cervix cancers among women, the Mobile Outreach Programme of TMH endeavoured to reach the slums and under-served areas of Mumbai. The women detected with cancers or pre-cancers were offered appropriate treatment free of cost. The project will cover 1,50,000 low socio-economic population residing in Mumbai.

A National Cancer Grid with the Tata Memorial Centre as the Apex Body and various cancer centres with 4-5 zonal and regional nodes was proposed to provide uniform standards of care, trained human resource, co-ordinated non-repetitive research of national and global importance.

For use in the diagnosis and treatment of various cancers, BRIT supplied Applicator Kits for brachytherapy, Teletherapy sources and Blood Irradiators to hospitals.

In BARC's Radiation Medicine Centre, the development of synthesis protocols, radiochemical evaluation and commercial production was carried out for two Flourine-18 (F-18) containing diagnostic agents for cancer.

The technology of Bhabhatron was transferred to a private entrepreneur for mass production and commercialization. Sixteen Bhabhatrons were operational at various cancer hospitals in the country. A large number of cancer patients, especially from rural areas, have been benefited by this development.

The Regional Radiation Medicine Centre (RRMC) at Kolkata continued to provide nuclear diagnostics service and radio nuclide therapy to patients. Imaging technologies for early detection of breast cancer was taken up by VECC.

A 5W single-transverse mode Erbium - Ytterbium (Er :Yb) co-doped fibre laser was developed at RRCAT. This laser will be useful in optical coherence tomography, microsurgery, skin resurfacing and nonlinear frequency conversion.

Industrial Applications of Radioisotopes & Radiation

Sealed radiation sources for industrial irradiators comprising a total activity of 770 kCi, were fabricated, processed and supplied by BRIT. More than 900 radiography sources were fabricated and supplied with 35 kCi Ir-192 activity.

BRIT supplied and installed Gamma Chamber GC-5000 at the Institute of Nuclear Chemistry & Technology, Warsaw, Poland as part of the IAEA order of US$ 187,990 (Rs.85 L). It also supplied two units of GC-5000 to ISRO, Bangalore and BARC, Kalpakkam. Two Blood Irradiators were supplied and installed at Prathama Blood Bank, Ahmedabad and Christian Medical College, Ludhiana.

A new Stainless Steel based ROLI-1 camera was introduced and 70 radiography exposure devices were supplied by BRIT.

BRIT's ISOMED Plant sterilized about 5400 cubic metres of medical products and Radiation Processing Plant at Vashi processed about 20,001,885 MT of spices and allied products.

Considerable progress was made in the commissioning of Install & Operate Irradiator

Installation of Gamma Chamber GC-5000 at Warsaw, Poland

10 MeV RF Linac System at the Electron Beam Centre at Navi Mumbai

(capacity 400 kCi of Co-60), suitable for radiation processing of frozen marine products.

The industrial applications of lasers developed at RRCAT included Standardization of a Laser Surface peening treatment for enhanced fatigue performance of automobile components, and methodology for laser rapid manufacturing of porous metallic structures.

The 3 MeV DC accelerator was regularly operated by BARC and dosimeter films and rubber samples from a local manufacturer were irradiated and analysed.

The 2-MeV electron beam accelerator (ILU-6) was operated at full power and was utilized for providing commercial irradiation services to the industry.

The 10 MeV RF linear electron accelerator at Electron Beam Centre at Navi Mumbai, was operated to establish stable and safe operation.

For tracking the fluid and solid particles in industrial process systems, a radioactive particle Tracking Technique was developed using Scandium-46 source in collaboration with Indian Institute of Technology, Delhi.

Radioisotope Application Services

The Isotope Application Services Group carried out leak detection studies using Br-82 in heat exchangers at three sections of RIL (Patalaganaga). Mo-99 was used to identify leakage in underground pipeline of RIL (Jamnagar), Indian Oil Corporation Ltd., Sewree Terminal, Mumbai and HPCL, Mumbai. Furnace blockage was detected at HPCL, Mahul. Gamma scanning was done for 3 columns at HPCL Visakhapatnam, 31 T1 process column; Fluidized Catalytic Cracking Unit (FCCU) at HPCL, Mumbai, and on two vacuum gas oil hydro treater reactors of DTA refinery of RIL (Patalganga).

New Radiation Processing Plants in the Private Sector

BRIT signed MoUs with private parties from Gujarat, Haryana, Chennai and Pune. The Radiation Processing Plant for Innova Agri Bio Park Ltd., Bangalore was commissioned with initial 100 kCi of C0-60 activity. BRIT also supplied 200 kCi radiation source to M/s. Jhunsons Chemicals (P) Ltd., Bhiwadi, Rajasthan.

Electronics & Instrumentation

A robotic device Compact Laparoscope Manipulator (CoLaM) for view-control during a laparoscopic surgery was developed at BARC. The

Compact Laparoscope Manipulator

first prototype of this device is undergoing field trials.

A facility was setup at BARC for remote control and accessing the synchrotron FIP beamline at Grenoble, France, through the National Knowledge Network (NKN).

A Scanning Electron Microscope (magnification 1,50,000) was developed in BARC in association with an industry partner. A unique and compact Hand Scan Biometric System was also devised for verification of identity of personnel.

Water Desalination

Nuclear Desalination Demonstration Plant consisting of multi-stage flash and reverse osmosis sections of 4.5 million litres/ day and 1.8 million litres/day capacities respectively, was continuously operated at Kalpakkam.

An Electro-De-Ionisation (EDI) unit was integrated to a low temperature evaporation sea water desalination plant for producing electronic grade ultra-pure water for high end applications such as super-computers.

A comprehensive technology comprising re-generable alumina followed by ultrafiltration was developed to bring down the fluoride level in water to 1mg/litre (ppm).

Electro-De-Ionisation unit (capacity: 5000 litres/day)

Ultra-Filtration (UF) assisted Fluoride Removal System

Under the AKRUTI programme of the Department, using isotope hydrology techniques, a huge groundwater source was detected in draught prone area of Amravati District of Maharashtra. Augmentation of recharge to a few drying springs in Himachal Pradesh, Maharashtra, Mizoram, Uttaranchal and other regions, were also carried out.

In order to deploy brackish water desalination technology in un-electrified remote areas, RO pilot plant supported by electricity produced through solar photo-voltaic panels were designed and developed at Trombay.

BASIC & APPLIED RESEARCH

Basic and applied research relevant to DAE's programme are carried out in the research centres of the Department. The autonomous research institutes supported by the grant-in-aid by DAE, are also engaged in basic research, in myriad of disciplines of fundamental and applied sciences.

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

Mathematics & Computation

K130 Cyclotron

A computer code, FIDOM (FIlm DryOut Modeling), solves the conservation equations of mass and energy for liquid film, entrained droplet and a central vapour core. At BARC, appropriate models for the entrainment and deposition of droplets relevant to BWR conditions were employed in FIDOM. The results indicated the appropriateness of these models under the BWR conditions.

At VECC, a modern network infrastructure was set up with a very high speed backbone. At RRCAT, a high capacity storage array Kshitij-1 was configured.

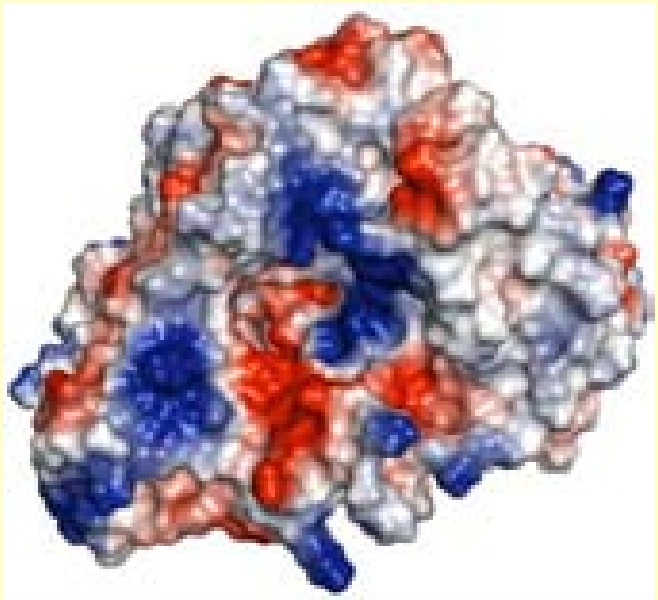
The dose-profile compilation is of immense importance for health physicists. Remote radiation mapping of the K-130 cyclotron at Kolkata was done using a mobile robot.

At the Institute of Mathematics, Chennai, researchers carried out Tsunami Analysis modeling, jointly with the National Institute of Oceanography, Goa.

Physics

At Trombay, the indigenously developed Supersonic Molecular Beam Facility was used to investigate electronic structures.

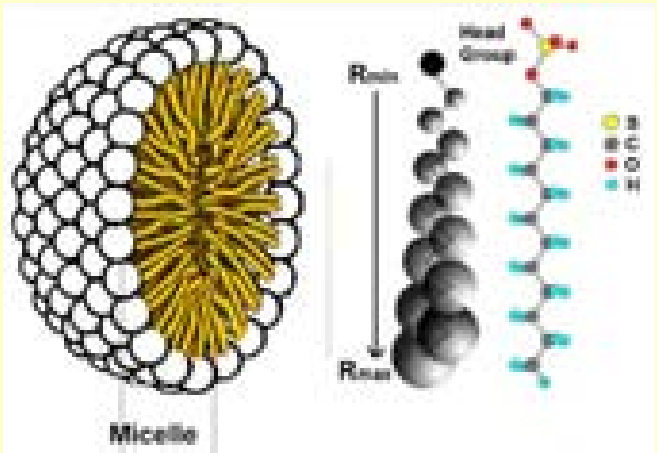
Recently, BARC commissioned a Phase Contrast Imaging Facility capable of revealing light element profile in a matrix of heavy elements, and a Neutron Induced Electron Radiography Facility for inspecting documents, paintings and biological samples.



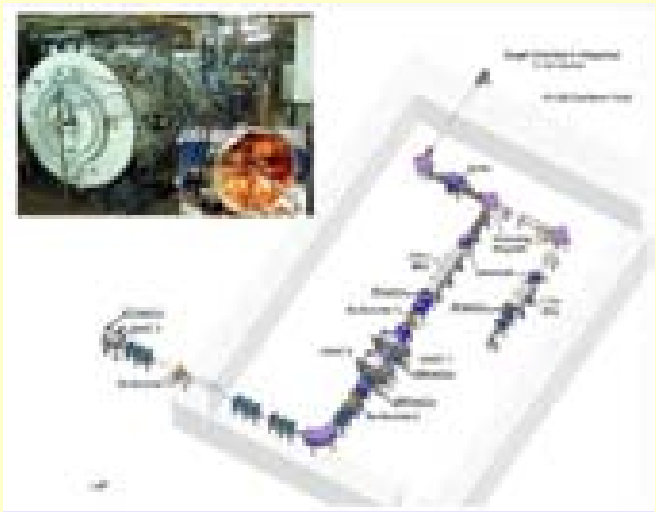
High-resolution structure of an enzyme suitable for bioprecipitation of U

A new 7-collector Thermal Ionization Mass Spectrometer was developed at BARC for use by AMD in high precision isotope ratio measurements in geo-chronological applications.

3-D structure of an enzyme suitable for bioprecipitation of uranium under alkaline conditions was determined using X-ray crystallography.



Internal Dynamics in SDS Micelles: Neutron Scattering Study



Layout of the RIB facility.
Inset Linac-2 module of the RIB facility

The National Facility for Neutron Beam Research at Dhruva was regularly utilized. The molecular dynamics of Sodium Dodecyl Sulphate (SDS) micelle was investigated using high-resolution incoherent quasi-elastic neutron scattering technique.

At VECC, Radioactive Ion Beam (RIB) Project, progressed considerably. This facility will help in the understanding of the physics of short-lived atomic nuclei.

Several nuclear physics experiments were carried out at VECC using the alpha beam for reaction dynamics and nuclear structure studies.

A parametric model was developed to predict neutron-nucleus total and reaction cross-sections accurately. The photo-fission cross sections of nuclei executing giant dipole oscillations were calculated.

Electron Cyclotron Resonance (ECR)
Ion-Source Facility at TIFR

The research at the Institute of Physics was pursued in diverse areas. In string theory, a 3-generation supersymmetric model was obtained. The mechanism for the formation of superheavy elements was studied at the institute. Different ion beams available from the 3 MV pelletron were used for modification and preparation of nanomaterials.

A novel phenomenon of “multiple splits” in the spectra of neutrinos from a supernova was discovered and analytically investigated at TIFR.

In the field of High Energy Physics, the TIFR team carried out observations of galactic and extra-galactic objects using the HAGAR telescope array.

The Institute of Mathematics finished the pilot stage of the India based Neutrino Observatory (INO) Project and identified a site that is awaiting environmental clearances. HRI's researchers were actively involved in the development and physics studies relating to INO.

A group of HRI focused on systematic studies of physics signals at the Large Hadron Collider which has recently started its operation in Geneva. Standard Model processes were also studied in detail.

Members of the String Theory group at HRI worked on the microscopic understanding of quantum states of supersymmetric black holes through the quantum entropy function,

Using microwave plasma carbon vapour deposition (CVD) technique, high quality and highly oriented CVD diamond thin films were grown on silicon wafer (1-5 cm^2 area) and characterized by SEM, XRD and Raman Spectroscopy.

Using the Giant Metrewave Radio Telescope (GMRT) set up near Pune, TIFR launched an ambitious project to image 80% of the sky at 150 Mhz.

EXECUTIVE SUMMARY

Chemistry

Thorium-loaded MEP membranes were synthesized for fluoride uptake studies. Fluoride uptake upto 75-80 % could be achieved with these membranes.

A simple method was developed at BARC to synthesize rectangular plate like gold nano-particles. The synthesized nano-materials could be further developed as potential bio-sensors.

Biology

A biological process was developed at Trombay, for removal of sulphate from sulphate-bearing barren effluents such as those produced at UCIL, Jaduguda.

A biocide releasing polymer system capable of continuous in situ production of chlorine dioxide was developed.

At Trombay, 21 rice genotypes, including 9 land races, 8 modern and 2 traditional cultivars, were analyzed by amplified fragment length polymorphism (AFLP).

Human pathogenic bacteria as well as plant pathogenic and soil bacterium when exposed to low dose gamma radiation, were found to undergo caspase dependent programmed cell death.

The number of new born children screened for congenital malformation in the high level natural radiation area and normal level natural radiation area of Kerala, reached 1.30 lakh. There was no difference in the frequency of these malformations in these two areas.

Health audit survey of Mayannad and Kollam corporation Division covering 81,000 population was completed.

Plasmodium falciparum enolase undergoes several post-translational modifications of relevance to its function. Using mass spectrometry, the TIFR researchers identified a tyrosine residue that gets phosphorylated.

Transcriptional mechanisms that regulate cell identity in the developing brain were examined. In another project, a novel migratory stream of neurons was discovered. To understand the Neural Basis of Brain Function, work continued at the National Centre for Biological Sciences at Bangalore, on the genetic analysis of chemo-sensory perception in Drosophila.

Material Science

New compositions with La_2O_3 additives in Ba-Zn/Sr-silicate system and Ba-Ca-Al-B-silicate P_2O_5/Cr_2O_3 were optimized for high temperature sealant and seals were made at Trombay.

A pilot facility was setup at Trombay for producing nuclear grade beryllia, which is moderator- cum-reflector for compact high temperature reactor and refurbished APSARA reactor.

Boron carbide and refractory/rare earth metal borides based, candidate materials for high temperature structures such as hypersonic re-entry vehicles were consolidated.

A large magneto-calorific effect was discovered by RRCAT in Cr and Cu doped NiMnIn alloys near room temperature and in $DyAg_2$ in the 10 - 60 K tempereature regime. At the Centre, the Transparent crystals of L-arginine phosphate monohydrate (LAP) were successfully grown.

Platinum loaded Carbon Aerogel-platinum catalyst made at RRCAT for heavy water application, was undergoing testing.

Cancer Research And Treatment

At ACTREC, several new protocols and clinical research programmes were initiated and the existing programmes were consolidated. The comparative oncology programme gained momentum. The Bone Marrow Transplant programme completed 135 transplants so far. Pharmacokinetic behavior of anti-cancer drugs in Indian pediatric cancer patients was undertaken by ACTREC in collaboration with the University of Newcastle.

The Cancer Genetics Clinic of ACTREC has evolved as the apex national referral centre for comprehensive clinical and laboratory genetic services and research into the genetics of the major cancer predisposition syndromes.

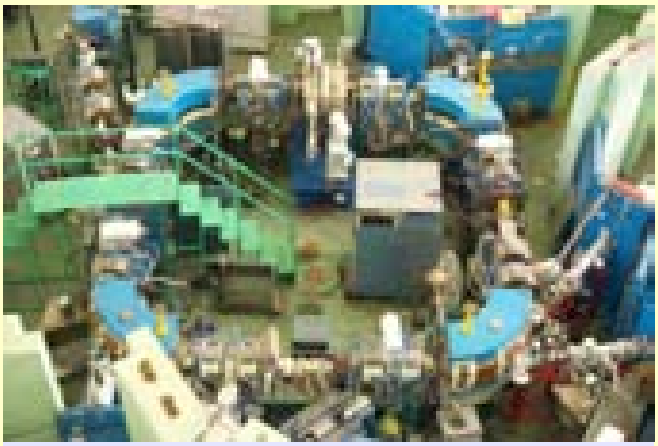
Development of synthesis protocols and radiochemical evaluation were carried out for two ^{18}F containing diagnostic agents for cancer viz. ^{18}F-Fluorothymidine (^{18}F-FLT) for imaging cell-proliferation in cancers and ^{18}F-Fluoromisonidazole (^{18}F-FMISO) for imaging of hypoxic regions in tumours.

Synchrotrons and their Applications

The Raja Ramanna Centre for Advanced Technology (RRCAT) has set up Synchrotron Radiation Sources Indus-1&2 for carrying out advanced basic research. Round-the-clock operation of the facility was started on February 08, 2010. During the report period, Indus-1 storage ring operated smoothly in user mode and storage of 100mA beam current at 2 GeV in Indus-2 was achieved on March 6, 2010.

During the year 2010, the beams from Indus-1 and Indus-2 were available for 3800 hrs and 3200 hrs respectively. The beamlines on Indus-1 were in use by several groups from IITs, Institutes, and universities. On Indus-2, three beamlines were made fully operational and installations of five other beamlines reached advanced stages.

On Indus-1, the indigenously developed high resolution vacuum ultra-violet beamline was commissioned by BARC. Upgraded beam position indicators fabricated at RRCAT for Indus-1, were ready for use. Ultrahigh vacuum compatible multi-functional beam slit monitors for transfer line on Indus-1 were developed.



Indus-1 is operating round the clock at 100 mA current

For Indus-2, the power conditioning system was undergoing commissioning.

For the development of multilayer soft X-ray mirrors for synchrotron radiation applications, a state-of-the-art Ion Beam Sputtering System was built by BARC.

Fusion and Other Plasma Technologies

A plasma ion source based Focused Ion Beam (FIB) system for micromachining applications was developed at VECC. Several micromachining experiments were carried out on silicon and copper substrates using Ar ion beam.

The Institute of Plasma Research (IPR) carried out research in plasma science including magnetically confined hot plasmas and plasma technologies for industrial applications. It operated Aditya Tokamak and was engaged in building the Steady State Superconducting Tokamak (SST-1).

Experiments for upgrading the operational window of Aditya tokamak were continued with different control systems. The proposed Time of Flight Diagnostics system reached the final stage of fabrication, Charge Exchange diagnostics were upgraded and charge exchange counts on all three channels could be realized.

Detailed technical specifications were generated for a new 42GHz 500kW Electron Cyclotron Resonance Heating system, which will be used to carry out pre-ionization and start-up experiments.

Work on the SST-1 Project made rapid progress. Fourteen of the sixteen SST-1 Toroidal Field magnets were successfully tested.

For the 200 kW, 42.5 GHz DST Gyrotron Project, IPR pursued fabrication of all the magnets, thermal design of the Gyrotron tube, all the components of the transmission line, power supplies and development of a Test Set-up etc.

International Research Collaborations

RRCAT played an active role in a number of international collaborations of DAE that included:

- A prototype solid state Long Pulse Bouncer Modulator developed and shipped to CERN as a part of the Novel Accelerator Technology (NAT), Project.

- Two 1.3GHz prototype Superconducting RF niobium cavities developed earlier, were processed and successfully tested recently at the Fermi National Accelerator Laboratory, (FNAL), USA. For performance evaluation of such cavities, RRCAT designed a Vertical Test Stand Cryostats in collaboration with FNAL.

- Under a collaborative programme with Fermilab, USA, the development of cavity forming tooling for 650 MHz superconducting RF cavity had started. The first trial tooling was designed and manufactured at RRCAT.

India is participating in the proposed Facility for Antiproton and Ion Research (FAIR) in Germany. This facility needs over 1400 magnet power supplies of various types. At RRCAT, preliminary design studies and simulations were carried out for the prototype of these magnets.

The Photon Multiplicity Detector, built by VECC in collaboration with other Indian groups, was successfully installed in the CERN-ALICE experiment. For the analysis of data, the use of GRID Computing facility at VECC was continued.

Global Centre for Nuclear Partnership

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

ITER-Project

IPR is a major participant in the International Thermonuclear Experimental Reactor (ITER) Project cominig up at Cadarache, France. During the report period, IPR vigorously pursued both the ongoing works and the XI plan projects including the ITER related activities.

For fulfilling the commitment of India to ITER project, five more Procurement Arrangements were signed by IPR and pre-procurement activities for remaining ITER packages continued. Preparation of documents related to Procurement Arrangement for the remaining procurement packages were continued. First interim review of preliminary design was held and the comments were incorporated in the design basis documents. Various Design Change Requests /Project Change Requests were studied at IPR and comments are submitted to ITER Organization. Construction of Laboratory building for ITER-INDIA was nearly completed. Other works related to the infrastructure development were continued.

For the fusion neutronic design of the ITER Project in France, computations and assessment were completed for heat generation rate in various components/systems of ITER, Helium production rate in stainless steel, atom damage rate of the components and the radiation dose rate in various accessible areas. This work was carried out by BARC in collaboration with IPR.

For the Test Blanket Module (TBM) to be tested in ITER, IPR is collaborating with BARC and IGCAR. The Institute was actively involved in the design and development of the TBMs.

OTHER ACTIVITIES

Research Education Linkages

DAE supports synergistic interaction amongst the national laboratories and the university systems through a number of mechanisms such as grants-in-aid to institutes of national eminence, funding of extra-mural research, DAE-UGC Consortium for Scientific Research, and others. Following is the profile of these activities during the report period :

The concept of Master Curve in fracture mechanics envisages a unique characterization of materials in terms of Reference Temperature. As a

A pipe undergoing tolerance test at SERC, Chennai

part of BARC's collaborative project with Jadavpur University, Kolkata, tests were conducted towards investigation on Master Curve on specimens at various temperatures. The test data generated material J-R curve and associated reference temperature.

To demonstrate the ability of piping in the Indian nuclear power plants to tolerate defects, many elbows with different crack configurations were tested under combined loading of bending moment and internal pressure. The tests were conducted by BARC at SERC, Chennai.

The Synchrotron Radiation Sources Indus-1&2 at RRCAT are used by researchers from various universities and institutes. During the report period, the Beamlines on Indus-1 were used by several groups from IITs, Institutes, and universities.

HUMAN RESOURCE DEVELOPMENT AND KNOWLEDGE MANAGEMENT

Homi Bhabha National Institute

The Homi Bhabha National Institute (HBNI), that has now completed 5 years of its existence, remained engaged with its regular academic programmes.

During the report period, Degrees and Diplomas (totaling 103) were awarded and a total of 328 results were declared. More than 120 Officers from DAE completed their MTech. In the PhD programme, 57 students completed the programme requirements and were issued degrees / provisional certificates.

The number of enrolments swelled to nearly 3000 since 2006, with PhD enrolment number alone being an impressive 1172. The enrolment number under the Post-Graduate Medical Programmes was also over 100.

An exhaustive review of the functioning of HBNI was conducted by the UGC Committee.

Training Schools

The recruitment and placement through the Training Schools is carried out under two schemes viz. Orientation Course for Engineering Graduates & Science Post-Graduates (OCES) and DAE Graduate Fellowship Scheme (DGFS).

On completion of the ongoing OCES/DGFS-2009 courses, placement of the trainee officers was of OCES-2009 was completed.

The selections for admission to the PhD programme of BARC under the aegis of Homi Bhabha National Institute were conducted. Selection of candidates with Master's Degree in Science/Bachelor's Degree in Engineering was carried along with that for the OCES/DGFS selection process. A separate selection process was carried for admission to PhD programme on the basis of Master's degree in engineering.

The practical training and project work of engineering/science students from different universities were arranged. About 800 students from all over India had undergone practical training / project work in various Divisions of BARC during the year 2010.

Under the Continued Education Programme advanced lecture courses were conducted for the benefit of the DAE employees.

The 1-year post-M.Sc. Diploma in Radiological Physics course, affiliated to HBNI, was continued. Radiation Safety Officer certification courses were

conducted in the field of Medical Physics and Nuclear Medicine. Training courses on “Radiation Safety Aspects in Nucleonic Gauges” and “Radiation Safety Aspects in Research Applications of Ionizing Radiation” were conducted in collaboration with Indian Association for Radiation Protection. Training courses on “Radiography Testing Level 1 (RT-1) were also conducted at various places in the country.

Two training programmes for defence personnel were also conducted.

At IGCAR, Kalpakkam, the 4th batch of 48 trainee scientific officers, completed their training in six disciplines and were placed in various units of DAE. At the Training School, in the current academic year, 37 trainee scientific officers were undergoing training. Research Scholars (41 nos.), inducted to pursue their doctoral programmes in the frontier areas of engineering and basic sciences under the aegis of HBNI, were undergoing coursework. At the Training Centre, employees pursued courses for higher qualifications.

BARC-Training School at AMD Campus, Hyderabad has started training of the Geology and Geophysics trainee scientific officers. AMD studentship programme was continued, in which 34 M.Sc./M.Tech. students of different Universities completed their project work during the period of report.

NPCIL organized a number of training programmes encompassing 'Honing the Managerial Skills', 'Human Resource Management for Line Managers','Internal Auditors Certification Course on ISO-9001:2008”, Awareness on Nuclear Security etc..

It implemented, managed and maintained 'Web Application' for 'DAE Training Schools Selection Process (OCES/DGFS-2010 batch)'. The Corporation also developed an online process for selection of experienced engineers for NPCIL.

After completion of the 1-year Orientation Training Programme, final placement of engineers from OCES-2009 batch was organized. Also, the 1-year Orientation Training of fresh NTPC/IOC engineers, along with fresh NPCIL engineers, was undertaken.

About 34,360 man-hours (around 860 man-weeks) of training were imparted with the faculty from NPCIL and outside Institutions.

To meet the increasing demand of construction of nuclear power plants, a "Qualification Programme for Construction" covering the administrative norms, subjects was developed.

The Institute of Physics continued to contribute towards quality human resource development by way of a 1-year Pre-Doctoral Course followed by a Ph.D. programme. Interactions with academic institutions were promoted. Since 2006, the Institute is involved in setting up of National Institute of Science Education and Research (NISER) and nurturing it in earlier years.

During the report period, Tata Memorial Centre increased the student-intake in some of the post-graduation courses. A total of 58 postgraduate students were registered during the year 2010. The Centre conducted various short-term and long-term training programmes for medical and paramedical professionals. At ACTREC a Clinical Training Programme in radiation biology was initiated for M.D. and M.Sc. students. ACTREC also provided short term / summer training to science postgraduate students.

The National Institute of Science Education and Research (NISER) continued with its activities in the fields of physical, chemical and biological sciences. NISER entered into strategic alliance in the field of scientific research and knowledge exchange programme during the report period, and signed two MoUs with the Institute of Life Sciences, Bhubaneswar and Kanungo Institute of Diabetes Specialities, Bhubaneswar.

The Institute of Mathematics continued with its regular academic programmes for the graduate, postgraduate and doctoral levels. IMS also organises summer vacation courses. Under its Visitors' Programme, the institute hosted visits of scientists from all over the world. IMS faculty members also interacted with researchers of other universities through Associateship Programme and Refresher Courses for college teachers.

The Administrative Training Institute (ATI)

works towards the continued professional development of officials from various cadres of DAE. The programmes of ATI cater to a wide spectrum of training and management development programmes covering grass root levels to Unit Heads.

This year ATI organized five 1-week duration and one 3-week duration Management Development Programmes. It also organized 74 Training Programmes for employees.

In its training programmes, ATI uses a variety of innovative methodologies apart from the conventional lecture method.

SPONSORED RESEARCH

Promotion of Extra-mural Research in Nuclear Science

The Board of Research in Nuclear Science (BRNS) is an advisory body of DAE. Besides funding research projects, BRNS provides financial assistance to organize symposia / conferences / workshops on topics of relevance to the programmes of DAE. BRNS also awards projects to young scientists to initiate them in a career of research and Dr. K. S. Krishnan Research Associateship to identify and encourage highly talented young scientists and technologists. The DAE Graduate Fellowship Scheme (DGFS) is meant for inducting Graduate Level students doing M.Tech. at the IITs. While the Visiting Scientists programme of BRNS is meant for promoting short term in-house interactions amongst senior level experts, the Raja Ramanna Fellowship of BRNS is for reasonably long-term involvement of the eminent scientists and engineers in the various ongoing programmes of the Department. The Homi Bhabha Chair sponsored by BRNS is instituted to avail the honorable services of Scientists and Technologists who have distinguished themselves at national and international levels.

During the year 2010, one hundred five new research projects were sanctioned and some more R&D projects were likely to be approved shortly. Financial sanctions were also issued for the various on-going research projects. Nine fellowships were offered/awarded under the Raja Ramanna Fellowship Scheme (Senior Scientists Scheme) & Homi Bhabha Chair. Twenty-one fellowships were awarded under the K.S. Krishnan Research Associateship Scheme and Twenty Five fellowships were offered/awarded under the DAE Graduate Fellowship Scheme (15 for M.Tech. & 10 for Ph.D.). Financial supports were extended to fully funded BRNS seminars as well as to partly funded seminars conducted by professional organizations on various topics of relevance to DAE, during the year 2010-11. Seventeen DAE-SRC were awarded to outstanding research investigators by the Science Research Council (SRC) of DAE.

The Prospective Research Funding (PRF) introduced under the Xlth Plan R&D proposals of the Department, was continued. The proposals funded through PRF facilitate new ideas in research that may accrue during the plan period. PRF will also help to cater to the proposals that may arise for filling critical gap areas of the main programmes of the Department during the course of the Xlth Plan. Processing of proposals and issue of financial sanctions under the PRF progressed. Five new projects were awarded under PRF, besides supporting nine ongoing projects.

Promotion of Mathematics

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

At the initiative of NBHM the prestigious International Congress of Mathematicians (ICM-2010) was held at Hyderabad during August 19-27, 2010. Over a thousand mathematicians from the country, including teachers and research scholars, were provided support for participation in the Congress.

The Board has been promoting scholarship and proficiency in mathematics at advanced level

through various programmes. During the report period, scholarships were awarded to talented students, selected through nationwide competitive tests, to pursue studies at masters and Ph.D. levels. Fellowships were also provided for the teachers at universities to undertake Ph.D. studies. NBHM continued to support a special programme called Mathematics Training and Talent Search (MTTS) at the undergraduate level. Under the programme, expert mathematicians provide supplementary training to the selected students from across the country during the vacation periods. Supplementary training activities were also undertaken for selected students at postgraduate level, in a coordinated fashion, under the Advanced Training in Mathematics (ATM) programme. Workshops were also held for college teachers, to refresh and strengthen their mathematical aptitude.

NBHM has been in charge of selecting the Indian Team to participate in the International Mathematics Olympiad (IMO). This is undertaken through an elaborate Mathematics Olympiad activity, with the help of the Homi Bhabha Centre for Science Education (HBCSE), targeting talented young students at higher secondary (the plus two) level. A team of six students was selected to participate in the 51st International Mathematics Olympiad (IMO-2010), held at Astana, Kazakhstan. The team secured 2 Silver, 1 Bronze Medals and 3 "Honorable Mention".

A new competition was also started at the undergraduate level, in Pune and Mumbai as a pilot project, called Madhava Mathematical Competition to generate interest in mathematics in early years of college.

NBHM provided grants to mathematics libraries around the country for the purchase of the latest books and journals in mathematics. Around 80 such libraries took advantage of this scheme. In the financial year, 2010-11, out of total allocated budget of Rs.20 crore, about Rs 5.50 crore were released to institutions as a support to libraries. NBHM also distributed selected books to various postgraduate institutions under its book distribution scheme.

NBHM gives grants to various special mathematical centers in the country, for carrying out their activities. The Chennai Mathematical Institute that runs a high quality undergraduate programme in mathematics has been a regular recipient of grants from NBHM. The Kerala School of Mathematics, Calicut is also being supported as under an MOU signed by DAE. During the review period, a supplementary MOU was signed between Kerala School of Mathematics and DAE to provide financial support for infrastructure development. The Institute of Mathematics and Applications, Bhubaneswar and the Bhaskaracharya Pratishthana, Pune, are two other centres that received substantial grant from NBHM based on various programme proposals. Rs 7.50 crore as a first installment were allocated to various centres mentioned above.

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, and for organizing conferences etc. Various institutions were also provided faculty support in the form of Visiting Professors, to strengthen the research and teaching potential at the institutions.

During the report period, financial support was provided to 44 national and international conferences held in India, and 14 Instructional Schools for advanced training in mathematics. Twelve research projects including ongoing as well as new ones, were funded by NBHM. Travel grants were provided to 56 mathematicians to enable them to participate in conferences held in India and abroad. 6 institutions were provided faculty support in the form of Visiting Professors, to strengthen the research and teaching potential at the institutions. Post Doctor Fellowships were awarded to 30 (including the ongoing ones) researchers for the period of 3 years.

GRANTS-IN-AID

Grants to Aided Institutions

The aided institutions of the DAE are an integral part of it. There is a growing synergy between these institutions and the Research and Development Organisations of the Department. Several joint projects are undertaken between the DAE Organisations and Aided Institutions and there is frequent interaction between the academicians of the aided Institutions and scientists of the R&D Organisations. The Department has following nine aided institutions fully funded in terms of their recurring and non-recurring expenditure. These institutions are growing at a faster pace in terms of the projects undertaken by them.

The funds (Plan & Non-Plan) allocated to these Aided Institutions by the DAE during the financial year 2010-2011 are as under :-

Sl. No.	Name of the Institutions	Budget Provision BE 2010 – 11 (Rs. in crore)
1.	Tata Institute of Fundamental Research (TIFR), Mumbai	423.50
2.	Tata Memorial Centre (TMC), Mumbai.	225.00
3.	Saha Institute of Nuclear Physics (SINP), Kolkata.	134.85
4.	Institute of Physics (IOP), Bhubaneswar	26.89
5.	Institute of Mathematical Sciences (IMS), Chennai.	26.30
6.	Harish-Chandra Research Institute (HRI), Allahabad	23.00
7.	Institute for Plasma Research (IPR), Gandhinagar.	388.04
8.	Atomic Energy Education Society (AEES), Mumbai.	41.51
9.	National Institute of Science Education and Research (NISER), Bhubaneswar.	55.00

Grants to Cancer Hospitals

DAE has extended the term of Third Tripartite Agreement (which was signed between DAE and the North-Eastern Council (NEC) and the Government of Assam) for another three years from 2009-10 to 2011-12 for the revitalization of the Dr. B. Barooah Cancer Institute (BBCI), Guwahati. This hospital is a Regional Cancer Centre (RCC) for cancer treatment and control in the North-Eastern Region (NER). The Department's total share as per the Tripartite agreement is approximately Rs.2449.35 lakh for revitalization of the BBCI which includes the cost of construction for expansion of the hospital as well as the procurement of major radiation related equipment during its Revitalization Project-III which has been started during the year 2004-05.

The Department also extends financial assistance to cancer hospitals located in other parts of the country. The budget provision for the year 2010-11 for such partial financial assistance is to the tune of Rs.18 crore.

An increasing need was also felt to use the expertise available in the DAE funded Tata Memorial Hospital for creating a better network between cancer institutions all over the country. This would include research & development, training and preparation of protocols for treatment as well as incentives for indigenization of much of the radiation related equipment for cancer treatment. For this purpose, an Apex Committee was formed under the Chairpersonship of Director, TMC. The Apex Committee has met 18 times so far 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, and Brachytherapy etc.

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

Olympiad Programme

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

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

Every student representing India bagged a medal in the five science and astronomy Olympiads of the year 2010. The participants bagged 33 medals (14 gold, 15 silver and 4 bronze).

The Homi Bhabha Centre for Science Education produced 2 resource books on Olympiads for teachers and students and organized 11 resource and exposure camps for a large number of school and college teachers.

TECHNOLOGY TRANSFER

The spin-off technologies developed and demonstrated at BARC are transferred to the public domain for further commercial proliferation. During the report period, the technologies transferred from BARC to industries included Membrane Assisted Defluoridation process for safe drinking water, Domestic water purification device based on photocatalysis using solar light, Arsenic removal from drinking water ultrafiltration membrane assisted process, Backwashable Spiral Ultrafiltration Technology for Domestic & Industrial Water Purification, Domestic Water Purifier based on ultrafiltration polysulfone membrane, Preparation of Composite Polyamide Reverse Osmosis (RO) Membrane for Brackish Water Desalination, Non-Invasive Blood Pressure Module (Add-on), Kitchen Waste Based Bio Gas Plant, and Ultra Filtration Membrane Assisted Device for removal of Iron from contaminated water for drinking purposes.

Licenses for the technologies renewed with different firms were On-line domestic water purifier based on ultrafiltration polysulfone membrane, Non Invasive Blood Pressure Module & Oximeter Module, and Dust respirators & Air-line respirators. The Agreement for Personnel Monitoring Services (PMS) of radiation workers using TLD badges, was renewed by BARC with M/s. Renentech Laboratories Pvt. Ltd., Mumbai.

IPR's Facilitation Centre for Industrial Plasma Technology (FCIPT) delivered many plasma technologies such as carbon-aluminium bilayer coating, magnetron based sputter coating system, Laboratory scale glow discharge and plasma diagnostics systems. The on-going activities included 40" long plasma based system for higher throughput of treated Angora wool, Plasma Aluminizing Process for Inconel (IN718) alloys, 25 kW plasma torch system and others. Various kinds of material characterization services were provided to external parties on commercial basis.

COLLABORATIVE PROGRAMMES

To augment nuclear power generation rapidly and also to promote other sources of energy, NPCIL took steps towards forming Joint Ventures. These included signing of Joint Venture Agreement with Indian Oil Corporation Ltd. and signing of the Joint Venture Agreement between NPCIL and NTPC to incorporate a Joint Venture Company, for setting up nuclear power plants. A Joint Venture between Larsen & Toubro (L&T) & NPCIL was also set up to manufacture special steels and large size forgings etc., to establish the supply chain for nuclear power projects.

In accordance with the MoU between NPCIL and Tehri Hydroelectric Development Corporation Ltd., the work on preparation of Detailed Project Report (DPR) for Malshej Ghat (700 MW) hydroelectric Pump Storage Scheme was completed.

During the year of report, BARC also signed a

number of collaborative MoUs with various parties. These included: Barge Mounted Sea Water Reverse Osmosis Plant for Production of Drinking Water (IRE) ; Design & Development of Gigabit Networking Solutions for C&I Applications" (IIT-Bombay); Shake Table Tests and Pseudo Static Cyclic Tests on Shear Walls" (SERC, Chennai); Seismic testing of pressured piping loops (Central Power Research Institute, Bangalore); Technical consultancy for third party evaluation on Desalination and Water Purification (Municipal Corporation of Greater Mumbai); Development & Supply of MEMS based Pressure Sensors/Modules and other Modules for DAE application (BEL Bangalore), and Development of Industrial Technology for production & supply of large sized PUF Blocks suitable for shock and heat shield for transportation packages of radioactive materials (Pine Resins & Chemicals, Taloja).

MoUs extended included Machining of Copper Gasket (BHEL), and Development of Process Tomography for Trickle Bed (IOC-R&D Centre Faridabad).

A Tripartite Agreement was signed by BARC with BRIT and MSAMB, Pune, for commercial use of KRUSHAK Irradiator, Lasalgaon for the period from 1-4-2009 till 31-3-2012.

As a part of BARC's collaborative project with Jadavpur University, Kolkata, tests were conducted towards investigation on Master Curve on Charpy, tensile, three point bend and compact tension specimens at temperatures ranging from -150^{o}C to +25^{o}C. The test data generated material J-R curve and associated reference temperature.

To demonstrate the ability of the piping in the nuclear power plants to tolerate defects, many elbows with different crack configurations were tested under combined loading of bending moment and internal pressure. The tests were conducted at SERC, Chennai. Apart from the demonstration of structural integrity, the extensive test data will be useful for studying fracture behaviour of elbow under different loading configurations.

SOCIETAL INITIATIVES

DAE has launched `DAE-Societal Initiative' for utilization of Non-Power Applications (NPAs) and Spin-off technologies (Spin-offs) in the areas of water, land, agriculture, food processing and urban rural waste management. Within this framework, a structured programme called `AKRUTI-KRUTIK-FORCE' was formulated and being implemented by BARC for techno-economic growth of the rural sector, as one of the many schemes for large scale deployment of NPAs and Spin-offs. During the report period, BARC signed AKRUTI Tech Pack Agreements with seven parties for deployment of technologies in rural sector.

INTELLECTUAL PROPERTY RIGHTS

During the calendar year 2010, DAE filed 26 patent applications resulting from both departmental as well as collaborative programmes. This included 7 in India, 5 in European Union, 4 in USA, 3 in Japan, 1 each in Australia, Canada, South Africa, and Russia and 3 under PCT. During this period, 10 of the previously filed patents were granted to the Department. This included 6 patents granted by the Controller of Patents in India, 2 by the USPTO (US Patent & Trade Mark Office) and 1 each by Japan and the European Union.

During the calendar year 2010, four technologies (HWB-1, BARC-2 and IGCAR-1) of the Department were licensed to different Indian companies.

The Ammonia Flue Gas Conditioning System based on the patent held by HWB, earned the highest revenue from licensing so far.

PUBLIC SECTOR UNDERTAKINGS
(Financial Performance)

Financial performance of DAE's public sector undertakings namely, the Nuclear Power Corporation of India Ltd., Uranium Corporation of

Chairman, AEC & Secretary, DAE inaugurates AKRUTI-NIRMITEE

AKRUTI activities

India Ltd., Indian Rare Earth Ltd. and Electronics Corporation of India Ltd. (BHAVINI is yet to commence commercial operations) are given below.

Nuclear Power Corporation of India Ltd.

NPCIL's provisional net profit (PAT) for the year 2010-11 (upto December 31, 2010) was Rs. 715 crore and the expected profit for the year is over Rs. 950 crore. The last year profit was Rs. 416 crore. The improvement in profit is due to better capacity utilization of the operating stations which in turn is due to improved fuel supply from both international as well as indigenous sources.

NPCIL bonds continued to be rated at AAA (highest safety) by CRISIL and CARE.

Uranium Corporation of India Ltd.

During the year 2009-10, the total income of the company increased to Rs.545.38 crore as against Rs.397.29 crore in the previous year, registering a rise of 37.27%. The profit after tax stood at Rs. 46.26 crore against Rs.18.01 crore in the previous year.

Indian Rare Earths Ltd.

During the year 2009-10, IRE's sales turnover was Rs.337.10 crore against Rs.339.75 crore in 2008-09. Profit before tax was Rs.47.81 crore against Rs. 82.88 crore in 2008-09. Also, the company earned foreign exchange of Rs.78.67 crore. Its foreign exchange earnings for the current year (up to October 2010) is Rs.45 crore. The Company paid 20% dividend on the paid-up capital amounting to Rs.17.27 crore for both the financial year 2008-09 and 2009-10.

For the year 2010, IRE expects a sales turnover of around Rs.390.00 crore.

Electronics Corporation of India

Against the annual MoU Target of Rs.1285 crore each of Production and Sales for the year 2010-11, the company achieved a production of Rs.783 crore and a sales (net) of Rs.698 crore upto November 2010 as compared to Rs.524 crore and Rs.457 crore respectively for the corresponding period during 2009-10. The Company is confident of meeting its targets set for the year.

INTERNATIONAL RELATIONS

During the year, India entered into bilateral agreements and MoUs with many countries for cooperation in peaceful uses of atomic energy. Some of these countries are Namibia, Mongolia, the Russian Federation, Canada and others. It had a joint declaration with the United Kingdom on Civil Nuclear Cooperation. India also signed an agreement with the European Atomic Energy Community for cooperation in the field of Fusion Energy Research.

During the report period, the Indian Parliament passed the Civil Liability for Nuclear Damage Bill, 2010 that will go a long way in creating a predictable environment in which leading vendors can participate in India's nuclear programme.

CRISIS MANAGEMENT

The Crisis Management Group (CMG) is a standing committee of senior officials of the DAE who are responsible for coordinating the Department's response to a radiation emergency in the public domain. Such an emergency could be due to events taking place within any nuclear facility, due to an accident involving the transport of nuclear material, due to events at other facilities handling radioactive materials such as hospitals or industries, or even due to any deliberate attempt to cause disruption in public activities, by involving radioactive material.

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.

During the year 2010 the following exercises

were carried out:

1. Communication Exercises	-	305
2. Fire Emergency Exercises	-	76
3. Plant Emergency Exercises	-	58
4. Site Emergency Exercises	-	11
5. Off-Site Emergency Exercises	-	5

The Off-Site Emergency Exercises were carried out in the public domain in the vicinity of nuclear power stations at Kakarapar in Gujarat, Rawatbhatta in Rajasthan, Kalpakkam in Tamil Nadu, and of the heavy water plant at Manuguru, Andhra Pradesh. These Off-Site Exercises were conducted by the concerned district officials (the District Magistrate or Collector is the Off Site Emergency Director) and information flows were established to the CMG as well as to the National Crisis Management Committee of the Union Government.

The Emergency Response System of DAE is also available to respond to a request from any public official in the event of the reported presence or suspected presence of radioactive material. For this purpose, guidelines 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 communications rooms at Mumbai, which are manned on a round the clock basis throughout the year. These have multiple modes of communication and are in constant contact with various nuclear facilities in the country as well as with IAEA in Vienna.

The CMG also provided its expertise in various forums in the field of disaster management at both National and International levels.

BARC-SAFETY COUNCIL

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

To comply with the requirement of licensing/authorization for operation of the variety of radiation installations in BARC, the BARC-Safety Council Secretariat 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, consisting of eminent scientists, continued with the peer reviews of basic research to ensure that highest possible level of excellence is maintained and selected next batch of DAE-SRC awardees.

NATIONAL SECURITY

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

VIGILANCE

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

During the report period, the vigilance functions included timely transmission of various vigilance returns to the Central Bureau of Investigation (CBI), Department of Personnel and Training (DP&T)/Central Vigilance Commission (CVC), issuance of prosecution sanctions, processing of vigilance and disciplinary cases, monitoring of the progress of inquiry proceedings, investigation of complaints and others. In addition, an Annual

Action Plan was worked out by all DAE units.

As per the directives of CVC, Vigilance Awareness Period was observed from October 25 to November 1, 2010 in the Department as well as its Constituent Units, Public Sector Undertakings and Aided Institutions, by taking the vigilance pledge, arranging lectures, essay competitions, quiz competitions, drawings etc. on vigilance awareness. Seminar for promoting vigilance awareness with invited talks on 'Vigilance : An overview', 'Disciplinary proceedings' and 'Vigilance in PSU with Focus on Purchase Procedure' was arranged on November 16, 2010.

PUBLIC AWARENESS

DAE and its organisations continued their efforts towards creating mass awareness about the various programmes of the Department, and their societal impact. DAE organised/participated in exhibitions, seminars, workshops and essays and quiz contests, and brought out information literature on various aspects of nuclear energy.

During the report period, DAE actively participated in the Indian Science Congress with a Mega Expo-Pride of India held at SRM University, Chennai, India Bio-2010 held in Bangalore, 16th All India National Expo 2010 held at Nadia, West Bengal, and 'Science & Technology - Contributions of Indian Scientific Institutions' during the Common Wealth Games-2010 in New Delhi.

DAE's participation in the India International Trade Fair-2010, held at Pragati Maidan, New Delhi projected its achievements in the areas of nuclear power, applications of radioisotopes for societal development, and other segments of the Nuclear Energy Programme.

India Energy-2010, Mumbai, Advances in Nuclear Technology--ADNUTECH 2010 at Anushaktinagar, Mumbai, Swasraya Bharat-2010, Kochi, and the 5th Science Expo at the Nehru Science Centre, Mumbai, were the other exhibitions where DAE participated.

As a part of the Founder's Day celebrations, DAE organised the 22nd All India Essay Contest on Nuclear Science & Technology in October 2010.

An awareness programme on Radiation and Radioactivity, was held for scrap dealers at Mayapuri, Delhi during May, 2010 to enable them

Participants of the 22nd All India Essay Contest in Nuclear Science and Technology

Public Awareness programme at IIT-Bombay Techfest international exhibition

to detect radioactive material that may have been accidentally discarded as scrap.

Besides the above activities, DAE also took part in a number of conferences and seminars.

NPCIL carried out various communication activities for dissemination of accurate and authentic information on nuclear power to different target groups. The Company's website (www.npcil.nic.in) was updated regularly. News article repository system, an internal communication strategy implemented by NPCIL, was uploaded regularly to the company's intranet.

The corporation organised exhibitions to communicate to the public, industry experts, and students, other audience groups, about nuclear power. It set up pavilions in local, national and international level exhibitions to showcase its technical capabilities. Some of the notable participations during the year of report were in AtomExpo in Moscow and at the WANO BGM in New Delhi.

Interaction with students of Tamil Nadu Agricultural University

NPCIL set up a permanent exhibition on “Hall of Nuclear Power”, at Nehru Science Centre, Mumbai to communicate nuclear science in an interactive way, to the general public.

The company also took up a structured programme on public awareness on nuclear power for engineering college students and faculty members. The programme was implemented in over twenty five colleges across the country including IITs in Mumbai and Guwahati.

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

BARC also conducted several public awareness programmes for the benefit of students, teachers and farmers. In all, 16 public awareness programmes were conducted. In addition, media coverage was provided to the various events organized at BARC. An exhibition on 'Thorium Technologies' was held in BARC where books, reports and multimedia resources related to thorium technologies were displayed.

The Institute of Physics was actively involved in popularizing science. The rural programme for scientific awareness through the Samanta Chandra Sekhar Amateur Astronomers' Association formed an important part of the outreach programme at the Institute.

AWARDS & RECOGNITIONS

DAE's organizations bagged a number of awards for efficient operations, safety and environment management.

NPCIL units received several awards for performance, industrial safety, environment protection and other areas.

EXECUTIVE SUMMARY

The Heavy Water Plants were recertified for ISO and BIS standards. Heavy Water Plant, Manuguru was awarded Prashansa Patra-2009 from the National Safety Council of India.

BRIT's Radiation Processing Plant, Navi Mumbai and ISOMED Plant, Trombay both received Accreditation from European Commission and ISO and MACCP based Food Management System certifications respectively.

For their contributions during the decade (2000-2009), two officers of AMD were honoured with AMD-Medals 'Smt. Mantripragad Sita Devi-Sri Rama Rao Medal', and 'Dr. G. R. Udas-Dr. K.K. Dwivedi Medal'.

Two faculty members of the Institute of Mathematical Sciences were elected as Fellow of the Indian Academy of Sciences.

CHAPTER : 1

NUCLEAR POWER PROGRAMME : STAGE - I

Enmasse Coolant Channel Replacement in action

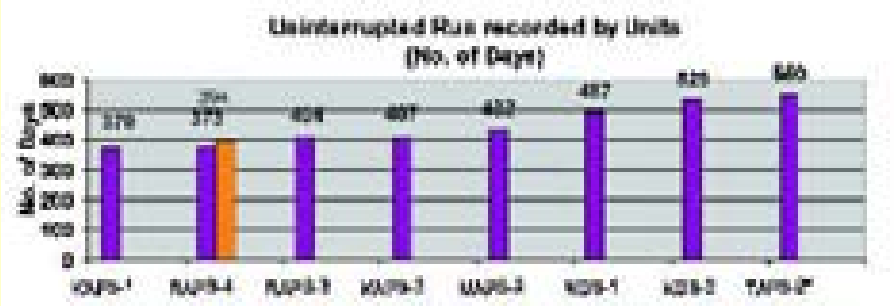
CHAPTER : 1

NUCLEAR POWER PROGRAMME : STAGE - I

PRESSURISED HEAVY WATER REACTORS & LIGHT WATER REACTORS

The Nuclear Power Corporation of India Limited (NPCIL), a public sector undertaking of DAE, is responsible for the design, construction, commissioning and operation of nuclear power reactors and is presently operating 20 reactors with an installed capacity of 4780 MWe.

The Company has achieved significant milestones in the year 2010. The details are given below:



Operating Reactors

Enhanced Power Generation

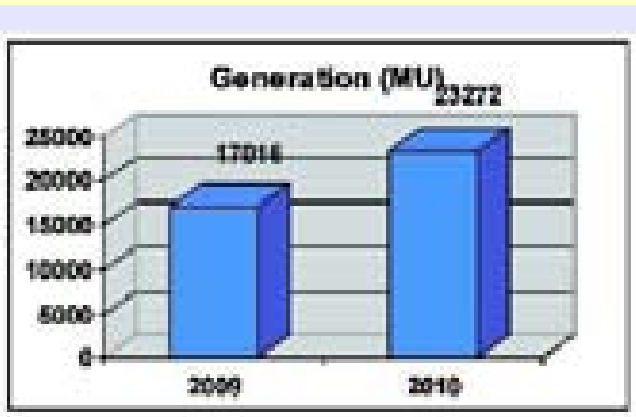
Improved fuel supply position enabled NPCIL to enhance the power generation from operating units. Generation of electricity from nuclear power plants during the calendar year 2010 rose by 37% over the generation in the previous calendar year. The generation was 23272 million units (MUs) during the year 2010 compared to 17016 MUs in the year 2009. The generation upto December 31, 2010 for the current financial year 2010-11 was 18012 MUs. The capacity utilization (CF) during the calendar year 2010 increased to 66% from 56% in 2009.

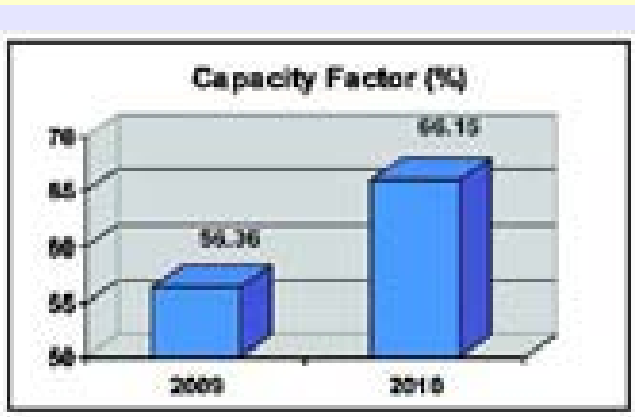
Continuous Operation of reactors

NPCIL continued its journey of operating its reactors continuously without outages by recording continuous operation of more than a year of Madras Atomic Power Station Unit-2 (MAPS-2) and Tarapur Atomic Power Station Unit-2 (TAPS-2). MAPS-2 registered 432 days of continuous run on April 1, 2010 while TAPS-2 continued running since July 22, 2009 (>550 days). So far, in various periods, eight reactors of NPCIL recorded continuous run of more than a year, demonstrating NPCIL efficient plant management.

High Availability Factors (AF)

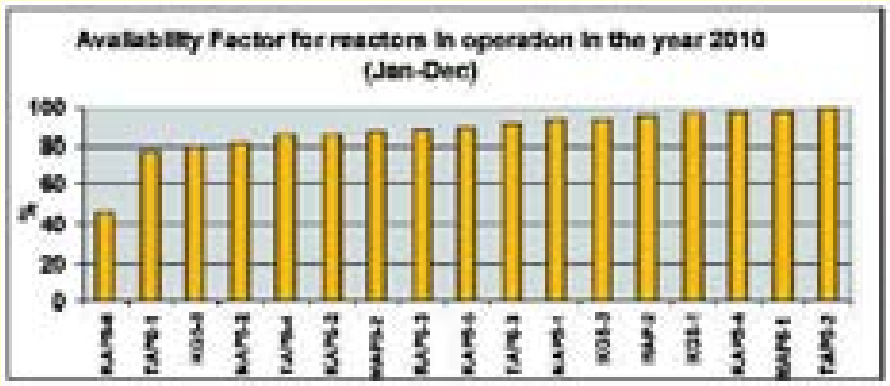
During the calendar year 2010, thirteen of the seventeen operating units achieved AF of more than 85%. The overall availability factor for the calendar year 2010 was 88%. In respect of financial year 2010-11, the overall weighted average





availability factor for the operating stations was 86% upto December 31, 2010.

The unitwise Availability Factors during the calendar year 2010 are depicted below:



Note : KAPS-1 was under shutdown for enmasse coolant channel replacement (EMCCR) and upgradation works. The unit was re- synchronised to the grid on January 12, 2011.

Six reactors RAPS-3,4,5&6 and KAPS-1&2 with a total capacity of 1320 MWe were placed under IAEA safeguards during the year 2010. These reactors have since been fuelled by imported fuel and operated at full power.

The reactors (2840 MWe capacity) fuelled with domestic fuel also showed upswing in the performance in view of improved fuel availability from the domestic sources during the year.

Projects Under Construction

Kaiga-3&4 (2x220 MWe PHWRs)

The project was completed with the commencement of commercial operation of Kaiga-4 on January 20, 2010. Kaiga-3 had commenced commercial operation much earlier on May 6, 2007.

Kaiga Atomic Power Project-3&4, located adjacent to the Kaiga Generating Station 1&2 at Kaiga in Uttar Kannada District, Karwar, Karnataka, was sanctioned in May, 2001. The construction activities of the project were commenced with the start of first pour of the concrete on March 30, 2002.

The power from Kaiga-4 will be fed to the beneficiary states of the southern grid.

Four new indigenously designed 700 MWe PHWRs launched

NPCIL launched four new indigenous reactors of 700 MWe PHWRs, two each at Kakrapar (KAPP-3&4, 2x700 MWe) in Gujarat and at Rawatbhata (RAPP-7&8, 2x700 MWe) in Rajasthan. The construction work related to these reactors were taken up.

KAPP-3&4 (2 x 700 MWe PHWRs)

The construction of Kakrapar Atomic Power Project-3&4 (KAPP-3&4) took off by laying the First Pour of Concrete (FPC)

Dr. Sri Kumar Banerjee, Chairman, AEC, addressing the employees of Kaiga during the event of first criticality of KGS-4

Dr. Sri Kumar Banerjee, AEC chairman, and Dr. S.K. Jain ,CMD NPCIL on the occasion of first Pour of concrete at KAPP-3&4

First Pour of Concrete in progress at KAPP-3&4

on November 22, 2010. KAPP-3&4 is the first twin Reactor of 700 MWe series being launched by NPCIL. Prior to FPC, AERB conveyed its consent for the same on November 20, 2010. The financial sanction for the project was received in October 2009.

The main plant civil construction activities were in full swing on round the clock basis. The excavation was completed in record time of four months. Works were under execution simultaneously for all main plant buildings. First pour of Reactor Building-3 (RB-3) raft was completed in December 2010 and entire raft of RB-3 is expected to be completed by March 2011. The PCC of Nuclear Building-4 (NB-4) and Control Building (CB) was approaching completion. The preparatory works on raft for CB were also taken up and the activity is likely to commence in January 2011. The completion of NB-3 & CB raft and commencement of first pour of concrete (FPC) in Unit-4 is expected by March 2011. The present rate of progress is well ahead of schedule for completion of project in about five years.

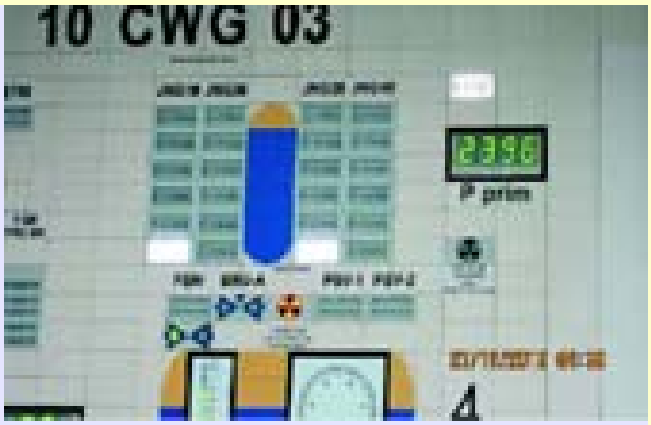
RAPP-7&8 (2 x 700 MWe PHWRs)

Subsequent to the administrative approval and financial sanction from the Government of India and clearance from regulatory authorities, the excavation work on RAPP-7&8 started on August, 19, 2010. It has reached an advanced stage of completion. The preparations for first pour of concrete were in full swing.

Light Water Reactors

Kudankulam Nuclear Power Project (KKNPP) (2x1000 MWe LWRs)

Excavation work in progress at RAPP-7&8



Successful completion of Containment pressure test of KKNPP-1

KKNPP Unit-1 reached advanced stage of commissioning and is expected to be commercial by June 2011 and Unit-2 a year later. The important milestones were : Integrity test of the primary containment at 0.46 MPa. "Hydro test (Strength test) of primary circuit at 24.5MPa of the nuclear steam supply system (NSSS) and Secondary circuit at 10.8MPa were completed in Unit-1. The hot run of NSSS, fuel loading and commencement of first criticality are planned in the first quarter of the year 2011.

In Unit-2, civil construction works were completed for all the buildings. Equipment erection works were also completed and the piping erection works inside the reactor building, reactor auxiliary buildings and turbine buildings were approaching completion stage. Turbine and generator erection was completed and the turbine box-up reached advanced stage.

A view of Kudankulam Nuclear Power Project -1&2

The project achieved overall physical progress of 95.1% (Unit-1: 97.4% Unit-2: 91.5%) as on December 31, 2010.

The Kudankulam project, located in Tirunelveli district of Tamilnadu, is being implemented with Technical Co-operation from Russian Federation within the framework of the Inter-Governmental Agreement signed between USSR and India. The construction of Kudankulam Project commenced on 31st March 2002 with the first pour of concrete, after receipt of the financial sanction in November 2001. The power generated from the project (2X1000 MWe) shall be fed to Tamilnadu and other beneficiary states in the southern grid.

New LWR Projects

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

The Government of India accorded "In principle approval" for 2x1000 MWe units at Jaitapur, Madban village, Ratnagiri district, Maharashtra state in

Open discussion meet at Mumbai on JNPP organised by Maharashtra Government

October, 2005.

Subsequently, to utilize full potential of site, the Government of India amended the "In Principle approval" to 6x1650 MWe units at Jaitapur in October, 2009. Accordingly, 6 x 1650 MWe EPR Units are proposed to be set up at Jaitapur in technical co-operation with M/s AREVA, France.

Techno-commercial offer submitted by AREVA was under final stages. NPCIL and AREVA entered into a General Frame Work Agreement (GFA) and an Early Work Agreement (EWA) on December 6, 2010 covering the Early Engineering Services to be rendered by the AREVA.

Various pre-project activities like geo-technical investigation, survey, boundary marking, boundary wall construction, consultancy contracts etc., were in progress at sites of Main Plant and residential complex.

The Ministry of Environment and Forest (MoEF) granted Environmental Clearance for Jaitapur Nuclear Power Project (JNPP) on November 26, 2010 for Jaitapur Nuclear Power Park (6X1650 MWe). Review of the site evaluation report on JNPP was in progress.

The Rehabilitation and Resettlement (R&R) Agreement was concluded between NPCIL and Maharashtra Government. Several Public awareness activities on the various aspects of Nuclear power and the project were undertaken to dispel misconceptions among the people from surrounding villages of the project , local and national press & media and the various activist groups .

Kudankulam Nuclear Power Project-3&4 (2x1000 MWe LWRs)

The Kudankulam project unit-3&4 is expansion of Unit-1&2, located in Tirunelveli district of Tamilnadu, and is being implemented with Co-operation from Russian Federation within the framework of the Inter-Governmental Agreement signed between Russian Federation and the Government of India in December, 2008.

Techno Commercial Offer (TCO) from Atomstroyexport (ASE), Russian Federation is in final stages of conclusion. A contract for the first priority design works for initial design activities was signed with ASE and the work is in progress. The preliminary activities for finalization of Design and Technical specification for the Indian scope of works were also in advanced stage of finalisation. Tendering for main plant excavation was completed and bids are under evaluation.

Environmental clearance for the project was obtained from the Ministry of Environment & Forest (MoEF). Application for siting consent and excavation consent is under review by AERB

Pre-project activities at Greenfield sites

Pre-project activities including land acquisition were in full swing at the four green field sites viz. Gorakhpur in Haryana and Chutka in Madhya Pradesh, for indigenous 700 MWe PHWRs, and Kovvada in Andhra Pradesh and Chhaya Mithi-virdi in Gujarat for 1000 MWe or higher unit sizes imported light water reactors. These activities included process

In-core repair work in the Calandria Vault of KAPS-1

of obtaining Environmental Clearances including Environmental Impact Assessment Studies by accredited agencies, site investigations, preparation of Detailed Project Reports, setting up site infrastructure etc. and are in various stages of progress at different sites.

Repair & Maintenance of Reactors

NPCIL once again demonstrated its capability and expertise in Enmasse Coolant Channel Replacement (EMCCR), En masse Feeder Replacement (EMFR) & Upgradation jobs of reactors by successfully completing the same at Narora Atomic Power Station Unit-2 (NAPS-2) and resynchronising the unit to the grid in September 2010. Similar work on Kakrapar Atomic Power Station Unit-1 (KAPS-1) was completed and the unit was re-synchronised to the grid on January 12, 2011.

In-core Repair in Calandria Vault of KAPS-1

NPCIL also carried out the leak detection and carried out its successful repair in an inaccessible and complex location of KAPS-1 calandria vault, a high radiation field area, using indigenously developed, innovative and inexpensive remote detection and repair tools. The job involved development of special tooling, inspection techniques, repair techniques, mockup trials, qualification of techniques, actual repair, examination and qualification of repaired areas and testing. The successful leak detection and repair in a high radiation field area (~50,000 rad/hour even during shutdown) demonstrated yet another step forward in India and NPCIL technological maturity and thus bring a distinction of being first ever in the world to take up such work.

Engineering and Procurement

The engineering of the indigenous 700 MWe PHWRs which are based on state-of-the-art in technology, achieved a major success when all the regulatory requirements were satisfied for getting timely clearance for starting excavation as well as first pour of concrete at Kakrapar in Gujarat and for start of excavation at Rawatbhata in Rajasthan.

3-D modeling of the plant which is being done for the first time in NPCIL along with Integrated Project Planning reached an advanced stage during the year.

Purchase requisitions for major equipment and packages were already placed. Manufacturing of critical equipment like Steam Generators, End Shield, Calandria, Reactor Headers, Coolant Channels, Reactivity Devices, Primary Coolant Pumps and Motors, Fuelling Machine Heads, Fuelling Machine Column & Bridge etc for eight units progressed during the year. Tendering actions for other

equipment and packages were in advance stages.

Export Model of PHWR

NPCIL is also working on the Export Model for the single unit plant for 220 MWe and 540 MWe PHWR reactors. Works on their Design Basis Information, layout and other documents along with animation film on construction methodology were finalized.

FRONT END FUEL CYCLE

Heavy Water Production

Heavy Water Plant, Manuguru

During the period of report, the plant achieved a cumulative percentage target of 98.3%. Performance of the plant was affected due to the constrained operation of cooling tower. Subsequent to completion of the revamping job on cooling tower, plant came back to full feed rate. It is expected to meet the targeted production for the year. The Plant was operated with an excellent on-stream factor of 0.98 excluding the turn around period.

As a result of implementation of various energy conservation schemes and also due to stabilization of captive power plant, surplus power was generated and the same is being exported to APTRANSCO. 10.3030 MU of net power export was done through Power Trading Corporation during the reported period.

HWP, Manuguru continued to implement many energy saving schemes such as installation of auxiliary steam turbine, installation of variable frequency drive for identified process pumps, installation of VFDs for the fans of steam generator.

Heavy Water Plant, Kota

Subsequent to commissioning of the DCS system and proper training of the plant personnel in operating the DCS system, the plant continued to operate smoothly. It achieved a cumulative percentage target of 96.5%. Performance of the plant during the period of report was affected due to the constrained operation of cooling tower. Subsequent to completion of the revamping job on cooling tower, plant could come back to full feed rate. It is expected to meet the targeted production for the year.

Erection of all four solar dishes of solar based steam generation system designed for 400 kg/hr steam generation was completed and commissioning activities and data logging by IIT, Bombay to improve performance progressed. As a part of the energy conservation programme, 8 VFDs were installed which resulted in 220 kW power saving.

Auxiliary Turbo-generator was under installation at the Plant to generate 2 MW power by recovering energy from throttling of steam. Implementation of the scheme continued for extracting

Visit of Dr. Baldev Raj, Director, IGCAR on the occasion of withdrawing the first batch of enriched boric acid at Heavy Water Plant, Manuguru

Solar Evaporator for steam generation at the Heavy Water Plant, Kota

of power from high pressure steam.

Heavy Water Plant, HAZIRA

Performance of the Plant was excellent during the report period in spite of the plant taking up a major turn around of about 44 days during April - May 2010. The plant achieved a cumulative percentage target of 106.2%. During MTA HWP, Hazira replaced the DCS in a smooth manner and in the shortest possible time.

Heavy Water Plant, Thal

Performance of the Plant was very good. The Plant achieved around 89.3% of targeted production in spite of low deuterium content in feed gas, interruptions in feed gas supply from ammonia plants of Rashtriya Chemical Fertilizers Ltd. (RCF) and low load operation of one plant for some period, on account of malfunctioning of one of the tower stage pumps and prolonged execution of DCS replacement activity. During the annual turn around, DCS replacement & other major overhauling jobs, including execution of few improvement schemes were smoothly accomplished.

Heavy Water Plant, Baroda

Revived Heavy water Plant, Baroda continued to operate for production of heavy water. Exhaustive maintenance jobs were carried out for the old hyper compressors 20 K4, convertor ammonia cooler 13R2, Cracker condensate pre-heater 16E1 and ammonia vaporizer.

Ammonia Absorption Refrigeration (AAR) system as well as air and nitrogen compressors were taken on high pressure cooling water system from low pressure cooling water system. This change in AAR promises to give higher ammonia absorption in feed water due to extra cooling and generating more refrigeration.

HWP (Baroda) continued to receive 25% exemption in water cess, fourth consecutive year, from Gujarat Pollution Control Board on effluent water as quality of effluent water meets GPCB requirement.

A Solvent Extraction Test Facility was set up at Heavy Water Plant, Talcher for testing the solvents and phosphoric acids for developing relevant processes for recovery of RM from Phosphoric acid by deploying solvent extraction technology. Bench Scale facility was successfully commissioned and was operational for last 4 years. Solvent extraction evaluation of phosphoric acid were carried out for the acid available from RCF, Trombay, TCL, Haldia and IFFCO, Paradeep. Data generated in the Test facility have already been used in design of TDP and preliminary design of first two Industrial scale plant at TCL, Haldia and IFFCO, Paradeep.

Boron Isotope Separation

Based on the data available from BARC, a pilot plant test column with laboratory grade packing was set up and operated at the Heavy Water Plant (Talcher) for process and technology development including identification of appropriate commercial/industrial grade gas-liquid contacting devices. Based on the process and engineering data from this pilot plant and

Boron Exchange Distillation Plant at Heavy Water Plant, Talcher

associated engineering scale test loops, an industrial facility to produce 50 kg/annum enriched boron for PFBR requirement (65% B-10) and 5 kg/annum detector grade Boron (90% B-10) was engineered and set up. This plant has been in stable operation for over last three years at the annual capacity utilization of over 150% and providing the enriched KBF4 at >65% B10 content to the elemental boron plant set up at HWP, Manuguru.

Production of the detector grade enriched boron at >90% B10 content in form of CaF_2-BF_3 complex continued and it was supplied to ECIL and BARC.

Operation of Mixer Settler in Solvent Extraction Facility at Heavy Water Plant, Tuticorin

Heavy Water Clean Up Facility

The technology demonstration facility at Heavy Water Plant, Kota which is aimed at reducing the tritium level in heavy water specifically from moderator loop was under execution. This will help in reducing the internal dose to occupational workers of nuclear power stations and safe recycle of heavy water if required.

Diversification activities at Heavy Water Plant, Tuticorin

Maintenance of the Plant at Tuticorin continued under long term preservation. The available manpower of the Plant was redeployed to other projects and the remaining plant personnel were engaged in establishing the various synthesis routes for production of organo phosphorous solvents and collecting performance data, trial operations of various sizes of centrifugal extractors and for operating a laboratory scale solvent extraction facility.

The bench scale Solvent Synthesis set up here, continued to produce DHOA (purity >99.5%) and supplied it to BARC. High purity TOPO (purity >99.5%) required for bench scale solvent extraction plant, was also synthesized

At the Solvent Extraction Process Development Laboratory, optimisation of various

View of the Oxygen-18 column top condensers at Heavy Water Plant, Tuticorin

parameters for RM recovery from hemi hydrate phosphoric acid produced by Sterlite industries, Tuticorin was continued.

The annular mix type and centrifugal extractors were tested for hydraulic capacity study.

The Heavy Water Plant, Tuticorin continued setting up a Versatile Solvent Synthesis Pilot plant. Synthesis procedure for three solvents TIAP, D2EHPA-II and DHOA were finalised. The data collected from bench scale studies was scaled up for 500 litre reactor that is intended to generate data for setting up of industrial scale solvent synthesis plant in future.

The process development for production of stable isotopes was initiated for separation of O-18 from natural/heavy water. The Experimental Set Up available at Talcher was shifted to Tuticorin. The Test Facility was operated to collect data on O-18 and deuterium enrichment in the distillation column. The data collected during these experiments were used to establish NTS/HETP for special packing, establishment of relative volatility factor for $D_2{}^{16}O$ - $D_2{}^{18}O$ system and effect of temperature on relative volatility.

Sodium Metal

During the experimental production of sodium metal in the prototype test cell at HWP, Manuguru, a number of safety and operational issues and electrical problems were encountered. The National Metallurgical Laboratory (NML) was asked to develop a safe and efficient closed Cell.

At NML, a 100 Amp cell was designed and fabrication & erection of the same was in progress. It will be in operation shortly for the validation of the optimum parameters established during the operation of 50 Amp cell and collection of more data for the design of 500 Amp closed cell.

A tender was floated for the appointment of an engineering agency for providing the engineering support to NML for the development of the closed cell and design, procurement, supply of equipment for setting up a 2000 Amp closed Cell & supervision of erection, commissioning and collection of data during the operation of the same at Manuguru, and finally for the submission of technical report for 20,000 amp closed cell, as a part of the tender document.

Uranyl Nitrate Conversion Facility

The project is taken up as a centralized facility to convert Uranyl nitrate solution from reprocessing plants, into depleted uranium oxide powder as final product. This facility will produce re-usable depleted uranium oxide. Design of the facility was completed and execution of the project has started. Letter of intent for major work was issued and mechanical completion is scheduled in April 2012.

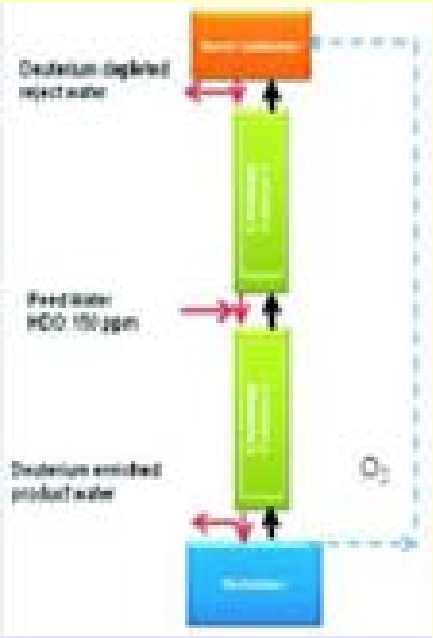
Tri Butyl Phosphate production at HWP, Baroda

Scaled-up Tri Butyl Phosphate plant of 130MT/ year capacity at Baroda is under final stages of commissioning.

Modification work of inter-stage pipelines successfully carried out by BARC in the heavy water upgrading plant to achieve better accessibility as well as operability. Stabilized operation with improved net-positive-suction-head of the inter-stage

TBP plant at Heavy Water Plant, Baroda

Modified Heavy water upgrading plant



Block diagram of CECE process

pumps was established within minimum possible time. Nuclear grade upgraded heavy water product was achieved.

An improved in-house hydrophobic catalyst was developed that can be used in the hydrogen-water isotope exchange column of Combined Electrolysis & Catalytic Exchange unit installed for the enrichment of heavy water. This process has distinct advantage over GS process due to high separation factor and mild operating conditions.

Mineral Exploration

During the period of Annual Programme of work (November 2009 to October 2010) of AMD, a total of 22,466t of uranium oxide was established, making the XIth Plan total of 54,905 t.

AMD continued uranium investigations in the thrust areas for unconformity related various types of mineralisstion. Substantial inputs of airborne and ground geophysical (departmental as well as outsourcing) survey, reconnaissance/detailed radiometric surveys, geochemical survey, and drilling (departmental and contract) helped in identification of the new areas/blocks and delineation of ore bodies.

Exploratory mining was continued for detailed assessment of the ore body at Gogi, Gulbarga district, Karnataka.

In addition, pegmatite belts of Chhattisgarh and Orissa for the rare metals and sand bodies of coastal stretches (east and west coast) and lake sediments of Tamil Nadu were targeted for

Electrolytic Cell of Combined Electrolysis Catalytic Exchange unit

Six mm raschig ring shaped hydro phobic catalyst (earlier catalyst) and (right) 3 mm SS Dixon ring supported hydrophobic catalyst Improved Catalyst

augmentation of rare metals and heavy mineral resources of the country.

Some of the significant highlights of the achievements during the period November 2009 to October 2010, are summarized below:

Uranium Investigations

Ground radiometric surveys

Reconnaissance (3837 sq km) and detailed (236 sq km) radiometric surveys resulted in locating new uranium anomalies/extension of known occurrences in the following geological environs:

North Delhi Fold Belt, Rajasthan : Uranium anomalies associated with pink granite gneisses at Bichun, foliated grey granite gneisses at Nayagaon, quartzo-feldspathic rock near Sakhun and with pink granite at Bandola Ki Dhani Ajmer/Sikar districts. Metamict Davidite bearing albitite over 1.7 km was identified near Bichun in BGC.

Garhwal Syncilne, Uttrakhand : Associated with calcareous mudstone (top horizon of Krol Formation) at Phulari, Shivpuri and Bawani, Tehri-Garhwal district.

Gondwana Group, Chhattisgarh : Uraniferous anomalies were located near Munuva, Kundi, Ginwar and Singhara. These were associated with Talchir sediments and underlying crystalline complex in Surguja district.

Bhima Basin, Karnataka: Uraniferous anomalies associated with grey granite, granite cataclasite and grey sandstone were located along Achhola Fault zone near Gogi, Gulbarga district.

Geochemical Surveys

Geochemical surveys (hydro, litho and pedo) were carried out (846 sq km) for delineating the target areas for detailed investigations. The important anomalous areas identified were:

- Makrumunda-Jaipur area, Bargarh district, Orissa
- Phalodi-Lohawat tract, Jhodhpur district, Rajasthan
- Jamsar-Kolayat area, Bikaner district, Rajasthan

Airborne survey and Remote Sensing

Heliborne geophysical survey comprising of electromagnetic, magnetic and radiometric systems, was carried out over Kaladagi-Badami block, Sonrai-Bijawar block, North Singhbhum block and Cuddapah block (northern part). A total of 39,938 line km was achieved against a target of 89700 line km. The Quality Assurance and Quality Control (QAQC) were done. The acquired data was of good quality. Preliminary interpretation of raw images (radiometric, magnetic and EM) indicated broad geological entities. Further interpretation was in progress.

Ground Geophysical surveys

Ground geophysical survey (Departmental: reconnaissance-13.70 sq km and detailed- 6.04 sq km; Outsourcing: detailed- 69 sq km) was carried out in parts of Rajasthan, Karnataka, West Bengal and Haryana. Following are the details.

Hurra Ki Dhani - Maota tract, Sikar district, Rajasthan : Magnetic image revealed relief difference in granite and metasediments and distinct linear magnetic high attributable to amphibolites bodies. Six chargeability anomalies associated with low resistivity were identified by IP/resistivity data and the targeted borehole has intercepted sulphide mineralisation.

Kerpura - Salwari tract (NDFB), Sikar district, Rajasthan : Magnetic image indicated three major linear magnetic features trending N-S, NW-SE and ENE-WSW attributable to amphibolites/pyroxenite bodies. Five chargeability zones were delineated, which were important for exploration when associated with resistivity zones.

Ground geophysical surveys comprising magnetic, IP/resistivity and transient electromagnetic (TEM) methods were carried out on outsourcing basis in the following areas and technical reports were under evaluation.

- Gogi-Darshnapur-Ukinal and Kanchankayi-Halbhavi-Muktapur sectors, Gulbarga District, Karnataka.
- Kharidungri-Porapahar area, Bankura District, West Bengal.
- Kusumjharia-Amghata area, Purulia District, West Bengal.

Koppunuru-Bodlaveidu area, Guntur District, Andhra Pradesh.
Gandi-Madyalabodu area, Cuddapah district, Andhra Pradesh.
Nizampur- Ghatasar area, Mahendragarh District, Haryana.

Augmentation of Geophysical facilities

(a) IP/resistivity system (Iris Instruments, France) with 10 kw transmitter procured, installed and commissioned.

(b) TDEM equipment (Alpha Geoscience Pvt. Ltd., Australia) with state-of-the-art technology was procured.

(c) Long pending installation of Multifunction Transimitter-Receiver system (Phoneix, Canada) was completed after replacement of faulty 40 kw generator.

Drilling

A total of 2,17,548m (Departmental: 74,460m and Contract: 1,43,088m) drilling (reconnoitory, exploratory and evaluation) was carried out during the 2009-10 field season to establish (a) additional uranium resources in the known occurrences and (b) sub- surface continuity of mineralisation in the new promising areas.

Departmental drilling target was achieved (110%) due to effective implementation of two shifts drilling in 20 rigs. However, the shortfall in contract drilling (143088.15m against the target of 2,69,220m) was mainly due to adverse logistic and local problems.

The exploratory/evaluation drilling established an additional ore reserve of 22466 t uranium oxide as detailed below:

(i) Additional uranium reserves of 18,306 t U_3O_8 were established in Tummalapalle and its extensions, Kadapa district, Andhra Pradesh.

(ii) Additional uranium reserves of 2,233 t U_3O_8 were established in Chitrial, Nalgonda district, Andhra Pradesh.

(iii) Additional uranium reserves of 601 t U_3O_8 were established in Rohil, Sikar district, Rajasthan.

(iv) Uranium reserves of 573 t U3O8 in Wahkut and 753 t U_3O_8 in Umthongkut, West Khasi Hills district, Meghalaya were established during this year.

Exploration in the extension/new areas

Significant mineralised intercepts / bands during the field season are listed below:

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

Chitrial, Nalgonda district, Andhra Pradesh: Uranium mineralisation was intercepted close to the unconformity between Srisailam quartzite and basement granite in Chitrial Main Block.

Rohil, Sikar district, Rajasthan: Correlatable uranium mineralisation was established in Rohil Central block and Rohil North block.

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

Gogi-Darshnapur, Gulbarga district, Karnataka: Uranium mineralisation was intercepted in the hangwall and footwall side, associated with brecciated granite in the Gogi uranium deposit.

Koppunuru, Guntur district, Andhra Pradesh: Correlatable uranium mineralisation was intercepted close to the unconformity between Banganapalle quartzite and basement granite and within the Banganapalle quartzite.
Deshnur, Belgaum district, Karnataka: Correlatable uranium mineralization in the

basal arenite was recorded at Deshnur, Kaladgi basin, Karnataka. Pitchblende, uraninite and coffinite were identified as main radioactive phases in the ore body.

Dumhath, Surguja district, Chhattisgarh: Correlatable uranium mineralisation associated with brecciated granite/ granitic pegmatite intercepted in boreholes.

Nalpani, Rajnandgaon district, Chhattisgarh: Correlatable uranium mineralisation associated with Bortalao sandstone of Khairagarh Group intercepted in boreholes.

Raghunathpura-Rambas-Gorir-Dhancholi sector, Mahendragarh district, Haryana: Uranium mineralisation associated with altered metasediments (albitised calc silicate rock) along the major fracture, was intercepted in boreholes.

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

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

Exploratory Mining

Exploratory mining at Gogi, Gulbarga district, Karnataka had commenced in June, 2007 on contract for underground development work.

During the current field season, 59m shaft sinking was developed and cumulative progress of 181m in shaft sinking was achieved.

Rare Metal and Rare Earths Investigations

Reconnaissance (210 sq km) and detailed (4.66 sq km) surveys resulted in location of new occurrences of columbite-tantalite and Beryl bearing pegmatites at Gaurpara, Gurlabahal and Kendupara in Jharsuguda and Sundargarh districts, Orissa.

Additional reserves of 3015 kg of columbite-tantalite were estimated in the pegmatites of Baghpara (Jharsuguda district, Orissa), Kotwalpara (Dantewara district, Chhattisgarh) and Sukopara (Bastar district, Chhattisgarh)..

The production of columbite-tantalite and recovery of beryl as by-product continued in the field units at Pandikimal and Jangapara in Jharsuguda district, Orissa and at Bodenar in Bastar district, Chhattisgarh as detailed below:

2180 kg of columbite-tantalite produced at Pandikimal,

1265 kg of columbite-tantalite produced in Bodenar, and

3200 kg of beryl was recovered as by product at Pandikimal.

Beach Sand and Offshore Investigations

Surveys (Reconnaissance - 229 sq km) and exploration (drilling, sampling and evaluation) were continued along the coastal tracts of Orissa, Gujarat, Kerala and Tamil Nadu for identifying the additional beach sand heavy mineral resources.

1312 boreholes (4480m) were drilled in a grid pattern, and 3417 individual and 25 composite samples were generated. Bulk samples were processed for separation of Monazite and Zircon.

A total of 3888 individual samples and 162 composite samples were analyzed for slime, shell and total heavy mineral contents. Grain Counting was carried out on 118 composite samples during the period.

The following potential Heavy Mineral Zones were delineated:

Machiwada and Onjal in Tapi-Par river Valsad and Navsari districts, Gujarat.

Nechanpur and Bagda in Nunia and Panchpara rivers, Balasore district, Orissa.

Nileswaram and Chandragiri river mouth, Kasargod district, Kerala.

Bordi and Dahanu coast over 12 km long sand body, Thane district, Maharashtra.

Lake sediments, Nammakal

district, Tamil Nadu.

A total of 58.88 MT (ilmenite 42.94 MT, rutile 2.29 MT, monazite 0.49 MT, zircon 3.99 MT, garnet 3.63 MT and sillimanite 5.54 MT) of beach sand heavy mineral resources were estimated during XI Plan. The country's total heavy mineral resources were updated to 942.58 MT.

Heavy Mineral Deposits Draft Reports

Draft reports on beach sand heavy mineral deposits of Tandava-Varaha deposit Phase-III and Amalapuram deposit Phase-I&II of Andhra Pradesh, Karimanal-Kazhakkuttam sector, Kerala and Cuddalore-Pudupattuchavadi sector, Tamil Nadu were completed. Preparation of seven reports-two deposits of Andhra Pradesh, one deposit of Orissa, one deposit of Tamil Nadu and three deposits of Kerala were in progress.

Mining & Mineral Processing

The Uranium Corporation of India Ltd. (UCIL), a public sector enterprise of DAE, produces uranium required for the Pressurized Heavy Water Reactors (PHWRs).

UCIL operates 5 underground mines (Jaduguda, Bhatin, Narwapahar, Turamdih & Bagjata), 1 open cast mine (Banduhurang), 2 processing plants (Jaduguda and Turamdih) all in Jharkhand state. To meet the increased demand of uranium, the company has taken up construction of Mohuldih Uranium Mining Project in the Saraikela-Kharsawan district of Jharkhand.

During the report period, Turamdih Processing Plant's expansion continued, construction work of Tummalapalle Uranium Mining & Milling Project at Andhra Pradesh was approaching completion, and expansion of Tummalapalle Uranium Project and a new Uranium Mining And Milling Project at Gogi in Karnataka were under pre-project stage.

UCIL also proposed to take up Uranium Ore Mining and Milling Project at Lambapur in Andhra Pradesh and Uranium Ore Mining And Milling Project at Kylleng Pyndengsohiong, Mawthabah in Meghalaya for which pre-project activities were started. The project construction would start after due approval from the Government of India.

At BARC, production of uranium metal ingots for research reactor Dhruva and Purnima Sub-critical facility requirements continued. A project report for the production of specific grade depleted U-metal for DRDO was prepared and reviewed. Efforts to enhance the production capability of natural uranium for PHWR programmes from various ores continued. Necessary engineering and scale-up data for setting up the uranium mill at Tummalapalle (Andhra Pradesh) and Gogi (Karnataka) were generated. Studies continued for uranium ore samples from other locations such as Rasimalai and Umra. A laboratory process was developed for recovery of rare earths such as yttrium, erbium and other heavy rare earths from concentrated phosphoric acid 'Merchant Grade Acid (MGA)' in di-nonyl phenyl phosphoric acid+tri-n-octyl phosphine oxide (DNPPA + TOPO) system as a by-product of uranium separation. The final product was >99% pure. An alternate precipitation route employing sulphamic acid yielded a product of >99.5% purity.

Nuclear Fuel Fabrication

The Nuclear Fuel Complex (NFC) carried out production of natural uranium oxide fuel bundles for PHWRs, enriched uranium fuel assemblies for Boiling Water Reactors, reactor core structurals, reactivity control mechanisms and special materials like tantalum, niobium etc. In addition, for Fast Breeder Reactors, NFC produced all the core sub-assemblies and other critical components such as fuel cladding tubes, hexagonal wrapper tubes etc., made out of special stainless steels/D9 materials. NFC also catered 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.

A Software for online nuclear material accounting and material processing data was introduced in

Dispatch of fuel for KAIGA-4

safe guarded assembly plants for ease of Advance Short Notice Inspections by IAEA. Fresh requirement of fuel for KAPS-1&2 was successfully met.

With magnesium di-uranate (MDU) from UCIL, 19-element & 37-element fuel bundles required for the reload fuel requirement of the operating PHWRs and initial core requirement for NAPS-1 and Kaiga-4 was met by reducing the conversion time from raw material receipt to manufacture of fuel bundles. Process parameters were optimised for processing the MDU supplies of UCIL from Turamdih mill so as to obtain excellent sintered density recovery (>90%) of produced UO_2 powder. Fuel pellets with central hole were fabricated and one fuel bundle with these pellets was fabricated for carrying out modelling studies under LOCA conditions. Requisite numbers of BWR fuel bundles were manufactured and sent for TAPS-1 to meet the reload requirement.

At the Fast Reactor Facility (FRF) of NFC, manufacturing of 2 nos. of carrier sub assemblies (16mm bore) were carried out for FBTR. Fabrication of 10 nos. of 22mm bore & 28 nos. of 16mm bore carrier subassemblies and 10 nos. of steel reflector subassemblies reached an advanced stage. About 28,000 sets of PFBR fuel pin components required for fabrication of MOX fuel pins were dispatched to Advanced Fuel Fabrication Facility (AFFF). Manufacturing of various subassemblies and subparts for some subassemblies for 500MWe PFBR was in progress.

All the equipment required for final assembly of subassemblies for PFBR were procured and were under erection at the Interim Fuel Storage Building of IGCAR.

A Pellet Loading Facilitator was developed for convenient, fast & simultaneous loading of multiple stacks of pellets into the close-fitting PHWR fuel tubes. An offline setup based on the principle of flexible screw conveying was installed to demonstrate the automatic handling of ADU powder to the calcination furnaces.

International patent application was filed for the work 'Modified solvent extraction process for producing high purity rare metal oxide powder for zirconium and the like'. 40% reduction in generation of solid

Pellets with central hole

Indigenously developed HPTR 10-20 pilger mills

effluent (MgCl2-Gr.II) at Zirconium Sponge Plant was achieved by modifying the process parameters of Vacuum Distillation.

Commissioning of sponge production facility at Zirconium Complex, Pazhayakayal was completed and trial production was started. Data generated during this trial production was presented to AERB for obtaining operation consent.

Experiments were carried at special materials plant for electron beam purification of Nb-1% Zr-0.1% C alloy prepared by open alumino thermic reduction at BARC. Civil works were started for the production facility of niobium at NFC to meet the requirement of ISRO.

Zr-Nb quadruple melted ingot weighing more than 5MT was produced for the first time. Two nos. of indigenously developed twin head HPTR 10-20 pilger mills were commissioned which enhanced the production of fuel tubes. Forging route for fabrication of Zr-2.5%Nb pressure tubes for 500MWe PHWRs was successfully developed to get superior microstructural characteristics compared to tubes made from the previous fabrication route using hot extrusion, as a major step.

Hexcans were manufactured at special tubes plant by developing hexcan to hexcan pilgering route instead of pilgering circular tubes to hexcan so as to reduce micro hardness variation across the cross section. Also, a 6-15 HPTR pilger mill was fabricated in house to meet the requirement of fuel tubes for PFBR by incorporating many modifications to increase efficiency, dimensional accuracy and ease of maintenance. Tool design was modified to produce square channels which met all the specifications for ?A' category. Trials carried out to develop Zr-2.5Nb heat treated pressure tubes for AHWRs with a view to enhance diametral creep resistance under the guidance of a task force setup for this purpose are giving encouraging results.

After successful technology development for producing the oxide dispersion strengthened fuel clad tubes required for higher burnups in future FBRs, full length tubes were successfully produced and handed over to IGCAR for further studies.

Old pilger mill HPT32 was revamped completely by incorporating state-of-the-art-technology of double feed & double turn in place of the existing single feed & turn mechanism along with continuous autoloading of tubes which increased productivity substantially.

HPTR 15-30 pilger mill was modified for incorporating additional feature of production of tubes by wall as well as OD reduction. In addition, modifications were carried out to replace the existing single feed & turn mechanism with double feed

& turn which would result in increased productivity as well as flexibility in producing a wide range of tubes for different types of reactors demanding different metallurgical requirements.

Proposal was sent for obtaining cabinet sanction for setting up PHWR fuel & zircaloy fabrication facilities at Kota, Rajasthan.

Following developments are expected shortly :

Incorporating equipment and process modifications at zirconium oxide plant for further increase in overall plant recovery by 6%.

50% reduction in the Sodium Nitrate liquid effluent generation by process modification.

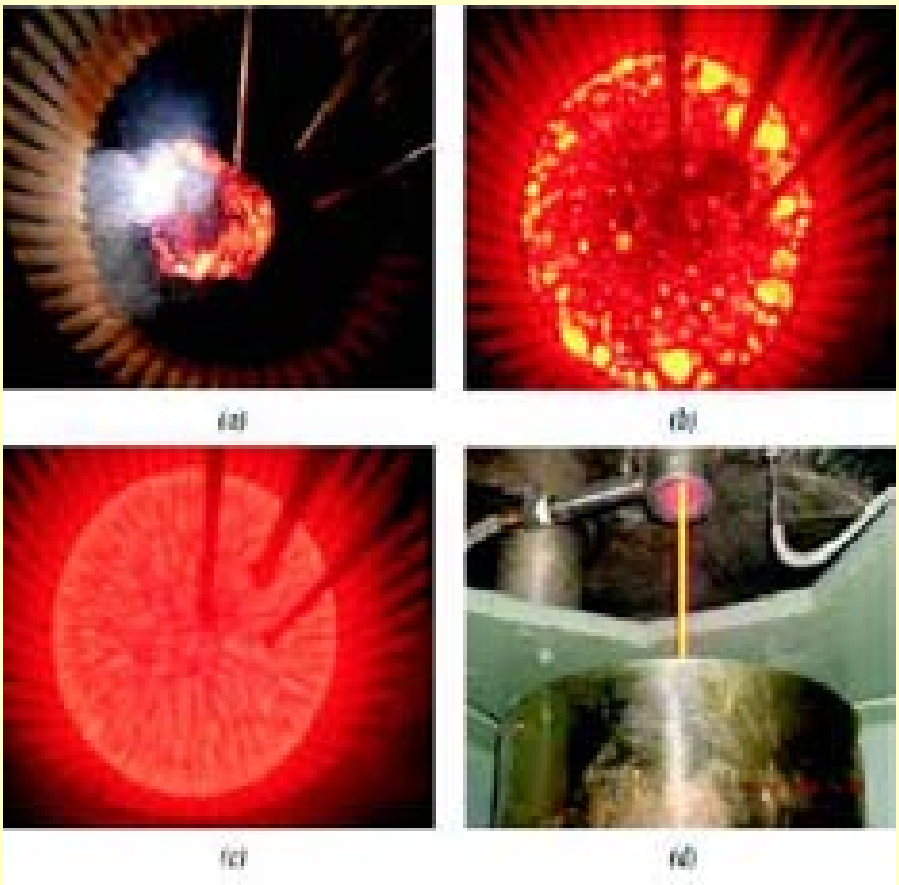
Installation and commissioning of Glass bead shot peening Unit and Gauge Blocks for production and testing of UNS 8800 U bend tubes for 700MWe PHWRs.

Supply of balance D9 core structural tubes for PFBR.

BACK END FUEL CYCLE

Fuel Reprocessing & Waste Management

To study the retention behavior of fluorine during vitrification in Barium borosilicate glass, a nondestructive method of analysis was standardized using Particle Induced gamma ray emission (PIGE) at folded tandem ion accelerator (FOTIA), BARC. The method was validated.



(a) start-up heating (b) glass heating
(c) glass soaking (d) glass pouring

Different stages of CCIM operation

To assess the long-term radiation damage behavior of nuclear waste glasses, irradiation studies using γ–rays, electron beam and heavy ions namely ^{12}C and ^{4}He were carried out on alkali based barium borosilicate glass matrix. The samples after irradiation were characterized by Time Resolved Fluorescence, Electron Paramagnetic Resonance (EPR), Positron Annihilation Lifetime, FTIR and HR Micro-Raman spectroscopic techniques. Defect centres formed on irradiation in the glass matrix were identified as (i) boron oxygen hole centres (BOHC), (ii) oxygen (Oxy) and silicon defect centres (HC1) and (iii) E centres. Positron annihilation data suggested overall increase in the free volume space in the glass sample after irradiation.

Waste Management Facilities at Trombay and Kalpakkam operated safely for collection, segregation, storage and treatment of radioactive waste. Discharge of activity to the

environment was kept well below the prescribed limits set by regulatory bodies.

At Waste Immobilisation Plant at Trombay works on waste concentration system were completed and testing of the systems was taken up. The plant continued to receive fresh High Level Waste (HLW) of specific activity of 100Ci/l. After obtaining safety clearances, arrangements were made to receive thorium lean raffinate waste at WIP from Uranium Thorium Separation Facility (UTSF). Construction clearance for treatment of Intermediate level waste was obtained and further work was started. The transportation of vitrified waste product from WIP, Trombay to SSSF, Tarapur for interim storage is continued. An Incinerator for radioactive solid waste at BARC was refurbished and commissioned. A volume reduction factor of hundred was achieved and the airborne activity during the incineration was below detection limit indicating effectiveness of air treatment system. Installation and testing of Resin Fixation Facility for conditioning of spent resins in polymer matrix is nearing completion at BARC. The facility has incorporated process for immobilization of spent resins in specific cement.

At the Central Waste Management Facility, Kalpakkam, a new facility for retrieval, volume reduction and disposal of stored pressure tubes, was designed and its procurement is in progress. A facility for melt densification was in continuous use for treatment of plastic/polythene waste. Based upon the experience gained from the facility, a new scaled up facility with certain modifications is being set up. Air cleaning services for insitu testing of HEPA and iodine filter banks were provided at Trombay, Tarapur and Kalpakkam. Spent radiation sources received from all over the country from various users are conditioned and disposed off safely at Trombay and Kalpakkam.

Feasibility studies were initiated for vitrification of high level waste from AHWR & Fast Reactor Fuel Cycle Facility (FRFCF) in sodium borosilicate glass matrix. Irradiation of typical sodium borosilicate glass composition to study long term radiation stability of glass matrix with respect to Alpha and recoil damage was completed. Thermal property of acid and molten glass resistant refractory material was enhanced by addition of bubble alumina. Development work continued on cold crucible induction melter technology for vitrification of high level waste (HLW). Engineering scale studies using 500 mm diameter crucible were carried out. Development of industrial scale melter is in progress. Gas tight version of articulated manipulators were developed to international quality and sixteen such arms were manufactured. Oblong shaped melter for vitrification of HLW was developed and tested. This melter will increase throughput of vitrification plant. Engineering demonstration facility for partitioning of actinides from HLW & spent solvent treatment was set-up at SSSF, Tarapur. Control room related I&C system was installed and the integrated testing of these systems was carried out. Studies on optimization of process parameters for separation of various components of the waste using commercially available extractants were taken up and the results are encouraging.

A laboratory process based on biodegradation was developed for treatment of nitrates upto 28000 ppm. The biodegradation pilot plant for treatment of nitrates upto 3000 ppm is in continued operation to generate engineering scale data. An Underground Research Laboratory (URL) was planned at a captive site and bore hole drilling upto 1200 m was completed for assessment of various parameters.

Based on these investigations subsurface location meeting requirements of an URL were identified. Safety Assessment of Solid Waste Management Facility (SWMF), Kakrapara was carried out and based on the report, regulatory clearances were obtained for disposal of radioactive solid waste generated from KAPP 3&4. Safety Assessment for SWMF, Kota is also in progress for licencing purpose for disposal of radioactive waste generated from RAPP 7&8. Clays from specific site is being characterized for its use as a backfill material in

Geological Repository. Separation and purification of 90Y using supported liquid membrane based 90Sr 90Y generator system was continued for supplying carrier free 90Y for medicinal use. Techniques for quality control of the recovered 90Y were also developed. Studies on U+4 production using platinum catalyst are in progress. Use of hydrogen and PtO2 (Adam's Catalyst) in place of hydrazine for reduction of uranyl nitrate improves the kinetics of the reaction.

Projects such as PRTRF and AWTF at Trombay, FRFCF at Kalpakkam and LLWMF at Vizag progressed.

A laboratory process for synthesis of cesium selective Calix-crown-6 was optimized from indigenously developed intermediates/ precursors at bench scale. The purity of the product was more than 99%. A process for separation of trivalent actinides (241Am) from lanthanides using diaza-diamide (DADA) solvent was optimized from strip aqueous of TEHDGA-Actinide partitioning process. Encouraging result of strontium separation was obtained when TEHDGA was used for separation of strontium from raffinate of actinides partitioning from actual HLW.

HEALTH, SAFETY& ENVIRONMENT

During the report period, following were the activities of the NPCIL in the fields of health, safety and environment:

Environmental Management System Implementation

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 by NPCIL at all the nuclear power stations. 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 occupational exposures of employees of the company at various NPPs were maintained well below the values specified by the regulator, Atomic Energy Regulatory Board (AERB). The environmental releases of radioactive effluents from NPPs were maintained significantly low (average less than 1% of the limits specified by AERB).

Safety Reviews

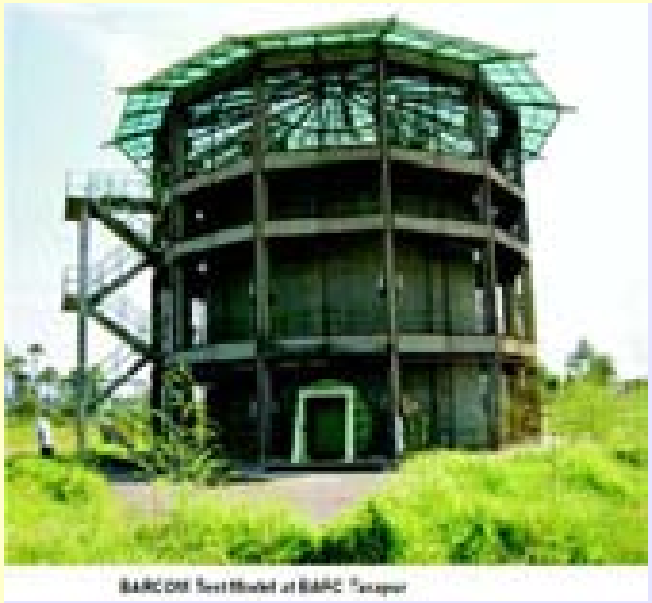
In line with the commitment of practicing the international safety standards, KGS-1&2 was opted for peer review by the international agency World Association of Nuclear Operators (WANO) and the same was carried out successfully. WANO Peer Review of TAPS-1&2 is planned in January, 2011. During the year, the Corporate Review was carried out for TAPS-1&2, TAPS-3&4, RAPS-1&2, RAPS-3&4, NAPS, KAPS and KKNPP. The Corporate review of KGS-1&2, KGS-3&4 and RAPS-5&6 is planned during period January to March, 2011.

Review of post closure safety assessment of Near Surface Disposal Facility (NSDF), Kakrapara Atomic Power Station was carried out. In the area of industrial and fire safety. The continual strengthening of Industrial & Fire Safety activities in NPCIL was the main focus during the year 2010-11. NPCIL plants received prestigious industrial & fire safety awards from National Safety Council, Central Labor Institute and Regulators.

Reactor Safety Analysis

The Preliminary Safety Analysis Report (PSAR) of the first 700 MW, KAPP-3&4 and the Final Safety Analysis Report (FSAR) of the last 220MW Project, KGS-3&4 were completed. Radiological Impact Assessment following the postulated DBA for proposed 700MWe PHWR for RAPP-7&8, Haryana and Madhya Pradesh sites were carried out and the estimated doses at respective exclusion radius during such unlikely event was found to be well within the AERB reference dose level.

Detailed containment studies were done for upcoming 700MWe PHWR projects. For efficient time management, system thermal hydraulic code ATMIKA and containment



First Appearance of Crack at MAL with Soap Bubble Test in BARCOM Test Model during Over-Pressure Test

system response code PACSR was integrated. For the first time, Integrated Leak Rate Test procedure for Steel-lined containment was prepared for 1000MW, Kudankulam-1&2.

For 700MWe PHWR, as part of PSAR requirement, comprehensive large break Loss of Coolant Accident (LOCA) analysis was completed. The analysis demonstrated adequacy of safety systems and availability of large safety margins.

NPCIL developed an innovative decision making tool, Symptom based Intervention Guidelines Management System (SIGMAS) for the plant operators under emergency conditions, which was implemented in RAPS-5&6. Analysis for dispersion of H_2S from Heavy Water Plant Kota, its impact on RAPP-7&8 site and its counter measures were also completed.

For the ultimate load capacity assessment of prestressed concrete containments used in NPP's, a 1:4 size BARC Containment (BARCOM) Test Model representing 540 MWe PHWR inner containment was constructed at Tarapur site. After checking the performance of the sensors by progressively pressurizing the model to design pressure (Pd) of 1.44 kg/cm^2, it was subjected to over-pressure

Glove box on Shake-table

Image analyser system

High sensitivity radon monitor

Portable radon monitor

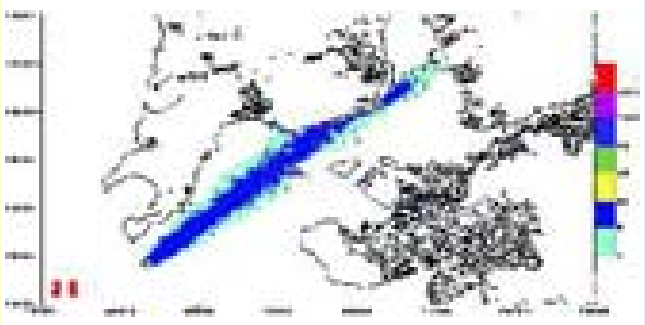
Powder sandwich technique set up for measurement of thoron emanation

test till the milestone "first appearance of crack" was realized. This occurred at a pressure of 0.2207 MPs (1.56 Pd) and was recognized by inelastic strains developed in the discontinuity regions of Main Air Lock and Emergency Air Lock and was further confirmed with soap bubble test during depressurization. Data collected was compared with analytical and numerical predictions with in-house code ULCA (ultimate load capacity assessment) and the results obtained from various International Round Robin Participants at 69 Specified Sensor Locations.

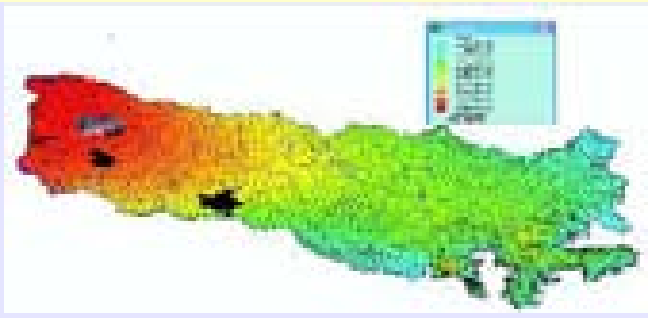
Seismic qualification tests were performed on different configurations of glove boxes viz. single glove box, glove box train and double module glove box. It was concluded that the glove boxes could safely withstand a ground acceleration of 0.2 g and could withstand higher acceleration if anchored and properly interconnected.

Dose response curves for cobalt-60 gamma rays (025 Gy) for induction of rings and fragments were established for the estimation of accidental exposure using Premature Chromosome Condensation (PCC) assay, which is a simpler and faster dose assessment technique. This technique in conjuction with the standard dicentric analysis technique was used for the biodosimetry of Mayapuri accident victims.

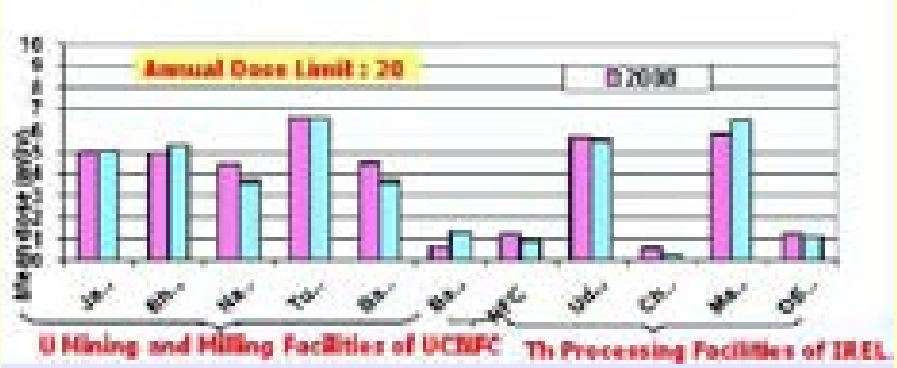
In order to meet the growing demand of radon and thoron monitoring in nuclear fuel cycle facility and the environment, different types of application specific online radon and thoron monitors were developed. Radon monitors are based on both electrostatic and scintillation cell techniques while thoron monitor is based on background compensated dual scintillation cell techniques. These instruments have high sensitivity, are cost effective and have no interference from humidity and trace gases. Performance of these monitors was tested both in the laboratory and in the field.



Theoretically evaluated Iso-contours of oil concentration 36 hours after the spill



Simulated groundwater heads in the study region



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

A new method, called Powder Sandwich technique was developed for correct estimation of thoron emanation coefficient for thorium bearing powders associated with thorium fuel cycle. The technique utilizes a closed loop setup in which thoron emitted from a thin layer of sample in the 'powder sandwich' was measured using suitable thoron detector and the mass exhalation rate was determined. The specific radium content was determined by sealing the powder sandwich and achieving secular equilibrium for the thoron progenies, followed by gamma counting. The emanation coefficient was then estimated using these two measured parameters.

Negative ionizer based activity concentration reduction method was validated in controlled chamber and room environments with observed concentration reduction factors of 3-5. Negative Ion Generators (NIGs) were employed in the thorium oxalate storage area at the Indian Rare Earths, Alwaye, which was characterized with an uncontrolled ventilation pattern and large source term.

Personal monitoring services for external radiation are provided to about 23,000 radiation workers in DAE through the BARC Laboratories at Trombay, Tarapur, Kolkatta and Hyderabad. Personal Monitoring of non DAE radiation workers is provided through Laboratories accredited by BARC. Quality control of all the Accredited Laboratories is regularly maintained. Personal monitoring service to a few institutions of a neighboring country was also provided.

Personal monitoring services for external radiation to the workers of nuclear power plants, were transferred to NPCIL from April 2010 subsequent to class room training and on the job training for six months at different NPP sites. Technical support required by TLD monitoring laboratories at different NPP sites was provided by BARC.

In order to assess the impact of oil spill incident occurred on August 7, 2010, off Mumbai coast, continuous analysis of oil & grease was carried out in sea water samples collected at intake point of CIRUS Jetty and the data was provided to Maharashtra Pollution Control Board. Additional environmental survey was carried out three times along the coast line of Mumbai harbour bay from Vashi Jetty to Uran and collected sea water, sediment and biota samples.Parameters analyzed included oil & grease,

Interior of system with 3 GM tubes

Complete system with Solar Panel GM tube

water quality, polycyclic aromatic hydrocarbons (PAHs), pesticides and trace elements. The problem was studied theoretically also.

Field and laboratory based hydrogeological investigations were carried out in and around the proposed uranium mining and tailings pond sites in Lambapur, Pedagattu and Seripalli watersheds in Andhra Pradesh. The site-specific data thus generated was used to model the groundwater flow in the region and transport of U-238 and its progenies from the tailings pond to estimate the radiological impact assessment of the tailings disposal. The finite element based subsurface model, FEFLOW was used for the study. Results showed highest groundwater head in the western margin which gradually decreases towards the east. Groundwater velocity over the study region varies from 0.01 m/day to 0.1 m/day. It was shown that the radiological impact of the proposed uranium tailings pond was trivial up to a period of 2000 years, and is of no concern after this period. The maximum dose that may be received by the members of the public through the groundwater drinking pathway worked out to be about 0.04 mSv/y after a period of 10,000 years at the shortest distance of 340 m from the tailings pond boundary.

Occupational radiation protection and environmental safety surveillance in the front end of nuclear fuel cycle was provided to all operating units of UCIL (Jharkhand), IRE (Kerala & TN), OSCOM (Orissa) and NFC (Hyderabad). During the last year, a total of 4358 nos. of occupational workers were monitored for external and internal radiation exposure in the front end of nuclear fuel cycle operations.

All exposures of workers were well below the dose limit of 20 mSv. In-plant radiological survey and radiation dose evaluations were carried out for all the units to ensure compliance with regulatory norms. Radiological baseline survey was carried out around the new uranium mining sites at Bagjata (Jharkhand), Tummalapalle (A.P.) and Gogi (Karnataka). Water samples were analysed for total uranium content collected in five districts of Punjab. A comprehensive radiological baseline study for BARC Vizag site is in progress. Under IAEA RCA Project, entire coastal marine environment of the country was mapped for 137Cs.

BARC has developed solar powered Environmental Radiation Monitor (ERM) for open field installation with wireless data communication using Short Message Service (SMS) of Global System for Mobile Networking (GSM).

The system consist of two low dose and one high dose GM tube detectors for measurement of environmental and fall out γ radiation. The system was deployed at various locations in India covering Nuclear Power Plant sites, uranium mining sites, major metropolitan cities etc. under the Indian Environmental Radiation Monitoring Network (IERMON).

These standalone automated systems transmit background environmental radiation data to a central station at Mumbai and serves as an early warning system in case of a nuclear emergency leading to increased gamma radiation levels in the environment. A room temperature technique employing ethanol-amine was developed to reveal the fission tracks in Lexan polycarbonate Solid State Nuclear Track Detector (SSNTD).

This new room temperature track development method will reduce the time required for quantitative analysis of trace concentration of U in environmental samples significantly.

RESEARCH & DEVELOPMENT

At NPCIL, the research and development activities are focused towards enhancement of plant safety, improvement in plant performance parameters, reducing project gestation period, indigenization of plant components. The Specific areas of in-house R&D are the Nuclear Systems and Electronic Systems.

During the report period, the major development works completed in Nuclear System included rehabilitation & up-grading of hydro-lancing machine for 220 MW steam generators, Turbine Missile Shield, 700 MW containment cooling spray system, Design of indirectly

heated 7-element & 37-element electric heater bundles for NTTF, etc. Testing, supply & deployment of shielded flask and cutting-crimping tools for removal of Cobalt-60 sensors of irradiated KAPS-1&2 SPNDs, testing & supply of modified feeder cutting machine, commissioning of Laser Based Feeder Cutting Machine at R&D Center etc. were approaching completion.

The Major works in Electronic Systems included CBS Retrofitting/Up-gradation, 700 MWe Design and Development, software development of Symptom Based Intervention Guidelines Management System (SIGMAS), design and development of Prototype for Infrared based Annulus Gas Monitoring System (AGMS), GM counter based Smart radiation monitor and Portal Monitoring System, etc. Modification of System Design Guidelines document as per D-25, Engineering Procedure document as per D-25, etc. are planned to be completed during the year.

During the report period, the research and development activities pertaining to the nuclear power programme were carried out at BARC were as follows :

Pressurised Heavy Water Reactor

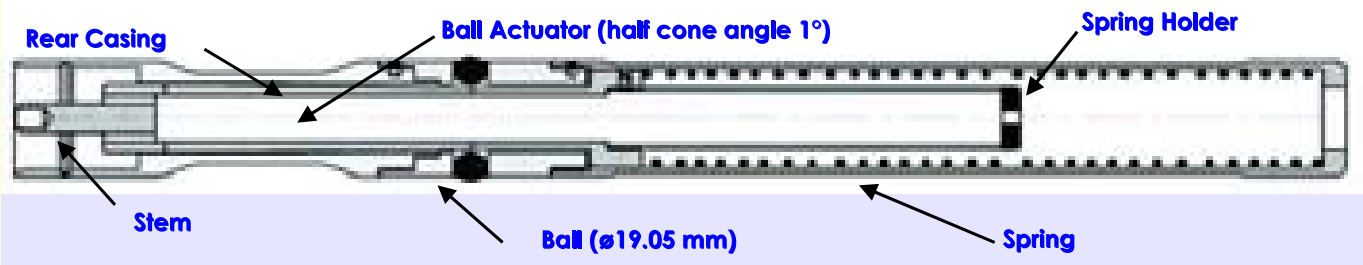
Wet Channel Sliver sample scraping operation was completed to obtain scraped material samples from coolant channels of RAPS-3 reactor to determine hydrogen/deuterium contents for predicting residual life. Sliver scraping operation on six pressure tubes at KAPS-2 was also completed.

The closure seal-face of end-fitting gets damaged due to presence of foreign debris causing leakage. A tool was designed, manufactured and qualified to carry out lapping operation remotely to save man-rem and time.

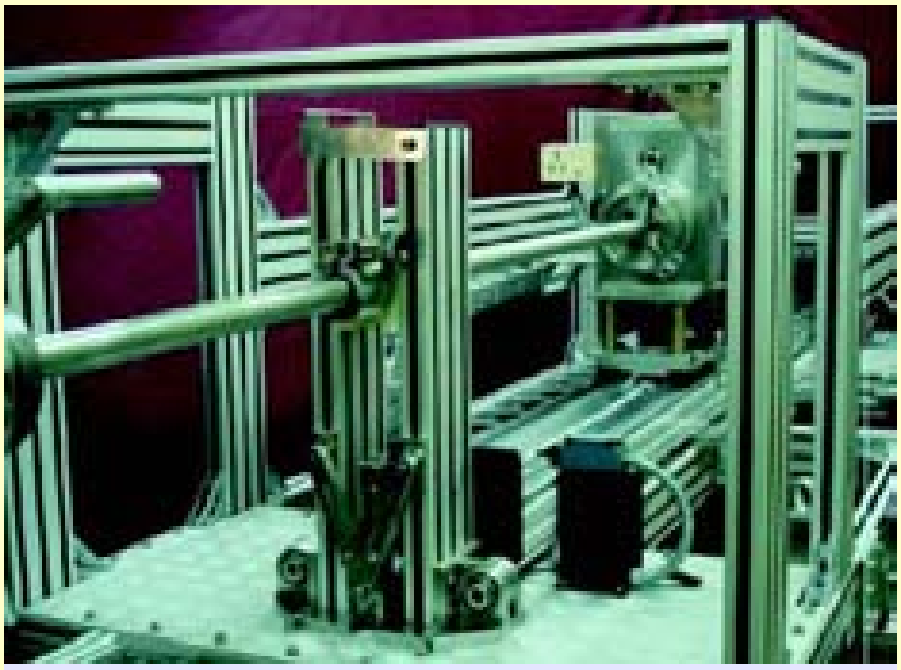
Internal Diameter (ID) measurement of coolant channels is to be carried out for diametric creep assessment. Inside diameter increase beyond acceptable limit may cause problem of flow bypass across the fuel bundles. Internal Diameter Measurement tool (IDMT) was developed for mass scale measurements of coolant channel ID remotely using existing Fuelling Machines. The tool, that has a number of operational advantages, was used at KAPS-2 for ID measurement in 26 channels.

During in-service-inspections, radial creep observed in the pressure tube of 220 MWe PHWR was higher than anticipated. Creep causes flow bypass which can lead to reduction in thermal margin, as signified by Minimum Critical Heat Flux Ratio (MCHFR). Sub-channel analysis was performed using COBRA-IIIC and the variation of MCHFR with creep at various powers was obtained. In a nuclear power station, Internal Service Inspection (ISI) of coolant channel is carried out periodically using BARCIS. During the report period, BARC delivered 6 BARCIS units to NPCIL. Thus every 220 MWe PHWR site was thus equipped with one BARCIS unit. In order to initiate coolant channel ISI programme in 540 MWe PHWRs, BARC and NPCIL had signed an MoU for development of BARCIS 540. This system was under development at BARC and will be delivered to TAPS 3&4 shortly.

During ISI, this system will be used to monitor the location of garter springs, measure coolant channel sag, the internal diameter and wall thickness of pressure tube and scan the pressure tube and rolled joint adjacent area for detection and characterization of



ID Measurement tool for 220 MWe PHWR



BARCIS 540 Drive Mechanism

defects. It was also planned to inspect the pressure tube ID visually using the indigenous radiation resistant CCTV camera system earlier developed at BARC. The system will have all the latest safety features and contingency handling devices.

Based on the gamma-spectrometry, the high neutron count rates observed during the initial criticality of RAPS-5 were explained. Prompt gamma-rays were monitored from the reactor core of RAPP-6 in several stages during the first approach to criticality.

Measurements were also carried out by BARC team to ascertain the sources of the radionuclides, contributing to the dose around the reactor core. As part of ageing management, KGS-2 coolant channels were analyzed for the deuterium pick-up. Failed clad of PHWR fuel bundle was analyzed for hydrogen and deuterium.

For the advanced component integrity test programme and life management studies, pipes/elbow specimens and large size cruciform test specimens were fabricated.

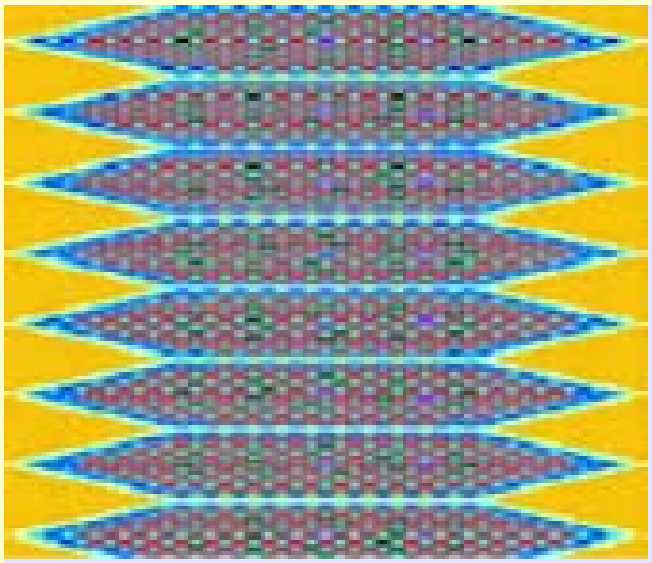
A scaled up version of Prototype Electro-Chemical Filter developed and tested at Kaiga and Kalpakkam earlier was designed to remove the Iron and Silica turbidity in secondary cooling water at PHWR Power Plants. During the report period, the detailed drawings of scaled up version were released for manufacturing. Studies were continued to develop alternate fabrication routes to improve the resistance of the PHWR pressure tube material Zr-2.5 Nb alloy to irradiation induced creep and growth through the modification of its microstructure.

As part of the ongoing process optimization for Zr-2.5Nb pressure/coolant tube fabrication at NFC, comparative studies of oxidation behaviour were taken up. More sensitive measurements using in-situ electrochemical impedance spectroscopy showed that heat-treated tube showed a slower rate of oxidation as compared to the standard cold worked and stress relieved pressure tube material under similar conditions.

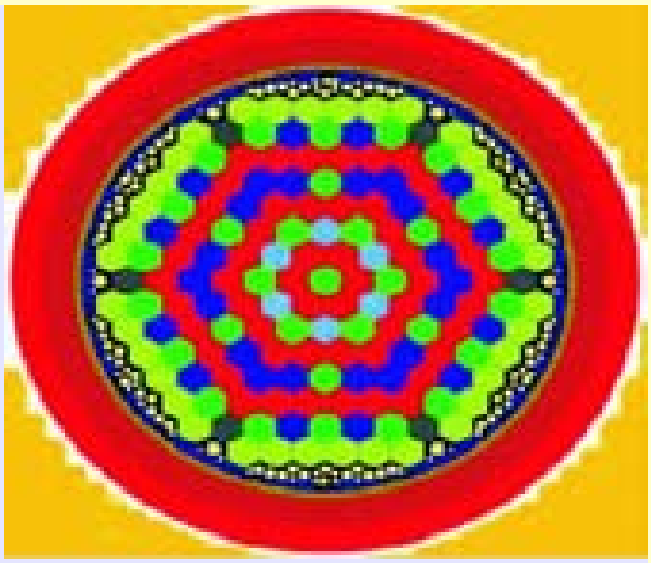
A deuterium charging facility was set up to charge controlled amounts of Deuterium in metals and alloys. The existing hydrogen charging facility was also augmented to charge hydrogen/deuterium in larger diameter Zr-alloy pressure tubes of both PHWR 700 and PHWR 500 of length 200 mm. These facilities support the ongoing investigations on the influence of hydrogen / deuterium on tensile properties, fracture toughness and delayed hydride cracking velocity.

Light Water Reactor

An updated Web based Information Management System (WIMS) library in 172 groups was generated in-house with burn up chain extended up to Cf-252. This library contains 185 nuclides and resonance integral tabulation for 48 resonant nuclides including several minor actinides with temperature extended up to 25000 K. This library has



VVER-KK Fuel Assembly Layout



VVER-KK Cycle-1core loading

performed successfully for the VVER simulations.

The pin-by-pin core diffusion code HEXPIN was commissioned in LINUX platform and made operational in the ANUPAM parallel machine with the number of parallel nodes same as the number of axial meshes. The VVER-KK cycle-1 core follow up calculations were done. The reduction in CP time was by a factor of 4.58.

At BARC, development of Canned Motor Pump was taken up. Design drawings were prepared and various manufacturing technologies were developed. After completing the first assembly of the pump, manufacturing of the second unit was taken up. A number of set ups, fixtures, tools and processes were developed for machining of Suspender Tube & Plunger component. Making of 20 Hanger Assemblies for Neutron Detectors for B1 Reactors was also taken up.

Low density Type-3 and Type-4 burnable poison rod (BPR) materials were produced using three different processes. After necessary process qualification, the batch size was scaled up. Regular production of high density BPR material continued. Two kg high density gadolinium aluminate based BPR material was supplied. Also, Boron-lined Ionization Chambers for B1 & B2 Reactors were fabricated at Trombay.

CHAPTER : 2

NUCLEAR POWER PROGRAMME : STAGE - II

Grid of Prototype Fast Breeder Reactor

CHAPTER : 2

NUCLEAR POWER PROGRAMME : STAGE II

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 Indira Gandhi Centre for Atomic Research (IGCAR) is engaged in the design and development of liquid sodium cooled fast breeder reactors, along with associated fuel cycle technologies. At IGCAR the fast reactor programme is supported by research and development in a variety of disciplines including reactor engineering chemistry, metallurgy, material science safety and instrumentation.

BHAVINI, a public sector undertaking of the DAE is responsible for the building of commercial fast breeder reactors. At present, this company is constructing a 500 MWe prototype breeder reactor at Kalpakkam.

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

The Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI) is implementing the India's first prototype Fast Breeder Reactor (PFBR) project at Kalpakkam, Tamil Nadu. PFBR is a pool type reactor using mixed oxide of uranium and plutonium as fuel and liquid sodium as coolant.

The civil construction of the Nuclear Island buildings reached an advanced stage of construction. The Nuclear Island houses 17 buildings, out of which 8 buildings namely reactor containment building, steam generator buildings (2nos), electrical buildings (2nos), control building, radioactive waste building and fuel building, are connected together as a single structure on a common raft and called as Nuclear Island Connected Buildings (NICB). The common raft foundation covers an area of 100m x 100m, and the operating floor level is at EL 30m.

During the report period, surrounding NICB, the other safety related structures like ventilation stack, horton sphere and the diesel generator building were completed. Fabrication of 3 nos. of horton spheres (for storage of high pressure nitrogen & argon gas) were completed. The hydro tests along with final painting were successfully completed.

The reactor vault is the critical civil structure in PFBR which houses all the reactor assembly components. Subsequent to erection of safety vessel and main vessel in reactor vault, the next major milestone achieved was erection of Thermal Baffle. Thermal baffle is to provide annular passage for the cold sodium, which is circulated to cool the main vessel and bring

Nuclear Island Connected Buildings (NICB) East Side view

Thermal Baffle erection

down the temperature during the normal operation of the reactor. It is made up of stainless steel SS316 LN with two concentric shells of diameter 12.44m and 12.67m respectively with a height of 5m.

The Grid Plate which holds the fuel sub-assemblies, was integrated with primary pipe and erected inside the main vessel.

Erection of the Inner Vessel was another milestone achieved. The Inner vessel serves as a leak resistant barrier between the hot and cold sodium of primary sodium inside the reactor. It is made up of stainless steel SS 316 LN and consists of a lower and upper cylindrical shell of diameter 12m with a height of 11m joined together by a conical shell called Redan.

The Roof Slab is a box type structure made of carbon steel plates of diameter 12m with a height of 1.5m interconnected by radial stiffeners and cylindrical shells for the various component penetrations. The fabrication of Roof slab was completed and pre-requisites for erection were approaching completion. The roof of Reactor Containment Building was concreted partially and the concreting of the left out portion will be completed after erection of Roof slab.

The erection of Girders (33m length) and Trolley (280/85T) Electric Overhead Traveling crane in the Reactor Containment Building were completed. One 15T EOT crane erection was also completed.

About 1500 MT of Sodium metal was transferred safely. Structural works of SG Buildings 1&2, was completed up to roof.

The entire civil structural works of Fuel Building, Electrical Building 1&2 were completed and the 6.6kV switchgear panels and Batteries were erected in position. Fifteen panels were erected in position in Control Building. 4 nos. of 7.5 T EOT crane erected in Diesel Generator

Grid Plate erection

Inner vessel erection

building and 4 Diesel Generator sets, each rated to supply 50% of the total emergency power supply demand with a rating of 4.5 MVA, were erected in Diesel Generator building and pre-requisites for commissioning the same was under progress.

The construction of Radioactive Waste Management building and in-situ fabrications of Effluent Treatment Tanks and structural works for liquid Waste Management Plant were also completed, and finishing works were in progress.

The Sea Water Outfall Channel was completed and the seal pit inlet and outlet were constructed. The connection of PFBR outfall channel and MAPS outfall channel was completed and connected with the seal pit. 50m deep Vertical Onshore Outlet Shaft for sea water intake, Horizontal Tunnel, length 565m, and the concrete lining works inside the tunnel were completed.

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 finished floor level of Power Island is at EL 27.50m which is 2.5m below the finished floor level of NICB (EL 30m).

Turbo-generator Deck concreting , structural works of Raw-water & Fire-water Pump House, DM Plant, and Auxiliary Boiler Plant were completed and equipment erection works were under progress. Civil construction of the open Raw Water Reservoir was completed and laying of pipeline between the reservoir and pump house was in progress. In Sea Water Pump House the entire raft, and three stages concreting of Volute Pump was completed.

The other completed works included construction of 230KV indoor Switchyard GIS Building, and erection of GIS equipment. Pre-commissioning works were under progress.

Roof slab

Overall view of Power Island

GIS Switchyard

Procurement and Manufacturing

Manufacture of major nuclear steam supply components such as Additional Inclined fuel transfer machine, Steam generator, Intermediate heat exchangers 3 nos., LRP & SRP, Control & safety rod drive mechanism (CSRDM) & Diverse & safety rod drive mechanism (DSRDM), special steel & internal storage location sub-assemblies, Inflatable seals, cold trap, 280/85 T EOT crane, 15T EOT crane for Reactor Containment Building, 4 nos. of 7.5T EOT carne for Diesel Generator building and Fuel handling Equipments like large components storage vessel, Transfer chamber carriage, Spent SA Storage rack, Fresh SA inspection facility, Carriage for fresh SA transport cask, Shielding doors, partition door, Trailing cable system, Liquid Honing machine and around 2000MTons of materials for TG system like rotor casing, IP turbines were completed and delivered to site.

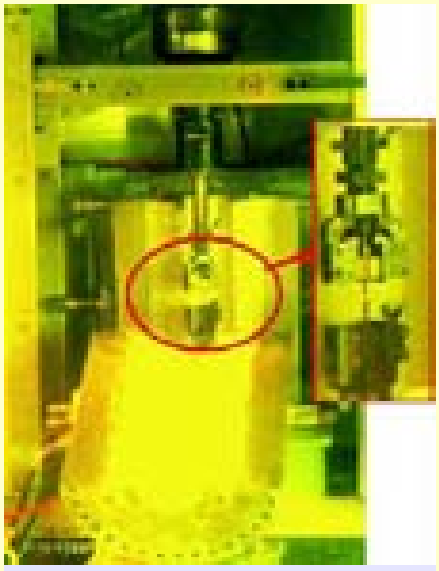
The project achieved an overall physical progress of 63% at the end of November-2010.

RESEARCH & DEVELOPMENT FOR FAST REACTORS

Fast Breeder Test Reactor (FBTR)

FBTR completed 25 years of operation in Oct 2010.The 16th irradiation campaign was completed. The reactor was operated at 18 MWt with the turbo generator synchronized to the grid and generating 3.2 MWe. Steam temperatures, as high as, 733 K could be realized. A major milestone was reached at the end of the campaign when the PFBR test fuel reached target burn-up of 112 GWd/t without failure. Second Main Boiler Feed Pump and second computer in central

Gamma measurement above the core



Remote tensile testing machine inside hot-cells

data processing system were commissioned. The high temperature fission counters developed for PFBR were tested upto a power level of 16 MWt and temperature of 673 K As part of testing gamma measurements were made above the core.

Gamma scanning of irradiated FBTR fuel pins after a peak burn-up of 155 GWd/t gave valuable information on the fission product redistribution along the length of the fuel pin, and inputs to estimate the active fuel column length and axial flux profile along the fuel column.

To evaluate the beginning-of-life gap-closure behaviour and to arrive at the required duration of pre-conditioning of fresh fuel, an experimental mixed-oxide fuel pin of PFBR fuel composition of uranium oxide was irradiated in FBTR for a duration of 14 days in an irradiation capsule at a maximum linear power of 400 W/cm. Remote metallography was done on the fuel pin during post-irradiation examination to measure the fuel-clad gap at five axial locations of the fuel column. The early reduction in the fuel-clad gap is a valuable feedback indicative of the optimum preconditioning period required for the fresh fuel before enhancing the linear heat rating to the design value.

For aging assessment of type 316 stainless steel grid plate of FBTR, which has operated for more than 25 years at about 623 K, an accelerated irradiation test was performed. An experimental subassembly with an irradiation capsule containing pre-fabricated miniature tensile and disc specimens of type 316 stainless steel was irradiated in FBTR to accumulated neutron damage upto 2.57 displacements per atom. Tensile tests of irradiated specimens carried out remotely, showed that the irradiated grid plate material would have undergone radiation hardening (increase in strength) accompanied by decrease in ductility.

Newer version of pre-pressurized capsules of D9 alloy was developed to subject to temperatures upto 973 K during irradiation in FBTR to determine the in-reactor creep behaviour of the material.

An accurate remotely operable diameter measuring system was developed to measure the diameter of pre-pressurized capsules after irradiation in the hot cells.

As part of development of a fuel instrumented irradiation capsule, a test instrumented capsule with heater pin and thermocouples was developed and tested in a water test rig.

R&D relating to PFBR

At Kalpakkam, the in-situ welding of roof slab with main vessel, the most challenging phase, was under meticulous planning. The achieved dimensions of the penetrations in roof slab for intermediate heat exchangers, primary pumps and other components penetrating the roof slab were studied for the insertability of the components and the locations of the axes for machining various support flanges in roof slab were finalized.

To ensure achieving the intended design and to establish confidence, a full scale mock-up of main vessel to roof slab welding was carried out at IGCAR, simulating all the physical constraints at PFBR site. The mock-up facilitates establishing the welding sequence, distortion control measures and detailed procedure to carry out the actual job at project site. This will also ensure timely integration of the components

The In-Service Inspection (ISI) device for operation in PFBR was tested with dummy payloads, for vertical and transverse movement in a mock-up test bed.

The wheel-liners, high-traction motor and steering motor

were successfully tested at 423K.

At IGCAR, comprehensive thermal hydraulic analysis for transportation of spent fuel from reactor site to reprocessing plant was carried out by detailed modelling of all the fuel pins in the spent subassemblies. Based on the studies, the number of subassemblies that can be handled with the prescribed decay power and the fluid medium in the transportation cask were finalized. It is established that no forced cooling is required for the cask during transportation.

Three dimensional transient computational fluid dynamics analysis of a postulated oil fire scenario with complete inventory of primary sodium pump lubrication oil leak was carried out for the preparation of fire hazard analysis report.

Manufacturing Technology

Manufacturing technology development exercises were undertaken for the embedded safety vessel, thick plate narrow gap welding and welded grid plate to ensure the manufacturing feasibility of innovative components. Towards confirming the choice of thick plate concept for the top shield, development work of 800 mm thick plate narrow gap welding technology for the carbon steel plates of SA 516 Gr. 65 using SAW was successfully completed

Future FBRs

For future 500 MWe FBRs, the emphasis is on the finalization of conceptual design of one twin unit (2x500 MWe units) of Commercial Fast Breeder Reactor (CFBR) to be constructed near PFBR site. Revised safety criteria have reached advanced stage of review. The plant layout for twin unit was finalized with significant cost savings, particularly sharing the fuel handling buildings.

The reactor assembly design concepts were completed. A dome shaped concept for the roof slab with mixed box and thick plate design features was conceived and analysed in detail. Preliminary estimation indicates a saving of 25 % on steel.

Towards enhancing the overall reliability of reactor shutdown system, active and passive shutdown systems were studied. In one of the options conceived, a stroke limiting device in control & safety rod drive mechanism for eliminating the possibility of unlimited withdrawal of control rods and an electromagnet in diverse safety rod drive mechanisms which de-energies once temperature exceeds Curie point temperature were incorporated.

Safety grade heat removal experiment

Thermal Hydraulics, Component Testing and Validation

Experiments in Safety Grade Decay Heat Removal in sodium loop

The Safety Grade Decay Heat Removal in sodium loop to study the thermal hydraulic behaviour of Safety Grade Decay Heat Removal system of PFBR completed around 2500 hrs of high temperature operation and the performance of the experimental system is satisfactory. Adequacy of the margins for pressure drop and heat transfer was established. Experiments were also conducted to evaluate the transient response of the system when the dampers opened suddenly with the temperature of the sodium pool maintained constant. Based on the experiments, it was established that the full sodium flow is achieved in approximately nine minutes.

Full scale slab model for Inter Wrapper Flow studies

Inter wrapper flow has a vital role in removing decay heat from the reactor. A scale model slab of the reactor was commissioned to conduct studies in water. Decay heat generation in the core was simulated by heaters provided inside the subassembly (SA) and decay heat exchanger (DHX) heat removal was also simulated.

Impingement wastage studies on SG tube materials

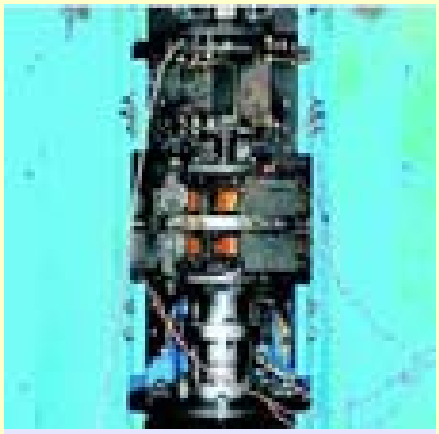
Experiments to study, impingement wastage phenomenon in a sodium heated steam generator were carried out in Sodium Water Reaction Test facility.

Qualification testing of PFBR Transfer Arm in air

A 23.4 m height and 23 t Transfer Arm of PFBR was tested in air. The results have increased confidence in the performance of the machine and which is now getting readied for sodium testing.

Development of oil less active magnetic bearings for centrifugal sodium pumps

Active Magnetic Bearing (AMB) does not require lubrication when used with ferrofluid seal. The use of these bearings eliminates the chances of accidental spillage of oil into

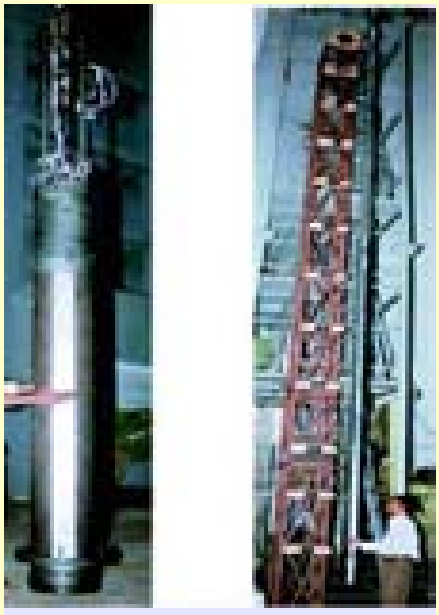


Active Magnetic Bearings

Transfer Arm

sodium circuit. AMB, capable of supporting a thrust load of 100 kg was developed to suit a small centrifugal sodium pump. The bearing was integrated with the vertical, centrifugal sodium pump and tested successfully in water at the designed speed of 2900 RPM.

Evaluation of Diverse Safety Rod Drive Mechanism (DSRDM) for PFBR



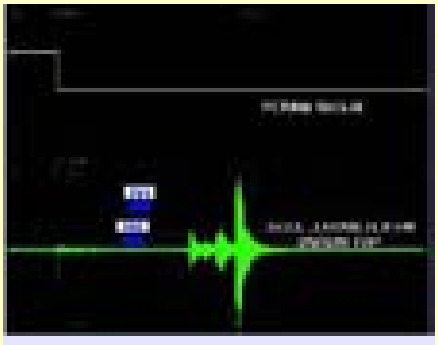
Upper & lower parts of DSRDM

Three diverse safety rod drive mechanism were tested successfully in the large components test rig and qualified for erection in PFBR. The tests also resulted in generating the base line data for future reference.

Innovative design of flow zoning devices using CFD for FBR

As the radial power profile across the reactor core is nonuniform, it is required to apportion flow through the core to maximize the mean outlet temperature. To achieve the uniform outlet temperature, the reactor core was grouped into different flow zones. Allocation of required flow rate to different zones was achieved by locating suitable pressure drop devices at the inlet of the subassemblies. Special honeycomb geometry orifice plates were developed for use in PFBR. Studies with slit orifices, cone orifices and ball orifices were carried out to improve the design and to enhance the cavitation performance of the devices.

Development of Diverse Safety Rod drop time measurement system for PFBR using acoustic technique



Time signal for Drop time measurement using Acoustic technique

An indigenous system using acoustic technique for measuring the time taken by the diverse safety rods to reach the core during a SCRAM was designed, developed and successfully tested.

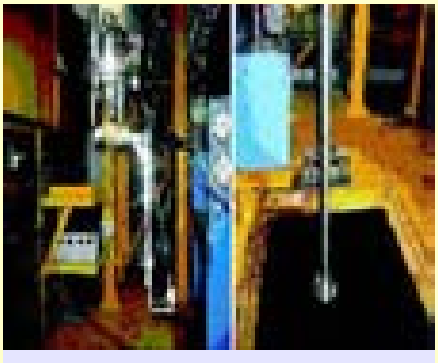
Boron isotope separation using ion exchange

Boron was enriched with strong base anion resins (particle size of 0.3-1.2 mm) upto 65% enrichment in 10B in an equilibration time of 48 months. A technology was developed using strong base fine resin (75-150 µm particle size) with the equilibration time to 12 months to get 65% of 10B. Both the technologies were transferred to Heavy Water Board for operation at Manuguru. Further to reduce the cost and equilibration time, a process using de-mineralized water as eluent was developed using weak base anion resin (75-150 micro metre)

Ultrasonic waveguide for high temperature applications

Feasibility of use of the ultrasonic wave guide for high temperature applications was studied.

Development of ultrasonic technique for detection of sub-assembly protrusion in PFBR



Ultrasonic technique for detection of Sub Assembly protrusion

Towards detection of any protrusion before moving the control plug of PFBR, an ultrasonic technique was developed and encouraging results were obtained by simulated tests in water.

Steam Generator Test Facility

The Steam Generator Test Facility (SGTF) was operated continuously at different powers. In order to protect the steam generator tube sheets from high temperature gradient during normal operation as well as during transient conditions, thermal baffle assemblies are provided near both top and bottom tube sheet regions. The loss of feed water flow incident results in maximum temperature variation in the steam generator. The occurrence of this incident in steam generator was simulated numerically and by experiments in SGTF.

The noise generated from the liberation of hydrogen during sodium-water reaction in SG in case of a tube leak is one of the promising methods for SG tube leak detection. To study the feasibility of the method, argon gas was injected in to SG sodium when SG was operating in power and the acoustic signal was collected through accelerometers fixed on waveguides. It is planned to develop an online leak detection system using acoustic technique for SGTF steam generator.

R&D towards Sodium Fast Reactors

A mini sodium (MINA) experimental facility was commissioned to address the science and technology aspects of sodium fire.

To achieve an efficient post accident heat removal system, molten fuel-coolant interaction, fragmentation, settlement on the core catcher and heat removal characteristics were investigated experimentally and extensive data was collected. The data generated with woods metal in water experiments provided good understanding of the complex phenomenon.

A dedicated water test facility was commissioned to understand the post accident heat removal mechanisms including natural convection flow paths.

Based on tests, temperature and flow patterns were generated and being used for the numerical simulations

Developmental Works

The fibre-optic based real-time leak detection was demonstrated using the sodium leak in sodium leak test facility. Pattern recognition approach was adopted to assist the human interpreter in evaluating the quality of the welds in radiographic images, especially tube-to-tube sheet weld joints in the steam generator assembly of PFBR.

Development of Electrochemical Hydrogen Meter

Electrochemical Hydrogen Meters (ECHMs) for use in PFBR were tested in mini sodium loop, simulating plant conditions and the response of the meters was recorded. One more mini sodium

Simulation of sodium spray fire scenarios in MINA Facility

Facility for post accident heat removal studies

loop was fabricated to test six more ECHMs simultaneously.

Proton exchange membrane based hydrogen sensor was successfully used for monitoring hydrogen released during mock sub assembly cleaning operation and the performance confirmed suitability of the sensor for the application.

Development of Safety Critical Instrumentation & Control Systems for PFBR

The safety critical instrumentation and control systems of PFBR were designed and developed in-house using programmable logic devices employing high level of integration to achieve high reliability. Environmental, electromagnetic interference / electromagnetic compatibility and seismic qualification tests were carried out to ensure that systems are reactor worthy.

Flight Trials of IGCAR Time Domain Electromagnetic (TDEM) System

Time domain electromagnetic system comprising an under slung, 16 m transmitter coil, bucking and receiver coils assembly, onboard equipment and data acquisition system developed by IGCAR was employed in the exploration of atomic minerals. The data generated by the system facilitates conductivity mapping of the sub surface geology.

The first phase of the flight trials were conducted successfully.

Development of Single Board Data Acquisition Remote Terminal Units (RTU) for PFBR.

Remote Terminal Unit (RTU) is a Microcontroller based single board data acquisition system, designed to acquire analog/ digital signals inputs and send digitized data packets over ethernet to the nearest local control centre and also generates control outputs in the form of potential free contacts. RTUs are designed to operate in the extreme field conditions of plant, so as to reduce the cabling from sensor and detectors. Seven different types of RTUs were designed & developed to cater various PFBR applications. RTUs were subjected to qualification of environmental & electromagnetic interference/ electromagnetic compatibilty tests. The design

Flight trials of the TDEM system

technology of RTUs along with PCB fabrication details and supporting documents were transferred to ECIL for bulk production.

Development of Distributed Digital Control System (DDCS) for PFBR

Graphical User Interface software & process computer software were developed for distributed digital control system, which gets plant data from different subsystems located at different buildings and provide all the information to the plant operator in the control room. Operator can access any data or status of any of the process parameters from the control room.

Development of safety related & non-nuclear safety I&C systems for PFBR

Real time computer systems, a part of safety related & non-nuclear safety I&C systems for PFBR, to be located at various local control centers were developed. All documents and codes required for the systems were verified & validated by an independent committee.

Pulsating sensor based instrumentation for rapid chemical assay at trace level

In-expensive and highly reliable pulsating sensor based instrumentation developed was deployed in rapid chemical assay at trace level concentrations. It also provided quantitative information on various chemical species present in a sample matrix.

A technique for rapid assay of boron at trace level was developed. The technique can be used for determination of boron in nuclear fuel materials, food and pharmaceutical industries after separating boron from the sample matrix by steam distillation.

Simulation and Transient Analysis of PFBR Process Models

Towards developing an operator training simulator, modeling and simulation of PFBR reactor sub-systems were under execution. It is a full scope replica type simulator that provides a platform for conducting scenario based training on design basis events, covering all plant status of PFBR to enhance the capability of the operators. Concurrent verification and validation of process models was carried out by a committee.

3D Visualization of PFBR Nuclear Buildings Walkthrough and Fuel handling system

Walkthrough developed for various PFBR buildings comprising equipments, piping, heating & ventilation ducts, electrical cable trays, civil, steel and support structures was ported to the advanced visualization centre facility for visualizing in a 3D environment.

To train the operators with efficient, sequential error free fuel handling operations, 3D modeling and assembly of ex-vessel fresh fuel handling were completed.

Reactor Safety

Reactor Physics and Shielding

Studies have shown that use of ferro-boron has the potential of improving economics and reduction of volume of shields of fast reactor core shielding. Ferro-boron is proposed to be used in powder form in Commercial Fast Breeder Reactor. PFBR uses boron carbide powder which is more costly. Experimental measurements of the neutron attenuation in the ferro-boron samples with 11.8% and 15% of boron and boron carbide powder were compared. It was found that ferro-boron with 15 % boron content is as good as boron carbide.

An FBR closed fuel cycle involves recycling of the discharge fuel, after it is reprocessed and re-fabricated. During the 40 year life of the reactor, 10 closed fuel cycles are expected to occur. Computations were performed using the recent nuclear data and specifications of the fuel composition.

Radiological safety

About 450 Occupational workers & contract workers had undergone whole body monitoring under routine and special monitoring program. A Phoswich detector based lung counting system was

Phoswich detection system for lung counting

High Efficiency Particulate Air (HEPA) Filter test rig

commissioned and 57 persons were screened.

A new radio chemical analysis method was developed for fast estimation of plutonium in urine matrix. Over 20,000 TLD cards from IGCAR & BARC facilities were processed. Filter banks from various laboratories of Kalpakkam DAE complex were tested in high efficiency particulate air (HEPA) filter test facility.

About 600 samples from DAE units and non-DAE institutions were analysed in the nuclear counting facility for radioactivity estimation. Radiation protection training was provided to all occupational & contract workers and also National Disaster Relief Force personnel.

Comprehensive Health Survey around Kalpakkam

A comprehensive health survey study including complete diagnostic investigations and other special tests was initiated to assess the health status of the 22,000 people living in 12 villages. The study will serve as a baseline data for future cohort studies.

Radiometry and gammatography testing of shielding components of FBR

Inclined Fuel Transfer Machine shield structures

PFBR shielding components such as Inclined Fuel Transfer Machine (IFTM) cast steel block, IFTM shield structures, flange & blocks, lead shielding for sodium condenser arrangement and lead shielding blocks of liquid effluent tank were successfully evaluated for their integrity using radiometry & gammatography techniques to sensitivity level of 3%.

Lead shielding for sodium condenser arrangement

Field Meteorological Experiment for Round robin exercise

Atmospheric flow field and its turbulence primarily determine the dispersion of airborne effluent releases in different spatial

ranges. IGCAR in collaboration with several universities and premier institutes is conducting a Round Robin Exercise programme to evaluate several existing approaches in meteorological modelling for wind field simulation and to identify a best acceptable methodology. A comprehensive field meteorological experiment was conducted in Kalpakkam site region to generate bench mark meteorological data in the meso (100 km), local (10-20 km) and micro scales (<2 km) for theoretical and model validation studies.

The experiment was conducted to capture the characteristic features of the mixing height, stability variations and diurnal trends of various meteorological parameters at different locations along the coastal site.

Development of a new turbulence Parameterization in Atmospheric Dispersion model

A new method of turbulence velocity estimation was incorporated in the operational dispersion model to give a realistic estimation of dispersion with less computational overheads. The method is validated with actual observed turbulence data obtained with sonic anemometer from Kalpakkam site.

Deposition velocity of strontium peroxide aerosols and particle morphology

Experiments were conducted in aerosol test facility and deposition velocity is determined.

MATERIALS

Materials Development and Characterisation

Oxide dispersion strengthened (ODS) ferritic martensitic steel tubes (6.6 mm outer diameter and 0.45 mm wall thickness) developed for fuel clad-tube application were evaluated for creep properties.

Saturation based eddy current technique was developed for quality assurance of metallic fuel oxide dispersion strengthened clad tubes made of T91 steel. Studies were carried out and the magnetization current and excitation frequency were optimised. This ensures detection of reference calibration defect i.e. 0.3 mm dia. hole with high signal to noise ratio. This technique will be used for detection of defects in T91 steel tubes during manufacturing stages.

The material for the Temperature Sensitive Magnetic Switch (TSMS), being developed for the DSRDM, requires a Curie temperature of about 620°C, low magnetic remanence, small coercivity, and magnetic susceptibility. Based on laboratory melts, it was determined that the 50Ni-37Fe-13Co ternary alloy has Curie temperature of around 620°C. While Curie temperature is decided by material chemistry, other magnetic properties depend on processing parameters. To obtain the tubular in shape, TSMS component manufacturing technique involving investment casting with melting and pouring in vacuum followed by finish machining proved to be successful. The absence of hysteresis at room temperature as well as at 600°C is a remarkable feature of the material and the method used to process it. The sharp transition in magnetisation at Curie temperature indicates high degree of homogeneity and excellent magnetic properties of the investment-cast alloy. Nickel-base Colmonoy, used for hardfacing of 316LN stainless steel components in PFBR, has considerable difference in melting point with 316LN resulting in significant dilution of the hardfaced deposit from the substrate. Although both 316LN and undiluted Ni-base hardfacing alloy deposit are non-magnetic, the hardface deposit diluted by 316LN becomes magnetic. This aspect was characterised for Colmonoy deposits on 316LN and for Colmonoy co-deposited with austenitic stainless steel filler wire (twin deposits) to achieve deposits with various dilution levels. Dilution of nickel-base hardfacing alloy by austenitic stainless steel substrate affects both the hardness and magnetic properties of deposits. A good correlation could be established between the magnetic property estimated from Feritscope, Magnegage equipments and saturated magnetic moment obtained from

magnetic hysteresis loop, with dilution for hardfaced deposits as well as different twin deposits. Also, the magnetic property of the deposit could be correlated to its hardness and this principle can be applied to estimate hardness of the deposit on finished component as a non-destructive technique.

A procedure was developed to estimate crack tip shielding in compact-tension test specimens that can be applied for assessing crack-tip shielding in materials with different microstructures.

The in-house developed single-pass activated TIG (A-TIG) welding process applied to 7 mm thick 316LN stainless steel weld joint resulted in reduction in residual stresses by 75% and in distortion by 33% compared to those made by other arc welding processes.

Stress-rupture values for 60 years design life were determined for 316LN stainless steel and modified 9Cr-1Mo steel. The average stress values for 60 years at 773, 823 and 873K were predicted from experimental data in literature and compared with RCC-MR average stress-rupture values obtained by linear extrapolation. The predicted average stress-rupture values for both the materials are higher than those obtained from RCC-MR data extrapolation indicating thereby that RCC-MR average stress rupture data is conservative in the temperature range 773-873K.

The traditional Fourier transform based ultrasonic grain size measurement in AISI type 316 stainless steel is prone to poor single to noise ratio when grain size is >140 m. To overcome this, short time Fourier transform method was developed and found to be working well upto a grain size of 210 m. This method enables inspection of thick austenitic stainless steel plates with large grain size. Type 316LN stainless steel and modified 9Cr-1Mo steel samples in bimetallic sodium loop completed 30,000 hours of exposure at 798 K.

Materials for Reprocessing Technology

Valuable long term corrosion rate data of type 316LN chosen for PFBR was obtained from bimetallic BIM Sodium Loop after 30,000 h of exposure at 778 K. Similarly long term corrosion rate data of type 304L was obtained from the operation of nitric acid loop after 10,000 hours revealed that the type 304L SS had acceptable corrosion rate (13 mils per year) in boiling nitric acid, however, the indigenous MIDHANI nitric acid grade type 304L SS showed lesser corrosion rate of 8 mils per year.

A new scheme of pre-weld laser surface treatment was developed for medium and high carbon type-304 stainless steel for enhanced resistance against HAZ-sensitization and intergranular corrosion. Corrosion-microstructure studies revealed that activated flux TIG welding resulted in good corrosion resistance of type 304L SS in comparison with manual TIG welding process. Thermal cycling studies indicated that upto 1123 K yttria stabilized zirconia coating on 9Cr-1Mo steel performed without spalling and failure. Nitric acid grade nitrogen containing type 304LN stainless steel (with 0.1, 0.2 and 0.4% nitrogen) developed in collaboration under Indo-Bulgarian cooperation was extensively investigated for reprocessing and waste management applications and the studies indicated the good performance of the alloys with nitrogen addition with improvement in strength and hardness of the alloys with fine grain size.

Retained helium content in irradiated Titanium based boron alloy, the proposed control rods in advanced reactors, was determined as a function of temperature, by BARC.

FBR-Front End Fuel Cycle

MOX Fuel for Fast Reactors

The experimental (U-30%Pu) MOX fuel for PFBR enriched with U-233 and fabricated at the Advanced Fuel Fabrication Facility, Tarapur exceeded the designed burn-up of 100,000 MWd/t. Fuel elements of the assembly will be subjected to post irradiation examination. Fabrication of MOX fuel pins for the first core of PFBR was under progress. Plutonium was introduced in the new welding line for PFBR. Safety clearance was obtained for the new pellet

New fabrication line of Advanced Fuel Fabrication Facility for PFBR

Shop testing of IFTM components

fabrication line for PFBR.

The major components of the Inclined Fuel Transfer Machine were manufactured and shop testing was completed. The components were shifted to the Large Component Test Rig at IGCAR, Kalpakkam for sodium testing.

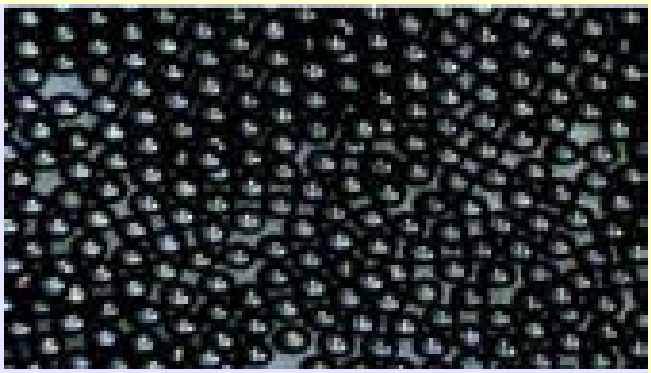
Design and drawings of six different types of handling-cum-shielding assemblies for Fission Chambers for neutron flux monitoring for reactor was completed. Drawings of all the Hanger Assemblies were completed.

Experimental conditions were optimized to prepare mixed $(U,Pu)O_2$ microspheres. These microspheres will be used for the fabrication of sphere-pac fuel pin for test irradiation in FBTR at Kalpakkam to study fuel bed stability under reactor irradiation conditions and restructuring of fuel.

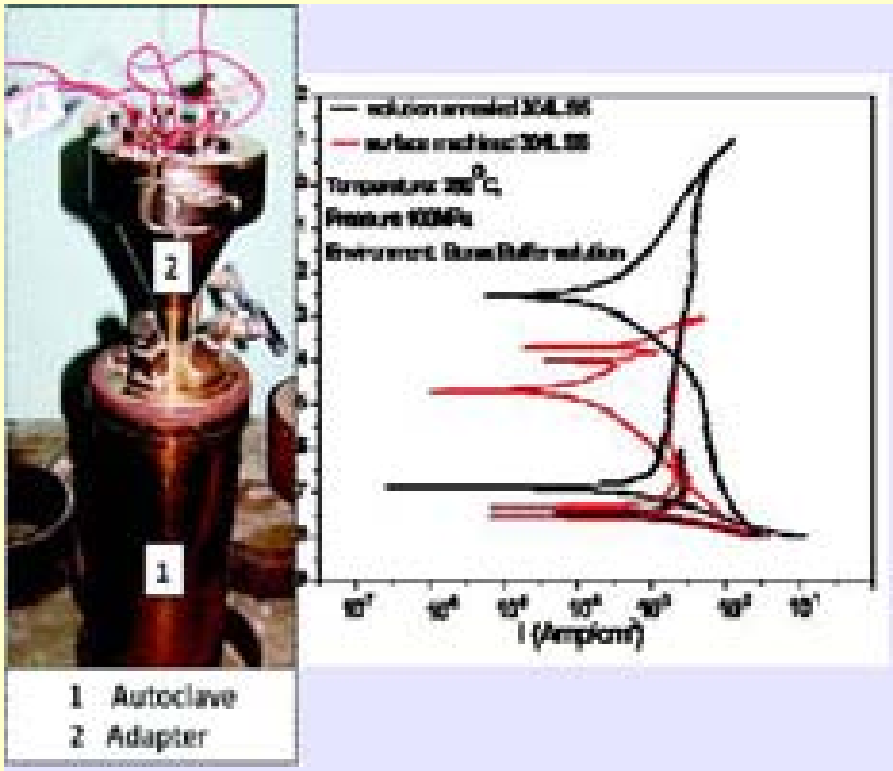
The creep behaviour of the delta phase of -Zr metallic fuel (U-50 wt% Zr) was investigated by the impression creep technique.

A Pd/H_2 reference electrode designed and built by BARC, allowed high temperature electrochemistry experiments in autoclave to better understand the corrosion processes that occur in nuclear reactor simulated conditions.

$(U_{0.47,}\ Pu_{0.53})O_2$ microspheres calcined at 100°C



$(U_{0.47,}\ Pu_{0.53})O_2$ microspheres sintered at 1450°C



The set up with provision of high temperature reference electrode designed and built in-house shown in attached condition to an autoclave. Electrochemical polarization curve for solution annealed and (b) surface machined SS 304 L stainless steel is shown on the right indicates higher susceptibility to corrosion of the surface machined stainless steel in high temperature aqueous environment.

Using this assembly, studies were conducted in situ to understand the nature of film produced on the surface of stainless steel ASTM grade 304L.

Pilot plant facility for sodium cleaning

Fuel Chemistry

As part of the fuel development programme, high plutonia Mixed Oxide (MOX) (44%) test irradiation at FBTR continued.

Sodium Chemistry

Sodium cleaning experiments, using water vapour - carbon dioxide process, were conducted in the pilot plant at IGCAR.

FBR -Back End Fuel Cycle

The engineering scale facility was commissioned for pyroprocess studies.

A salt purification system was also commissioned and about 13 kg of LiCl-KCl eutectic salt mixture was purified from moisture by chlorination at 673 K. The first electrorefining experiment was carried out at 773 K with 1 kg of U metal as the anode and uranium metal was deposited on a solid cathode.

The elemental and radio isotopic composition of fast reactor high-active liquid waste (at 155 GWd/t burn-up) was characterized. Routing of trivalent actinides was studied in batch mode, to develop a method for partitioning of minor actinides from fast reactor high-active waste. Based on the results, partitioning of minor actinides was carried out, using a novel 16-stage ejector mixer settler.

Burn-up measurement on the dissolver solution of fast reactor fuel poses a great challenge due to high radioactivity. A dynamic ion-exchange method was developed

Facility for pyro process studies

Uranium metal deposited on a solid cathode

and applied for the separation and determination of lanthanide fission products, uranium and plutonium present in the dissolver solution of fast reactor fuel subjected to a nominal burn-up of 155 GWd/ton.

Waste Management

Extraction of Palladium (Pd) from simulated waste-loaded borosilicate glass, using a metal solvent was studied to investigate removal of platinum group metals from high level waste before vitrification of the waste.

The high level waste arising from fast breeder reactor consists of cesium, strontium and noble metals. It is essential to separate these isotopes and immobilize in a suitable matrix. Further, the 137Cs loaded glass matrix can also serve as the gamma-source for the medical and industrial applications. The cesium loaded glass was characterized. The studies indicated that iron phosphate glass is a promising matrix for the immobilization of cesium.

Supercritical fluid extraction technique was demonstrated for the recovery of plutonium from cellulose based waste matrix.

Fast Reactor Fuel Reprocessing in CORAL

Campaigns of FBTR spent fuel reprocessing, completed in CORAL facility provided valuable information on the operation and maintenance of centrifugal extractor and centrifuge. Direct spectro-photometric measurements, using fibre-optic spectro photometry for determining the concentrations of plutonium in different valency states, were deployed for active process solutions. This reduced the active waste generation volumes substantially.

R&D for Reprocessing

Design of high capacity Centrifugal Extractors

Large volume metallic and non-metallic annular centrifugal extractors required for high throughput reprocessing plants were designed.

Development of Solvent Regeneration Process by Vacuum Distillation

A pilot plant scale solvent purification system based on vacuum distillation method was commissioned successfully.

Thermal Stability of Extractants and Pressurization during Heating in Adiabatic Conditions

Red-oil formation with nitric acid- tri-butyl phosphate (TBP) runaway reaction is a safety concern in the reprocessing plant using PUREX process. An adiabatic calorimeter was setup to study the thermal stability of different solvents and studies were carried out.

Passive Neutron based Alpha Waste Drum Assay System

A passive neutron counting based waste drum monitor,

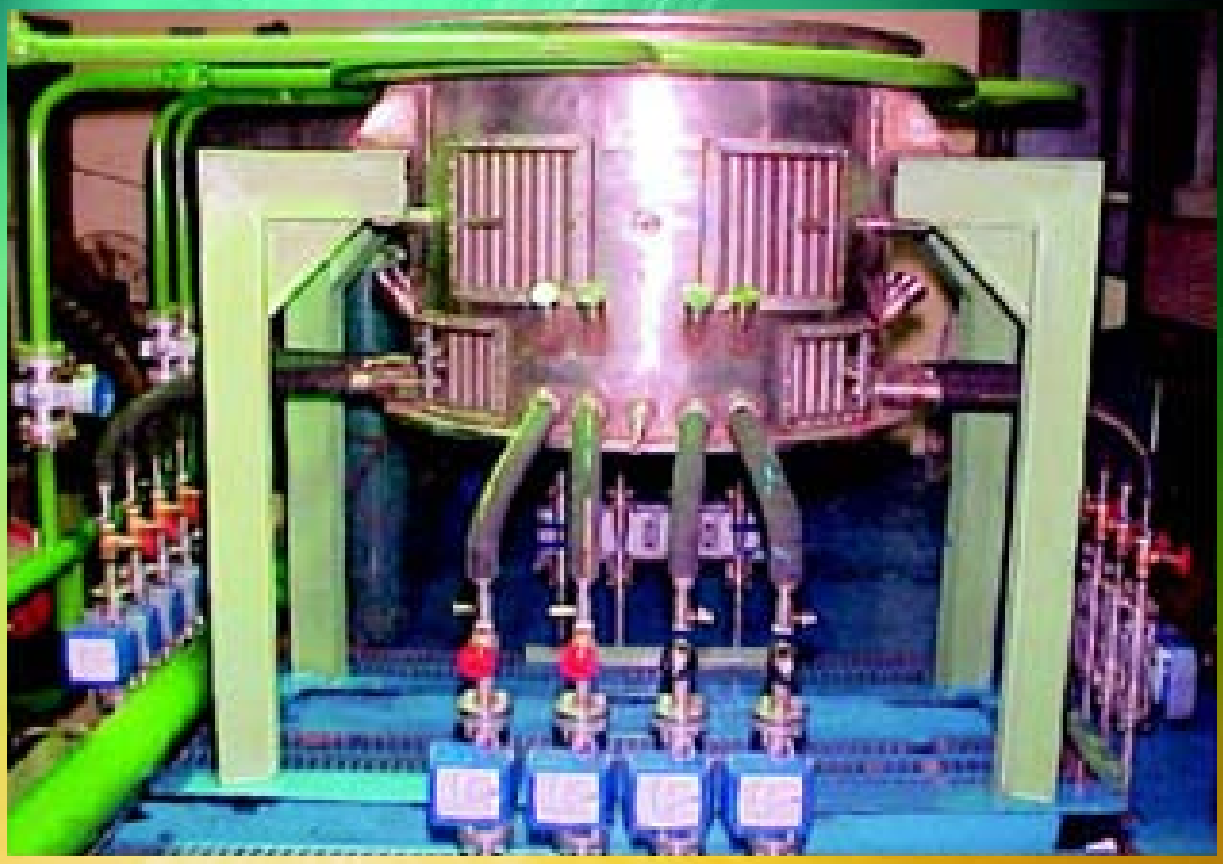
manufactured at ECIL, was installed. The system is getting ready to receive wastes generated in the glove boxes during various campaigns of CORAL before disposal.

Fast Reactor Fuel Cycle Facility

Approval of Atomic Energy Regulatory Board for the site of Fast Reactor Fuel Cycle Facility (FRFCF) was obtained, and the Detailed Project Report for the facility was submitted for obtaining financial sanction. Basic infrastructure was created at the site. Detailed design of the FRFCF to close the fuel cycle of PFBR and Review of the preliminary safety analysis report by the Project Design Safety Committee for FRFCF and specialist working groups, were in progress. Construction work on the project will commence during the year 2011.

CHAPTER : 3

NUCLEAR POWER PROGRAMME : STAGE - III



Test facility for moderator flow and liquid poison distribution studies

CHAPTER : 3

NUCLEAR POWER PROGRAMME : STAGE - III

ADVANCED HEAVY WATER REACTOR

The Integral Test Loop (ITL) is a single channel scaled test facility simulating the main heat transport system along with various safety systems and controls of Advanced Heavy Water Reactor (AHWR). However, as the parallel channel instability is the limiting one with respect to stable operating zone, the ITL was taken up for augmentation. The augmented ITL was provided with a programmable power supply for decay heat simulation.

A test fuel cluster was fabricated and installed in the pressurised water loop of CIRUS reactor for experimental irradiation. The practice of re-irradiation provides greater flexibility in planning long duration / high burnup experiments and helps in better utilisation of experimental loops. Fuel cluster had four short length fresh (Th-Pu)MOX fuel pins of AHWR type and two short length (Th-Pu)MOX fuel pins of TAPS-BWR type earlier irradiated in PWL, CIRUS to about 20 GWd/t. These fuel pins were qualified for re-irradiation by non-destructive examinations. A test cluster with six (Th-Pu) MOX fuel pins of AHWR type was fabricated in the Advanced Fuel Fabrication Facility (AFFF), Tarapur for experimental irradiation in Dhruva.

Thoria fuel clusters were fabricated for carrying out experiments in AHWR-Critical Facility. Fuel handling station and tools developed for handling experimental fuel clusters were used for assembly/disassembly of the experimental U fuel cluster and installation of activation detectors for flux measurements both inside and outside the experimental fuel clusters. Thoria cluster was loaded and reactor made critical.

The fuelling machine was designed and manufactured to validate the design. For seismic qualification a 1:4 scale model was designed, fabricated and delivered to perform shake-table testing at SERC, Chennai. Work for development of hot pull-out technology for integral nozzles in AHWR components was started. The detailed engineering of major Structures/Systems/Components of AHWR was planned to be carried out in consultancy mode.

The evaluation of proposals (technical & financial), submitted by qualified consultants for Engineering Services Consultancy of AHWR, was completed, and contract will be awarded shortly.

Finite Element analyses of end shield and calandria assembly of AHWR were carried out to

Parallel Channel as installed in ITL


Setup for programmable power supply for ITL

AHWR Type (Th-Pu) MOX Fuel Pins

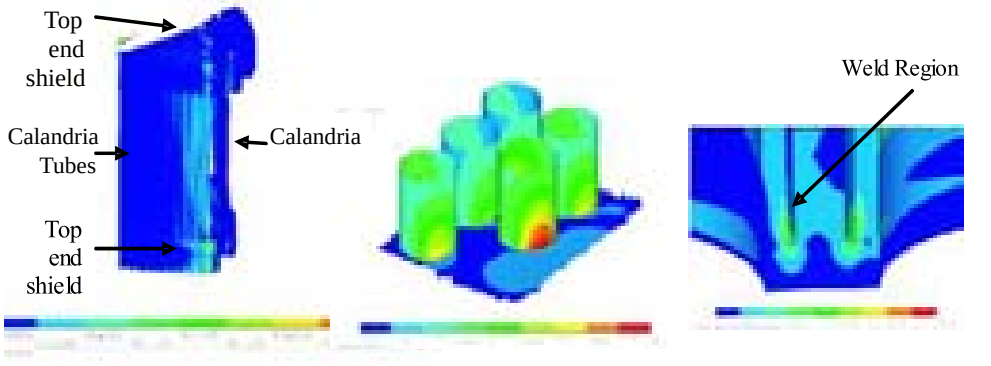
AHWR Fueling Machine under testing at shop floor

Seismic Model of AHWR fuelling machine

minimize the tube sheet thickness of end shields. A local finite element analysis to evaluate stresses in the weld joint was carried out by generating detailed 3D Finite Element model of the weld joint and adjacent tubes. Boundary conditions for this analysis were taken from global analysis of end shield and calandria assembly. Stresses in weld joint were within limits as per ASME code.

Earlier, shielding experiments were carried out with straight duct, annular duct and single lattice assembly shield models for AHWR at APSARA Reactor shielding corner. A significant back scattering was observed. Experiments were further carried out by providing collimator and reducing rear side air gap to minimize the back scattering. The collimator was designed to allow only direct radiations from the core and cut-off the scattered radiations.

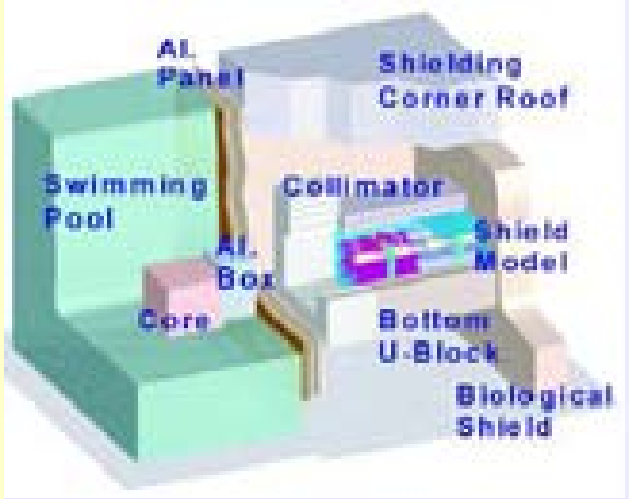
A semi-transparent 1/6th linear scaled experimental setup of AHWR calandria was designed, fabricated and installed for moderator flow distribution studies. The model consists of Calandria shell with acrylic flanges at its top and bottom,



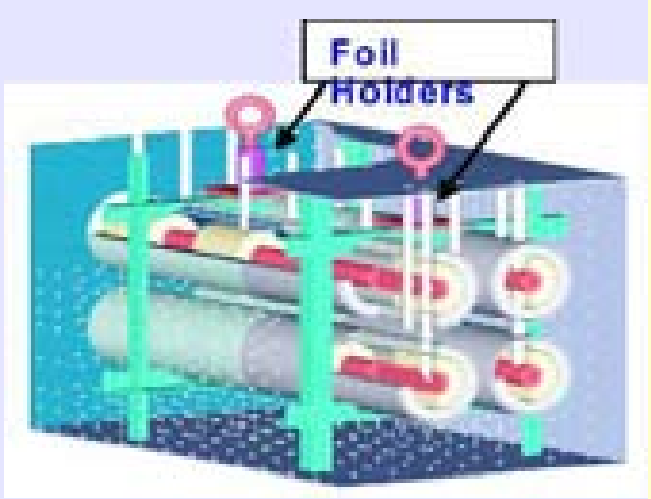
Stress intensity contours of end shield calandria assembly

Tube to tube sheet joint of bottom end shield

Stress intensity contours in weld region in 3D FE model



Experimental Set-up in APSARA reactor Shielding Corner



Larger view of Shield Model with 2x2 Channels

inlet-outlet nozzles, acrylic windows provided in the calandria shell for visualization. In the scaled model, heat generation is simulated by direct electrical heating of calandria tubes. Various instruments like magnetic flow meters, thermocouples, rotameters, pressure gauge, level indicator and level transmitter were installed in the test setup for measurement purpose.

The test facility was hooked up to a PLC based SCADA System. It was commissioned and experiments were in progress.

In AHWR, Shut Down System No.2 (SDS-2) is a liquid poison injection system consisting of poison injection headers with poison tanks and gas tank. The SDS-2 objective is to achieve very fast shutdown. It is required to experimentally validate the adequacy of the SDS-2 design. The 1/6th linear scaled calandria model was provided with 8 segmental circumferential poison injection headers at mid-elevation. A PLC based data acquisition system was incorporated. The poison injection test facility was commissioned.

The design of the equilibrium core of AHWR was finalised. Certain design modifications were also carried out.

Equilibrium core AHWR cluster was re-optimised for achieving self sustenance in U-233 by using only one type of cluster in the equilibrium core.

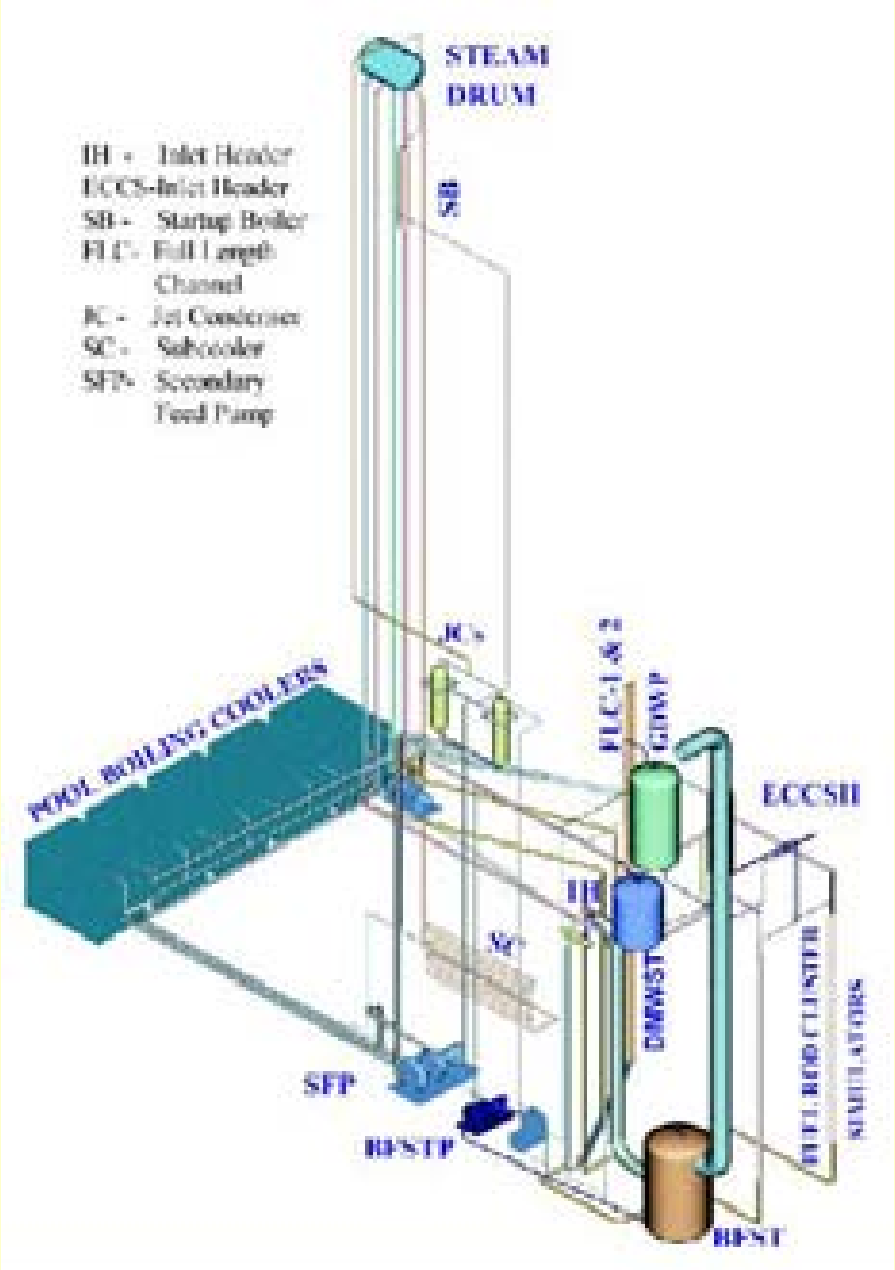
The new design of SDS-2 consists of 8 poison tubes, four each at two elevations which ensures a more effective poison injection. The worths of the poison jets for the new SDS-2 design were estimated.

The Design Basis Report for MLPAS and the various design criteria for its actuation were worked out. Use of enriched boron in MLPAS and other poison addition systems was proposed which has the advantage of reduction in radioactive waste generation.

Detailed core calculational studies related to AHWR core with Th-LEU (light enriched uranium) fuel for a target burnup of 60 GWd/Te were carried out. Gd as burnable poison was used in the LEU cluster to suppress the power peaking. Other types of burnable poisons like Er were also tried to facilitate online refuelling. An initial core with LEU fuel was designed with desirable operational features during refuelling and transition to equilibrium core.

Thermal hydraulic analysis of AHWR-LEU was carried out to investigate the thermal margin. It was found that adequate thermal margin exists with LEU fuel in the AHWR core. A feasibility study was carried out for power uprating of AHWR using pumped circulation and with LEU. The preliminary thermal hydraulic calculations indicated that the core power can be uprated to 1400 MWth from the existing 920 MWth.

Setting up of the AHWR



3-D Layout of ATTF at R&D Centre, Tarapur

Thermal-Hydraulic Test Facility (ATTF) at the R&D Centre, Tarapur, continued in collaboration with NPCIL as a part of Integrated Test Facility Tarapur.

ATTF simulates two channels of the main heat transport system and emergency core cooling system of AHWR. The main objective of this facility is so as to establish the thermal and stability design margins for AHWR and to further explore the possibility of power uprating. The various modules of the project like civil, mechanical, electrical, instrumentation and control reached an advanced stage of execution. The fabrication / procurement of the mechanical, electrical, instrumentation and control equipments of the facilities were in progress. The relevant documents were submitted to the safety committee for review. ATTF is planned to be commissioned by August 2011.

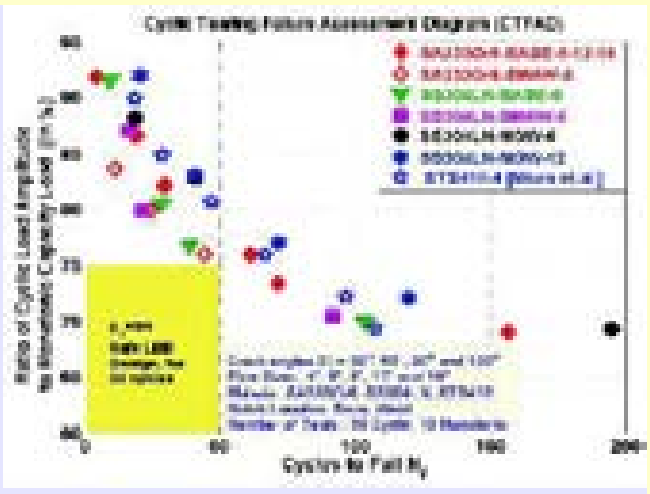
The analysis of the AHWR core was pursued for a small transient with the coolant density feedback. Work was in progress to take the fuel temperature feedback into account.

A comprehensive computer program AUTOFUEL for automatic selection of channels for in-core fuel management was developed. This program was extensively used for AHWR and working out of new guidelines for refueling of the AHWR core continued.

A program was written to read point cross-sections in the ACE (A Compact ENDF) format nuclear data library used for Monte Carlo simulations. Gravity Driven Water Pool of AHWR stores 6000 cu.m of water and acts as heat sink during steady state operation as well as during transients. This makes it prone to thermal stratification. Temperature gradients due to such stratification were computed using computational fluid dynamics code for use as additional thermal loading in structural design.

To deal with the effect of cyclic loading anticipated during a seismic event, cyclic fracture tests

Cyclic tearing test on 12 inch diameter narrow gap welded stainless steel pipe



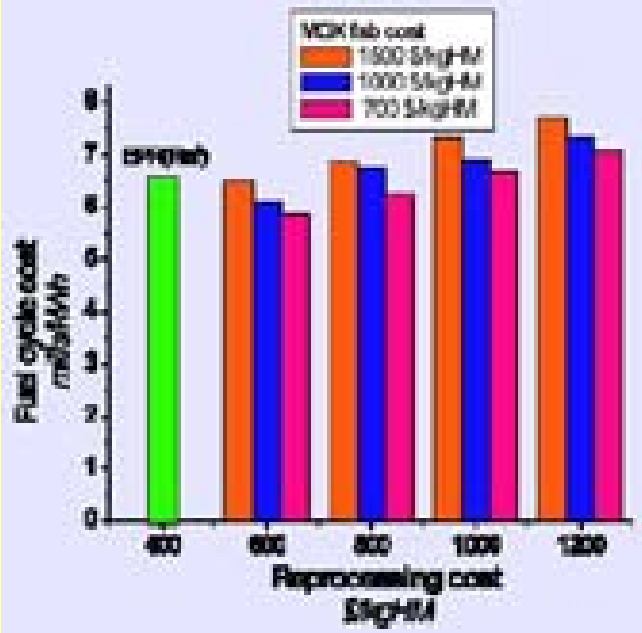
Cyclic Tearing Failure Assessment Diagram (CTFAD)

were conducted. Apart from pipes with cracks in base metal, conventionally welded pipes using Submerged Metal Arc Welding (SMAW) and those welded using hot wire pulsed Gas Tungsten Arc Welding (GTAW) with narrow gap, were tested. Investigation revealed that cyclic tearing and monotonic fracture resistance of narrow gap GTAW is superior to SMAW. This supplemented other advantages of GTAW.

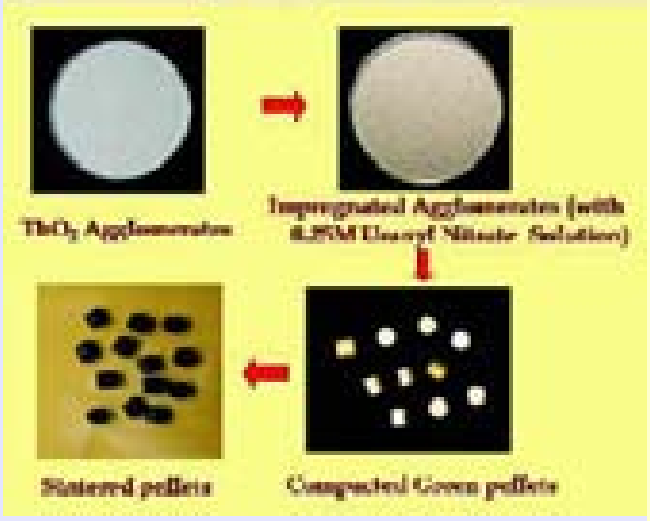
Development of dissimilar material welding process for higher thickness (11 mm) of SS 304L pipe to SS 403 for Top End-fitting of AHWR was taken up.

Thorium Fuel Cycle

The economic competitiveness of different cases involving usage of Thorium-Uranium based fuel with recycle of fissile materials in a pressurized water reactor was evaluated and compared with the reference case using enriched



Economics of using Thorium in EPR



Impregnated agglomeration Process (IAP)

uranium fuel with direct disposal option of spent fuel.

A new process - Impregnated Agglomeration Process (IAP) - was developed for the fabrication of (Th-U)O_2 fuel for AHWR.

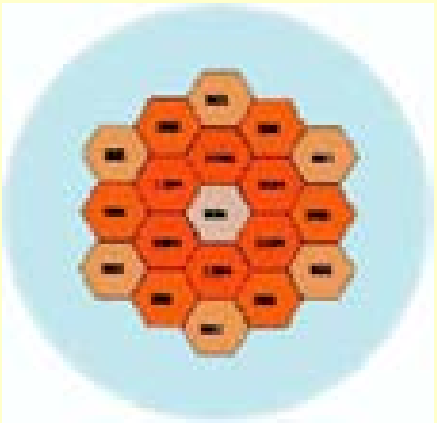
The methodology for 'HPLC Separation of lanthanide fission products from irradiated (Th,Pu)O_2' was validated. The above method was used for carrying out the sequential separation of lanthanides from dissolver solution of irradiated (Th,Pu)O_2. Sm, Pm, Nd, Pr, Ce, La were sequentially separated and were not interfered by other fission products, Th, U or Pu. Studies for the separation of Th, U and Pu from irradiated thoria-plutonia sample were carried out on a monolith C-18 reversed-phase column using a mobile phase.

Following completion of the first characterization of neutron spectrum of Dhruva beam hole, making of the mechanical chopper specifications continued and their investigation was carried out.

The PURNIMA-I fast reactor criticality benchmark was successfully completed according to international standards after a detailed internal peer review. Raw experimental measurement data were communicated by coding in an international Exchange Format (EXFOR) for use by the nuclear data evaluators, experimenters and theoreticians. India is a recognized and an active member of the International Nuclear Reaction Data Centre Network (NRDC Club). Over 130 Indian entries to EXFOR have now been coded.

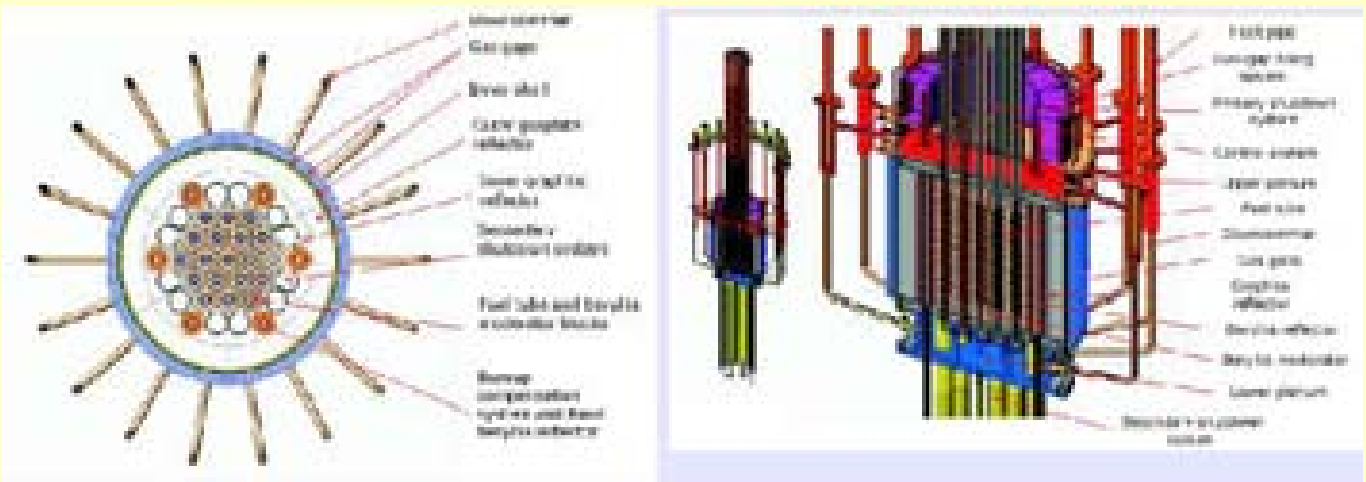
Other Thorium Reactor Systems

The Compact High Temperature Reactor (CHTR) is being built as a technology demonstrator for the comprehensive Indian high temperature reactor programme. CHTR physics design simulations were performed with new design modifications such as use of thinner control rods for finer control, reduction in the available locations (18 to 12) for control rod etc. A typical power distribution profile is given in Figure. Nuclear cross-section data (for thermal scattering) of Beryllium in Beryllium Oxide and Oxygen in Beryllium Oxide was considered. Worth gradients for control and shutdown systems were also computed.



Power distribution in CHTR

Solid modeling of CHTR systems and components was completed. Preparation of drawings and specifications for procurement and manufacture of



Core cross-section and 3-Dimensional Solid model of CHTR components and systems

components were in advanced stage. Work related to civil, electrical, ventilation, and PLC based control system for CHTR stage-1 demonstration was initiated.

The 600 MWth Innovative High Temperature Reactor (IHTR) design was revisited to optimally compute the TRISO particle packing fraction in the pebbles. A study was also done to compute location of the interface of fuelled and un-fuelled zones in the fuel pebble to have optimum moderation. The challenging task of treating the double heterogeneity effect created by lumping the fuel into particles and those into pebbles was done using the reactivity equivalent physical transform method. The results were compared with reference results from Monte Carlo simulation of a pebble in which double heterogeneity was treated explicitly.

European Pressurised Water Reactor (EPR) cores fuelled with thorium, having same geometry but different composition were studied.

A study was made to look into the possibility of loading significant amount of thorium in the present core of the High Temperature Test Reactor (HTTR) of Japan with minimal change in the existing core design. The proposed design is called HTTR-M design. Reactor grade LWR Pu is considered as seed in thorium

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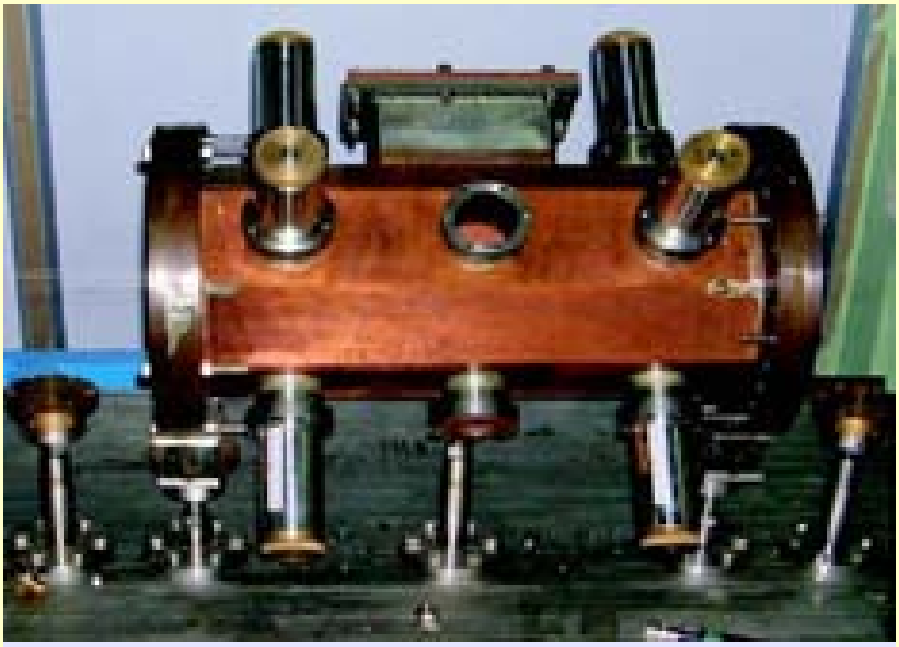
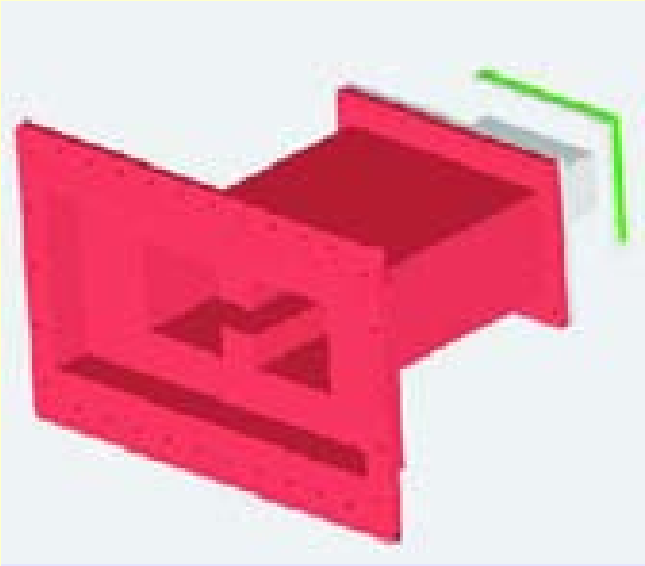


A 600 mm long prototype RFQ

A test bench used to characterize Low Energy Beam Transport System. Two solenoids used for focussing and matching the beam

Accelerator Driven Sub Critical Systems

At Trombay, an Electron Cyclotron Resonance (ECR) Microwave Ion Source is under development delivering 50 mA proton beam at a voltage of 50 KV.



Cross sectional view of 250 kW RF coupler

A 1.2 m long Drift-Tube Linac tank

Mechanical design of its critical systems like microwave ion source, beam diagnostic chamber and beam dump chamber were completed. Manufacturing of plasma chamber, five electrodes & beam diagnostic chamber was completed. The first trial assembly of the Micro-Wave ECR Ion Source was done. Design modifications for ceramic vessels & electrodes for weight reduction carried out.

Development of various processes & techniques for Sub-Critical Facility of Accelerator Driven Sub-Critical System was carried out. Manufacturing of the Calandria as per approved procedure was done, tested and it was delivered to User division.

As a part of high power accelerator development for ADS programme at BARC, a prototype of RFQ was fabricated and characterized for its RF parameters. Fabrication of the 3 MeV RFQ has also been in progress. A test bench was set up and used to characterize the Low Energy Beam Transport System.

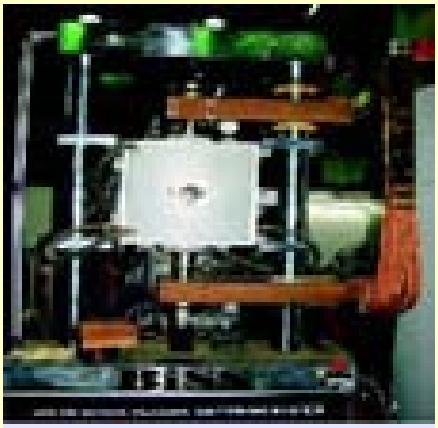
The design of 250 kW, 352.2 MHz ridge waveguide coupler was completed. Fabrication of low power prototype was in progress. Further developments of RF couplers were being pursued.

The Drift-Tube Linac (DTL) was designed to accelerate proton beam from 3 to 20 MeV, over a length of 12 m, in four 'tanks' each of around 3m length. To validate the design, a 1.2m long prototype was built. Permanent Magnet Quadrupoles (PMQ) will be used for focusing the beam. Prototype PMQ was designed and developed and required gradient of 50 T/m was achieved. Accelerator will be housed in the LEHIPA tunnel at BARC. The civil work of the LEHIPA tunnel was completed.

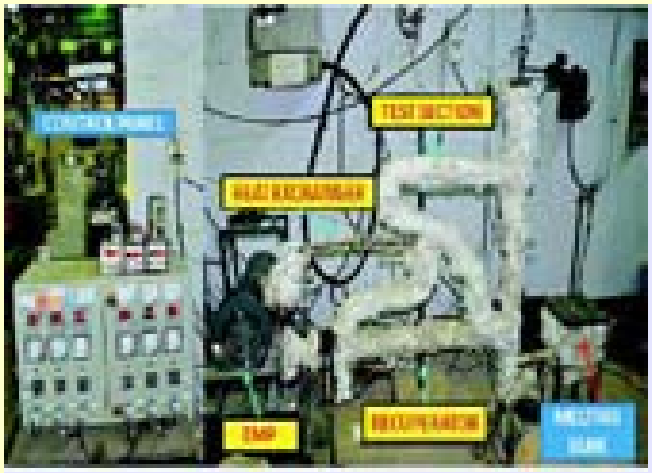
Materials

Solvent Extraction process for Dysprosium comprising two cycles based on 2-ethylhexyl phosphonic acid mono-2-ethylhexyl ester (EHEHPA) extractant using multi-stage separating funnel cascade was continued. Dy was further upgraded and 1 kg of Dy product of nuclear grade was produced with a recovery of >95 %.

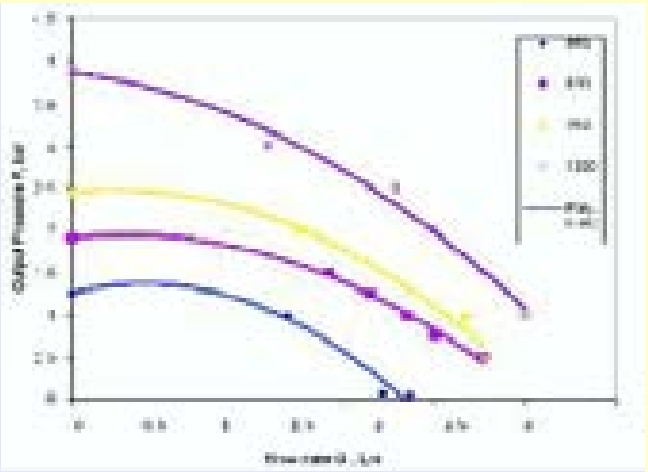
A spark plasma sintering



200 kN Spark Plasma Sintering facility



Electromagnetic pump driven lead-bismuth eutectic loop



Pressure vs. Discharge characteristics

system was designed, fabricated and commissioned. Preliminary studies on the consolidation of boron carbide, hafnium diboride and zirconium diboride were carried out. It was possible to obtain near theoretical densities, using SPS facility, at relatively lower temperature of ~1400°C.

Corrosion experiments were carried out in an electromagnetic pump driven loop to address the liquid metal corrosion of the material for the containment in Accelerator Driven Subcritical System (ADS).

Development of fuel tubes of CHTR using ceramic matrix composites were taken up.

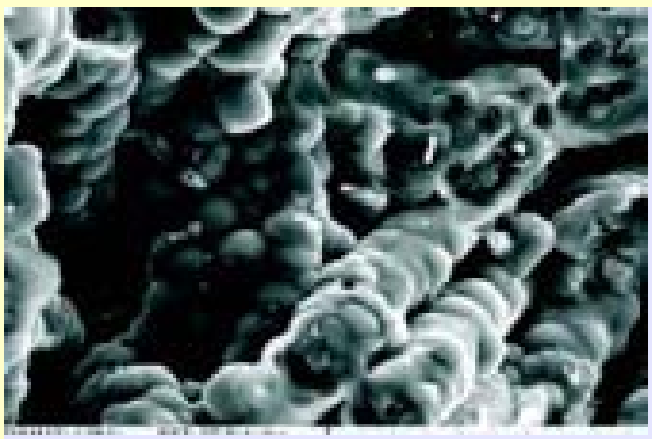
A pilot plant was set up at Vashi to meet the requirement of high purity and high density beryllia blocks of different sizes and shapes for use as moderators and reflectors in APSARA reactor and Indian High Temperature Reactor (IHTR) programme. 10 kg nuclear grade beryllium hydroxide was produced.

Reduction of beryllium fluoride for production of beryllium in pebble form was taken up on regular basis.

The development of TRISO-coated particles using a surrogate material (zirconia) was successfully completed using a high temperature spouted-bed reactor.

The process parameters for depositing all layers of TRISO particle in a single batch were standardized reproducibly.

Chemical vapour deposition was employed with methyl



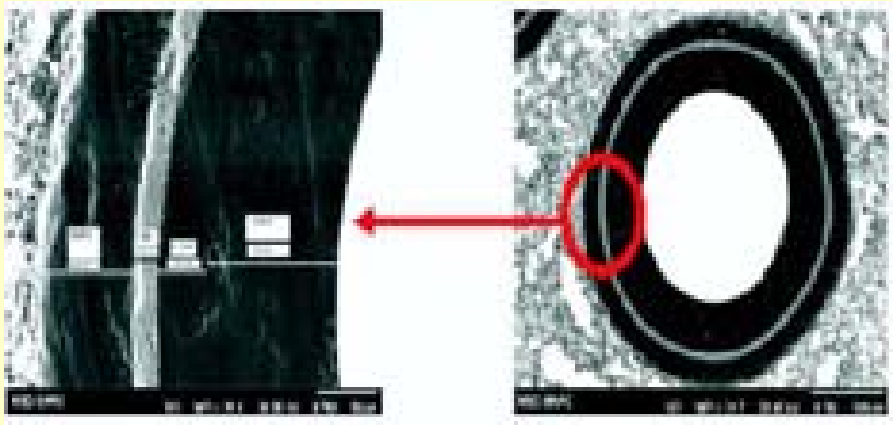
SEM image of infiltrated carbon felt after 25 h operation of CVI at 900°C using acetylene (30% vol.). 1000X

Prototype of fuel tube of CHTR made of high density graphite

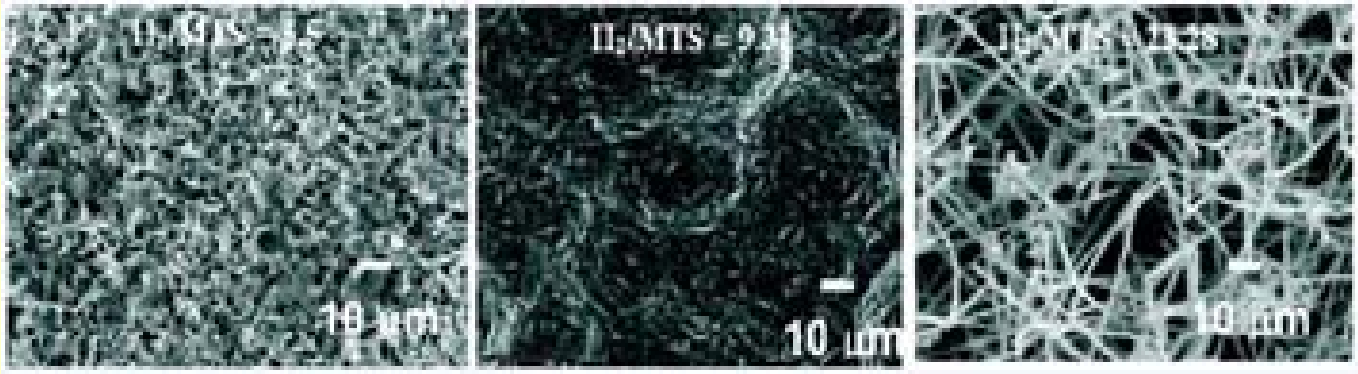
Beryllium pebbles *Reduction of beryllium fluoride operations*

trichlorosilane (MTS) as the precursor to synthesize SiC coatings on graphite. Hydrogen was also used in conjunction with MTS to positively influence the deposition rate. A detailed Taguchi method was used to study the effect of various parameters on the coating profile, and SiC coating was demonstrated on graphite. Some alternative potential precursors of SiC, like tri-(dichloro-silylmethylene) $(CH_2SiCl_2)_3$, and other organosilicon compounds obtained by substituting chlorine of this compound by different groups such as SiR3 (trialkylsilyl group) were synthesized.

SiC coatings find application as a fuel tube protective coating by virtue of their exceptional mechanical, chemical resistance and thermal properties. A novel idea of immersing a heated graphite sample in a bed of fluidized silicon was conceptualized and implemented.

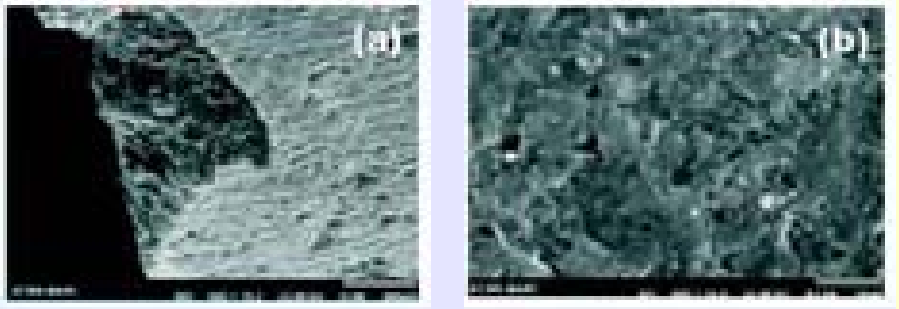


SEM image of the TRISO-coated particle produced in the spouted bed reactor



SEM images of SiC coating formed using CVD with MTS as the precursor

Setup for fluidized bed coating of SiC



SEM images of SiC coating at (a) Low magnification & (b) High magnification

Lithium titanate (Li_2TiO_3) based ceramic was proposed as breeding material for fusion reactor blankets. Using the concept of solution combustion synthesis Lithium titanate based ceramic powders were synthesized using $LiNO_3$ and hydrous titania powder as starting raw materials. The process parameters were optimized to obtain the desired microstructure and density in the sintered specimens. The studies were continued to optimize conditions for formation of phase pure lithium titanate by solid state reaction of lithium carbonate - titania.

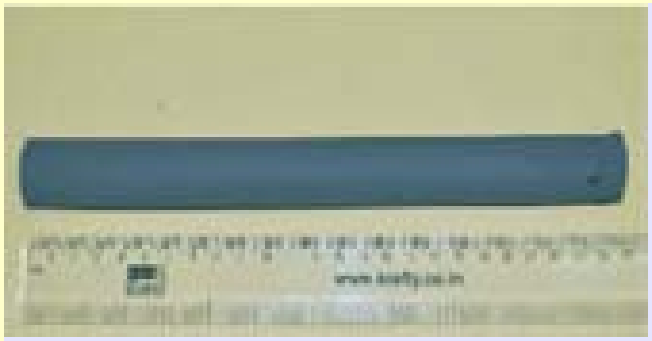
Hydrogen Energy

Lanthanum Strontium Manganite (LSM) tubes are required as cathode support tubes for development of tubular solid oxide fuel cell. The tube was formed by ceramic extrusion. 25 cm long tubes were extruded using LSM powder produced in-house. On two stage sintering, the sintered tube was found to meet all the requirements in terms of dimensional tolerance, porosity, electrical conductivity, thermal expansion.

The Solid Oxide Fuel Cell development work was continued .Development of materials for fabrication of electrochemical cell for hydrogen production through steam electrolysis at temperature (700-800^{o}C) was initiated. Gadolinium doped ceria (GDC) was studied for use as an electrolyte material. Doped gadolinium cobaltate was studied as a potential cathode material. Ni-GDC was used as the anode material.

Experiments were designed and performed to evaluate interfacial polarization resistances by electrochemical impedance spectroscopy. Compatibility of gadolinium cobaltate with GDC electrolyte was confirmed. Work was underway in setting up a testing facility for characterization of electrolyser cells.

Two novel materials, namely, ß ßtYC Ç¸# 9 ¡Ñ¤ Ÿ$ ó Ç¸™ ÂÓÿ• • a Fe-Co based perovskite material and Pr_2NiO_{4+} a Ruddelsden-Popper series based material, were investigated for optimization of process parameters in integrating these



Extruded green tubes (with end cap)

Sintered LSM tube

electrodes with electrolyte for application as air electrode. Studies indicated that these were promising materials for oxygen electrode in intermediate temperature SOEC / Solid Oxide Fuel Cell applications. Ni-1Ce10ScSZ cermet was investigated for application in hydrogen electrode. The composition 60%NiO-40%1Ce10ScSZ (by volume) was found to be optimum.

High surface area (30 m^2/gm) chromium doped iron oxide powder was prepared for using it as a catalyst in the decomposition of sulphuric acid in I-S process for hydrogen production.

Fusion Energy

A smaller sized specimen with less channels than the actual first wall of the ITER Test Blanket Module (TBM) was fabricated.

A 3-channel specimen of first wall of ITER TBM with a single bend fabricated through drilling and bending route

Studies were initiated on laser welding of ASTM A387 Grade 91 steel in large thicknesses required for use as a potential technique for the manufacture of the ITER test blanket module using an 8 kW CO_2 laser.

To determine a suitable post-weld heat treatment method, the laser weld joints were characterized.

CHAPTER : 4

ADVANCED TECHNOLOGIES AND RADIATION TECHNOLOGIES AND THEIR APPLICATIONS

Linac assembly at ECIL, Hyderabad

CHAPTER : 4

ADVANCED TECHNOLOGIES AND RADIATION TECHNOLOGIES AND THEIR APPLICATIONS

DAE's research organizations BARC, IGCAR, CAT and VECC have developed a number of advanced technologies and hi-tech facilities and sophisticated equipment. These include Research Reactors, Accelerators, lasers and laser based equipment, special materials and others, that find many applications in the fields of medicine, industry and research.

In the field of radioisotope production and applications of radiation technology having wide applications in the areas of nuclear agriculture, food preservation and industry, India has made remarkable progress.

The radioisotopes are produced in research reactors at Trombay, accelerator at Kolkata and various nuclear power plants. BARC, BRIT, RRCAT and VECC are the organizations of DAE that are engaged in the development of radiation technologies and their applications in the areas of health, agriculture, industry and research.

DAE is also working in close cooperation with other organizations of the Government of India to widen the reach of these technologies for the benefit of the common man.

Following are described the salient achievements and major activities, in this major programme segment of DAE, during the year of report.

RESEARCH REACTORS

APSARA

During the report period, APSARA reactor was de-commissioned to facilitate XI Plan Project on APSARA Up-gradation and Refurbishment. Reactor core and support structure were dismantled and all the systems were decommissioned. Preliminary inspection of APSARA pool lining, thermal column, beam holes, shielding corner were completed and no reportable deficiency was noticed. Adequate lead capping and shielding were provided over the active

Shipping cask (along with tie down structure) used cages (holding the fuel assemblies) inside cask

Extracting the irradiated activation foils from fuel pin assembly

components inside the pool towards reducing the radiation field to the acceptable limits for working over the pool area during refurbishment.

All the 34 spent fuel elements of third charge APSARA fuel were transported to Away From Reactor (AFR) complex at Tarapur for permanent storage under safeguards. Transportation of the fuel assemblies under special arrangement and its storage in AFR, Tarapur were reviewed in various safety committees and the required regulatory clearances and approvals were obtained. Procedures were prepared for the operations and qualified through mock up trials. The spent fuel could be shifted shortly.

Work on Up-gradation of APSARA reactor to a 2 MW reactor progressed. Detailed engineering of various reactor systems and Safety classification and seismic categorization of Systems, Structures & Components were carried out. Detailed architectural drawings for the reactor building and annex structure were prepared.

Critical Facility for Advanced Heavy Water Reactor and 540 MWe PHWR was operated on 79 occasions for various experiments. The experiments for measurement of moderator level coefficient of reactivity were completed and a reasonable matching of observed values was obtained with estimated values. Fine structure flux measurements inside the central lattice cell of reference core were carried out by irradiating activation foils. An integral experiment was carried out with one (Th-U) mixed pin cluster at centre core location towards validating the theoretical evaluations like critical height. Determination of thermal flux profile in spare detector locations and on reactor tank surface were carried out. Critical Facility was also used for testing of nuclear detectors and irradiations of large volume samples for Neutron Activation Analysis. The reactor was operated on 19 occasions for irradiation of various foils. for neutron spectrum measurement around fuel assembly.

Critical Facility core configuration was modified to accommodate a (U,ThO_2) mixed pin cluster consisting of 7 pins of (U,ThO_2) and 12 pins of natural uranium in the central E-5 location. Studies were carried out at lattice and core level and critical height, worth of shut off rods, missing rod worth were estimated for different core configurations. The neutron spectrum was measured at maximum flux location on the central cluster housing tube (E-5) of the Critical Facility. Multiple foils were irradiated to obtain the reaction rates in various energy regions and SAND-II code was used for the spectrum unfolding. Neutron fluxes were measured at several locations inside central (E-5) fuel lattice cell.

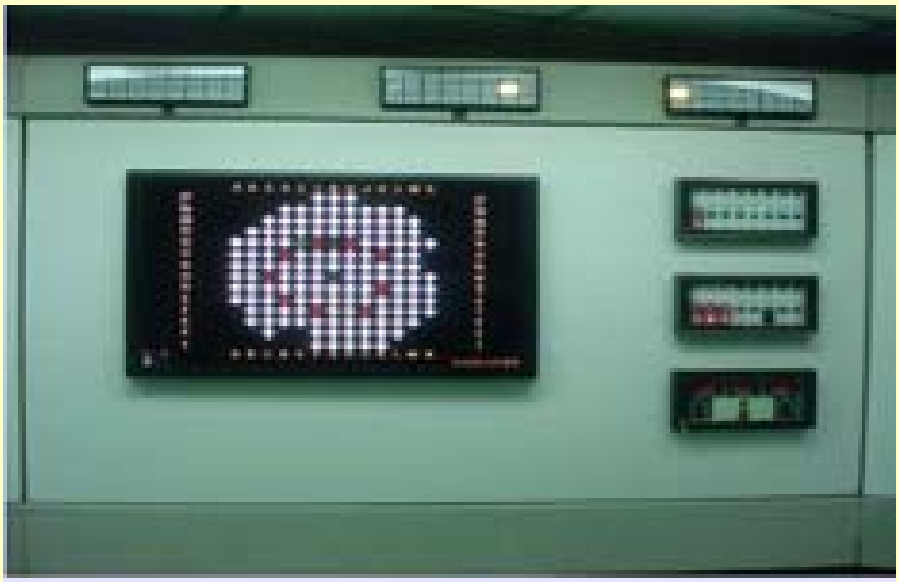
CIRUS

CIRUS reactor was generally operated at 20 MWth. Power was raised to higher levels as and when required for sample irradiation and experiments. The reactor Availability Factor for the

year was 87.2%. 577 radioisotope and other samples were irradiated in various irradiation facilities. The performance of the Desalination Unit integrated with CIRUS for utilizing the waste heat was excellent and supplemented the de-mineralized water requirement of the plant.

Neutron tomography and phase imaging facility was set up at beam tube E-12 and put into use. A facility for neutron radiography of irradiated PHWR fuel elements was set up at beam tube E- 14. Test fuel assembly consisting of 4 nos of fresh AHWR fuel pins and 2 nos of irradiated fuel pins of AC-6 (TAPS BWR type assembly) were loaded in PWL test section. Special tools and gadgets were developed and used for successful loading of the assembly consisting of irradiated fuel pins.

Reactor was permanently shut down. Actions for defueling and removal of heavy water from reactor were in progress.



New upgraded "G" panel

DHRUVA

Research reactor Dhruva continued to operate with a high level of safety and an availability factor of over 72%. The reactor was generally operated at 55 MWth and higher power as per the research requirements. Towards radioisotope production, over 580 samples were irradiated during the year. Over 60 samples were irradiated in the Pneumatic Carrier Facility for neutron activation analysis. Dhruva continued to be the major facility for radioisotope production and served as a national facility for neutron beam research. A number of research scholars from various academic institutions in the country utilized the reactor under the aegis of the UGC-DAE Consortium for Scientific

New EDPIS gauge

SCADA control panel of new MA set

Neutron focusing to enhance Intensity at Neutron Instruments at Dhruva

Research. DHRUVA's control room panels "A, B, G and I" were replaced with upgraded panels.

As a part of the XI plan project, all the 144 coolant channel flow monitoring differential pressure gauges in Dhruva were replaced with electronic differential pressure indicating switches (EDPIS).

As a step towards midterm refurbishment of electrical equipments works were carried out to reduce maintenance and enhance system reliability.

Activities pertaining to replacement of the process water/seawater heat exchangers, relocation and upgradation of spent fuel storage bay water purification system and upgradation of various control and instrumentations related to reactor trip logic system, coolant flow monitoring system, emergency core cooling system & alarm annunciation system were in progress.

Conceptual design of precision slit for controlling width and height of neutron beam at DHRUVA was completed. Design of a radioactive waste drum monitoring system based on computed tomography to segregate huge amount of waste from decommissioning of CIRUS was completed. The System's configuration and algorithms to be used for measurement scheme were developed and validated experimentally.

A double-focusing neutron monochromator was installed in the Filter-Detector spectrometer at Dhruva. This has resulted in substantial increase of about 20 times in neutron flux at the sample position for experimental studies of dynamics.Observed intensity profile and gain factor were reproduced by Monte-Carlo simulations.

High Flux Research Reactor

Various core configurations for the proposed High Flux Research Reactor were worked out for optimum design. The proposed reactor is a pool type reactor with a maximum thermal neutron flux of 6.7×10^{14} n/cm^2/sec & fast neutron flux of 1.8×10^{14} n/cm^2/sec. In addition to meeting the large requirements of high specific activity radioisotopes, the reactor will also have enhanced facilities for neutron beam research, applied research related to development and testing of nuclear fuel & reactor materials, production of NTD (neutron transmutation doping) Silicon, cold neutron source, etc.

As a part of analysis and monitoring of chemistry parameters of different fluid systems of research reactors at Trombay, approximately 100 samples were analyzed daily. Analytical support was provided to NPCIL for inter laboratory comparison values of isotopic purity of heavy water samples for confirmation.

Design stage Preliminary Level-1 Probabilistic Safety Assessment for upgraded APSARA Reactor was completed utilizing plant specific data & generic data. System configuration was evaluated and

potential accident sequences contributing to core damage frequency were identified. The plant model was computerized as Risk-monitor that can be used in support of plant operation and maintenance in future as a part of risk-informed strategy. A Life Cycle and Reliability Engineering Laboratory was setup in Dhruva for development of risk-base applications, root cause analysis, reliability and probabilistic safety assessment activities.

BARC's participation in OECD-NEA (Nuclear Energy Agency, Paris) activities in the area of Probabilistic Safety Assessment was continued.

In-Service-Inspection (ISI) programme for research reactors, non-destructive examinations of systems, structure and components as detailed in ISI document of CIRUS and Dhruva was continued.

ACCELERATORS

At BARC, slot machining and finish machining of LINAC cell cavities and associated structures were completed. The design and drawing work of Beam Diagnostic Chamber for LINAC were also completed. Work on the various sub-assemblies of the Angle Resolved Photoemission Spectroscopy/Photoemission Electron Microscopy (ARPES/PEEM) Beam line for INDUS-II project was started. General assembly drawing for the design of plane grating monochromator for ARPES / PEEM Beam Line was completed. Design modification of the 320° electron spectrum Torroidal analyzer used to measure energy and polar angle distribution of electron from solid surfaces made progress. Conceptual design of Hexapod for Spherical Mirror Chamber (ARPES BL), and the design of first and second Mirror Chamber for BL-9 beam line and related calculations and analyis were completed.

The Superconducting Magnetic Energy Storage (SMES) system is a clean and environment friendly attractive solution for the power quality problems with the ability to mitigate short time voltage fluctuations. With the expertise gained by the realization of the large superconducting cyclotron magnet and related cryogenics, VECC ventured on taking up the task of developing SMES devices in XIth five year plan in a three stage programme of developing 0.6 MJ, 5 MJ and 30 MJ systems.

The detailed design of NbTi based cryostable and solenoid type 0.6 MJ SMES coil was carried out, fabricated and assembled at VECC. High temperature superconductor (BSCCO-2223) based current leads for significant heat load reduction were also designed, fabricated and tested.

Fabrication of the Power Conditioning System (PCS) with the energy storage capability working as a Dynamic Voltage Restorer, which is the most effective and viable solution for mitigating the voltage sag of the electrical utility supply, was in progress at VECC.

For energizing Super-conducting Cavities of the Proton Linac, development of a 30 kW (Continuous Wave), 650 MHz solid state amplifier continued at RRCAT. Theoretical studies and prototype testing of various combiner structures, suitable for 650 MHz were done. The measured performance of these components was found to be in good agreement with theoretical calculation.

At RRCAT, setting up of infrastructure facilities for development of Superconducting Radio Frequency (SCRF) cavities continued. For obtaining high accelerating gradients, the inside surface of SCRF cavity must be smooth. To remove the weld bead formed by electron-beam welding, cavities are mechanically polished using the Centrifugal Barrel Polishing technique. A centrifugal barrel polishing machine was developed with the help of a local vendor. The non-uniform surface layer formed in the cavity during machining and welding, can be polished to a get surface finish up to 200 nm.

Two pre-prototype laminated, sector type (outer radius: 1900 mm & 24 sector angle) dipole magnets (one each from 0.5 mm thick silicon steel & 1.5 mm thick low carbon steel laminations) were developed for validating the magnet design parameters for up-gradation of dipole magnets of the existing 700

Centrifugal barrel polishing machine

Polished single cell cavity

Pre-prototype dipole magnet core with 1.5mm thick low carbon laminations

MeV Booster Ring.

A sector type 90 degree bending dipole magnet was developed for use in the mass-spectrometer developed at BARC. The magnetic field generated in a pole gap was 1 Tesla. This magnet has movable exit edge, so that one can get highly focused spectrum for analysis.

5 W Erbium -Ytterbium co-doped CW fiber laser at 1564 nm

LASER TECHNOLOGY

Development of 110 W Copper-HyBrID laser

A Copper-HyBrID laser with average laser power of 110 W was developed at RRCAT. The electrical to optical conversion efficiency of this laser was about 2%.

Development of 10 kW peak power industrial Nd:YAG laser

A rugged 10 kW peak power fibre optic coupled pulsed industrial Nd:YAG laser with 500 W average power was developed. Using this laser, drilling of holes up to 200 mm in RCC in 2 min, metal cutting up to 25 mm, and welding (~ 4 mm) was demonstrated. The system has potential applications for cutting/welding during installation of new reactors and refurbishing of nuclear power plants as the fibre optically guided beam can reach remote locations and can also be used in radioactive environment.

Development of a fibre-coupled short pulse duration Nd:YAG laser for cleaning applications

A 55 microsec pulse-duration flash lamp-pumped Nd:YAG laser system for surface cleaning applications was developed. This laser has potential applications for nuclear decontamination.

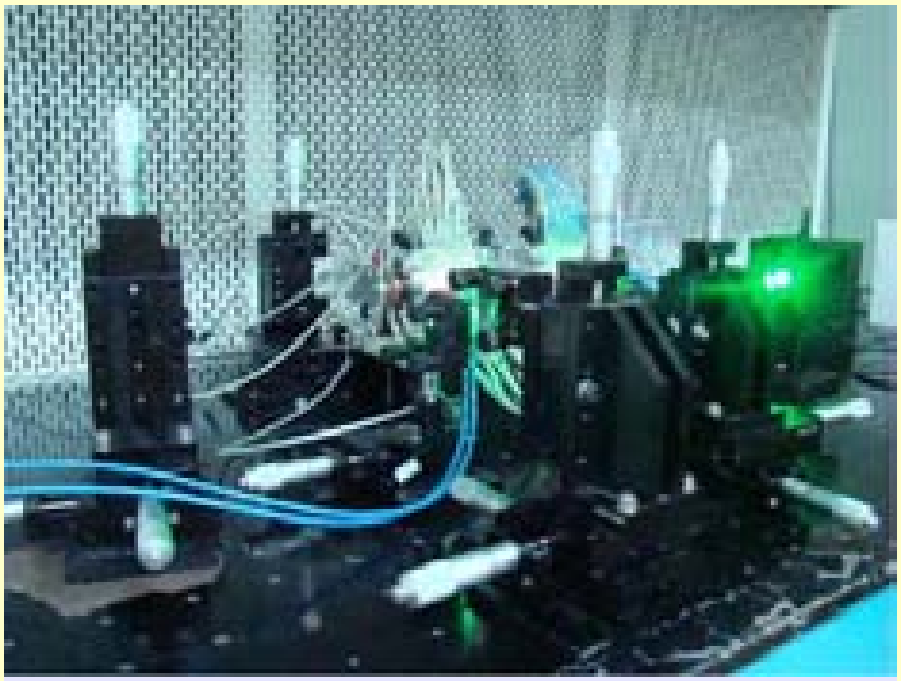
Development of a 5 W continuous wave (CW) single transverse mode Erbium - Ytterbium co-doped fibre laser at 1564 nm

A 5W single-transverse mode Erbium -Ytterbium (Er :Yb) co-doped fibre laser at 1564 nm with a slope efficiency of about 18%, was developed. This development will be useful for medical applications such as optical coherence tomography, microsurgery, skin resurfacing and nonlinear frequency conversion.

110W average power Copper-HyBrID laser

High power CW green (at 532nm) beam generation by intracavity frequency doubling of diode side-pumped Nd:YAG laser

80W of CW green beam from Nd:YAG/ KTP based laser using a Z-shape cavity, was demonstrated. At the maximum pump power of 750 W, the CW



80 W Continuous Wave Green Laser in a Z-cavity

green power obtained was 82.5 W corresponding to 11 % optical to optical conversion efficiency.

Development of 455 mW/Facet CW Semiconductor Laser at 980 nm

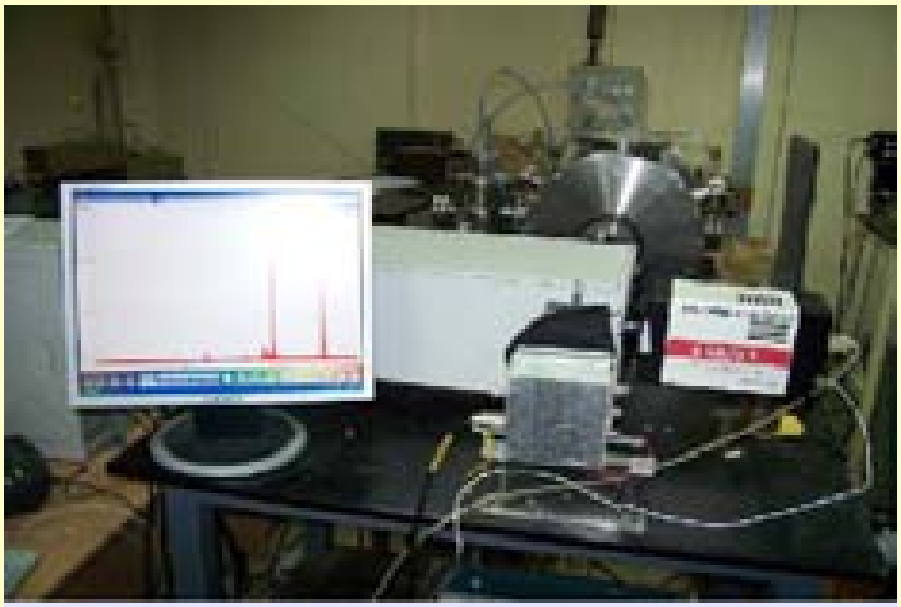
Metal Organic Vapour Phase Epitaxy grown laser structures processed through conventional optical lithography and with varying parameters to achieve better photon confinement to reduce internal resistance of the device for increasing average output power, were developed. This device yielded 455 mW/facet power output in CW operation emitting at 980 nm without facet coating.

Development of GaAs based P-I-N detector and effect of gamma-ray irradiation on detector parameters

GaAs P-I-N diodes were exposed to Co-60 gamma-ray irradiation and the effects of gamma-ray irradiation on the current-voltage (I-V) characteristics of the diodes were determined using temperature dependent I-V measurements. The series resistance was found to increase with the gamma-ray irradiation, which could be explained due to the production of radiation induced defects.

Continuous Wave Laser Diode Emission Image on Infra Red card

Compact Ultrafast Terahertz Free Electron Laser (CUTE-FEL) setup



Indigenously developed ICCD based laser induced fluorescence (LIF) spectrometer

Terahertz Spontaneous Emission Observed in CUTE-FEL

The Compact Ultrafast Terahertz Free Electron Laser (CUTE-FEL) being built at RRCAT, was designed to lase in the 80-150 micro metre wavelength band. The first measurement of terahertz undulator radiation from the CUTE-FEL was made using a liquid Helium cooled bolometer. It corresponded to an average power of 6.5 nW.

At Trombay, the degradation mechanisms of Pyrromethene laser dyes were established. Among different additives in dye solutions to retard degradation and/or effect of degradation, 1.4-diazabicyclo [2.2.2] octane (DABCO) was demonstrated as an effective singlet oxygen quencher in the Pyrromethene dye solutions, which offers very stable operation of dye lasers. Its concentration was optimised.

Spectrally and temporally resolved two-colour laser-induced fluorescence technique using gated intensified charge couple device camera, was developed to simultaneously measure radioactive lifetimes of highly excited atomic levels, branching fractions of different decay channels from excited states and excited-state-to-excited-state absolute atomic transition probabilities. Extensive data was generated for atomic samarium. The developed technique has general applicability and can be applied for elements with complex atomic spectra. The technique and measurements are very useful for many areas of basic and applied sciences such as atomic physics, plasma physics, laser chemistry and atmospheric sciences. These results are of significant importance for determination of solar and stellar abundances of elements and in search for new laser materials.

A programme of characterizing and perfecting the process of laser assisted cleaning of fuel pin surfaces was developed and the technique was integrated with the PFBR fuel line and was used to routinely clean the loaded fuel pins before they are removed from the glove box. It was established that the laser technique can bring down the activity to within permissible levels (8-10 cpm) and has decided advantage over the generally adopted technique of ultrasonic cleaning where the residual activity is relatively high making manual cleaning compulsory.

Yttrium oxide is used for coating of crucibles and moulds used at high temperature to handle highly reactive molten metals Yttrium oxide coating on tantalum substrates by thermal plasma spray was found to be a stable protective barrier against liquid uranium at 1573 K upto 200 hrs in vacuum.

The new strip beam electron gun powered with AC filament heating, was tested.

The effect of ripple present in the accelerating voltage on the dynamics of an electron beam from a strip-type electron gun was investigated. The inherent ripple in the accelerating voltage is shown to be useful in avoiding material sputtering, yet maintaining a high evaporation rate.

A new charge density probe based on high temperature iridium alloy was developed at

Trombay, to measure the electron density in the high temperature re-entry plasma surrounding re-entry vehicles. The probe was ground tested at the Vikram Sarabhai Space Centre's high enthalpy facility.

An innovative experiment using a radially split anode where each radial segment is connected to grounds through an appropriate resistance was conducted to study the mode of current transfer in to the anode of an arc plasma torch. Axial magnetic field was used to induce rotational motion of arc attachment. It was found that high gas flow rates and larger anode diameter resulted in arc root formation.

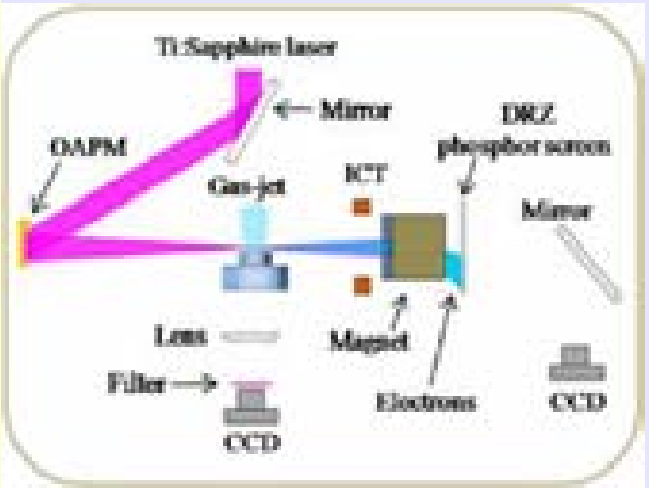
Fabrication of components for the Copper-Vapour Laser (CVL) Assemblies for U-233 cleanup project continued at BARC. Design and drawings of the Lifting Mechanism for CVL Assemblies and detailed technical specification for its procurement was completed. Single longitudinal mode (SLM) Dye Laser is to be used for U-233 cleanup programme. Mechanical design of the prototype SLM Dye laser was developed and parts were manufactured with highest possible accuracy.

An indigenously developed high power Nd:Glass laser system (20 J/300-800ps) with focusable intensity more than 5x1014 W/cm2, was used successfully for studies on matter at high density and high temperature, to generate shock pressure exceeding 25 Mbar in several materials and also for several experiments in frontier area of Intense Laser Plasma interaction such as opacity measurement of hot electron heated iron and interaction with low density foam.

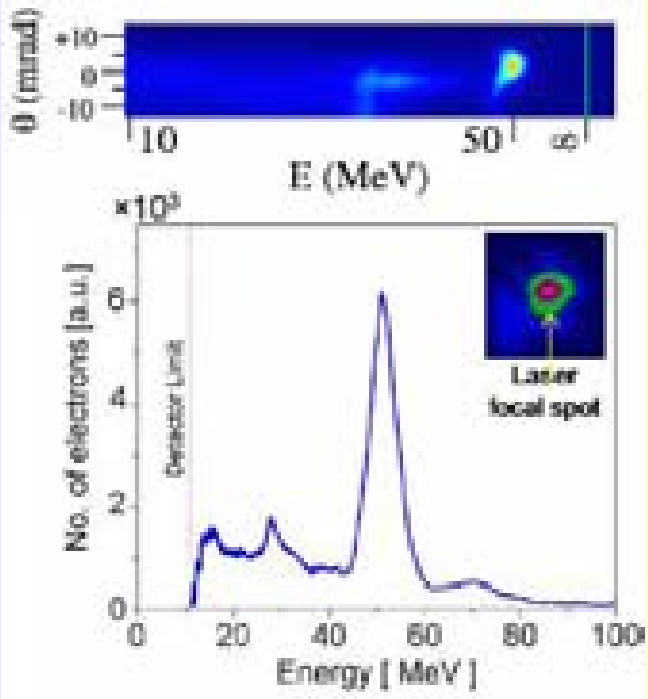
Laser Applications

Laser based electron acceleration

Studies on laser based electron acceleration were continued using higher laser intensity of the laser. Mono-energetic electron beam was observed with an energy of ~50 MeV and reproducibility in 50% of the laser shots. It was highly collimated with a low divergence of < 10 mrad. The effect of pre-pulse on the beam stability and stable acceleration was also investigated.



Experimental setup for electron acceleration



The electron energy spectrum
Inset : Laser focal spot intensity distribution

Efficient harmonic generation in carbon containing targets

Higher Harmonic Generation (HHG) in nanoparticles and carbon targets

For the first time, HHG in plasma plumes of silver nanoparticles produced in situ was demonstrated. The HHG was also produced in plasma plumes of materials such as graphite, C60, polyethylene, carbon-aerogel, Teflon, carbon nanotubes etc. All these targets gave harmonics with very high conversion efficiency in lower orders.

Nanoripple formation by femto second laser pulse irradiation

A study was carried out on the surface nanoripple formation using ultra-short laser pulse irradiation (in air) of various materials. The semiconductor materials of low band gap such as InAs, GaAs, InP and high band gap such as GaP, GaN, SiC, ZnSe, were used. A grating-like structure (nanoripple) was generated on the GaP substrate with 200 nm (/4) spacing at mild focussing conditions of linearly polarised fs pulses. The ripples were found to always orient normal to the laser polarisation direction. The effect of laser wavelength, number of laser shots, angle of incidence, polarisation, fluence, band gap and ambient medium was studied.

Capillary Discharge setup

Control and data acquisition system for capillary discharge setup

An electronic control and data acquisition system was developed at RRCAT for the operation of the pulsed power based capillary discharge setup. The capillary discharge setup, as a high intensity pulsed X-ray source, was under development.

Saturation absorption spectroscopy of metastable Kr atoms

Saturation absorption spectroscopy (SAS) is frequency locking of lasers that is used for atom cooling experiments. A setup was developed at RRCAT for generating SAS signal for metastable Kr atoms.

RF discharge in the Kr cell for Doppler-free signal of metastable Kr atoms

Reshaping of metal nanoparticles due to femtosecond laser irradiation

A fine-tuning of the surface plasmon resonance of a silver nanoplatelet colloid towards the blue was achieved by a controlled exposure to 800 nm femtosecond laser radiation. The blue shift was up to 40 nm. Calculation of absorption spectra for triangular platelets of different shapes showed that the shift resulted from smoothening of the tips and edges of the platelets.

Biomedical Applications

Comparative evaluation of Raman and fluorescence spectroscopy for optical diagnosis of oral neoplasia

A comparative evaluation of the relative capabilities of in-vivo fluorescence and near-infrared Raman spectroscopy for simultaneously discriminating the various oral tissue pathologies in a clinical setting was carried out.

Detection of urea adulteration in milk using near-infrared Raman spectroscopy

An exploratory study was carried out at RRCAT to assess the applicability of near-infrared Raman spectroscopy for rapid quantitative determination of urea adulteration in milk.

Wound Healing Studies with Optical Coherence Tomography

In a study, real time Optical Coherence Tomography imaging was used to monitor the response of healing of wounds on treatment with curcumin. This data correlates with faster wound closure in curcumin treated wounds.

Photodynamic efficacy of poly-lysine conjugated chlorine p6 (plcp6) for eradication of Pseudomona aeruginosa in excisional wounds developed in immunocomprised and immunocompetent mice, was evaluated.

Studies on Photodynamic Effects

Studies on antibacterial photodynamic effects of chlorophyll-a derivatives on different bacteria responsible for wound infection and studies on the uptake and phototoxicity of chlorin p6-histamine conjugate (Cp6-his) in oral and breast carcinoma cells were continued. Studies were initiated to examine tumour selectivity and photodynamic efficacy of Cp6-his conjugate in hamster cheek pouch model of oral cancer.

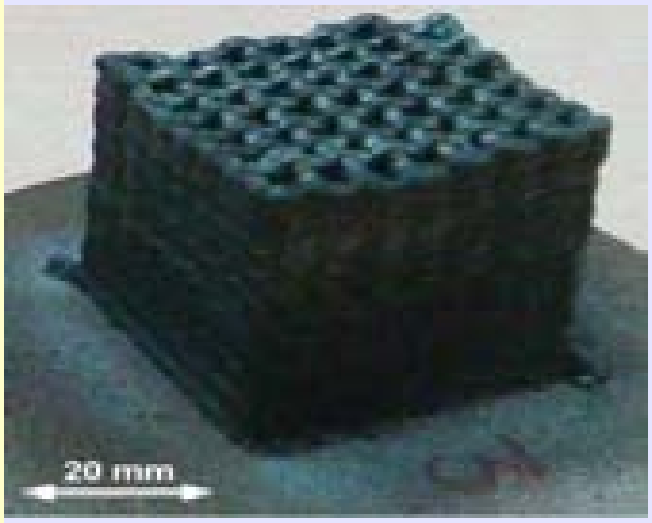
Industrial Applications

Laser Surface peening treatment

A technique of laser peening surface treatment was standardized for enhanced fatigue performance of automobile components. Laser treated specimens demonstrated significant increase in fatigue life over conventionally shot peened as well as untreated base metal specimens.

Laser rapid manufactured structures

A methodology for laser rapid manufacturing of porous metallic



Laser Rapid Manufactured Porous Structure of Inconel-625

Compact high average power Nitrogen Laser for treatment of tuberculosis of lung and lymph node

structures was established and Inconel-625 structures with about 12% porosity and compressive yield strength of 225 MPa were fabricated using this methodology.

Laser Instrumentation

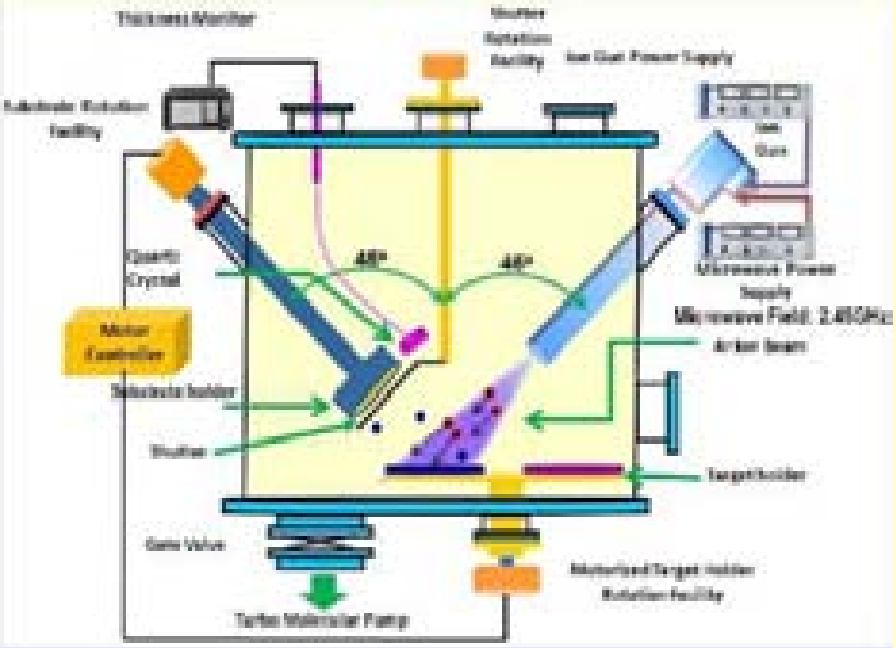
Production version of Nitrogen Laser for Medical Applications

As part of the technology transfer of the compact high average power nitrogen laser to Nexus Mechatronics, Pune, RRCAT helped to build a production version of the laser. Nexus Mechatronics would be manufacturing the laser system for hospitals where it will be used in the treatment of tuberculosis of the lung and the lymph node.

SPECIAL MATERIALS

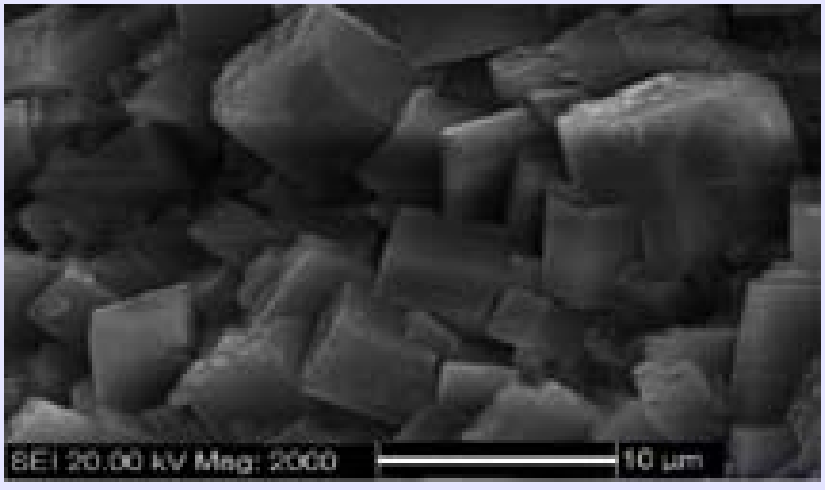
At Trombay, a state-of-the-art Ion beam Sputtering (IBS) System was built indigenously for the development of multilayer soft X-ray mirrors for synchrotron radiation applications. Several prototype soft X-ray mirrors utilizing W/Si multilayers were developed for the wavelength of 45Å and were characterized by lab source based grazing incidence X-ray reflectivity (GIXR) as well as synchrotron reflectivity beam line of INDUS-I.

A process based on the solid state reaction of lithium-carbonate and titanium-dioxide,

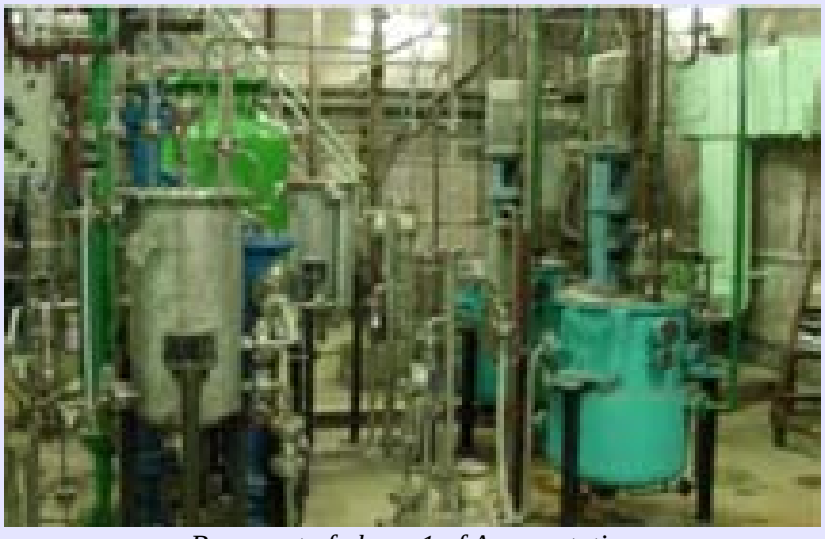


Schematic of Ion Beam Sputtering System

Ion beam sputtering (IBS) deposition system



XRD-analysis of synthesized Li_2TiO_3 powder



Basement of phase-1 of Augmentation of Lithium Metal Plant

was developed for the synthesis of lithium-titanate and pebble fabrication.

No solid and liquid waste was generated in the process. Synthesized Li_2TiO_3 and fabricated pebbles were characterized. The measured values were consistent with the values reported in the literature. Fabrication facility set up is capable of producing 2 kg pebbles per batch.

At Trombay, a computation facility was set up to screen the existing extractant/solvent system as well as to design a new extractant/solvent system for a given separation. The methodology for molecular property calculation which is useful for various separation processes was standardized by comparing the calculated results with the experimental results.

Cis-syn-cis Di cyclohexano 18-crown-6 was found to be a suitable extractant for Sr metal ion pick up from the nuclear waste. Similarly, Nitro phenyl Octyl Ether (NPOE) was found to be suitable as solvent for Strontium ion extraction from nuclear waste. This theoretical work helped the BARC team to select solvent systems in their experimental work for developing the separation flow sheet.

The Phase-1 of the augmentation of Lithium Metal Plant, which was taken up in two phases, was taken up for cold

Nd:YVO_4 grown crystal

commissioning after completing the required modifications involving civil work, installation of additional process equipment and electrical works. Phase-2 work was in progress.

Crystal Growth

Optical floating zone (OFZ) facility

A four mirror optical floating zone facility was set up for the growth of single crystals having high melting point (up to 2000^0C) and high volatility. Single crystals of Nd:YVO4 with ~ 40 mm length and ~5 mm diameter were grown.

Growth and characterization of LAP crystals

Transparent crystals of L-arginine phosphate monohydrate (LAP) were grown up to a dimension of 20x20x5 mm^3 using platform technique. The grown crystals have 88% transmittance in the visible-NIR region with UV cut off near 230 nm.

Yb doped Lead-Lanthanum-Zirconate-Titanate (PLZT) transparent ceramics

Transparent Yb2O3 (1mol%) doped PLZT ceramic was prepared by hot-pressing at 1175°C under a load of 0.5 Ton .The transparency of 0.3 mm thick sample at 1µm wavelength was found to be 55%.

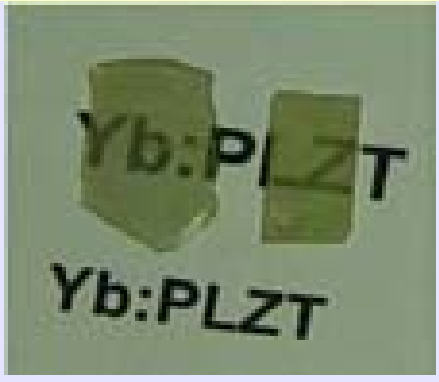
Carbon- platinum catalyst for heavy water application

Extensive testing of Platinum loaded Carbon Aerogel (Pt-CA) catalyst made at RRCAT, was performed at the Heavy Water Plant, Baroda.

ADVANCED TECHNOLOGIES

At BARC, a Quadrupole Mass Spectrometer (QMS) with a mass range of 150 amu was developed for oxygen enrichment studies and for residual gas analysis.

Transparent crystals of L-Arginine Phosphate monohydrate



Transparent Ytterbium doped Lead-Lanthanum-Zirconate-Titanate

Single Dixon ring

QMS for oxygen applications enrichment studies set up W @ 350 MHz

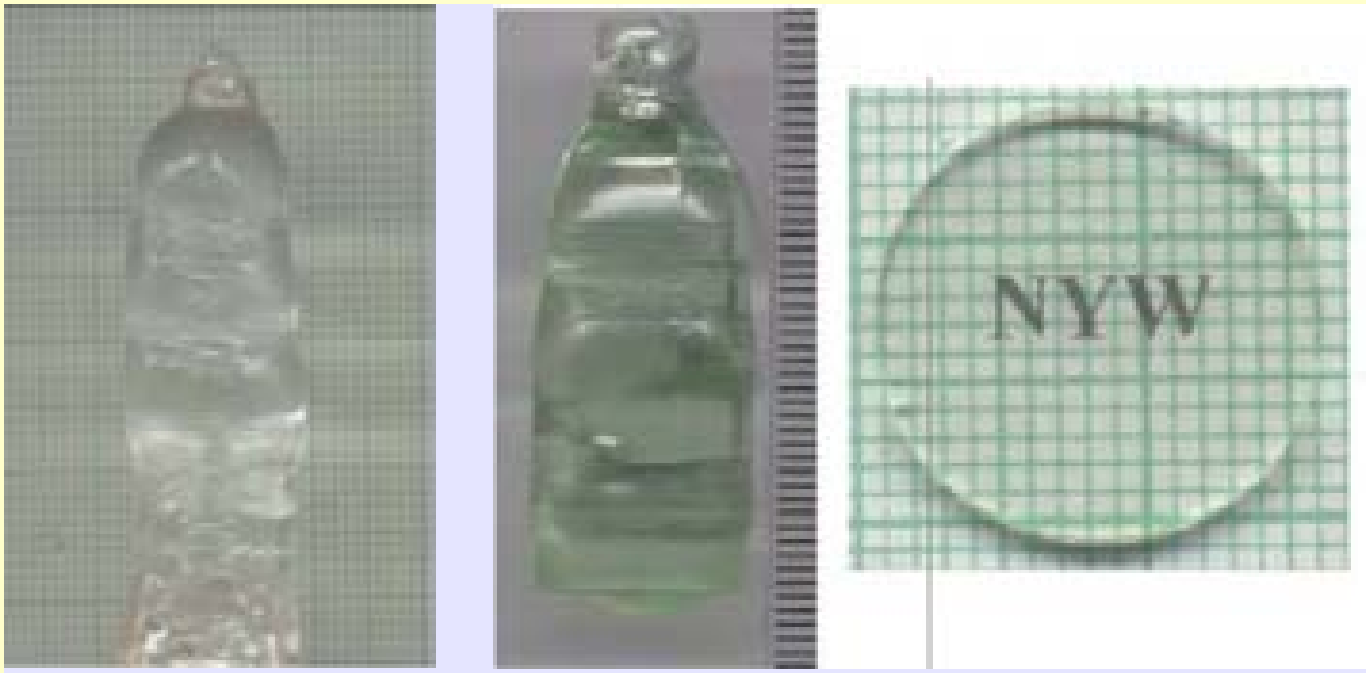
ICPMS for trace element analysis in Uranium

Inductively Coupled Plasma Mass Spectrometer (ICPMS) with quadrupole mass analyser was developed for trace impurity analysis in Uranium samples and isotope ratio analysis of Molybdenum. Thermal Ionisation Mass Spectrometer (TIMS) with seven collectors was developed for geochronology applications. It is capable of measuring isotope ratios in Sr and Nd samples with a precision of better than 20 ppm.

TIMS for geochronological applications

Secondary ion, time-of-flight mass Spectrometer was developed for studying impurities and trace elements on various sample surfaces.

At BARC, Thermoelectric generators (TEG) were fabricated using 32 pairs of n-PbTe and p-$(AgSbTe_2)_{0.15}(GeTe)_{0.85}$. For a hot side temperature of 400ºC, the TEG shows a power output of 8.5 W and 6% efficiency of conversion. Good quality transparent single crystals of



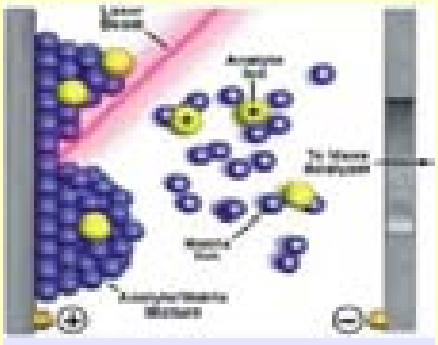
Undoped $Li_6Gd(BO_3)_3$ and $NaY(WO_4)_2$ crystals

lithium gadolinium borate and sodium yttrium tungstet were grown using the Czochralski technique. While Cerium doped lithium gadolinium crystals will find applications in neutron detection, neodymium doped sodium yttrium tungstet will be used in the diode pumped lasers. Silicon charged-particle detectors,both surface barrier and oxide-passivated ion-implanted types, were fabricated. Large area (1500 mm^2) detectors with their oxide protected against moisture, were made for use in air. The thick E and the ultra-thin ΔE detectors were regularly produced for use in BARC and TIFR.

A Scanning Electron Microscope (SEM) was developed in BARC in association with an industry partner. It features a resolution of 4 nanometers at 30 KV and a maximum magnification of 1,50,000. The Centre also developed a prototype of a unique and compact Hand Scan Biometric System (HSBS) for verification of identity of personnel.

RF system Radio Frequency Quadrupole (RFQ) accelerator based 14 MeV neutron generator was tested up to 14 kW across 50-ohm resistive load with 17 dB power gain and 48 % efficiency. While it uses 1 kW driver to give the RF power, a new 3 kW RF driver for this RF system was also developed and tested up to 3 kW, with 15 dB power gain and 56 % efficiency.

The indigenously developed state-of-the-art Matrix Assisted Laser Desorption Ionization Time-of-Flight Mass Spectrometer (MALDI-TOFMS) was put into regular use for the determination of precise molecular weight, and to identify the sequence of aminoacid residue in proteins. The MALDI is capable of detecting the biomolecules of molecular weight up to 50,000 Da (viz., Angiotensin, Lysozyme, Trypsin etc.) at sub pico mol level. Recently, insulin, its fragments, and its cluster (up to hexamer) are



Schematic of MALDI TOFMS experimental scheme

14 kW @ 350 MHz RF system

3 kW @ 350 MHZ Driver for RF system

PES Beam line with hutch

Helium liquefier cold box being integrated with process compressor and Dewar

Helium Liquefier cold box connected to HP and LP lines of process compressor

detected and mass characterized at sub pico-mol concentration.

This instrument has the mass detection limit in the range of 1 Da to 40,000 Da with a sensitivity of sub picomoles. It has the resolving power of 200 (2 Mr of 1347 Da) and a mass accuracy of 0.1% @ 5 KDa.

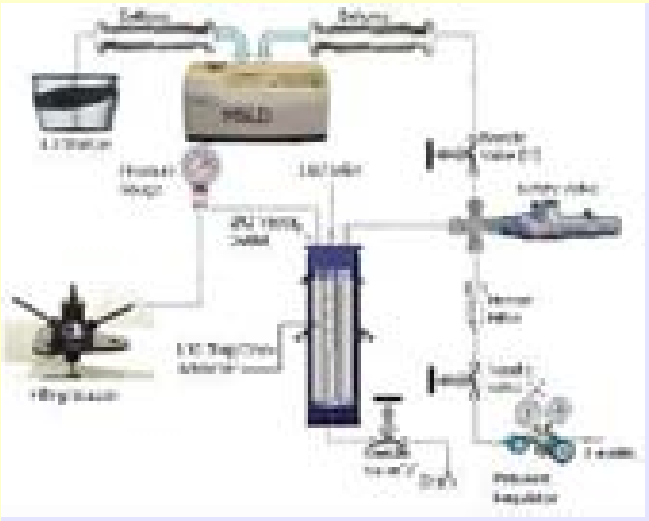
Fabrication of a Helium liquefier (maximum capacity 100 l/hr) cold box was completed. The liquefier system was under integration with the process screw compressor (1.5 bar to 17 bar, 100 g/s flow) and a 1000 l liquid Helium Dewar cum receiver vessel.

A cryogenic turbine impeller, size 16 mm, service speed 2,64,000 RPM was designed and developed at Trombay. The turbine was tested for stable operation up to a speed of 2,70,000 RPM with very low vibration levels.

Indigenously developed micro cryo-cooler unit was fabricated, tested and integrated with Hand Held Thermal Imager meant for night vision device.

A minimum temperature of 59 K was achieved without load

16 mm cryogenic turbine impeller (L) and nozzle components (R)



Combined Helium gas purifier, filling and leak detection station for cryocooler

and it is supposed to provide 250 mw cooling for the sensors at 77 Kelvin. A combined Helium gas purifier, filling and leak detection station was developed for micro cryocoolers. The filling station takes in industrially available 99.995% pure Helium and reduces the concentration of impurities such as carbon dioxide and moisture to a level safe enough for components exposed to 77 K. A state of the art Helium leak detection facility is included in the system to check for leaks in the assembled cryocooler.

At RRCAT, Helium liquefaction was achieved in a totally indigenous system, for the first time in the country. All the subsystems, namely reciprocating type cryogenic expanders, cryogenic heat exchangers Joule Thomson (J-T) expansion valve, and oil removal system, were designed at RRCAT. The main Helium compressor used was also of Indian make. The system was further modified to liquefy and collect liquid Helium in an external Dewar. The liquefaction rate achieved was about 6 lit/ hour.

A pool type Liquid Helium Cryostat for operating down to -271^{O} C (2O Kelvin) was designed and developed at RRCAT. Superconducting RF cavities were tested at this temperature.

Helium Liquefaction system developed at RRCAT

2K Cryostat

Cold Box of Helial 2000

At VECC, a new Helium liquefier, Helial 2000 of 415 W refrigeration capacity at 4.5K was successfully installed and interfaced with the existing one (Helial 50) to cater to the Superconducting Cyclotron (SCC) and other refrigeration loads.

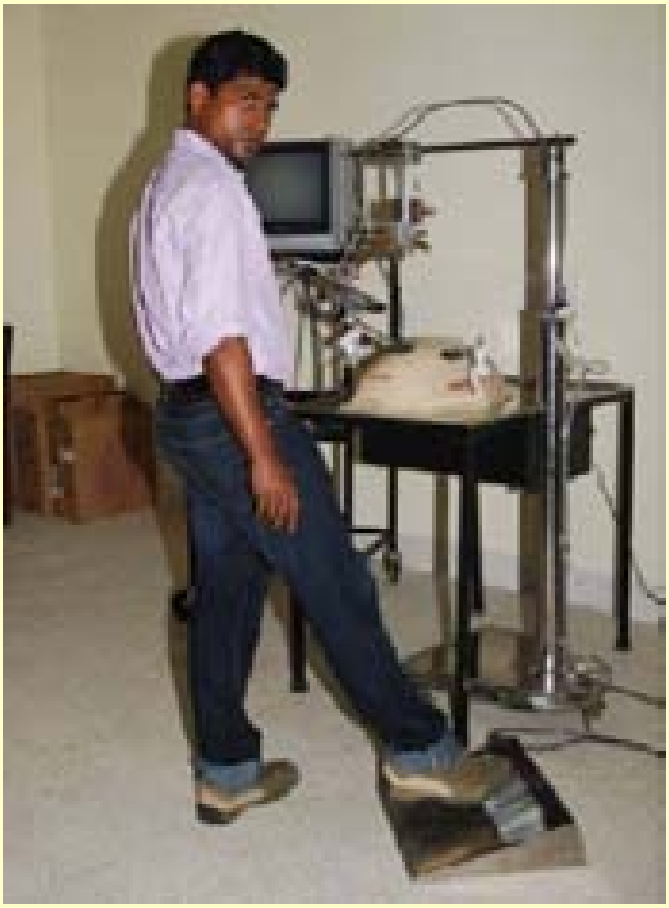
Further, in collaboration with National Institute of Technology (NIT), Rourkela, VECC indigenously developed and successfully commissioned a cryosorption based Helium purifier with a novel design.

Float zone single crystal silicon ingot pulling facility continued to produce 100 mm diameter single crystal silicon ingots. These ingots were processed for demonstration of wafer production and characterization. Parameters and sequence of processing have now been standardized ensuring quality wafers.

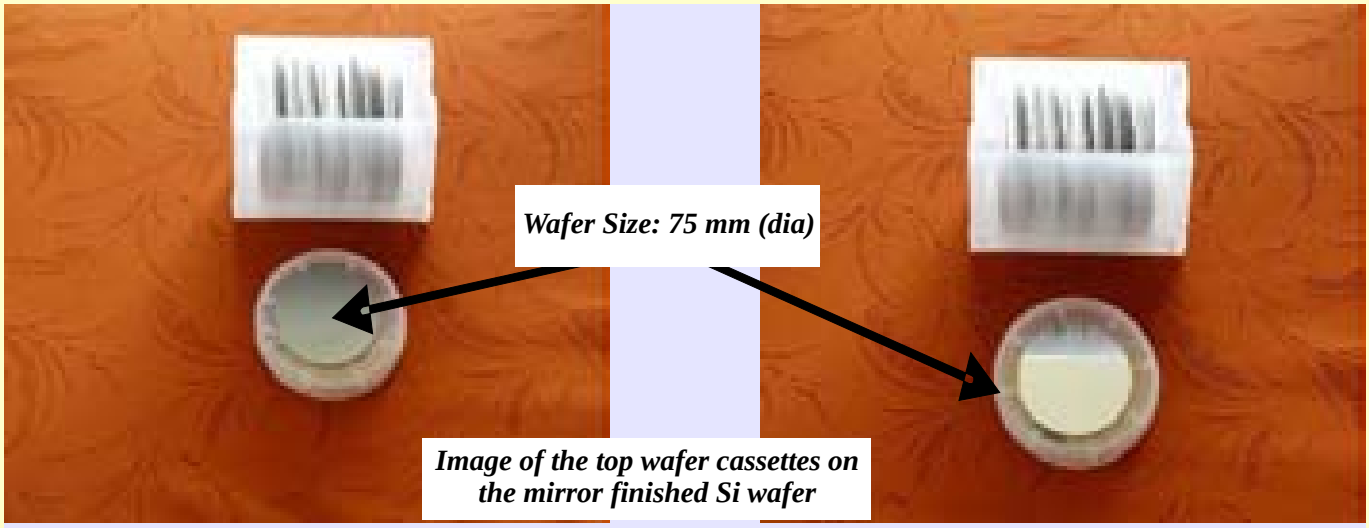
BARC has developed a robotic device - Laparoscope Manipulator (CoLaM) for direct control of the laparoscope by the surgeon for aiding him during laparoscopic surgery. The surgeon can move the laparoscope with foot-operated joystick of the CoLaM. Prototype of CoLaM was delivered to Christian Medical College, Vellore. The recent model of Servo Manipulator developed is Four-Piece Servo Manipulator (FPSM), which can be used in hot cells that are designed for mechanical MSMs. In FPSM, all motors and other electric components are kept outside the hot cell and motion is transmitted to the cell through a set of parallel shafts. As no electric component is present in the hot cell, they are not subjected to radiation damage or contamination. They are also accessible for maintenance. The design of FPSM is such that, it can

Poly-Silicon ingot (top) & single crystal ingot (bottom) (double size) pulled by FZ

Compact Laparoscope Manipulator



CoLaM and Laparoscopic Training kit



As-cut (500 µm thick) silicon wafers

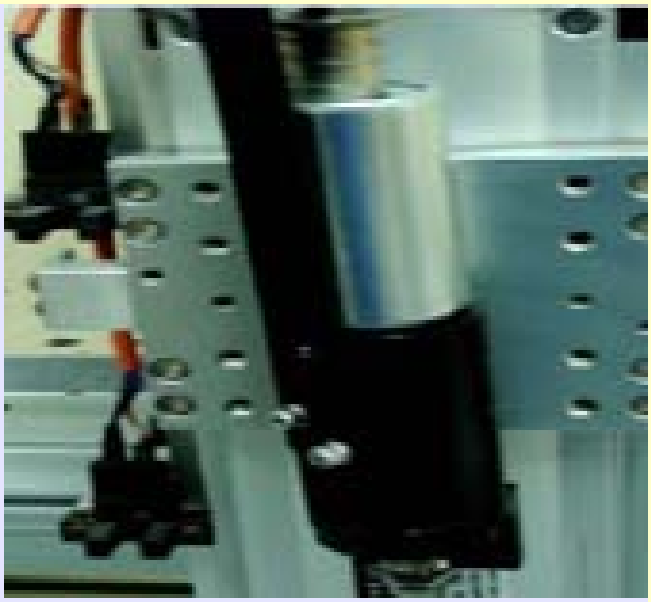
Polished Silicon single crystal (5 nm surface finish)

be easily converted into a conventional mechanical master slave manipulator, a conventional servo manipulator or a tele-robot to suit the situation.

BARC had developed an Advanced Servo Manipulator with features like force reflection, indexing, soft limits and artificial force reflection. The capabilities of the manipulator are enhanced by providing autonomous control to the slave arm directly from a computer instead of the master arm, which can improve safety and productivity. Features like teach and playback, constrained motion, tremor removal and indexing in world coordinates were implemented. It is planned to deploy the telerobot for fabrication of thorium-based fuels for advanced nuclear reactors.

'Spot picker' is an indigenous

Spot Picker Robot



Protein Spot Cutting Tool

The Slave Arm and the Master Arm of Four-Piece Servo Manipulator

The Slave Arm and the Master Arms of the Telerobot

2D Electrophoresis Protein Gel Image

technology for precise protein spot excision. It accurately picks spots from 2D protein gels electrophoresis and transfers the picked proteins into micro plates for analyzing protein with a cutting tip made of surgical grade stainless steel either 1.0 mm or 1.5 mm in diameter Spot was indigenously designed and developed to minimize carry over or damage the Gel or Membrane when properly handled.

Development of a Counter Terrorist Robot was taken up. It is a lightweight (18 kg) mobile tracked robot designed to enter doors or thrown through the window, work on rough terrain and climb staircases. It fits into the backpack of active security personnel. The basic robot carries with it a colour camera and a thermal/night vision camera. The response time for deployment is designed for three minutes max including fitting of additional accessories like a small manipulator, a IED digging device or a metal detector. The robot can be deployed by RF control or cable.

A portable hand held unit contains the controls and displays for cameras. The first prototype is expected to be ready by March 2011.

Development of a remote surveillance robot during fire was attempted at Trombay. It is lightweight (approx. 8 kg) almost the size of basketball and can be thrown through a window or rolled towards fire. It is built rugged enough to take the impact of throw and roll and its run time is just ten minutes.

It carries a camera and microphone, both having a transmission distance of 100 mts. When produced in numbers, its cost is extremely low and can be considered as disposable robot.

The objective of this robot is not to fight the fire, but to do a survey of the location and give the fire brigade team a general idea of the intensity of the fire, its origin and to search out victims, so that the fire personnel know their exact location and attempt a rescue mission.

Neutron Chopper was developed to separate neutrons of various speeds/energies according to their time of flight between a chopper and a detector. Neutron chopper allows passage of neutrons of some specific energy for carrying out experiments. This would be installed at neutron beam experimental facility at Dhruva.

A 1504 pixel MACE Camera

Counter Terrorist Robot

Remote surveillance robot

for imaging of the Cerenkov radiation in atmosphere caused by very high energy gamma rays emanating from celestial bodies like supernova, black holes etc., was fabricated. Linear Distancing System is a x-y-z-θ positioning and calibrating device for all kinds of radiation detectors. This system has a remote viewing and switching system to be used during calibration. Linear distance movement is 3000 mm.

The 400 keV Radio Frequency Quadrupole (RFQ) sub-assemblies is a octagonal shaped deuteron accelerator. It consists of two pairs of major and minor vanes having modulations at tips in longitudinal direction. There are conflate flanges at both ends of the 1 meter long RFQ Assembly. There are vacuum ports, tuner ports and RF feed ports. Whole assembly is made of OFHC copper and furnace brazed.

Integrated trial of Boat Sampling Module with Handling Manipulator was demonstrated on a full scale mock-up trial at BARC and one good quality boat sample was obtained from SS-304 plate. The performance of all the subsystems was satisfactory. PC based control system was devised for monitoring the critical parameters of the tool.

To determine the design life of different materials in rolling/sliding conditions, a test set up was indigenously developed and commissioned to obtain wear and friction data in rolling/sliding at various lubrication conditions/ high temperature conditions. It can simulate gears, rail-wheel and other rolling conditions.

A high precision servo hydraulic motor was developed based on conventional radial piston hydraulic motor and indigenously developed digital servo control card. The servo hydraulic motor was proven in the in-house developed test facility. It has potential use in low speed precise position control applications like high payload robotic manipulators, winches and machine tools.

In specialized hydraulic system, it is required to control many rotary/linear hydraulic actuators. Multi axis digital servo controller cards were developed indigenously and successfully deployed in areas like robotic applications, Pressure control of Water Hydraulic Proportional Valve, Oil Hydraulic Proportional Valves. These have substituted expensive imported servo controller cards.

To verify the effect of impact between coolant channel and shut off rod guide tube during strong motion earthquake, a full length simulated test was carried out in R&D centre at Tarapur. The two channels were extensively instrumented with sensors. The impact force, velocity, strain and acceleration were recorded and

Boat Sampling Module

Rolling / Sliding Wear and Friction Test

High precision servo hydraulic motor test facility

Multi Axis Servo Control Card for robotic applications

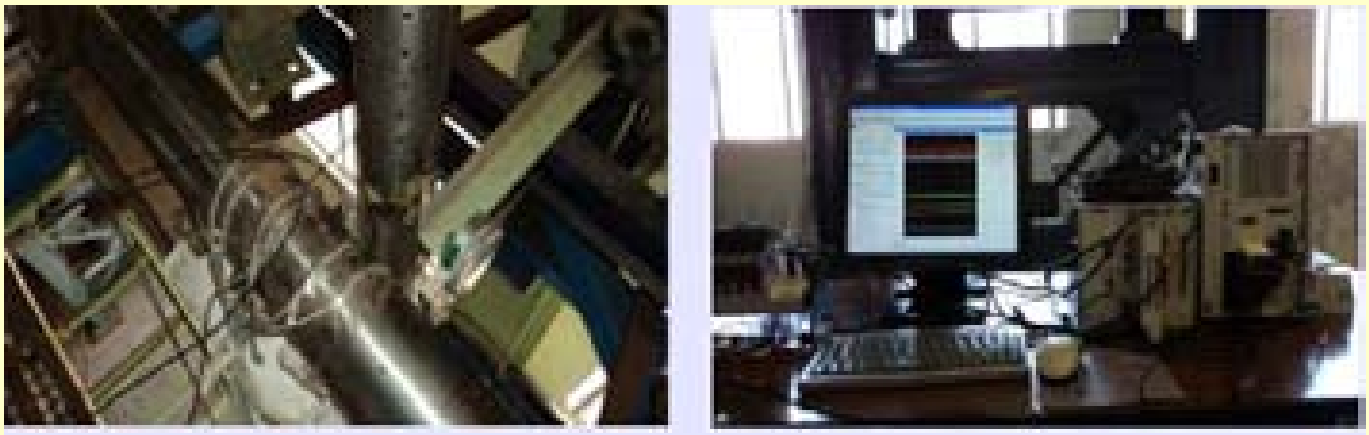
analyzed. No permanent effect on either tube was noticed after the test.

Online shaft vibration monitoring system was integrated on one of the main pump. The total display is enough for effective diagnosis of shaft related distress in the machine.

Two advanced technologies were developed for testing components of advanced missile. Acoustic topography technique is for testing quality of embedded braze joints between top cover plates and central base panel of wing assembly that serves for creating lifting forces and stabilization of the position of the advanced missile in the flight. BOKMY technique is for testing quality of bond between rubber like thermal insulation cover on metallic F3 section of the defence product. Thermal insulation protects interior of the section from external heat. High quality bonding is required to achieve the functional objective. High frequency technique tests and certifies the quality of bonding.

A 65 NB Poison Injection Passive Valve (PIPV) was designed, fabricated and tested at dedicated setup simulating different pressures in poison tank, MHT and in Calandria. Various tests were carried out at rated conditions. Other parameters of the valve such as actuation pressure, linearity, repeatability and stem travel were captured during experimentation. Analysis of the data was in progress.

A systematic experimental and analytical study was taken up along with IGCAR, Kalpakkam under a dedicated task force to qualify the metal bellows in the passive valves of AHWR. The analysis on U-shape bellows was completed as per the code. Improvement in high pressure performance of U-shape bellows is attempted by shape optimization. A bellows test facility (BTF) was designed by the task force and installed at IGCAR. One set of bellows procured for HSPV of AHWR,



Simulated impact test

was successfully tested at 80 bar and 300 °C for 50000 cycles. Further tests are in progress.

Design, analysis and experimental validation of B-1 & B-2 type thermowell used in 220 & 540 MWe PHWR was taken up. No comparative study was available on B1, B2 design (for Indian PHWR) and ASME thermowell design. A computer code for designing conical & cylindrical thermowell was completed. Series of lab experiments were conducted to study the effect of thermowell on sensor response time and contribution of conduction error on temperature measurement.

Two facilities namely Pressure and Temperature Cycling Facility (PTCF) and Calandria model experimental facility were commissioned using new PLC based SCADA system and field HMI with remote I/Os. These are located 150 meters from centralized control room where PLC system is housed. I/O modules and HMI is located in the field control panel. Both facilities are simultaneously operated from control room operator console using Ethernet. Four PID loops were configured for continuous operation of PTCF.

Poison Injection Passive Valve Test Facility

A new centralized BOSSES code was installed at NTPC Energy Technology & Research Alliance (NETRA) centre and scope of monitoring of creep & fatigue damage by BOSSES is expanded to a total of 20 components of 4 NTPC-DADRI units.

This new system eliminates the need of multiple DAQ systems and computers to be installed at various sites. In each of the 4 units, 5 critical components namely super heater outlet header (SHOH), reheater inlet header (RHIH), reheater outlet header (RHOH), hot reheat pipe bend left (HRHL) and hot reheat pipe bend right (HRHR) are being monitored for the damage

Bellows Test Facility (BTF) at IGCAR

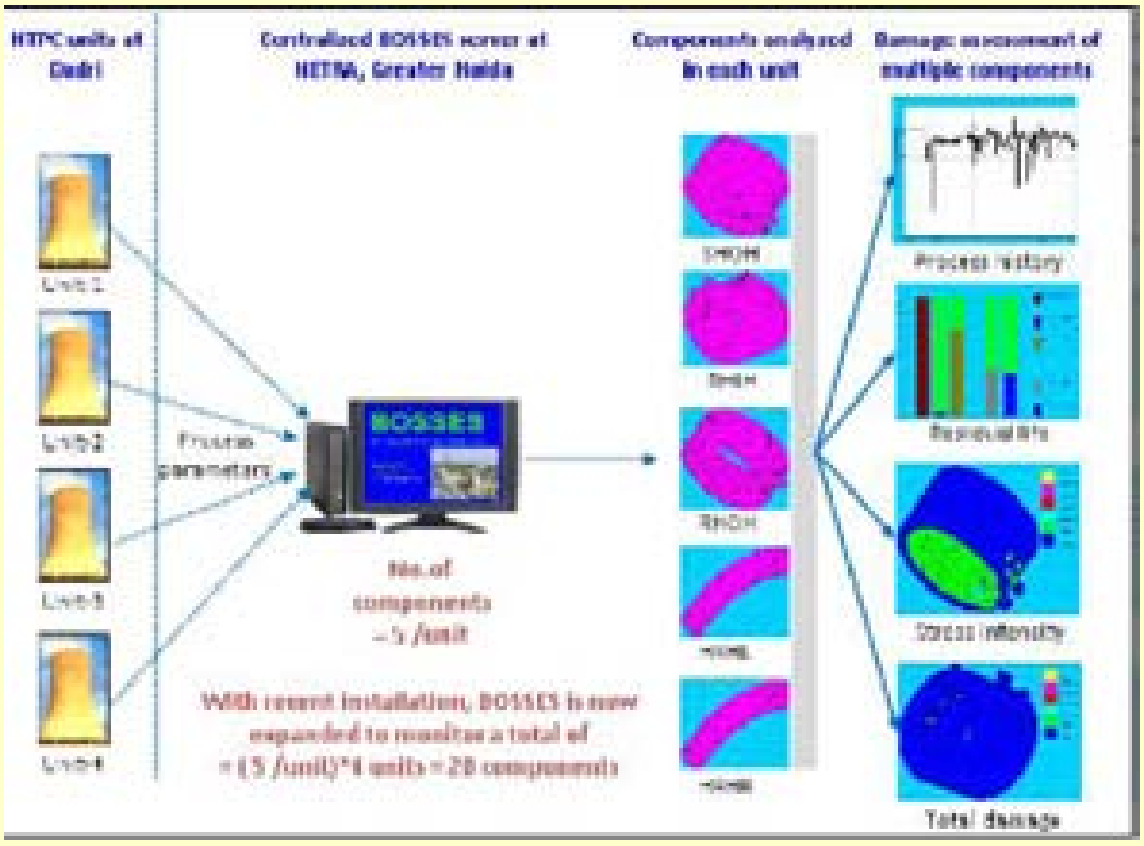
Thermowell Conduction error measurement

assessment.

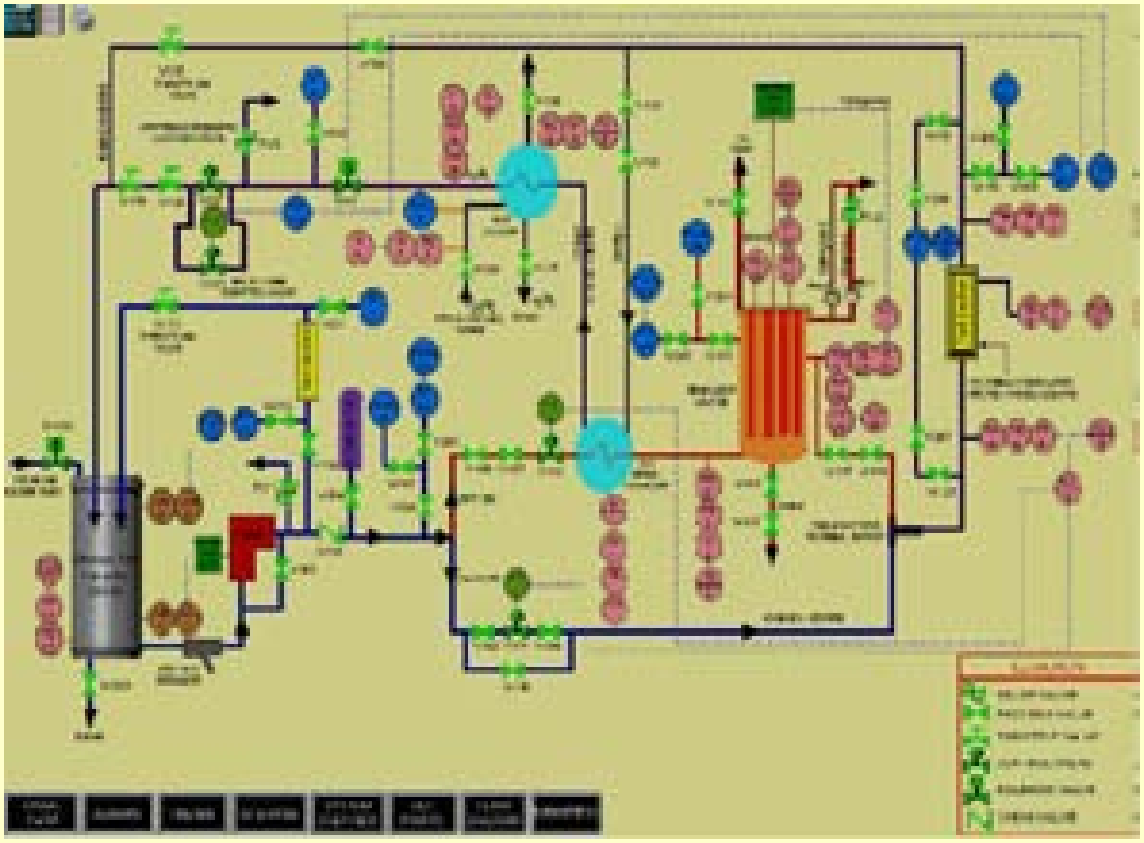
A zircaloy sample with selective hydrogen ingress was prepared to test the capability of detecting presence of hydrogen blister and its intrusion within zircollay matrix. Figure shows the radiographic data of the sample where the dark spots correspond to presence of hydrogen blisters. It is very difficult to analyse the depth to which hydrogen might have penetrated within the bulk and hence 3D tomography reconstruction is carried out. Tomographically reconstructed data and its depth profile is given in the next figure. The potential of neutrons to detect hydrogen in High Z material in combination with neutron tomography makes it an important tool for study of hydrogen ingress within the bulk of materials. Last figure shows the reconstructed volume of the single blister which is of inverted ellipsoidal shape.

A zircaloy sample was charged with hydrogen having different concentration using non-homogenised hydrogen to study the feasibility of detecting hydrogen distribution. Figure shows the neutron radiograph of three samples mounted on sample manipulator. The hydrogen content of the three sample was 0 ppm, 50 ppm,100 ppm. It is very obvious that conventional from neutron radiography one can not detect the presence of minute quantities of hydrogen in samples. However the neutron-tomography reconstruction we could detect the distribution of hydrogen even upto 50ppm and also the fact the charging process did not produce uniform hydrogen distribution.

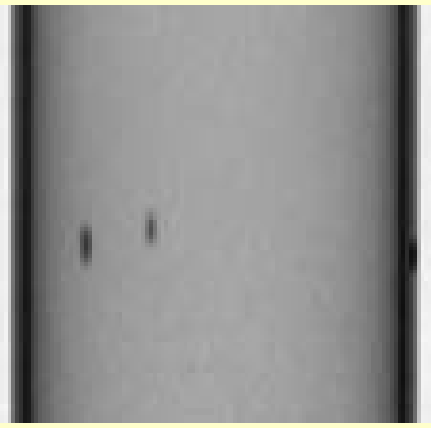
Specially designed collimators of pinhole sizes 1mm and 500 micron were used to make a coherent neutron source. The high resolution images were recorded



Schematic of Centralized BOSSES installation

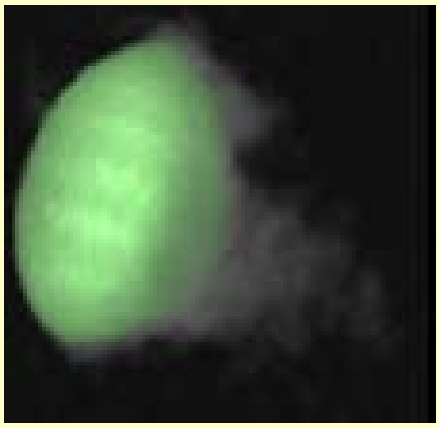


New PLC based SCADA system

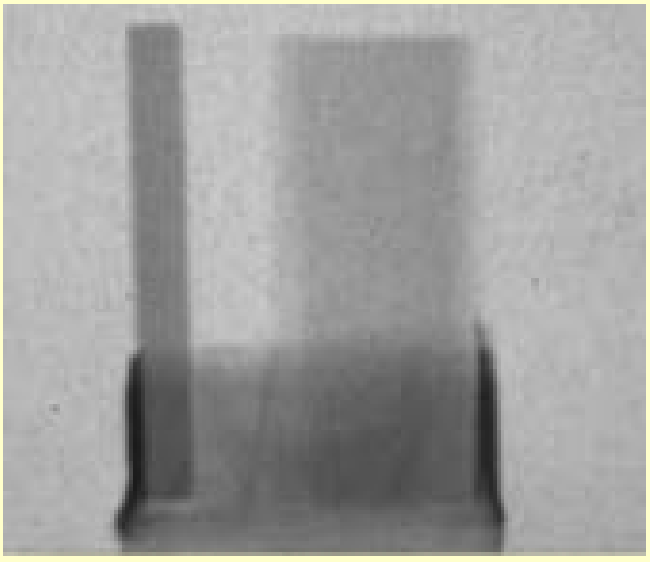


Radiograph of zircaloy containing hydrogen blister (dark black spots)

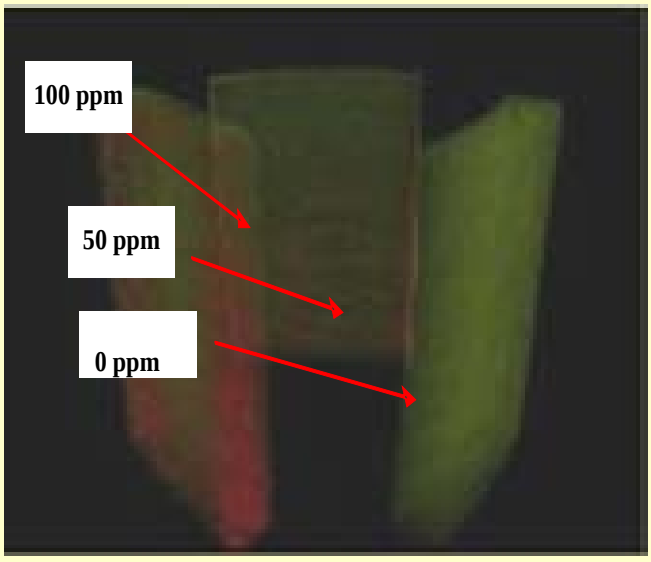
Reconstructed profile of Hydrogen blister (rendered green) in zircaloy tube using neutron tomography



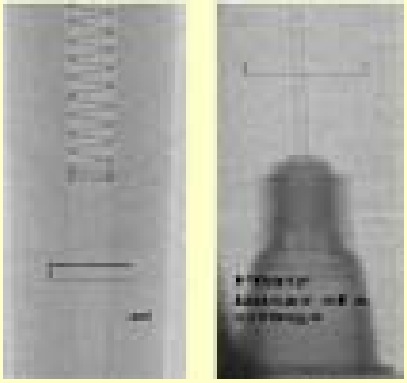
Reconstructed volume of a single blister (maximum diameter 2mm) using using neutron tomography



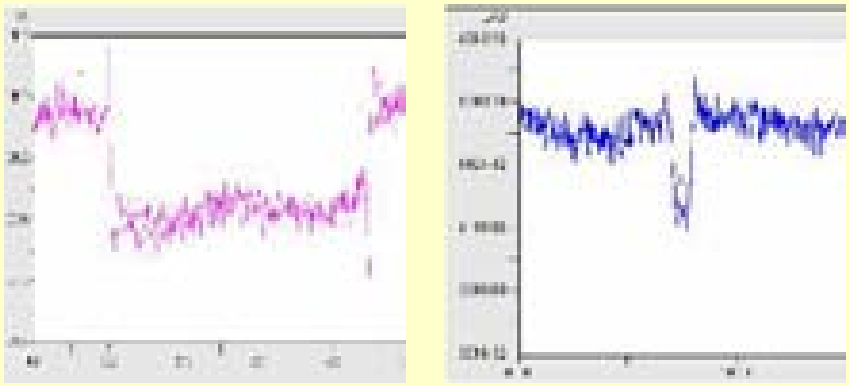
Neutron radiography of zircaloy samples containing 0 ppm, 50 ppm & 100 ppm of hydrogen in the same zircaloy tubes



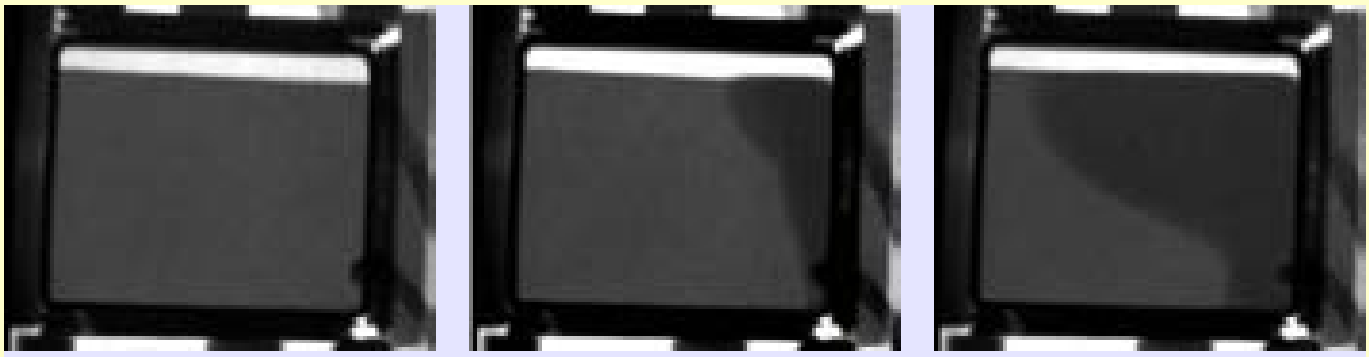
Neutron tomography reconstruction of hydrogen distribution (rendered red)



Phase contrast image of Lead cylinder with a spring and syringe



Intensity profile of the highlighted region indicate phase contrast effects



Different stages of melting phenomena in lead observed using neutron radiography (a) solid lead (b) Showing the onset of liquid phase from right side (c) Movement of liquid front after 10 minutes from onset of melting

on neutron sensitive image plates. Figure shows the result of neutron phase contrast imaging experiments on variety of samples which demonstrate the dramatic improvement in phase mode as compared to conventional absorption mode.

Neutron radiography was used for online visualization and study of lead melting. The radiographic images were acquired continuously and melting phenomena was observed.

ISOTOPE PROCESSING

A wide variety of radioisotopes for medical, industrial and research applications were produced and supplied by BARC. Radioisotopes produced for medical applications were ^{131}I, ^{99}Mo, ^{125}I, ^{153}Sm, ^{32}P, ^{51}Cr, ^{177}Lu with total activity as 122155 GBq. ^{203}Hg, ^{82}Br, ^{35}S, ^{43}Ca, ^{60}Co, ^{64}Cu, ^{65}Zn, ^{75}Se, $^{85+89}$Sr, ^{133}Ba, ^{134}Cs, ^{111}Ag, ^{103}Pd, ^{124}Sb etc were the other radioisotopes produced for industrial and research applications.

Production of ^{131}I by dry distillation route, has reduced volume of radioactive waste. A method to produce ^{64}Cu by (n,p) route using zinc target was optimized. Clinical grade $^{177}LuC_{l3}$ was ready for commercial deployment. About 900 reference sources of activities ranging from 37 KBq to 3.7 MBq were supplied to various users through BRIT and 175 numbers of ^{60}Co polymer film sources (~37 kBq each) were prepared and supplied for oil & well exploration studies.

A prototype multi-cavity powder compaction die set of 10 mm x 10 mm matrix for compacting 100 pellets at a time was designed & manufactured for compacting Cobalt powder to miniature pellets of size 1.2 mm diameter and 1.2 mm thickness. These pellets will be sintered to obtain pellets of 1.0 dia. x 1.0 thick which will be used for production of Cobalt-60 isotope sources. Fabrication of the modified version of a multi-cavity die set of a 10 mm x 15 mm matrix, incorporating the design revisions as required by the user for compacting 150 pellets at a time was completed.

AGRICULTURE

Crop Improvement

Groundnut variety Trombay Dharwad Groundnut (TDG) -39 was released and notified by the Central Sub-Committee on Crop Standards, Release and Notification of Varieties, Ministry of Agriculture, Government of India in 2009 for commercial cultivation. TDG-39 is a confectionary large seed groundnut variety released for rainy (Kharif) season for northern transitional Zone-8 and northern dry Zone-2 and 3 of Karnataka in collaboration with the University of Agricultural Sciences, Dharwad. It was also released for arid and semi-arid regions of Rajashtan. It is a Virginia bunch variety developed by crossing TAG 24 and TG 19.

In Karnataka, TDG-39 showed superiority of 12.8 to 19.7% for pod yields. Plant is erect, semi-dwarf with alternate flowering and 120 days maturity. Pods are with moderate beak, prominent

Plant, large pods and seeds of Trombay groundnut variety, TDG 39

constriction and reticulation with average shelling out turn of 70-72%. Seeds are more cylindrical with rose colour with average size of 70-75g/100seeds. Seeds contain 50% oil, 26% protein, 59% oleic acid and 23% linoleic acid.

Trombay mungbean variety TM-2000-2 (Pairy mung) developed in collaboration with the Indira Gandhi Krishi Vishwa Vidyalaya, Raipur, Chhatisgarh, was released and notified for commercial cultivation for Chhattisgarh State during 2010 by the Central Sub-Committee of Crop Standards for Notification and Release of Varieties for Agricultural Crops, Government of India. TM-2000-2 is high yielding (1090 kg/ha), early maturing (88-94 days), resistant to powdery mildew disease, moderately resistant to pod borer and suitable for rabi and utera (rice fallow) conditions.

Trombay pigeonpea variety, TJT (Trombay Jawahar Tur) -501 developed in collaboration with Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur was released and notified for commercial cultivation for Central Zone by Central Sub-Committee of Crop Standards for Notification and Release of Varieties for Agricultural Crops, Government of India.

TJT-501 out-yielded the national check variety UPAS-120 by 34.5% with an average yield of 1860kg/ha. TJT-501 is early maturing (152 days), tolerant to Phytophythora blight and promising against pod borer and podfly pests.

Incidence of rust and late leaf spot diseases cause severe yield losses (over 50% in groundnut). With an objective to incorporate disease resistance, F2 seeds from the cross between TAG 24 and V 9514 were irradiated with gamma rays or advanced. Selection in subsequent generations for higher

Trombay Pigeonpea variety-TJT-501

Plant of Trombay mungbean variety, TM-2000-2

yield, desired plant type, pod features and seed size as well as field resistance to late leaf spot and rust diseases resulted in Trombay Foliar Disease Resistant Groundnut (TFDRG) 1 and 3. Both the lines were high yielding and resistant to rust and late leaf spot and tolerant to peanut bud necrosis diseases. TFDRG 1 having rose testa belonged to var. vulgaris while TFDRG 3 having red testa belonged to var. hypogaea. These mutants were submitted to National Bureau of Plant Genetic Resources, New Delhi and they were assigned national identity numbers, IC573415 and IC573416, respectively.

Breeding line, TG 60 was promoted to A VT in All India Coordinated Research Project on Groundnut for rabi/summer season; Mungbean (TMB-21) and blackgram (TU-40) mutants were promoted from IVT to AVT-l in the ICAR Rabi and rice fallow trials; TMI02, a high yielding genotype has entered in ICAR PYT. A high oleic acid (68-70%) mutant (TGM 192M) of groundnut was identified and characterized.

In wheat, recombinants selected for two markers for two different rust resistance genes showed that the lines were resistant to stem and leaf rust at a hot spot location. Twenty lines in F7 generation derived from thermotolerant parent wheat varieties, exceeding the higher parent in grain weight per line and Thousand Kernel Weight were identified for carrying forward. Seventeen rice mutants were analysed for amylose content and variation was observed. Highest amylose content was 31.7 and lowest amylose content was 24.7%.

In plant biotechnology, transgenic tobacco plants expressing a fungal glutathione transferase gene showed enhanced cadmium tolerance. A novel multiple stress inducible gene WRKY - from banana cv. Karibale, was identified, cloned, sequenced and characterized. A new family of plasma membrane transporters with conserved sodium solute symporter domain was identified in rice blast fungus, Magnaporthe oryzae using bioinformatics approach. Development of novel matrix for immobilization of biomaterials obtained through evaporation driven self assembly of silica nanoparticles was noteworthy.

Fertilizer

Following two patents were granted for biofertilizer formulations:

i) Zn fertilizer formulation and process for making it (Patent No.: 239929, Year 2010). Objectives of this invention was to develop a Zn fertilizer formulation using zinc sulphate heptahydrate and bio-sludge of molasses based distilleries.

ii) P fertilizer formulation and a process of making it (Patent No. 238485 Year 2010). Objectives of this invention was to develop a P fertilizer formulation using single superphosphate, phosphoric acid and bio-sludge of molasses based distilleries.

The above fertilizer formulations are more efficient when applied to the soil and consequently improve the yield of the crops and ensures better availability of residual fertilizer to the next crop, thereby reducing the cost of the fertilizers.

FOOD PROCESSING

KRUSHAK Food Irradiation Facility at Lasalgaon is commercially operated by Maharashtra State Agricultural Marketing Board (MSAMB) under a tripartite MOU signed by BARC, BRIT and MSAMB. BARC carried out the upgradation of this facility to increase the product range covering both low dose and high dose applications including processing of onion, mango and spices. A 250 kCi cobalt-60 source was loaded. The PLC SCADA software was also upgraded to incorporate changes resulting from the modifications. The facility was approved by AERB for irradiation of mango for export to USA. Approval was also obtained from local FDA for processing food products. In April 2010, KRUSHAK facility was handed over to MSAMB to prepare the same to comply with the requirements of USDA-

APHIS. The plant dosimetry was performed using a new optichromic film dosimeter and was validated using alanine dosimeters. Following the visit of USDA-APHIS inspectors, this facility was recertified for quarantine treatment for export of mangoes to USA on April 15, 2010. Computation of absorbed dose inside the tote box of Food Package irradiator using a point kernel based physics code (IGSHIELD) was carried out. Computational studies were carried out to optimize source pencil distribution in refurbished KRUSHAK. Experimental dosimetric results were found to be in good agreement with the computed results. Theoretical estimation of absorbed dose using Monte Carlo particle transport physics code was also validated by detailed experimental dosimetry of modified irradiation geometry at KRUSHAK.

Radiation processing at a dose of 7.5 kGy was found to extend shelf life of an antidiabetic herbal formulation up to 18 months without affecting its microbial, biochemical, anti oxidant capacity and organoleptic quality when stored at ambient temperature. Radiation processing (10 kGy) of commercial Mukhwas and digestive Pancharas Chruna also improved the microbiological quality of these products. Phenolics including anthocyanin, and carotenoids were found to be the major bioactive compounds responsible for the antibacterial, antioxidant and radioprotective activity of guggul. Vitexin was identified as the major constituent of fenugreek responsible for high radical scavenging and anti-lipid peroxidation capacity of the spice while elimicin was the major antioxidant compound of nutmeg. Honey and plumbagin were demonstrated to be antimutagenic and radioprotective.

Radiation processing (1-2 kGy) of cut RTC ash gourd and drumstick packed in cling films resulted in an extension in shelf life by 10 days when stored at 10°C. The products had acceptable color, texture, microbial and sensory quality during the entire storage period. An enhanced fresh green note was also perceived in drumstick as a result of increased release of compounds such as 1-hexanol and 3-hexene-1-ol. Radiation processing was demonstrated to improve aroma quality of grapes as a consequence of enhanced liberation of key aroma volatiles such as ethyl hexanol, vitispirane, benzene acetaldehyde and linalool. Benzaldehyde, hexanal, ethyl hexanol and benzyl alcohol were established as the major aroma active compounds of sapota. Radioprotective property of several raw vegetables was established. Inter Simple Sequence Repeat (ISSR) marker profiles were generated for kesar variety of mango.

Among the cereals, black pea and horse gram exhibited high ACE inhibitory activity with an enhancement in this activity during germination. Sequential digestion of dry soaked and germinated seeds of chickpea, cowpea and horsegram by pepsin, trypsin and chymotrypsin resulted in an increased ACE inhibitory activity. A dose dependent decrease in the content of phytohemagglutinin (PHA) was noted in kidney beans. Hull extracts from chana, moong and tuar were shown to be effective antioxidants, significantly reducing lipid peroxidation when incorporated as a preservative in meat. A protocol for shelf-life extension and quarantine treatment of litchi was developed using a combination of radiation dose of 500 Gy, packaging and low temperature storage (4°C).

A new packaging material was developed from Guar gum. A method was optimized for obtaining soluble dietary fibre from radiation depolymerized guar gum. Irradiated product had higher glucose and bile uptake retardation index compared to the commercial guar samples. Composite films of chitosan and polyvinyl alcohol with mint/pomegranate extract displayed antibacterial activity. Similar composite film of carboxymethyl cellulose and polyvinyl alcohol containing glycerol was prepared. Addition of clove oil resulted in an active food packaging with improved antimicrobial properties. Packaging films prepared using chitosan and guar gum showed very low oxygen permeability, good tensile and puncture strength and antimicrobial activity.

Gamma irradiation of meat

Shelf life extension & Quarantine treatment for export

New packaging material for radiation processed food

products in Styrofoam trays containing moisture absorbent pads resulted in an extension in shelf life by 3 weeks at 0-3°C compared to non-irradiated samples that lasted 3 days. Microbiological, chemical and sensory properties of the irradiated products were unaffected. Chitosan coating on Ready-To-Cook (RTC) meat products was shown to enhance their shelf- life by 14-21 days. Poultry viscera protein hydrolysate exhibited excellent radical scavenging activity and total antioxidant activity. It also showed good reducing power and antioxidant activity index. The hydrolysate also exhibited good ACE inhibitory activity. Radiation processed (1 & 5 kGy) intermediate moisture (30%) prawns could be stored up to 2 months with good acceptability and microbial quality. A radiation resistant Macrococcus was isolated for the first time from semidried prawns.

Seed irradiation studies using the 750 keV DC accelerator

As part of a BRNS collaborative project between RRCAT and the National Bureau of Plant Genetic Resources, New Delhi, studies on the potential of electron beam irradiation as quarantine disinfestation treatment against insects and pests in seeds, were continued.

HEALTH

RADIATION TECHNOLOGY

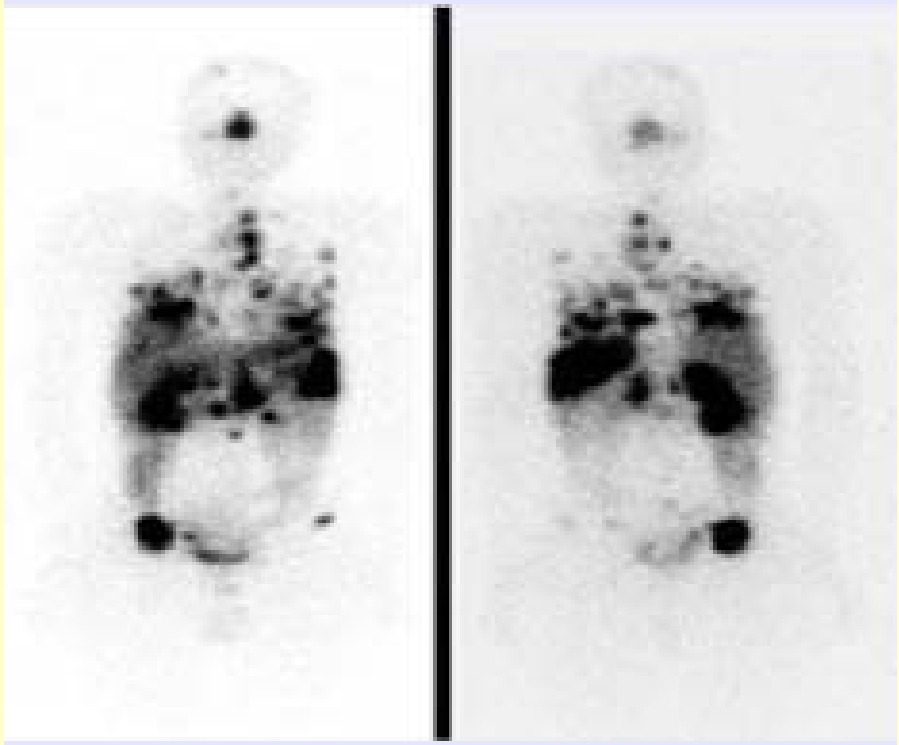
Seed in the irradiation tray on the conveyor belt ready for irradiation. Electron beam scanner of the accelerator is seen above the tray

At Trombay, a cylindrical graphite ionization chamber of nominal volume 1000 cu.m was designed and fabricated for use as a reference standard for low dose rate ^{137}Cs and high dose rate ^{192}Ir brachytherapy sources. The air kerma calibration coefficient of this ionization chamber was estimated theoretically The chamber was ready for use in hospitals for calibrating brachytherapy dosimeters.

A methodology was developed by BARC for the pre-concentration of large volume of fresh water and marine water samples. A twenty fold improvement in sensitivity for the estimation of ^{137}Cs in water samples was achieved. Evaluation of nuclides concentration in the body/organs was carried out. A national inter-comparison exercise involving shadow shield whole body monitors operating at various DAE facilities and environmental survey laboratories was conducted using BOMAB phantom.

Development of brachy-therapy sources was continued and 135 seeds of ^{125}I (111-130 MBq each) were supplied to various hospitals for the treatment of ocular cancers. During the report period, BARC supplied 6 brachytherapy sources of 32P (~250 MBq each) to ACTREC for the treatment of veterinary patients. ^{68}Ge-^{68}Ga generators for use in nuclear medicine were developed using novel nanomaterials such as, 'nano-ceria-PAN composite' and

Experimental set up showing measurement of RAKR of ^{137}Cs and ^{192}Ir brachytherapy sources using in-house developed cylindrical graphite ionization chamber



A typical scan in a human patient

'tetragonal nanozirconia' synthesized indigenously.

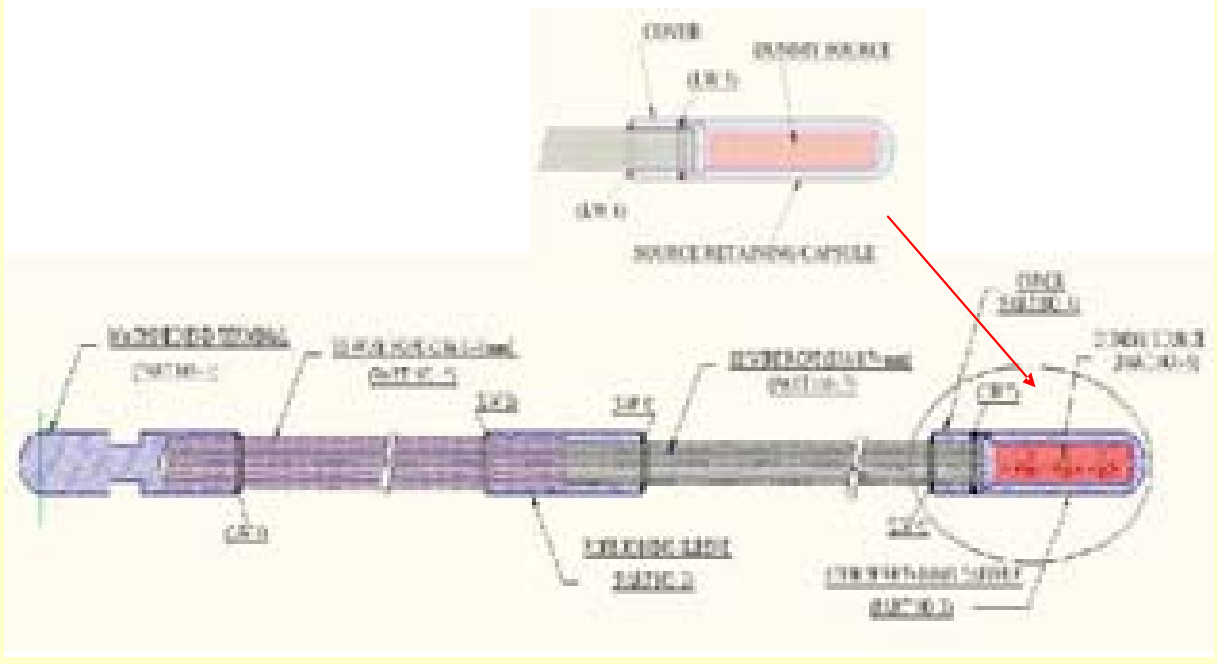
Six hospitals in the country started therapy of neuroendocrine tumours using ^{177}Lu-DOTA-TATE. ^{99m}Tc labeled biologically-avid substrates, specific for tumour hypoxia. At Trombay, different types of receptors over-expressed in tumours, were prepared using suitable precursors.

Radiolabeled RituxiMab, a promising candidate for the treatment of non-Hodgkin's Lymphoma, was labeled with ^{125}I, ^{131}I, ^{90}Y and the binding of these radiolabeled preparations with cells expressing CD20 were initiated. Lymphoscintigraphy using ^{99m}Tc labeled nanocolloids was effectively used for the sentinel lymph node imaging which helps in the further management of primary cancers such as, melanoma and breast. BARC also developed a cold kit formulation for preparation of ^{99m}Tc-TRODAT, a useful imaging agent for Parkinson's conditions.

The technology of Bhabhatron was transferred to a private entrepreneur for mass production and commercialization. Sixteen Bhabhatrons were operational at various cancer hospitals in the country. A large number of cancer patients, especially from rural areas, have been benefited by this development.

Through the Programme of Action for Cancer Therapy (PACT) of IAEA, Government of India donated one Bhabhatron to Vietnam. The machine has been in

Radiotherapy Simulator installed at Indian Red Cross Society Hospital, Nellore



HDR Source Assembly for Brachytherapy (Overall diam: φ 1.1 mm x 2300 mm long)

HDR source assembly after welding

Welding fixture for use in the Hot-cell

operation at Can Tho Oncology Hospital in Vietnam. In the recent General Conference of the IAEA, India committed to donate one Bhabhatron to Sri Lanka and another to an African country through the PACT initiative.

The radiotherapy simulator is an essential tool in cancer hospitals for accurate planning and delivery of radiation therapy. BARC had developed the Radiotherapy Simulator technology and the first unit of the Simulator was installed at the Indian Red Cross Society Hospital, Nellore, Andhra Pradesh.

At Trombay, a high dose rate (HDR) source assembly for Brachytherapy was developed for BRIT. This indigenously developed HDR source will be considerably less expensive than the imported ones.

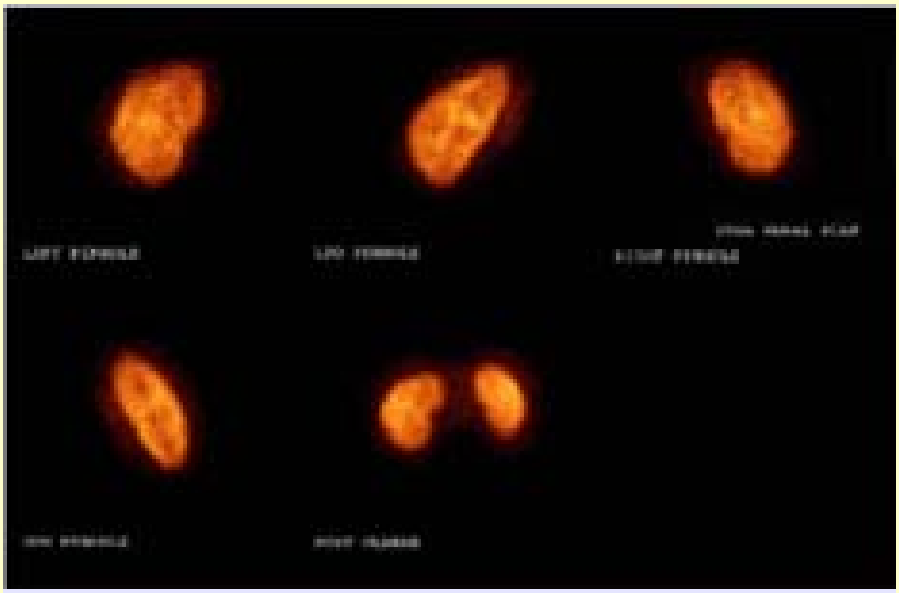
The assembly was designed and tested in accordance with the AERB stipulated test procedures and guidelines.

A Whole Body Counter with in-vivo counting system and calibration, automatic scanning and home positioning, and liquid nitrogen cooling system were designed at BARC.

RADIO-PHARMACEUTICALS

During the report period, the Board of Radiation & Isotope Technology (BRIT) continued regular production and supply of a wide range of high quality radioisotope products which included sealed radiation sources for medical and industrial uses, radiation technology equipment, radiopharmaceuticals, immunoassay kits, radiochemicals, labeled compounds, labeled biomolecules, ^{99m}Tc generators, 'cold' kits, oligo nucleotides, self-luminous compounds, and others.

More than 58,000 cold kits for formulation of ^{99m}Tc radiopharmaceuticals (code-



Renal Scan using of ^{99m}Tc(III)-DMSA

TCK: 11 Products) were supplied to the nuclear medicine centers. 410 Ci of ^{99}Mo (TCM-2) was supplied for extraction of ^{99m}Tc at hospitals. In addition to this, various accessories of ^{99m}Tc solvent extraction generator systems and other products were also supplied.

Nearly 15,000 consignments of ready to use radio-pharmaceuticals of ^{131}I , ^{32}P, ^{51}Cr and ^{153}Sm were supplied to various nuclear medicine centers. The supply of injectable products ^{153}Sm-EDTMP and ^{131}I MIBG to nuclear medicine centers in India, was increased.

The ongoing contract work, of monoclonal antibody (ch TNT 1/B) labelling with ^{131}I, for M/s Peregrine Pharmaceuticals Inc., USA, was continued during the year 2010. The phase II of clinical trials was completed.

The production of ^{99}Mo /^{99m}Tc Column generator using high specific activity ^{99}Mo was a part of XI plan project. The fabrication of facility and inspection at the works of supplier German Company was completed.

The erection and installation of hot cells and in-cell equipments at Radiopharmaceutical Laboratory, BRIT was also completed and commissioning reached at advanced stages. The design and procurement works relating to the setting up of Medical use Mo99 production (LEU fission based) Facility was initiated.

Two new products a) Kit for the preparation of ^{99m}Tc(III)-DMSA injection (Code: TCK-33), for renal imaging, and b) Single component Kit for the preparation of ^{99m}Tc-MIBI injection (code:TCK-50A), for myocardial perfusion imaging were introduced in the list of regular products, after successful use at the Radiation Medicine Centre.

Regular production and supply of 'Geltech' generator had started since Nov 2006. During the period, Jan-Dec 2010, 51 batches of Geltech generators were processed and supplied to the nuclear medicine hospitals across India. Numbers of generator supplied were 811 which is about 48% growth in comparison to the previous year. The batches were prepared using indigenously produced ^{99}Mo.

Molybdenum-99 Column Generator Plant

Column Generator Plant

Major components were arrived from Germany and installation was in progress of ^{99}Mo-^{99m}Tc Column Generator Plant. The Plant will be commissioned shortly after training of personnel.

RADIODIAGNOSTIC & TREATMENT SERVICES

About 10,000 radio-immunoassay (RIA) and immunoradiometric assay (IRMA) kits were produced and supplied to about 300 immunoassay laboratories throughout the country.

The work on development of IRMA kit for human thyroid stimulating hormone (TSH) based on magnetizable particles was completed.

The work on the modification of RIA kit for human insulin to measure the relative concentrations of insulin in rat serum was completed. More than 700 samples were analyzed for various academic institutions using this kit during this year.

Regional Centre, BRIT, Delhi carried out production and supply of around 90,000 mCi of various ready-to-use Tc-99m Radiopharmaceuticals injections for diagnostic nuclear medicine studies.

Development and evaluation of prototype Tc-99m generator progressed further.

RCR, Bangalore carried out 4500 RIA investigations and supplied 76,400 mCi of ready-to-use ^{99m}Tc formulations.

At the BRIT's Regional Centre, Kolkata, significant progress was made in the Medical Cyclotron Project.

An automated ^{99}Mo / ^{99m}Tc generator using alumina column and MEK was developed. This generator is based on the technique of separation of ^{99m}Tc from indigenously produced low specific activity ^{99}Mo.

Electrodeposition of Zinc and Cobalt were done and excellent deposit quality was obtained under the optimized conditions.

^{67}Ga and ^{69}Ge were produced from Zn target by irradiating with alpha beam in the VECC Room Temperature Cyclotron.

Production of ^{61}Cu from natural Ni and Co target and Cobalt targets was carried out with 40 MeV alpha beam.

Synthesis, labeling and evaluation of HYNIC-Tyr3Octreotide (HYNIC-TOC) was carried out at RCR Kolkata.

The Regional Centre, Dibrugarh provided RIA & IRMA diagnostic services for the patients of the entire North-Eastern region. More than 10,000 patients of the region availed of the services from this centre. Apart from medical colleges, patients also come from the nearby tea garden hospitals, civil hospitals etc.

The Regional Radiation Medicine Centre (RRMC) of VECC has been engaged in bringing to the common man the benefits of nuclear science by way of radiodiagnosis and treatment of human diseases. The services include in-vivo nuclear imaging and non-imaging studies, in-vitro diagnostic studies, and radionuclide therapy.

RRMC has the state-of-art Dual Head Gamma Camera that is used for sophisticated imaging that is useful in diagnosing diseases like cancer of various organs, kidney problems, ischemic heart diseases, disorders of thyroid and other endocrine glands. Currently, around 180 patients undergo various imaging studies on the Gamma Camera in every month.

In-vivo non-imaging studies carried out at RRMC include Thyroidal I-131 uptake studies for diagnosing diseases of the thyroid gland. Nuclear hematological studies with Cr-51 labeled RBC, like total RBC mass estimation, RBC survival, and Splenic RBC sequestration studies are also being performed. These nuclear hematological studies are important for management of blood disorders like Thalassemia. Around 35 patients undergo in-vivo non-imaging studies every month.

Among the in-vitro diagnostic studies that are performed at RRMC regularly, include radioimmunoassay (RIA) of thyroid hormones (Tri-iodothyronine, T-3 and Thyroxin, T-4), as well as Thyroid Stimulating Hormone (TSH) and Free thyroxin (Free T-4). A PC based multi detector automatic RIA counter installed during the period of report, ensures rapid

generation and better quality of RIA reports. Around 250 patients undergo various in vitro studies every month.

Using the the facility for high dose I-131 therapy, RRMC had treated 32 patients for thyroid cancer.

RRMC also carried out research collaboration projects with Indian Institute of Chemical Biology, Kolkata, and BRIT that included animal trials of various newly developed radio-pharmaceuticals for imaging and therapy.

Nuclear & Biotechnological Tools

Under its Labelled Compounds Programme, BRIT continued to prepare and supply a variety of ^{14}C, ^{3}H and ^{35}S-labelled products, oligonucleotides (DNA primers) and ready-to-use non-radioactive (cold) kits used for labeling nucleic acid with ^{32}P-labelled nucleotides. These products, used as radiotracers, find use in diverse investigations in the fields of biology, agriculture, medicine and chemistry.

At the Labelled Compounds Laboratory, tritium filled light sources of various types were also regularly prepared and supplied for defence applications. These sources are used for the illumination of various types of military gadgets and instruments. Custom-synthesis of a few radiolabelled compounds was also carried out to meet the specific requirements from researchers. In addition, development work for the preparation of selected deuterated NMR solvents was also carried out.

JONAKI, the Labelled Biomolecules Laboratory of BRIT at Hyderabad continued with the production of ^{32}P- labeled nucleotides for molecular biology, biotechnology, biomedical and drug discovery research, and marketing of 35S labelled amino acids produced at the Labelled Compounds Laboratory at BRIT, Mumbai.

JONAKI also produced and supplied many nucleic acid purification kits, polymerase chain reaction kits and Taq DNA polymerase. This laboratory also met the requirements of about 100 research institutes and universities and many industrial research centres, and in addition, served the nuclear medicine centres around Andhra Pradesh by locally providing nuclear imaging cold kits produced at the Radiopharmaceuticals Laboratory of BRIT at Mumbai.

JONAKI had entered the field of molecular diagnostics last year by introducing an agarose gel based PCR-kit for the detection of M. Tuberculosis. An improved multiplex PCR based M.Tuberculosis detection kit was developed. It is in the process of introduction. Real time PCR kit for detection M Tuberculosis and detection of EGFR mutants required for better cancer treatment based on the patented Real time PCR chemistry developed at Jonaki laboratory made progress.

The BRIT's Radio-Analytical Laboratory, Navi Mumbai, remained engaged in the measurement and certification of man-made residual radioactivity in various commodities such as

Channel SQUID based system for magnetocardiography

food samples, animal feed supplements, steel samples, water samples and other miscellaneous items.

In addition to the analysis of representative steel sample, the service of survey and certification of steel consignments at factory site was also initiated.

Magneto-cardiography studies were carried out at IGCAR using the indigenously built 13 channel superconducting quantum interference device (SQUID) based system to extract the weak magnetic signal arising due to the electrical activity of the "His bundle" a fine structure in the heart surrounded by fibrous tissues. Development of a non-invasive technique for recording the "His bundle" activity is very significant and augurs well for the clinical management of arrhythmias.

Cancer Diagnostic & Treatment services

During the year of report, BRIT supplied 8 Teletherapy sources (84 kCi of Co-60 activity) to various hospitals for the treatment of cancer, 2 Cs-137 applicator kits (1366 mCi) were supplied to hospitals for brachytherapy, 4 metres of Ir-192+Pt medical wires (1658 mCi activity) were supplied for brachytherapy, and 4 blood irradiators were loaded with a total of 37 Cobalt-60 pencils of the activity 3156 Ci.

The Tata Memorial Centre (TMC) comprising Tata Memorial Hospital (TMH) and the Advanced Centre for Treatment, Research and Education in Cancer (ACTREC), continued with its activities in diagnosis, treatment and research in cancer as well as in training and education to provide the highest standard of care to cancer patients.

The programmes and activities of TMC, relating to healthcare of cancer patients have been covered here, whereas those relating to research and education in cancer have been covered in the following chapters.

During the year of report, TMH saw an overall increase of 13% in new cases registered as compared to last year. About 32,000 new cases were registered. Over 4900 cases were registered in Preventive Oncology and about 16,500 Referral Cards were issued for various investigations. Radiation treatment was provided to 5238 new patients. 5675 PET/CT, 3012 SPECT/CT and 444 CT scans were done. About 1.03 lakh radiological investigations, over 22.07 lakh pathological investigations, around 87,500 cytology investigations and about 1.30 lakh investigations in microbiology were carried out. Around 22,000 patients received various therapies. During 2010, over 17,800 units of blood were collected, 48,770 components were prepared, and about 42,600 components were issued.

Procedures such as vertebroplasty, intracranial and pulmonary thrombolysis, IVC filter placement, angioplasty stenting, intravascular foreign body removal and radiofrequency ablation of hepatic tumors and vertebral metastases were introduced at TMC. In the year 2010, many innovative and purposeful splints/orthoses were made to facilitate overall rehabilitation of the patients.

Bone Marrow Transplant

The Bone Marrow Transplant (BMT) programme of TMC completed 135 transplants. Of these, 54 BMT (29 autologous, 25 allogeneic) were done at ACTREC during the year 2010. Four unrelated donor transplants and one unrelated cord transplant were also carried out. Haploidentical transplants were undertaken for patients who did not have a fully matched related/ unrelated donor.

Cancer prevention

As part of cancer prevention programme, TMC provided cancer screening services for common cancers and created a model for cancer control programmes for the country. It also conducted information, education and communication programmes aimed at risk prevention, life style modification and improving health seeking behaviour towards early cancer detection and tobacco cessation programmes at various places.

As a part of TMC's Societal Imitative, the efforts relating to 'Tata Memorial Centre Urban Outreach Programme' in the

slums of Mumbai and the 'Tata Memorial Centre Rural Outreach Programme' in the districts of Ratnagiri and Sindhudurg, of Maharashtra, continued. In addition, TMH Mobile Outreach Programme (TMHMOP) endeavoured to reach the slums and underserved areas of Mumbai, for early detection of oral, breast and uterine cervix cancers among women. The women detected with cancers or pre-cancers were offered appropriate treatment free of cost at the Tata Memorial Hospital thereby improving their survival. The project will cover 1,50,000 low socio-economic population residing in Mumbai.

The Clinical Research Secretariat (CRS) and DAE-CTC renewed its mandate of improving the quality of research in TMC through various initiatives. The CRS also initiated the process of registering clinical trials in a central registry which is now mandatory for publication as per the International Committee of Medical Journal Editors (ICMJE). The Hospital Scientific Review Committee and the Hospital Ethics Committee of Tata Memorial Hospital reviewed 107 projects, out of which 90 projects were approved.

The Centre conducted a Peer Review by a panel of eminent international and national oncologists and scientists in October 2010.

National Cancer Grid

A National Cancer Grid with TMC as the Apex Body and various cancer centres with 4-5 zonal and regional nodes was proposed, with the aim of providing uniform standards of care, trained human resource, co-ordinated non-repetitive research of national and global importance.

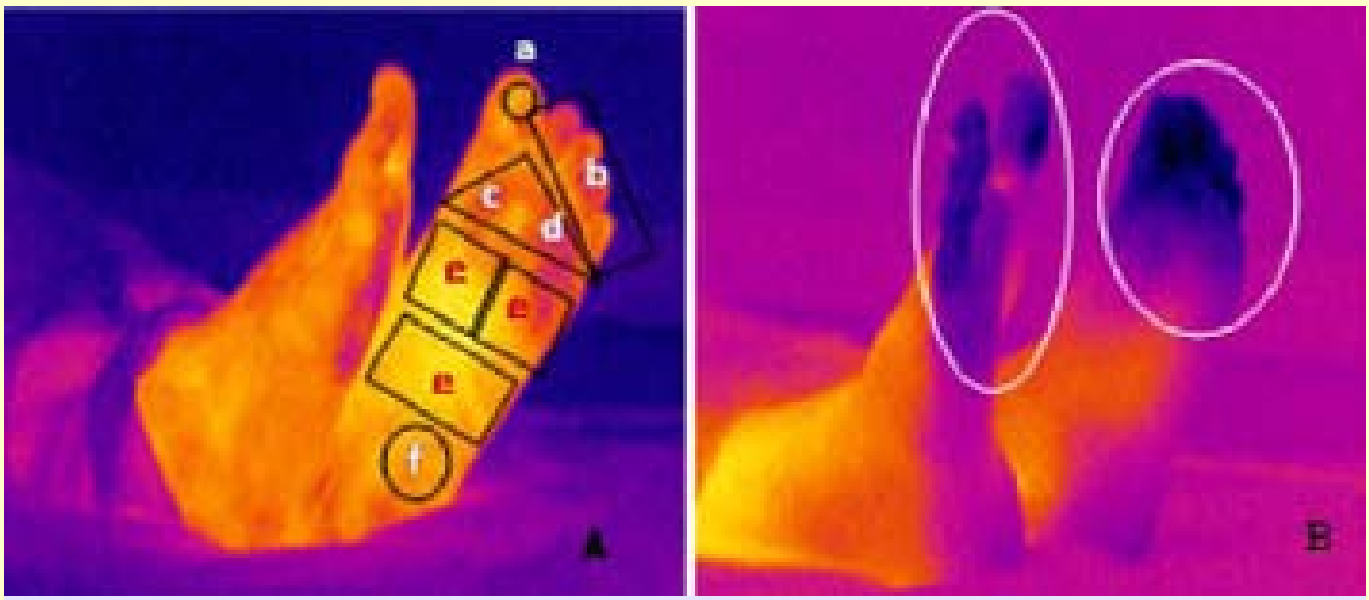
Miscellaneous

At IGCAR, Infrared thermal imaging survey was carried out on patients with diabetic neuropathy. Patients with higher mean foot temperature were compared to non-neuropathic patients. A positive correlation was observed of right great toe and left great toe with the vibration perception threshold values.

At TMC, new tests were added for the detection of malarial antigen for the rapid diagnosis of malaria. An automated system for the rapid identification of micro organisms including yeasts was commissioned.

INDUSTRIAL APPLICATIONS

Sludge Hygienization Research Irradiator (SHRI) facility at Vadodara was operated continuously to hygienise sewage and produce enriched manure for



Thermal image foot with hot and cold regions

Industrial Computed Tomography set up

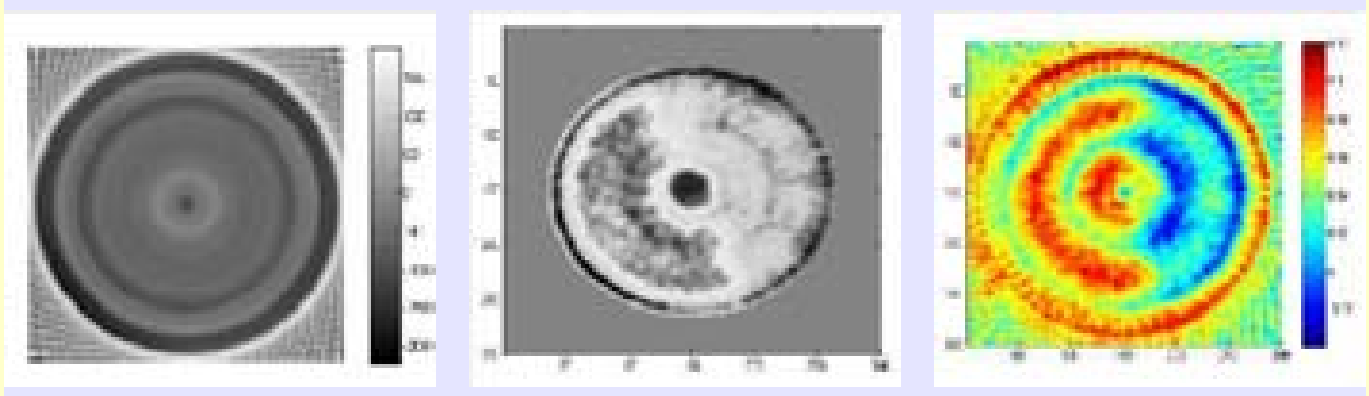
use at local farms. About 400 tons of irradiated sludge was supplied so far during the year for the field applications for use as enriched manure and soil conditioner for a variety of agricultural crops.

The 2 MeV electron beam accelerator (ILU-6) was operated at full power and was utilized for providing commercial irradiation services to the industry. A new technology of electron beam cured polymer sheets that can be moulded at high temperature (1500 °C) was developed and demonstrated on a pilot scale. Industrial Computed Tomography (ICT) consisting of a direct digital radiography and computed tomography facility was established using a flat panel detector system along with 160 kV and 420 kV CP X-Ray equipment.

A Process Tomography (PT) system for Indian Oil Corporation was set up for examination of a column of 625 mm diameter made of Perspex filled with catalyst alumina with both liquid and air flowing through it as per the process requirements. A mechanical system was specially designed and fabricated for carrying out tomographic experiments.

Cs-137 of 300 mCi along with 32 collimated Bismuth Germanate (BGO) scintillator detectors were used for examination. Some of the results from the recent experiments are shown below.

A radioactive particle tracking technique was developed using Scandium-46 source in collaboration with IIT-Delhi for tracking the fluid and solid particles in industrial process systems. An import substitute 100 Curie Co-60 exposure device was

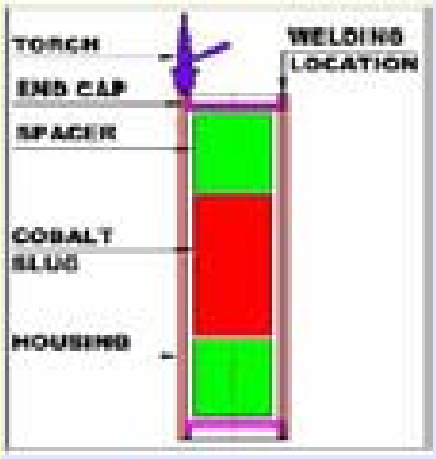


High sensitivity ion chamber for measurement of X-Ray dose from RAPI SCAN system

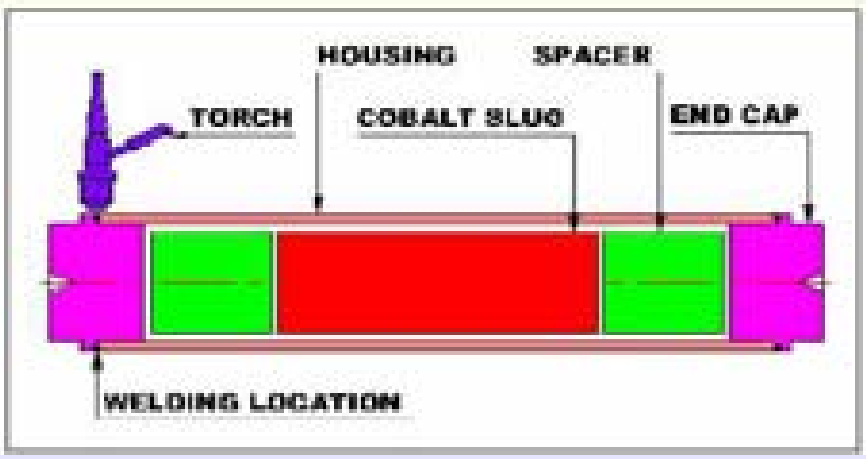
developed and fabricated.

On request from Authorities of Indira Gandhi International Airport, New Delhi, technical expertise was extended for measurements of radiation levels and image qualities of the X ray body scanner (Model RAPISCAN SECURE 1000) proposed to be installed at the airport.

The 10 MeV RF linear electron accelerator at Electron Beam Centre, Kharghar, Navi Mumbai, was operated at 10 MeV, 300 Hz prf (pulse repetition frequency) and 3 kW average beam power for continuous 24 hours to establish stable and safe operation. The accelerator was operated at beam power of 5.5 kW for short time. The beam was employed for demonstrating industrial application towards cross-linking of poly-ethylene, diamond colouration, Teflon degradation and production of photoneutrons. Depth dose distribution of the 10 MeV electron beam was measured using B3 Radiochromic



Existing practice



Modified design

10 MeV RF Linac System on the first floor

10 MeV RF Linac System on the ground floor

High Voltage Multiplier Column on the first floor

Linac assembly at ECIL, Hyderabad

1kJ Compact Marx generator and Reflex Triode

300kV Fast Marx generator

Remotely Operated Semi-automated Two-axis Welding Fixture

films with interfacing of Perspex sheets. Experiments for determining uniformity in dose distribution were carried out using dosimeter films HD 810 and B-3 at 2 kGy. The system was regularly operated for material irradiation studies. Delayed neutron studies with uranium sample irradiation was completed at beam ratings of 10 MeV, 50 mA, 50 Hz prf for 10 to 60s. Radiation grafting was done at 10 MeV, 2.5 kW beam power for 210 seconds for a dose of 25 mRad. Irradiation experiments for morganite, sapphire and gemstones colouration were conducted at beam ratings of 10 MeV and 1.5-2.5 kW beam power for 5 to 20 minutes. The white transparent colour of gemstone changed to light green. X-rays were produced in the energy range of 3.0 MeV to 3.8 MeV using a 1.8 mm thick tantalum sheet placed on beam dump and employed for irradiation of mangoes. Experiments were conducted to study the effect of irradiation on the reverse recovery time of semiconductors, at 10 MeV, 1 kW beam power level.

The trial testing and operation of the 30 kW DC electron beam accelerator at Electron Beam Centre, Kharghar was carried out.

The subsystems of 9 MeV cargo scanning RF Linac for technology demonstration were integrated and beam experiments were conducted at ECIL and experiments on electron beam transport and beam focusing at X-ray target were carried out.

A bipolar type six stage 1 kJ compact Marx generator and a Reflex Triode with output ratings of 300 kV, 12 kA, 300 ns, 10 Hz for use in high power microwaves (HPM) generation, was developed and tested upto 280 kV in single shot mode.

A compact Marx generator of ratings 300 kV, 3 kA, 100 ns with a fast peaking circuit driving a half TEM horn antenna was developed and commissioned. The system was used for ultra-wideband vulnerability testing of electronic systems.

A semi-automated two-axis welding fixture for producing sealed sources was developed for BRIT. A semi-automated two-axis welding fixture was developed for making the weld joint to be circumferential weld. The fixture that is remotely operable, was installed inside the hot cell.

Radioisotope Sources

48 numbers of Industrial irradiator pencils with 770 kCi of Cobalt-60 activity were fabricated and loaded in 4 irradiators at Vasai, Ambernath, Vadodara and Jhunsons Chemicals. Two consignments of 100 kCi with 11 pencils for Vietnam and 20 kCi with 2 pencils for Indonesia will be exported. 900 Ir-192 radiography sources (35 kCi), 13 Co-60 radiography sources (640 Ci), and one Thulium-170 radiography (13 Ci) were fabricated and despatched to various users. One Gamma Chamber 1200 was loaded with 4750 cuire activity in 10 pencils.

Gamma Radiation Processing Services

Radiation Sterilization Plant for Medical Products (ISOMED)

The facility continued to operate, in confirmation with all the requisite regulatory requirements with an average plant load availability factor above 99% and average plant utilization factor of 90%, providing customer friendly quality gamma sterilization services to large numbers of customers spread all over the country. Total 5415 cu.m. of healthcare products were processed from April 2010 to November 2010.

The novel access monitoring-cum-control system for the personnel cell door was successfully implemented at the facility which was appreciated at various national/ international forums.

Introduction of advanced automation features in the existing Ceric-Cerous Potentiometer Dose measurement continued, so as to reduce the potential likelihood of manual error of omission / commission.

The facility acquired European Union (EU) GMP compliance certification from medicine and healthcare regulatory agency (MHRA) UK accredited with ISO 9001:2008 Quality Management System and ISO 22000: 2005 - Food Safety Management System; accreditation as a certified foreign device manufacturer from Government of Japan; approval from EU for Radiation processing of Food Products meant for export to European union in March 2010.

Regular audits in respect of Supplier Quality Management system, and Quality Management System Surveillance pertaining to various customers of the facility were also conducted.

Radiation Processing Plant, Vashi (RPP, Vashi)

Radiation Processing Plant, Vashi is providing gamma radiation processing services for spices, ayurvedic raw material and pet feed etc. to more than 135 customers from all over the country.

During the current financial year, about 1884.5 MT of spices and other products were processed till November 2010.

During the report period, the plant is expected to process around 2800 MT spices and allied products. Since its inception, this facility has processed about 15,900 tonnes of products.

Source replenishment was planned to enhance source strength from 350 kCi to 500kCi to cope up with the increased demand for radiation processing.

The facility was certified with ISO-9001:2000 (Quality Management Systems) during 2009, and in the current year it received ISO-22000:2005 (Food Safety Management Systems) certification. The facility was also included in the list of EU Approved irradiators.

New Radiation Processing Plants in Private Sector

The radiation processing plant M/s Innova Agri Bio Park Ltd., Bangalore was commissioned and loaded with 100 kCi of Co-60.

MoU for setting up of Radiation Processing Plant was signed with M/s CCCL Pearl City Food Port SEZ Ltd., Chennai, M/s NIPRO INDIA Pvt. Ltd., Pune and M/s Aligned Industries, Haryana.

Electron Beam Processing

The ILU-6 EB commercial processing services included processing of around 1 lakh pieces of automobile polymer adaptors, diamond irradiation. Parameter optimization of EB process for imparting required degree of cross linking of polymer blend insulation sheets was completed. A material handling

Installation of Gamma Chamber GC-5000 at Warsaw, Poland

system comprising of a pay-off and take-up equipment was designed and fabricated which is under installation at the facility. The local chiller unit was modified and put in use for its increased cooling efficiency of the accelerator equipment and it is working satisfactorily.

Radiation Technology Equipment

Gamma Chamber GC 5000

BRIT supplied a Gamma Chamber GC 5000 to ISRO, Bangalore and BARC Kalpakkam. A few more Gamma Chambers will be supplied shortly to Mangalore University, BARC, Inter-University Accelerator Centre, New Delhi and to Rumania against IAEA order. The GC-5000 was installed at the Institute of Nuclear Chemistry & Technology Warsaw, Poland, as a part of IAEA order.

Radiography Camera ROLI-1 & III

BRIT supplied 41 radiography exposure devices up December 2010. It is expected to sell another 30 cameras by March 2011. A new SS based ROLI-1 camera will be introduced in the market shortly.

Blood Irradiator

Production and supply of Blood Irradiator BI 2000 was pursued at BRIT. Two Blood Irradiators were installed at the Prathama Blood Bank, Ahmedabad and Christian Medical College, Ludhiana, and some more orders were received.

Install & Operate Irradiator

The civil work for the irradiator was completed, fabrication of components was completed and installation was in progress.

Install and Operate Irradiator being installed

Isotope Application Services

During the report period, the Isotope Application Services Group of BRIT successfully carried out leak detection studies in heat exchangers at Reliance Industries Limited (RIL), Patalaganaga using Br-82. Radiotracer studies using Mo-99 was carried out to identify leakage in the underground pipeline of RIL, Jamnagar, Indian Oil Corporation Ltd., Sewree Terminal, Mumbai and Hindustan Petroleum Corporation Limited (HPCL), Mumbai. Furnace blockage was detected at HPCL, Mahu. Gamma scanning was done for 3 columns at HPCL Visakhapatnam, on the 31T1 process column and the fluidized catalytic cracking unit at HPCL, Mumbai, and on the two vacuum gas oil hydro treater reactors of DTA refinery of RIL, Patalganga.

X Plan Projects

BRIT toop up several projects for execution under the plan project scheme. The progress made in these projects is given below:

All these projects were aimed to enhance its capacity for the development of new products, improvement in quality and also development of infrastructural facilities.

Integrated Facility for Radiation Technology (IFRT)

Under the project a Hot Cell will be set up for handling, storage and fabrication of sealed sources up 300 kCi of Co-60 at the BRIT Vashi Complex.

This project reached advanced stage of execution as civil construction for administrative building, water pool, radiometry room and Hot Cell was completed.

Revamping & Augmentation of Infrastructural Facilities (RAIF)

The project aims at Revamping and Augmentation of Infrastructural Facilities of BRIT at Vashi to enhance infrastructural support for production facility.

Civil construction for install and operate irradiator was completed, clean room facility was commissioned, and procurement of equipment made progress. Fabrication of installed and operate irradiator was completed and installation was in progress

DAE Medical Cyclotron Project: Pharmaceuticals Facility

Installation of the Medical Cyclotron Facility at VECC, Kolkata continued. This cyclotron will be used for the production of PET and SPECT radioisotopes for diagnostic and therapeutic purposes. Major equipment including hot cells was procured.

XI Plan Projects

These projects of BRIT are aimed towards development of new products, improvement in quality of existing products and improvement in manufacturing

Integrated Facility for Radiation Technology

Mobile Hot Cell work in progress

processes. Brief description of the XI plan projects is given below:

Integrator Irradiator Development Project

The project aims at upgrading safety and security features in the Radio Pharmaceutical Plant, Vashi and ISOMED facilities and to set up an Irradiator Training Facility for training of personnel for operation of irradiator.

The progress made during the report period included installation of the Access Control System at Vashi and the System for Vehicle Tracking, procurement of the Early Fire Warning System for ISOMED and Pamcrash software for safety evaluation of cask, and design and fabrication of the Aerosol Generator.

Production Facility for ^{99}Mo / ^{99m}Tc Column Generators of High Specific Activity Mo-99

The objective of the project is to set up a new automated facility for production of Mo-99 Tc-99m Column Generators using high specific activity Mo-99.

During the report period, the Automated Facility for Mo-99 Tc-99m column generators was supplied and its commissioning progressed.

Construction of State-ofthe-Art Immunoassay Facility

The project aims at development and building of infrastructure for coated tube technology and state-of-the-art Laboratory with a focus on contract manufacturing, development and building of immunoassay based on non-isotopic labels, and development of diagnostic kits for infectious diseases.

Under the project, procurement of equipment needed for development of isotopic/non-isotopic assays was completed.

Construction of State-of-the-Art GLP and GMP

Karknidon

Work carried out included : Completion of decontamination of working tables and fume hoods in the 2 laboratories; Order for procurement of stainless steel fumehoods, new working tables, flooring, paneling etc., and Procurement of HPLC instrument, UV spectrophotometer and Portable liquid scintillation. Refurb-ishment of Lab made progress.

Indigenous HDR Brachytherapy Equipment (IHDR)

During the report period, the AERB's type-approval for the high dose rate source for machine "Karknidon" was obtained by BRIT.

WATER

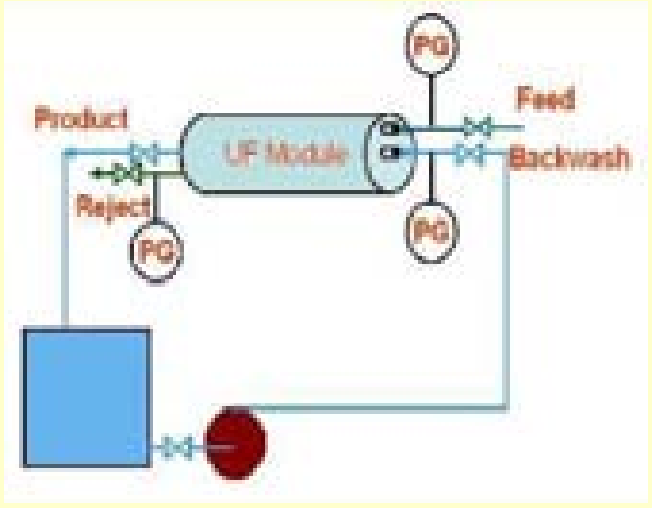
Under the AKRUTI programme of the Department, Isotope Hydrology Techniques were used successfully and a huge groundwater source was detected in draught prone area of Amravati District of Maharashtra. Augmentation of recharge to a few drying springs in Uttaranchal (Uttarkashi, Dehradun), Himachal Pradesh (Sirmaur), Maharashtra (Thane, Raigad) and Mizoram (Humifang) etc were also carried out.

Nuclear Desalination Demonstration Plant (NDDP) consisting of Multi-Stage Flash and Reverse Osmosis (RO) sections of 4.5 Million Litres/Day (MLD) and 1.8 MLD capacities respectively were operated round the clock at Kalpakkam. Product quality of better than 5 ppm total dissolved solids (TDS) from sea water having 35,000 ppm TDS was achieved in the Multi-Stage Flash section which was better than the designed quality. The product water was supplied to Madras Atomic Power Station (MAPS) for high end applications. The rest of it, was sent to the IGCAR water reservoir after blending with the desalinated water from Reverse Osmosis (RO) plant giving high quality potable water.

Low Temperature Evaporation (LTE) desalination plant coupled

EDI unit
(capacity: 5000 LPD)

UF Assisted Fluoride
Removal System



Back-washable Ultra-Filtration Element

Solar PV based Brackish Water RO Unit

to CIRUS reactor was operated and the product water of 1-2 ppm TDS was continuously utilized as make-up water in CIRUS since April, 2004. The product and feed water were analyzed for radioactivity (Gross α, β and Tritium) and found that the integrity of coupling system performed well as per the designed intent.

The 50 kilo-litres/day LTE & 50 kilo-litres/day Multi-Effect-Desalination pilot plants were operated regularly for verification of design parameters and validation of software developed for simulation under the aegis of Indo-French collaboration.

BARC has set up an Electro-De-Ionisation (EDI) unit of 200 litres/hour capacity producing ultra pure water for high end requirements such as super-computers etc. The unit was integrated with low temperature evaporation (LTE) plant for producing ultra pure water from sea water.

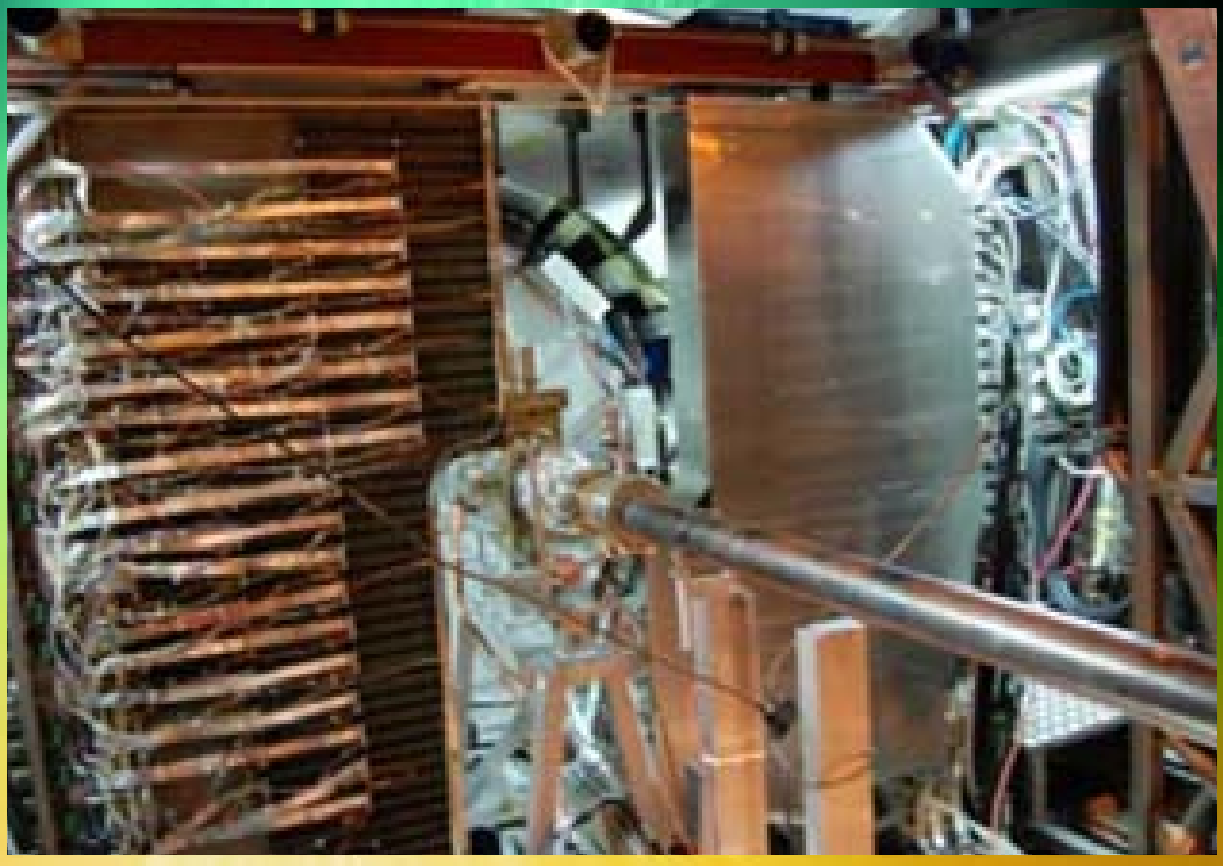
A comprehensive technology comprising re-generable alumina followed by ultrafiltration was developed to bring down the fluoride level in water to 1mg/litre (ppm) and transferred to three private parties for wider deployment.

Extensive pilot studies were carried out for the in-house developed back-washable spiral configuration ultra-filtration (UF) technology for endurance test and evolving the operating parameters of the UF technology as a pretreatment to reverse osmosis desalination plant and water purification plants.

In order to deploy brackish water desalination technology in un-electrified remote areas, RO pilot plant supported by electricity produced through solar photo-voltaic were designed and developed.

CHAPTER : 5

BASIC RESEARCH



The ALICE-PMD (Photo Multiplicity Detector) at CERN-LHC

CHAPTER : 5

BASIC RESEARCH

The basic research relevant to the programmes of DAE is done in DAE's research organizations. The autonomous research institutes under the aegis of DAE, pursue frontline basic research ranging from mathematics to computers, physics to astronomy, and biology to cancers. During the report period, following were the major activities of these organization in basic research.

MATHEMATICS & COMPUTATIONAL SCIENCES

At Trombay, new Simulation Strategies applicable to systems differing in length and time scales, were developed during the report period. A quantum / classical mechanical simulator was developed and implemented in ANUPAM supercomputing facility.

At RRCAT, a high capacity storage cluster Kshitij-1 was configured. The 1 Gbps capacity NKN link was integrated with RRCAT network and tested to work successfully both for internet browsing and intra DAE communication purposes.

A dose-profile is of immense importance for health physicists. To determine distribution of radiation dose during operation of the K-130 Room Temperature Cyclotron, at different regions in the cyclotron vault as well as in the adjoining experimental caves at different energy levels, an indigenously built mobile robot was deployed at VECC. The mobile robot, equipped with a neutron and a gamma monitor, is tele-operated from the control room. At the Centre, a modern network infrastructure was set up with a very high speed (Gigabit) backbone.

In the School of Mathematics of TIFR, research work continued in Pure Mathematics, as described below.

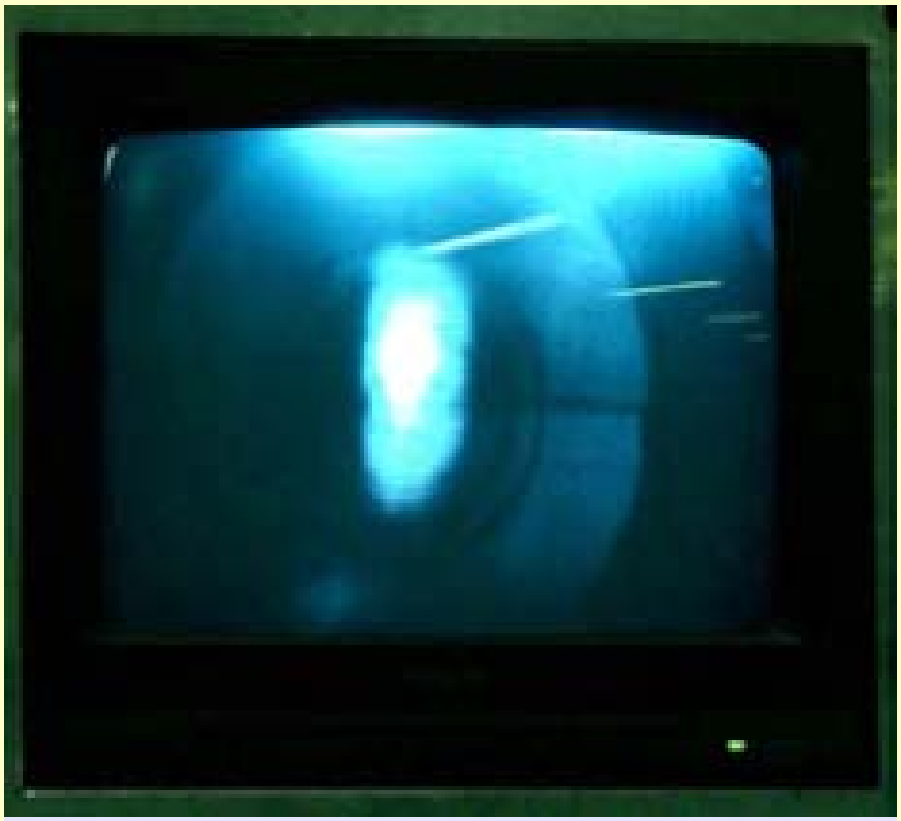
For a normal affine surface V whose integral homology is that of a point and the logarithmic Kodaira dimension of the smooth locus of V is 2, then V has at most one singular point and it is a cyclic quotient singular point. A complete classification of smooth affine surfaces V defined by $z^n = f(x,y)$, such that the logarithmic Kodaira dimension of V is at most one, was obtained. Some foundational results about actions of the additive group G_a on normal affine 3-folds were proved.

A bijective correspondence between the unitary representations of the fundamental group of a projective Deligne-Mumford stack M and the polystable bundles on M with vanishing Chern classes, was established.

It was shown that the correspondence between Higgs bundles and representations of the fundamental group for a compact Kaehler manifold does not extend to compact Gauduchon manifolds.

The upper bound on the

K-130 Cyclotron



First extracted beam after recommissioning of K-130 Cyclotron

averages of classical Kloosterman sums over arithmetic progressions was obtained. In particular the dependence of the bound on the parameters m and n of the Kloosterman sum and the common difference q of the arithmetic progression was explicitly demonstrated.

The existence of smooth numbers in short intervals was investigated. Some unconditional results were obtained. A study of the local Galois representations attached to cuspidal automorphic representations of GL(n) for n > 2 was carried out.

In the area of communications, TIFR investigated the problem of OFDM receiver design under the constraint of low-precision analog-to-digital conversion. A new external architecture using some analog processing was studied in detail. New designs which combine the benefits of both the usual OFDM receivers and the analog processing based architecture were also under investigation.

In the area of verification, the industrial strength embedded system programming language SCADE and its development environment were studied by the TIFR team. Experiments were carried out to compare the verification and testing capabilities of the SCADE and open source SAL environment. A scheme for compositional translation of SCADE models into SAL model was formulated. (Joint work with BARC). The API and tool chain for programming Firebird educational robot using SCADE, was set up. A prototype of campus autonomous vehicle was developed in SCADE over the firebird platform and demonstrated. Verification of safety properties of this design was in progress. This was a joint work with IIT-Bombay.

In addition, two new mid-plan projects were started, one on Quantum Information Processing and the other on Formal Aspects of New Computational Paradigms.

At HRI, some new simple Whittaker modules for the Virasoro algebra were constructed. A series of simple Whittaker modules for the Lie algebra of derivations of the polynomial algebra were also constructed. In the category of Whittaker modules over solvable Lie algebras and their relation to Koszul algebras, several finite dimensional examples were given.

Central automorphisms of finite groups were studied. In a joint work, counter examples to a conjecture were constructed. Some examples of groups of odd prime power order, which do not have any non-trivial abelian direct factor, whose all automorphisms are central and the group of all automorphisms is non-abelian, were also constructed.

Work continued at HRI, on catastrophe theory in minimal surfaces. Finding of some examples of bifurcation

phenomenon which can be explained using Thom catastrophe theory, continued. Work also continued on bifurcation phenomenon in blackhole accretion disc.

Work was done earlier on geometric quantization of the vertex moduli space, both abelian and non-abelian vertices. Now further developments of this are being studied. Changing the vertex equation, letting the metric on the Riemann surface vary, one can possibly get a conformal field theory.

Work also continued on understanding the co-adjoint orbit structure of the phase space of Toda systems with an eye towards geometric quantization of the Toda system.

In the field of Harmonic Analysis, an existence result for a class of nonlinear Schrodinger equations with low regular initial data, namely for initial data coming from certain first order Sobolev space associated to the special hermite operator, was established. Strichartz type estimate for the Schrodinger propagator for a class of differential operators with discrete spectrum, was also under investigation.

In the fields of Algebraic Geometry, Algebraic Topology and in Arithmetic, work progressed on certain aspects of semi stable vector bundles over real abelian varieties and in finding the relation between parabolic vector bundles and equivariant vector bundles over real algebraic curves. Research continued on co-homological dimension theory, group actions and non-metrizable manifolds. A topological proof of Knesers conjecture, as given by Laslo Lovasz, was found. Further, various generalizations were also studied.

The compositum of all separable extensions of a given field of given prime degree, such that the galoisian closure is solvable, was determined. As an application, a direct proof of Serre's mass formula in prime degree was found by TIFR researchers.

At HRI, research in various areas of Number Theory continued. Applications of a number of themes in Analytic Number Theory were studied. In Combinatorial Number Theory, work was done on several questions in additive combinatorics. One of them involved weighted analogue of some constant considered Harborth. Weighted Davenport constants were also calculated for some specific weight sets. The collected works of an Indian number theorist namely S. Sivasankaranarayana Pillai was successfully completed.

Additive Combinatorics is the study of approximate mathematical structures that have applications in various other branches of mathematics. One such application is in the work of Bourgain, Glibichuk and Konyagin, who used the results of the topic to obtain a nontrivial upper bound of the Fourier transform of an arbitrary small multiplicative subgroup of a cyclic group of prime order under any nontrivial additive character. In a work in progress, this result was reinterpreted in terms of an upper bound for trace of certain representation and also formulated a general question.

In Automorphic Forms, expressions for the special values of certain Dirichlet L-function in terms of finite sums involving Jacobi symbols were given. In 1997, W. Kohnen showed that a certain average of L-functions over a basis of cusp forms of integral weight on SL(2,Z) does not vanish in large parts of the critical strip. This result of Kohnen was generalised to L-functions of forms of half-integral weight.

In Algebraic Number Theory, work was completed in finding an estimate on the pairs of integers which are mutually squares. Zeta-functions satisfying functional equations with multiple gamma factors were also studied and an intermediate modular equation which gives rise to many arithmetical Fourier series as a consequence of the functional equation was proved.

The Institute of Mathematical Sciences researchers carried out Tsunami Analysis modeling, jointly with the National Institute of Oceanography, Goa. Extensive work was also done on PRISM-Simulation and modelling of diverse phenomena. The other activities of the Institute were related to Indo-French Centre for promotion of advanced research in physics, mathematics and

theoretical computer science; Cell response to parasites supported; Algorithms, Complexity, Automata and Logic; Non-Commutative geometry; Cryptography, and Parametrised Algorithms jointly with University of Jena, Germany continues.

PHYSICS

At Trombay, indigenously developed Supersonic Molecular Beam Facility was used to investigate electronic structure of scandium nitride molecule and to obtain the symmetries and molecular parameters of the ground and excited states. Spectroscopic data useful for isotope selective photoionization of zirconium was obtained. Single molecule fluorescence spectroscopy set-up was used to establish the photo-induced conformational jump in carbocyanine derivative Cy5 and to obtain the fluorescence lifetime imaging of GaInN nano-crystals.

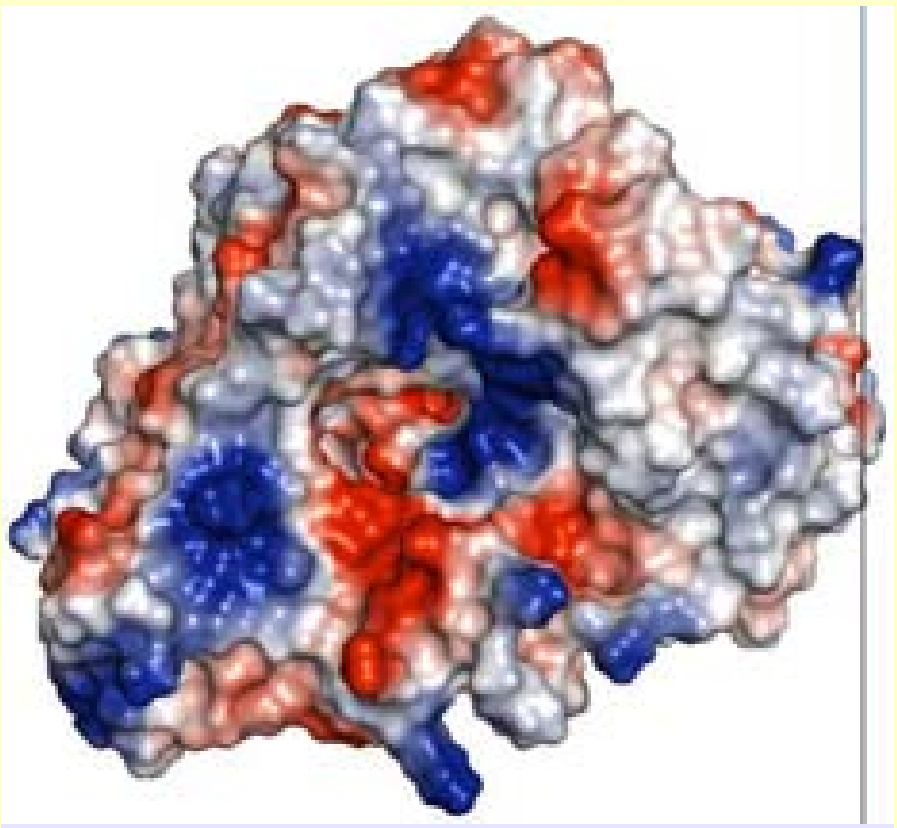
The crystal field splitting of rovibrational transitions of solid para-hydrogen was investigated to identify the role of anisotropic interactions. High resolution Fourier transform emission spectroscopy of $^{74}Ge^{80}Se$ in 33,500-26,000/cm region, was investigated to obtain accurate vibrational and rotational constants, and reveal perturbations therein.

Several new results were obtained in the areas of coherent spectroscopy, quantum coherence and interference and on the possibility of observing negative refractive index in three and four level atomic systems. A novel experimental scheme for frequency offset locking was established for the clock transition of cesium. Magnetic switching of electromagnetically induced transparency and absorption was demonstrated in a series of precision spectroscopy experiments.

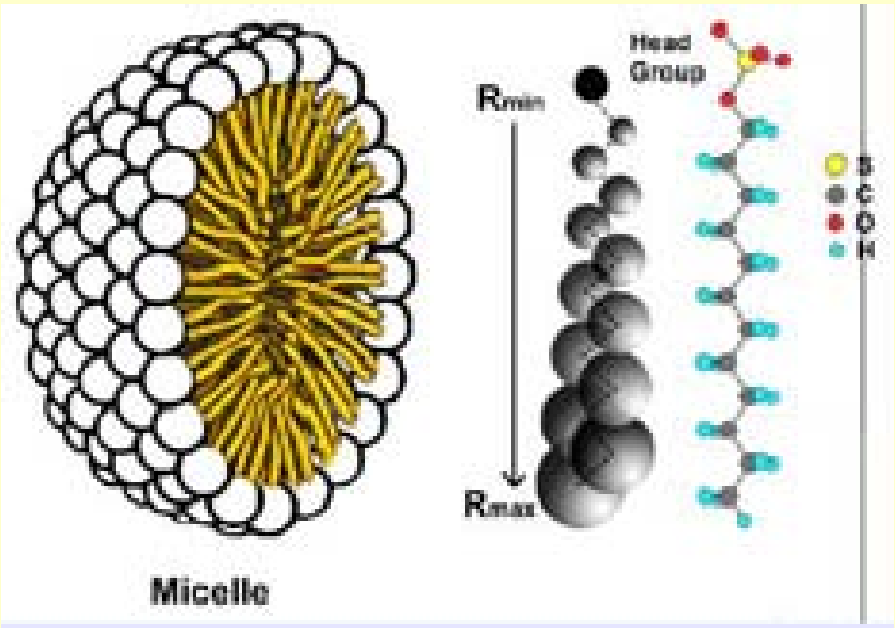
The three dimensional structure of a complex between active HIV-1 protease and a substrate oligopeptide, converted in-situ into a tetrahedral reaction intermediate, was determined. Three dimensional high-resolution structure of an enzyme suitable for bioprecipitation of uranium under alkaline conditions, was determined using X-ray crystallography. This structure will help in engineering this protein for improved usefulness in bioremediation.

The National Facility for Neutron Beam Research at Dhruva was regularly utilized by the users from DAE research organizations, various universities and other academic institutions. The molecular dynamics of Sodium Dodecyl Sulphate (SDS) micelle was investigated using high-resolution incoherent quasi-elastic neutron scattering technique.

Neutron Focusing Mechanism for double curvature mono-chromator was developed for



High-resolution structure of an enzyme suitable for bioprecipitation of U



Internal Dynamics in SDS Micelles: Neutron Scattering Study

focusing the neutron beam. Experimental station for Small Angle X-ray Scattering/wide Angle X-ray Scattering beam line studies of synchrotron radiation was designed. Detailed drawings of the support structure sub-assembly were completed and released for manufacturing.

At VECC, Radioactive Ion Beam (RIB) Project, progressed considerably in terms of developing a number of advanced accelerators for the first time in the country, such as the Radio Frequency Quadrupole and IH-Linacs. The facility that will accelerate RIBs as well as stable heavy-ions of high intensity, will help in the understanding of the physics of short-lived atomic nuclei.

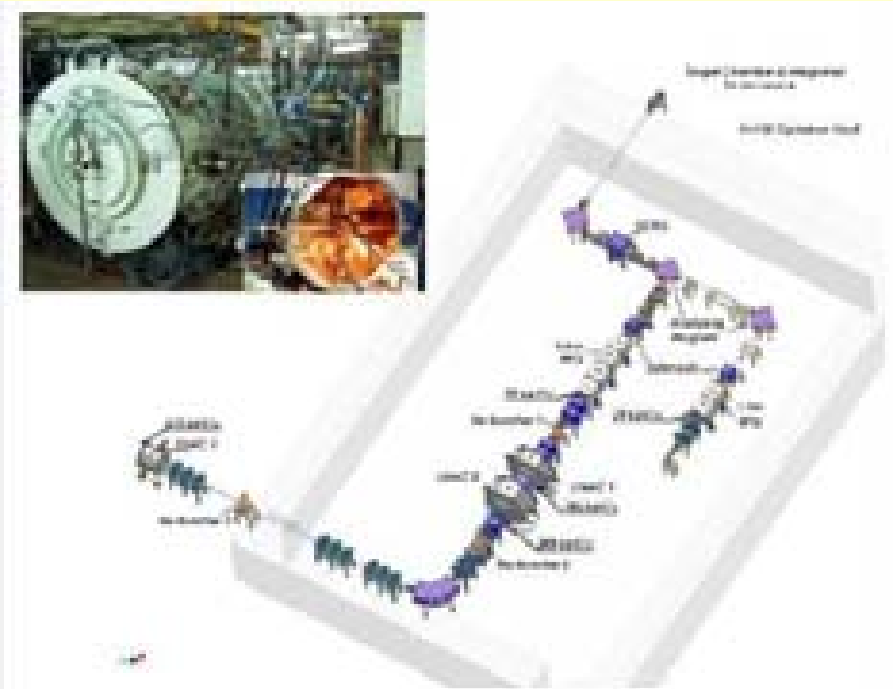
Several nuclear physics experiments were carried out at VECC using the alpha beam for reaction dynamics and nuclear structure studies. An experiment was setup to probe temperature dependence of GDR using the large area BaF_2 detector array developed at VECC.

At TIFR, proportionate growth that occurs in nature when organisms grow, was successfully modeled by a simple sandpile model.

A novel Kondo effect was discovered in a study of magnetic impurity effects in the honeycomb lattice S = 1/2 Kitaev model which showed a Z2 spin liquid behaviour over a range of parameters.

A set of discriminating variables was devised to solve the "LHC inverse problem" and a novel phenomenon of "multiple splits" in the spectra of neutrinos from a supernova was discovered and analytically investigated.

The chiral anomaly relation was shown non-perturbatively to survive even at finite density. Smooth behaviour was predicted for certain observables at current RHIC and future LHC energies,



Layout of the RIB facility. Inset Linac-2 module of the RIB facility

ECR Ion-Source Facility at TIFR

any deviations from which signal the presence of a nearby critical point.

A state of massive "constituent" quarks was argued to exist as an intermediate phase between confined nuclear matter and the plasma of deconfined massless quarks and gluons. Charmonium suppression in strongly coupled quark-gluon plasma was demonstrated.

New black hole solutions, with charged scalar condensates, were constructed in global AdS spaces in a perturbative expansion in the charge of the solutions. Gauged matrix quantum mechanics was studied in the limit of a large number of flavours.

A novel Higgs mechanism was used to determine the leading higher derivative corrections to Bagger-Lambert-Gustavsson field theories related to membranes in M-theory and evidence for a universal answer was obtained.

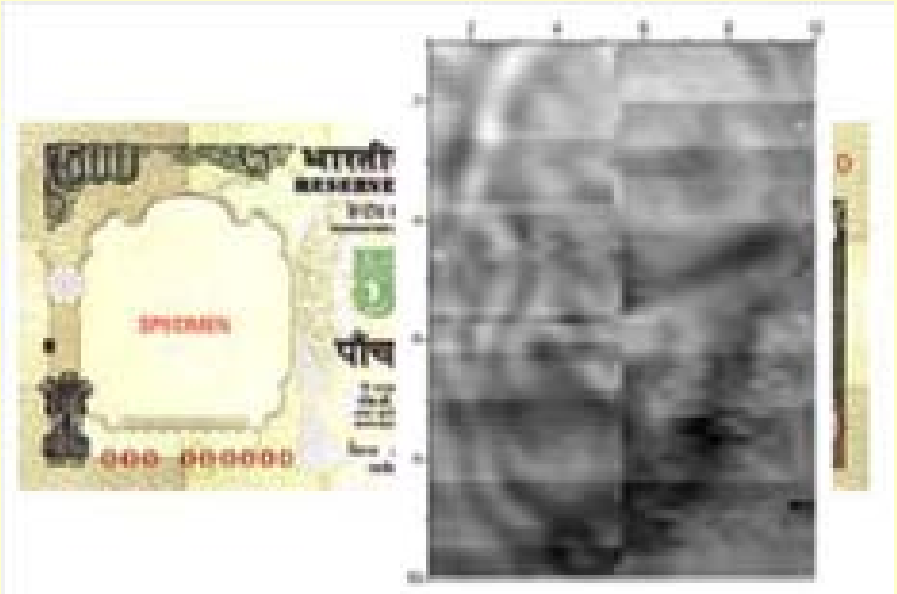
Renormalizable, asymptotically free four-fermi theories with Lifshitz scaling were constructed. The RG flows in the space of couplings of this system were shown to include a new fixed point characterized by z=1 scaling and a violation of Lorentz invariance.

The TIFR team carried out observations of galactic and extra-galactic objects using the HAGAR telescope array. The data on Mkn421, an AGN (active galactic nucleus), taken in the month of February indicated flaring activity in the object as also seen by various other experiments.

Fermion-Boson ultra-cold atoms experiment with Potassium isotopes was set up and running with K39 and K40 atoms cooled to 30 micro-Kelvin.

A better constraint on quantum gravity's space-time foam was obtained from strong polarization of gamma rays from Crab pulsar.

TIFR carried out investigation of isomeric states in transitional nuclei due to coupling of gamma vibrations and rotational excitations, through discrete gamma ray spectroscopy. A new



THz imaging : Image of the watermark of the Rs. 500 currency note of the government of India is visible

data acquisition system based on digital signal processing was implemented for a large array of high purity germanium detectors and charged particle detectors to enhance the overall efficiency of the array.

Emission frequency of a random laser was stabilized to a range of 1.2 nm, maintaining the ultranarrow bandwidth of 0.12 nm. In another project, the intensity statistics of a disordered nanostructured random laser were quantified, and a characterization parameter was proposed for the same.

Some of the rare-earth systems were found by TIFR that exhibit exceptional field-induced first-order magnetic phase transitions indicating 'inverse meta-magnetism'. Comparison of the magnetic anomalies in some of the spin-chain systems were made in the polycrystalline, single-crystalline and nano-form, which led to the understanding of the novel magnetic anomalies. Also, strongly correlated electron behaviour in $R_2Ru_3Ga_9$ (R = Ce and U) was found.

A major finding was of a real system exhibiting spin density wave quantum criticality.

TIFR researchers successfully performed the Time Resolved Pump-Probe measurements in the Transmission and Reflection geometry on various materials.

In the fields of Astronomy and Astrophysics, at TIFR, the development of large area high sensitivity detectors for spectral and imaging observations above 20 keV was completed. The analysis of data from the RT-2 experiment onboard the Coronas-Photon satellite was completed. The CZT-Imager payload for ASTROSAT reached final stage of fabrication.

A programme to develop high resolution near room temperature hybrid X-ray detector systems for future space missions was undertaken.

Mechanical drawings of the TIFR near-infrared spectrometer and imager were completed. The TIRSPEC first light observations will be made with 2-m Himalayan Chandra Telescope from Hanle (Ladakh) shortly.

TIFR's Phase-1 plan for the development of a Laboratory Model of IRSIS was completed.

Research was carried out at TIFR in the areas of helioseismology, neutron stars, accretion-powered pulsars, black holes, supernovae, gravitational lensing, large scale structure, cosmology, general relativity, quantum gravity and gravitational waves.

Exploration of the origin and growth of astronomy in India from prehistoric periods to recent period continued by studying megalithic structures, eclipse records on copper plates and stone engravings and analytical studies of the Indus Valley Civilisation.

At the TIFR's National Centre for Radio Astrophysics, Pune, final release of the 32 MHz, 30 antenna Giant Metrewave Radio Telescope (GMRT) Software Back-end (GSB) as the default for GMRT was achieved. Using GMRT, an ambitious 1-year project to image 80% of the sky at 150 MHz, was launched. This survey will be an order-of-magnitude more sensitive than

21 metre Major Atmospheric Cerenkov Events (MACE) Telescope under construction for Gamma Ray Hanle Astronomy in Ladakh (photo:ECIL)

any made so far at metre wavelengths.

The new RF front-end system for the L-band (900-1500 MHz), including protection against mobile phone interference, was developed & installed on 14 antennas of GMRT, and extended to all 30 antennas shortly.

Development of a modern, high-level antenna control software, in collaboration with TCS was completed and tested on 3 antennas of the GMRT.

Detailed computer models of the GMRT antennas were developed using modern software packages for evaluating the mechanical health of the antenna structures.

At SINP, research in the frontline areas of condensed matter physics with synthesis, characterization and study of physical properties of conducting nano-composites, rare-earth based intermetallics, perovskites, double perovskites, quasi low-dimensional system, quantum spin chains, strongly correlated systems, nanocrystalline materials and surfaces and interfaces of ultra thin films and nanomaterials were carried out.

The Centre for Nanoscience and Surface Physics (CENSUP) was created at SINP to promote national and international scientific exchanges involving cutting-edge research on nanoscience and surface physics.

The activity in the area of theoretical condensed matter physics studies were made in strongly correlated systems and statistical physics. The Centre for Applied Mathematics and Computational Sciences was created for interdisciplinary research.

The research activities in High Energy Physics involve the experimental and theoretical studies of matter produced in Ultra-relativistic High Ion Collisions and nuclear structure studies at high spin. Setting up of a Facility for Research in Experimental Nuclear Astrophysics (FRENA) progressed here. Research in experimental condensed matter physics was conducted in the areas of conducting nano-composites, rare-earth based intermetallics, perovskites, double perovskites, quasi low-dimensional system, quantum spin chains, strongly correlated systems and nanocrystalline materials.

Basic research in the frontline areas of synthesis, characterization and study of physical properties of surfaces and interfaces of ultra thin films and nanomaterials were actively carried out. A new Center for Nanoscience and Surface Physics (CENSUP) was created to promote national and international scientific exchanges involving cutting-edge research on nanoscience and surface physics. The other notable activities included theoretical research, developmental activities, EDXRF spectrometry, and identification of magnetic rotation bands in certain elements. Alpha cluster states were studied from resonance breakup of O-18 from C-12 target into α and C-14 particles; several new states between 11-18 MeV were observed, and new spin parity for the 11.59 MeV cluster state was proposed. A generalized mass formula was developed for non-strange, strange and multi-strange nuclei.

Development of different types of gas based radiation detectors operating in ionization, proportional, avalanche and streamer modes was carried out. These detectors will be helpful in the development of indigenously built large area active detectors for a 50 kT iron calorimeter as planned for the India based Neutrino Observatory.

At SINP, emphasis continued on the indigenous development of the various systems and subsystems beginning from design. In the area of experimental Plasma Physics research in the following disciplines was pursued (a) Ion Acceleration by MHD Activities; (b) Intermittency in heat and Particle transport in the Scrape off layer; (c) Radial transport of nonthermal electrons in SINP Tokamak; (d) Hard x-ray correlation analysis as a diagnostic tool for the measurement of magnetic turbulence in tokamaks; (e) Improved Confinement due to Current Profile Modification and Suppression of Drift-Alfven Mode by Biased Electrode in SINP-Tokamak and (f) DNTBA (Diamond Nano Technology for Biological Applications). Also, the experimental fabrications

were undertaken for MaPLE device (Magnetized plasma Linear Experimental Setup), Deep Space Plasma Propulsion Experiment, and Nonliner Dynamics experiments.

Challenging problems of sine-Gordon field model with defect, as a quantum and classical integrable system and 1D model of delta-anyon gas were solved. The static and mass-shedding limit sequences of hybrid stars, composed of colour flavour locked quark matter core, for a set of equations of state were constructed. Work on lattice gauge theory was pursued.

At IoP, stochastic dynamics of nuclear fission was studied in the framework of Langevin equations. The role of shape-dependence of nuclear dissipation was investigated in terms of the number of neutrons emitted at different stages of fission. Fission widths were calculated by considering fission as diffusion of a Brownian particle with variable collective inertia.

In the pursuit of obtaining nuclear properties from basic interactions, the proton radioactive decay rates were calculated from a finite-range effective Yukawa interaction. Equation of state calculated using the same effective interaction was also found to account for the properties of pure hadronic compact stars. A parametric model was developed to predict neutron-nucleus total and reaction cross-sections accurately. The photo-fission cross sections of nuclei executing giant dipole oscillations were calculated.

Space-time evolution of the hot matter created in nuclear collisions at ultra-relativistic energies was studied using the relativistic viscous hydrodynamics. The charged particle energy spectra and the elliptic flow of the matter were evaluated in order to investigate signatures of phase transition from hadrons to quark gluon plasma. The effective drag and diffusion coefficients of the quark gluon matter were evaluated by using both the radiative and collisional processes. Using these transport coefficients as inputs the Fokker-Planck equation was solved to characterize the quark gluon matter formed in nuclear collisions by evaluating the nuclear suppression factor and azimuthal anisotropy of heavy quarks. Two particle correlation functions with both real and virtual photons were evaluated and it was shown that this can be used as a very efficient tool to understand the phase transition from hadronic to quark matter.

The High Energy Theory Group of IOP remained actively involved in pursuing research in diverse areas. In string theory, three generation SU(5) supersymmetric GUT model was obtained by toroidal compactification of the type I theory with magnetized branes. Using gauge-gravity duality, instabilities of certain strongly coupled gauge theories were understood via constructing off-shell effective potentials, and studying various transport coefficients. A mapping was obtained between generalized nonlinear Schrodinger equations and neutral scalar field theories, and new solutions obtained. An attempt was made to look for signatures of Z3 walls in relativistic heavy ion collisions, and to establish the possibility of string network formation resulting from the percolation of string loops.

In condensed matter and statistical physics, research at IOP was focused on diverse areas as well. In the unzipping of the DNA, it was proposed that a softening interfacial instability leads to a fork reversal which results in a propagating front into the unzipped state. The phase transition between A and B forms of DNA was studied using free energy formulation, and confirmed that the transition is of first order. It was shown that purely nonequilibrium noise, repeated many times, could be used to reconstruct equilibrium. It was pointed out that S-matrix formulation of mesoscopic systems needed reinterpretation in quasi one dimensional systems because of evanescent modes. Entropy production theorems in transient state were studied and average entropy production as a new quantifier of irreversibility in finite time nonequilibrium processes, was proposed. In the context of nonequilibrium fluctuation theorems it was shown that the free energy can depend on the magnetic field and friction coefficient, which is concomitant with the appearance of classical

diagmanetism in the real space-time approach using the Langevin equation. Interfacial fluctuations in different classes of sandpile models were studied and it was shown that the hydrodynamic description seems to be valid in the limited models, the unlimited models were not amenable to this description although they have well defined scaling behavior. Quantum critical behaviour of magnetic quantum paraelectrics was studied and the temperature dependence of dielectric susceptibility near both anti-ferromagnetic quantum critical point and ferromagnetic quantum critical point was described with scaling arguments. The effects of in-plane and inter-plane overlap and site energy difference between atoms in the in-plane sublattices on the asymmetry in electronic spectra of graphene was studied.

In Nuclear Physics, research focused on nuclear structure and nuclear reaction. The mechanism for the formation of superheavy elements in astrophysical objects, nucleon-nucleus and nucleus-nucleus reaction, study of cluster decay properties and the giant monopole resonance of neutron-rich nuclei were pursued. Recently discovered super heavy nuclei and a new mode of fission decay for neutron-rich heavy nuclei was studied. Nuclear matter based on QCD motivated model at extreme densities and temperature was compared with the results of heavy-ion collisions and astrophysical systems. Study of nuclear properties related to radioactive ion beam and neutron stars has been undertaken.

In experimental Physics, the major activities include the preparation of certain nano systems on various surfaces, and studying them using photoluminiscence spectroscopy, high resolution transmission and scanning electron microscopy, focussed ion beam, high energy electron diffraction, X-ray diffraction, atomic force microscopy, X-ray photoelectron microscopy and Raman spectroscopy. Different ion beams available from the 3 MV pelletron were used for modification and preparation of many of these nanomaterials. Analysis of valence band electronic structure and band mapping of transition metal-oxide compounds and carbon systems using photoelectron spectroscopy was undertaken.

A state-of-the-art thin film growth laboratory which includes UHV e-beam evaporation facility and DC/RF magnetron sputtering facility with glancing angle deposition attachment was developed, and a surface profilometer to measure film thickness and stress analysis was installed. A low-energy (up to 2 keV) broad beam ion source was installed along with a 5-axes sample manipulator for the synthesis of ion-beam induced self-organized surface nanostructures. A high-resolution XRD facility also came up. Experiments were also carried out to study the isotropic-nematic phase transition in a film on a cylindrical surface.

The HRI carried out research in the astrophysical fluid dynamics, compact objects, cosmological dark energy, large scale structure formation in the Universe, reionization and the intergalactic medium, inflationary cosmology and the early universe, and different aspects of black hole physics and semi-classical gravity. In the area of astrophysical fluid dynamics, chaos was investigated. Investigations were also done in the area of compact objects, properties and formation routes of the millisecond pulsars found in globular clusters and galactic discs. Perturbations in the scalar field models of dark energy and their scale-dependence were studied. In the area of large scale structure formation, the scale of homogeneity of the Universe was determined using N-body simulations. Simulations were used to make predictions about future surveys of neutral hydrogen at high redshifts. The hyperfine transition of singly ionized helium-3 was proposed as a probe of the high redshift universe. In the field of reionization and intergalactic medium, the physical processes related to the cosmological reionization, like star formation, chemical enrichment and feedback, were modelled using semi-analytical methods. General relativistic accretion phenomena onto astrophysical black hole was under examination at a close proximity of the event horizon to reveal the spectral signature of

black hole spin. In the area of semi-classical gravity, duality modified propagators in spacetimes with constant curvature were calculated.

The work in condensed matter was focused on three major areas namely strongly correlated systems, electronic structure, and mesoscopic physics and spintronics. In the area of strongly correlated systems, HRI made some progress in elucidating the impact of positional randomness on physical properties of double perovskites. A second class of problems pursued involves the effects such as superfluidity, frustrated magnetism, and superconductor-insulator transitions in ultracold systems in the presence of disorder and thermal fluctuations. The structure and semiclassical dynamics of Jahn-Teller polaron in oxides were studied. Electronic structure calculations based on density functional theory were in use for a detailed exploration of transition metal doped alkaline earth clusters with a view towards identifying magnetic superatoms with novel properties and the possibility of building an assembly of such clusters. HRI was also trying to understand the microscopic origin of spin gapless semiconductors. In the area of mesoscopic physics and spintronics, HRI worked on spin polarised scanning tunneling microscopy of helical Luttinger liquids and shown signatures for charge and spin fractionalisation. The Institute explored the spin dependent scattering and transport in various models in analogy with optical double refraction. HRI team also carried out studies of spin transport in topological insulators. Another work focuses on formulating strategies to generate tunable spin currents using quantum wire networks.

In the field of high energy physics, HRI continued its research relating to neutrino and collider physics. Neutrinos are tiny, very light particles which hardly interact with ordinary matter, but which have an important impact in many areas of physics. The main unresolved questions in neutrino physics today are the precise magnitude of the masses of different neutrino species and their mixing pattern. These are among the key inputs when constructing unified theories beyond the Standard Model of particle physics. HRI researchers worked on models to explain some of the properties of neutrinos and studied their signals at various experiments. They were actively involved in the development and physics studies of the India-based Neutrino Observatory. It will measure the properties of neutrinos by detecting neutrinos generated in the atmosphere and using long-baseline neutrino beams. Other important results include work on the fluxes of ultra high energy neutrinos in the presence of physics beyond the Standard Model.

The collider physics group of the Regional Centre for Accelerator-based Particle Physics (RECAPP) in HRI, focused on systematic studies of physics signals at the Large Hadron Collider, Geneva. The LHC is expected to shed light on fundamental theoretical issues like the origin of mass (search for the Higgs boson) and the prevalence of matter over antimatter in the universe. It is also expected to directly produce so-called dark matter particles, a mysterious invisible component of the Universe. Intensively work continued on all these aspects, mostly in the context of super-symmetric extensions of the Standard Model. Work on the implications of a non-standard Higgs sector and extra space-time dimensions was also carried out. An important activity was to find out how to distinguish all these models at the LHC, i.e. how to deduce the underlying theory from the experimentally measured data. The importance of same-sign tri-lepton and four-lepton events in eliciting the signature of a class of new physics scenarios was recently conclusively demonstrated.

Work was done on the baryon asymmetry in the Universe, Grand Unified Theories and the anomalous magnetic moment of the muon.

In the field of quantum information and computation, HRI carried out research mainly at the interface of quantum information science with condensed matter physics and ultracold gases. The group proposed an entanglement mean field theory-inspired approach for

efficiently dealing with interacting classical many-body systems that cannot be solved exactly (arXiv: 1008:5099). In another work, atom counting theory was used to study the role of thermal noise in quantum phase transitions and to monitor the dynamics of a quantum system. Studies were also conducted on the measures of quantum correlation defined from an information-theoretic perspective, and applied them to study the time-evolution of an infinite quantum spin model (arXiv:1011.5309). It was shown that such measures can be associated with the collapse and revival of nearest-neighbor entanglement in a dynamical phase transition present in the system. This could potentially be useful in applications of entanglement as a resource in quantum communication and other quantum information tasks.

The String Theory group at HRI worked on Microscopic understanding of quantum states of supersymmetric black holes through the quantum entropy function; Applications of AdS/CFT to condensed matter physics; String cosmology and quintessence model building; Non-relativistic limits of supergravity, higher spin theories and W-symmetries in AdS/CFT, and Scattering amplitudes in gauge theories.

During the report period, the IMS's India based Neutrino Observatory (INO) Project finished the pilot stage and identified a site that is awaiting some environmental clearances.

NISER carried out a collaborative research project on stringy black holes. The studies carried out included kinetics and thermodynamics of phase transformations in group-IV and II-VI nanostructures during hydrostatic or uniaxial compressions employing the ab-initio molecular dynamics simulations.

Research endeavour of the Institute included studies relating to electron transport through carbon based nanostructures towards all-carbon nano-electronic circuitry, New solid state materials for storage and desorption of hydrogen at ambient conditions, and New schemes for calculation of excited states and electron transport with excited states. The electronic-enthalpy density functional was used to carry out accurate and efficient simulations of extended as well as finite-size quantum systems under pressure.

With the aim to push the limit of tunable coherent radiation deep into the mid-infrared and ultraviolet regime, the Institute took steps towards generation of high power , continuous wave tunable coherent radiation using the concept of Optical Parametric Oscillators.

Based on the new understanding, NISER propose to continue exploring the possibility of photovoltaic applications of three coordinated carbon based nanostructures.

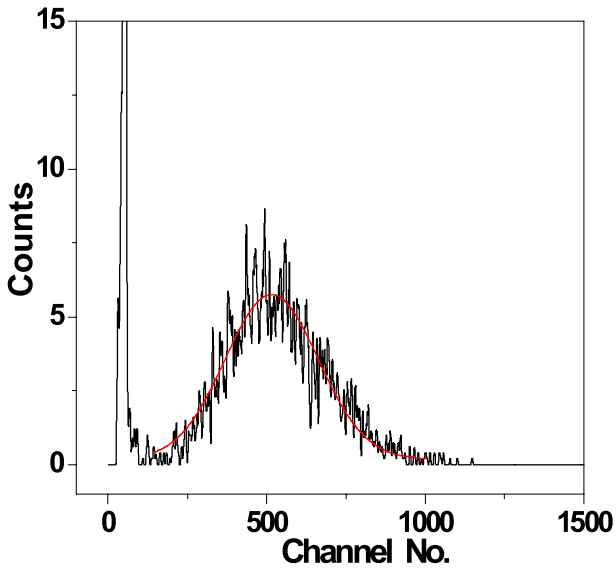
CHEMISTRY

At BARC, the kombucha tea, obtained by fermenting black tea with the kombucha culture showed excellent healing activity against the NSAID (non-steroidal anti inflammatory drug) - mediated gastric ulceration in mice. The anti-inflammatory property of black tea was also established using animal and cell culture models.

Clinical trial for the multiple medicinal benefits of the grape-derived polyphenol resveratrol continued at Trombay. Several synthetic resveratrol analogues designed were found to possess differential anti-cancer property against a large array of human cancer cell lines.

A (L)-proline-based organocatalyst was developed to carry out regio- and enantio-selective organo-catalytic conjugate additions. Enantio-selective chemical and enzymatic asymmetric protocols were formulated and used for the syntheses of a diverse array of anti-cancer and immuno-modulatory compounds. A novel low-valent titanium-mediated carbonyl-alkene radical cyclization protocol was designed to synthesize benzopyrans of pharmaceutical importance. A novel type of electronic memory material was developed by electro-grafting a pyrromethene compound on a silicon wafer followed by supramolecular bi-layer attachment of another PM compound. A chemi-resistive thin

Detectors developed from diamond films



a-response of the detector in air

film chlorine sensor was designed by spin-coating a new bis-porphyrin molecule on glass surfaces.

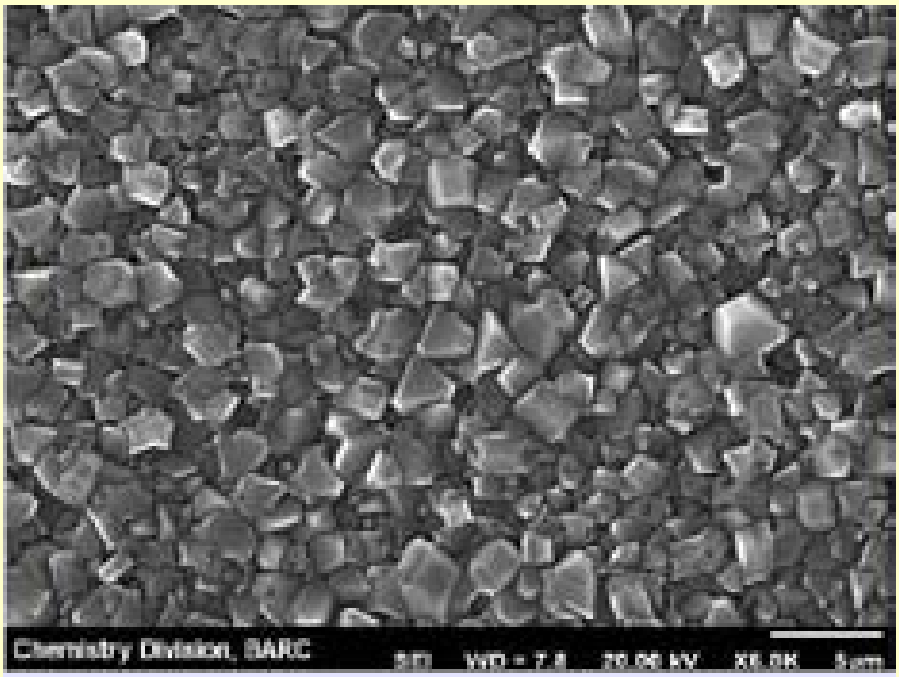
Using microwave plasma carbon vapour deposition technique, high quality diamond thin films were grown on silicon wafer (1-5 cm^2 area) and characterized.

A study was made using post-irradiation annealing technique to evaluate the augmented transport and release property of Xe expected from fine grained alloy matrix.

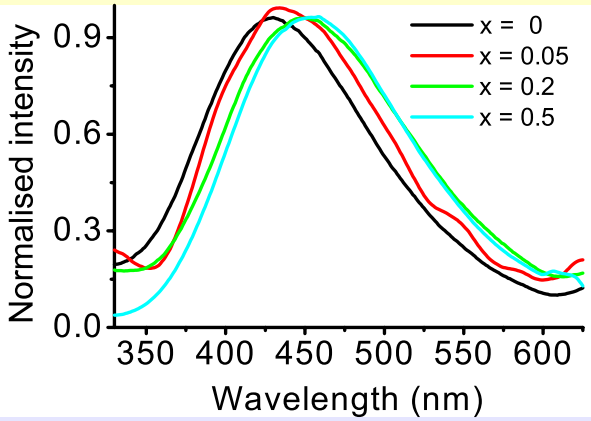
As compared to the conventionally used alumina, nano-structured oxides of Ti and Zr developed at BARC showed improved uptakes with high selectivities of the parent radionuclides ^{188}W and ^{99}Mo and better elution profile for its daughter radionuclides, ^{188}Re and ^{99m}Tc respectively.

Strong blue light emitting In^{3+} doped $ZnGa_2O_4$ nanoparticles easily dispersible in organic polymer, were prepared at a relatively low temperature of 120°C.

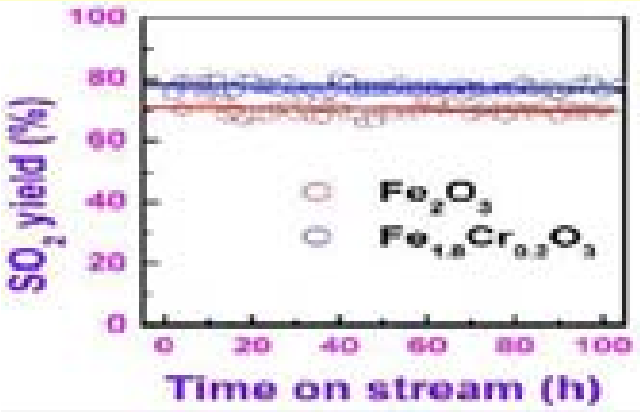
Photocatalytic activity of self-doped titania nanoparticles (TiO_2 doped with Ti^{3+}) synthesized by solvothermal route and that of nano-titania with finely dispersed indium oxide and tin oxide were



Highly oriented diamond films



Luminescence from $ZnGa_{2-x}In_xO_4$ nanoparticles



Catalytic performance of iron oxide catalysts for Sulphuric Acid decomposition

evaluated for water splitting reaction under sunlight type irradiation using Pd as co-catalyst and methanol as sacrificing agent.

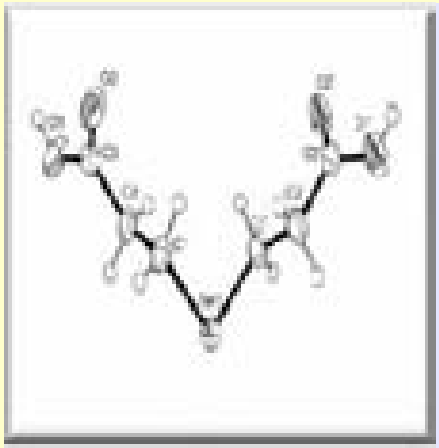
The nano-titania with finely dispersed tin oxide with Pd as co-catalyst showed a higher value of 40 ml hydrogen generation per gram of catalyst during 12 h irradiation.

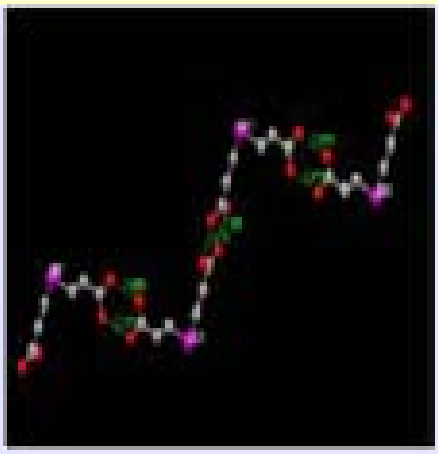
Synthesis, chemical/structural characterization and radio-pharmaceutical studies of a large number of organo selenium compounds were carried out.

Two Dye-Sensitized Solar Cell (DSSC) module were made from D1421 and C343 dyes on TiO_2 nanoparticle systems.

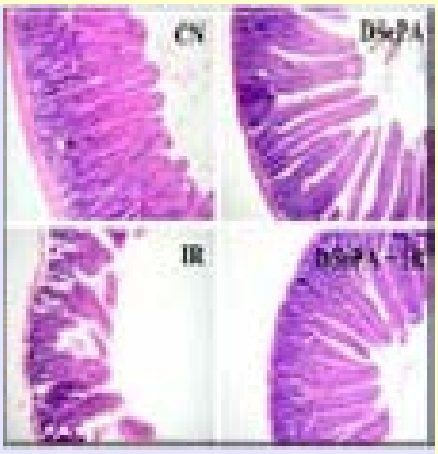
In the area of host-guest chemistry, stimulus responsive cooperative metal ion binding to the stoichiometrically, selected cucurbit [7] uril - Thioflavin T complex was carried out. Illustrated capsular supra-molecular assemblies are promising for applications in targeted drug delivery, on-off switch and building blocks for tailor made functional materials & molecular architectures.

Molecular understanding of photodissociation dynamics of various halogen containing compounds were studied by monitoring atomic bromine signal in both of its spin orbit states using indigenously developed resonance-enhanced multiphoton ionization (REMPI) set up.





DSePA molecule (bottom) and its conformal structure (top)



Effects on DSePA on gastro-intestinal tissue as monitored on day-3 post irradiation (7.5 Gy). (CN: control; IR: irradiation)

Studies on the radiolytic degradation of extractant tetra (2-ethylhexyl) diglycolamide (TEHDGA) / isodecyl alcohol / n-dodecane system were carried out. Synthesized micro-porous PAN-curcumin beads were evaluated for their ability to extract U from an aqueous solution at different temperatures and pHs.

Theoretical calculations were carried out to (i) investigate the complexation of actinide/ lanthanide ions with cyanex ligands for validation of experimental results, (ii) predict nonlinear optical properties of gold nano-clusters, (iii) investigate the photoelectron spectra of titanium dioxide clusters, (iv) design new dye molecules for better laser efficiency and stability, (v) interpret aluminium analogues of boron hydrides, and (vi) understand the speciation of heavy metal oxides in various types of chemical environment.

Extensive ab-initio calculations were performed to investigate (i) improvement of hydrogen storage properties of lithium decorated metal organic frameworks through boron doping, (ii) hydrogen adsorption in Li-doped closo-boranes, and (iii) hydrogen adsorption properties of all metal aromatic systems.

A wide variety of new simulation strategies applicable to systems differing in length and time scales was developed. Monte Carlo and self-consistent density functional theory was designed to study the structure of colloidal solution in presence of supporting electrolytes.

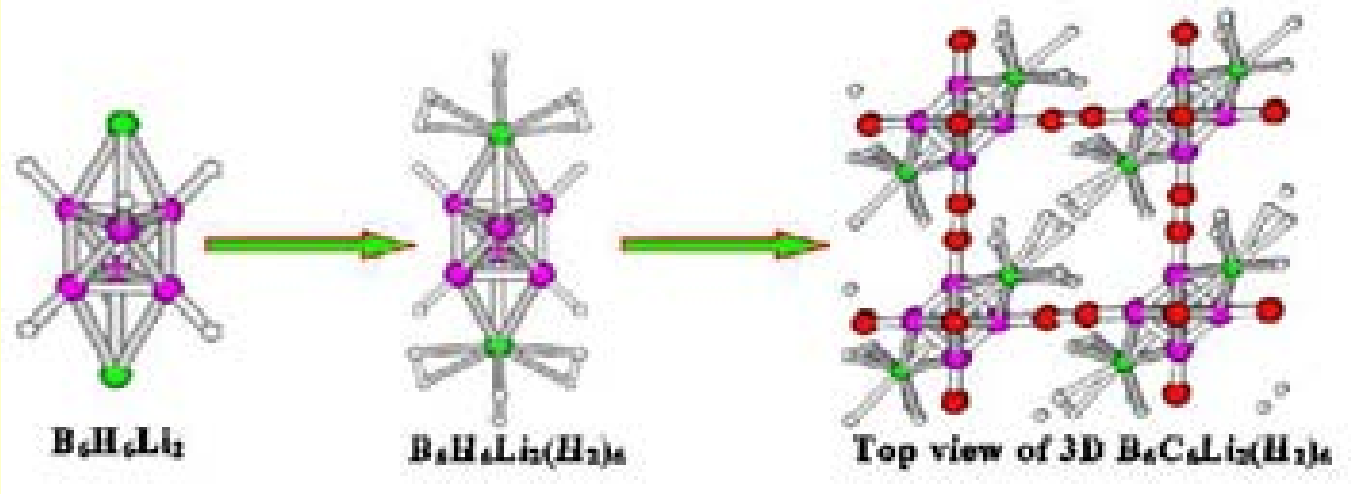
Flow accelerated corrosion (FAC) was observed to cause wall thinning of carbon steel pipes in primary and secondary coolant systems of PHWRs. In order to understand the factors controlling the phenomenon of flow accelerated corrosion thin layer activation method was adopted.

The activated specimen was exposed to high temperature water in high temperature high pressure loop in FAC module simulating a straight pipe. This method of measurement enabled shortening the duration of measurement of wall thinning and also the possibility of on-line measurement.

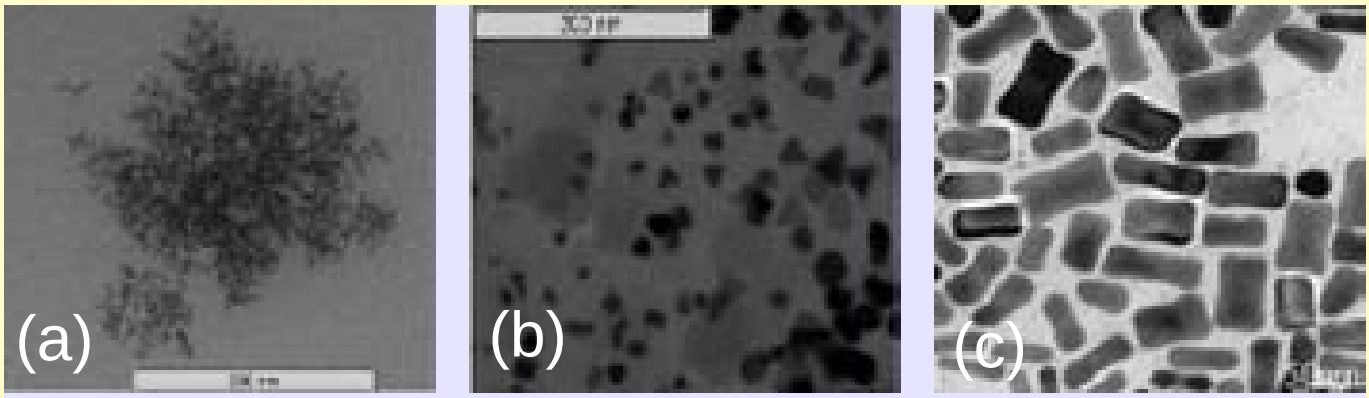
As a continuation, studies were initiated on using biosorbents for metal ion imprinting technique. Chitosan, a biopolymer derived from crustacean shells, which is known to have good metal ion sorption properties, was chosen for these studies.

Studies with metal ion-complexing agent solutions indicated good pick up of both metal ions and complexing agents on this biosorbent. Imprinting of cobaltous ions on chitosan for inducing higher selectivity for cobalt uptake was further carried out. The studies showed that the imprinted chitosan could pick up the cobalt ions from the complexing medium as well. This paved the way for exploring biodegradable sorbents for such special applications as in nuclear industry.

Work towards development of



Hydrogen adsorption in Lithium decorated boron hydrides



TEM image showing cross-section of membrane samples containing Rh cluster (a) and Au nanoparticles (b) in the Nafion-117 membrane

TEM image of rectangular plate like gold nanoparticles

granular biofilm-based process for denitrification of concentrated nitrate bearing effluents, where nitrate can be biologically reduced to gaseous nitrogen, recorded good progress. A biological process was developed for removal of sulphate from sulphate-bearing barren effluents such as those produced at UCIL, Jaduguda. A series of bioreactors employing sulphate reducing bacteria was used to bring down sulphate concentration from 18,000 ppm to below 100 ppm, suitable for dilution and discharge.

A biocide releasing polymer system capable of continuous in situ production of chlorine dioxide (a superior antifouling biocide) was developed. Reproducible well - textured Bi-thin films were prepared by electrodeposition on the carbon paste electrode surface. Sensitivity of Bi film was enhanced by Nafion coating on the Bi-thin films.

A Laboratory scale unit was developed for the decontamination of low level of Am-241 from potable water without affecting the drinking water quality, by a two column process consisting of sodium alginate beads complimented with activated charcoal column. Concentration of Am-241was reduced to 0.1 Bq, which is permissible limit in the drinking water. Thirteen different water quality parameters were rigorously monitored before and after the decontamination process. Mira mist nebulizers of ICP-OES in combination with argon humidifier were used for quantitative determination of Na/K ratio and traces of impurities in eutectic mixture of sodium and potassium nitrate. This mixture of molten salt was used as a heat transfer medium to transport thermal energy required to initiate the thermo-chemical system. Humus nano-suspension of Fe, Mn, Ca, Mg, Cd and Pb was developed in aquatic medium and their preferential size separation was studied to quantify the impact on human physiological system. Characterization of composition of nimonic alloy (Nimonic 75, Nimonic 80A, and Nimonic 90) was carried out.

At Trombay, Thorium-loaded MEP membranes were synthesized for fluoride uptake studies. Fluoride uptake upto 75-80 % could be achieved with these membranes. Samarium-loaded poly hydroxamic acid (PHA) resin was also investigated for fluoride uptake from aqueous solution. A flow injection method for the preconcentration of rare earth elements and their separation from sea water matrix using PHA was developed. A method was developed for the determination of Sb(V) and Sb(III) in simulated primary coolant water. A procedure was optimised for the determination of molybdenum, copper and zinc in blood and serum samples of patients suffering from oral cancer.

Hydrogenated diamond-like carbon films were synthesized on Si(100) and fuctionalised with BSA protein to study their bio-compatibility in view of its atomically smooth surface with large specific surface area and

hence high loading capacity for proteins for biomedical and biosensors. Endohedral fullerenes [^{86}Kr@C60] were prepared by both direct and nuclear reaction implantation methods. They were separated and purified and their chemical properties were investigated. Uptake of As(III) and As(V) on manganese dioxide was studied using radiotracer technique for remediation studies. Thin layer activation analysis technique was used for the determination of loss of materials by surface erosion during the laser ablation process which is proposed to decontaminate the mixed oxide powder from the outer surface of the zircaloy. The ablation data obtained suggest that the decontamination of MOX from zircaloy can be performed without significant loss of the material.

Reference Materials such as Boron carbide, Ilmenite and Quartz samples were prepared and analytical methodologies were developed for distribution for inter laboratory comparison exercise. Complete interfacial composition and structural characteristics of nano-structured Mg/Pd material were studied under the hydrogenation - dehydrogenation thermal stress. A titanium layer between the Mg and Pd layer improved the cyclability without affecting the hydrogen storage.

Testing of atomic beam furnace and optimizing the thermal ion signal in QMS were carried out. The detection of thermal ions of Rb isotopes was optimized for both the analog and pulse counting mode of detection. After the testing of atomic beam furnace and optimizing the extraction and focusing voltages of the QMS, a thermal ion suppresser was included into the furnace assembly for its use as an atom source for laser.

Work was carried out to develop micro-extraction techniques for pre-concentration of chromium, mercury, gold, thallium, silver and uranium from a variety of matrices for determination down to parts per billion levels. A UV photolysis method was standardized for the determination of many trace elements in dietary liquid supplements. As part of establishing procedures for the determination of trace elements in plastics, determination of total chromium and Cr(VI) were carried out.

Hydrogen absorption-desorption behavior, cyclic life stability as well as pressure-composition isotherms were investigated for the intermetallic compound U^2Ti. Li-N-H system was studied for chemical storage of hydrogen isotopes. Equilibrium hydrogen pressure over the ternary phase mixtures in the Li-N-H system was measured using static manometric method and the gas composition was analyzed using an online quadrupole mass spectrometer in order to predict reaction mechanism of hydrogen release in this system. The lead-bismuth eutectic is considered as the potential candidate for liquid metal spallation neutron source in ADS reactor systems and as a coolant for critical and subcritical reactors of new generation. A study of phase diagrams of Pb and Bi with steel components Fe, Cr and Ni was conducted. Extensive calorimetric investigations of these compounds were carried out by solution calorimetry and partial precipitation methods.

Effect of non-ideal solution behaviour of different components on thermodynamic properties and phase-diagram behaviour of mixed carbide and nitride fuels was studied.

A new route involving galvanic reactions was developed for the synthesis of metal nanoparticles in the Nafion-117 and polymer inclusion membranes. These metal nanoparticles embedded membranes can be utilized for modifying the transport properties of the membrane and as a base material for developing the membrane based chemical sensors.

Gold-nanoparticles-embedded cellulose triacetate-modifiedelectrode was prepared by chemical route and was employed to investigate the behavior of U(VI)/U(V) redox couple in saturated Na_2CO_3. A simple method was developed to synthesize rectangular plate like gold nanoparticles directly by irradiating the reaction medium containing Au(I), ascorbic acid in presence of cetyltrimethyl ammonium bromide. The synthesized nano-materials could be further developed as potential bio-sensors.

Attempts were made to

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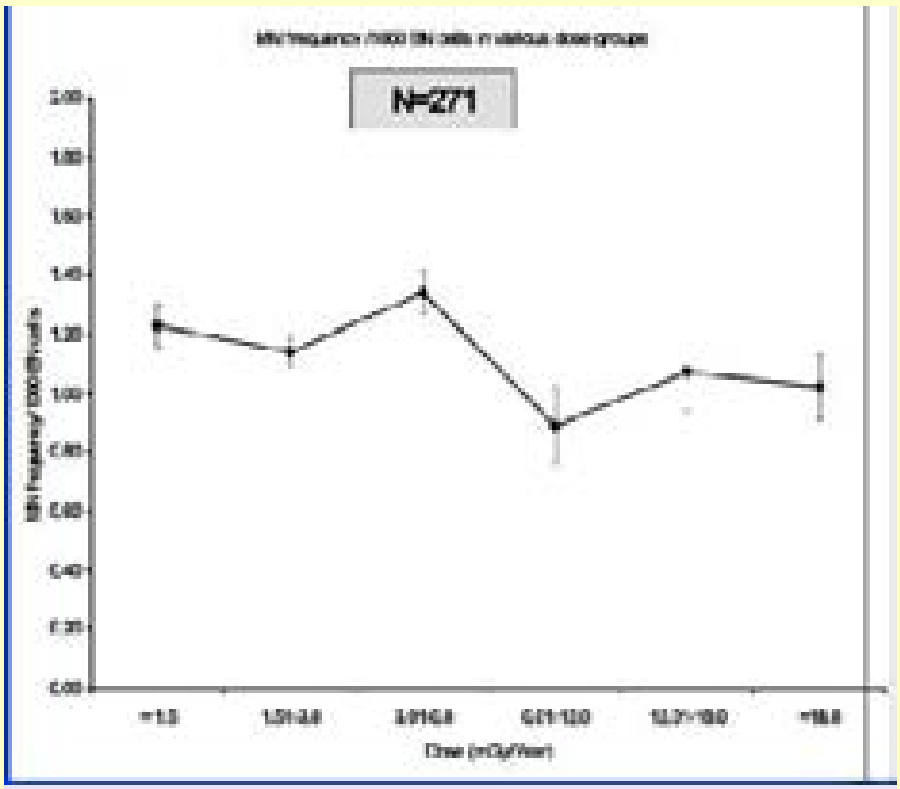
Pseudomonas strain.

Earlier studies had shown interaction of polynucleotide phosphorylase (PNPase) with DNA repair genes, such as uvrD, recB, recJ, recQ and recG in E.coli. Spontaneous mutation frequency (SMF), a measure of the mismatch repair capacity of the cells, was elevated in strains mutated in mismatch repair pathway. Deletion of uvrD resulted in 30-fold increase in SMF over the wild type strain, while pnp deletion did not alter SMF appreciably. Absence of pnp in the uvrD background brought down SMF significantly. These results suggest that pnp negatively regulates a functional homologue of uvrD.

A gamma radiation responsive membrane protein kinase was characterized from Deinococcus radiodurans and its role in radiation resistance and DSB repair was assessed. Few proteins that have a role in DNA strand break repair or oxidative stress, were found to be cognate substrates for this novel kinase. A thermotolerant phosphoesterase was identified from D. radiodurans and its role in processing of DNA ends generated upon gamma damage was studied in vitro. Two novel proteins, DRA0282 and DR2417, having human Ku80 type and an abberant Artemis type functions respectively were identified from Deinococcus radiodurans. Exploration of the role of these proteins in DNA repair/radiation resistance was pursued.

Anabaena 7120 has three ssb (Single Strand DNA Binding protein) genes coding for a 13 kDa (SSB1), 14 kDa (SSB2) and 22 kDa (SSB3) proteins. All the three proteins were overexpressed in E. coli, purified under native conditions and used for generation of specific polyclonal antibodies. Anabaena 7120 expressed all three SSB proteins under normal growth conditions, with the levels of the SSB3 protein being the maximum. Levels of SSB1 protein, were found to be enhanced during UV and mitomycin C stress, that of SSB2 during gamma-irradiation stress, while that of SSB3 remained unchanged under stress. Generation of recombinant Anabaena strains over-expressing each of these SSB proteins progressed, to analyze for their role in DNA repair activities.



Micronuclei frequencies in newborn from HLNRA

Nucleosome trans-transfer activity partially purified from wheat nuclei using cellulose phosphate showed ATP dependent nucleosome displacement in trans in presence of ATP and donor chromatin isolated from wheat nuclei and nucleosome dependent ATPase activity.

A total of 21 rice genotypes, including 9 land races, 8 modern and 2 traditional cultivars were analyzed by amplified fragment length polymorphism (AFLP). Twenty different primer combinations were used that generated 461 scorable bands (Average: 23 DNA bands per primer). Approximately 57% bands (265 of 461) were found to be polymorphic among the rice

accessions. Cluster analysis showed that two moderate tolerant rice genotypes, Damodar and CSR06220, were closest and showed least (~10%) divergence, whereas the remaining genotypes showed divergence ranging from ~25% to ~45%. The twenty-one genotypes were placed into six groups.

Human pathogenic bacteria such as Salmonella typhimurium, Bordetella bronchiseptica, and Escherichia coli, as well as plant pathogenic Xanthomonas campestris pv. glycines, and soil bacterium Bacillus subtilis when exposed to low dose gamma radiation, were found to undergo caspase dependent programmed cell death (PCD). In another study metabolic stress induced reactive oxygen species was found to be the prime cause of PCD in Xanthomonas. Sporulation in Bacillus was found to be associated with caspase-mediated PCD of sporulating cells.

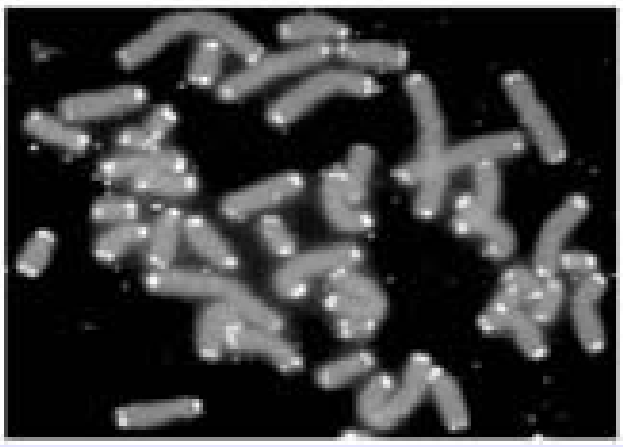
The metallothionein protein, SmtA (6.1 kDa), from Synechococcus was over-expressed in E. coli and purified. MALDI-TOF analysis identified this band to be SmtA, which suggests multimerization and stabilization of SmtA protein in the presence of heavy metals. The smtA a gene from Synechococcus was cloned downstream of the sequence coding for the signal peptide of fliY, an ABC transporter gene from Deinococcus. E. coli cells expressing this construct could efficiently remove cadmium from solution.

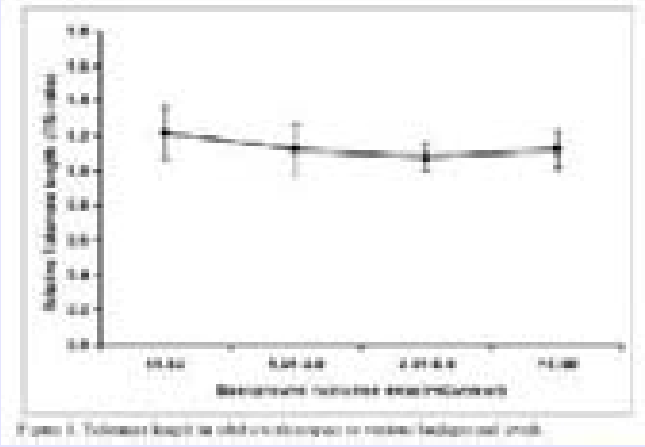
The number of new born children screened for congenital malformation in the high level natural radiation area (HLNRA) and normal level natural radiation area (NLNRA) of Kerala reached 1,30,000. There was no difference in the frequency of these malformations in these two areas. The frequency of spontaneous micronuclei among the 210 newborns from a natural high background radiation area was estimated using cord blood samples and was compared with that from 61 newborn from normal level radiation background area.

The baseline frequency of micronuclei in HLNRA newborns was not statistically different from that in NLNRA newborns suggesting that elevated level of naturally occurring radiation has no significant effect on the induction of micronuclei frequency among the newborns. No dose response in the mean frequency of MN was observed.

Telomere length is a biomarker for aging, stress and cancer. Telomere shortening was reported after exposure to high doses of ionizing radiation. In a study, the telomere length was estimated in 310 adult individuals including 233 from high background radiation area and 77 from NLNRA. The elevated level of natural background radiation showed no significant effect on telomere length among the adult population residing in HLNRA of Kerala coast. No significant difference in telomere length was observed between male and female individuals studied. No radiation dose response was observed.

Microarray studies on adults





Telomerecaps & Telomere length in adults from HLNRA

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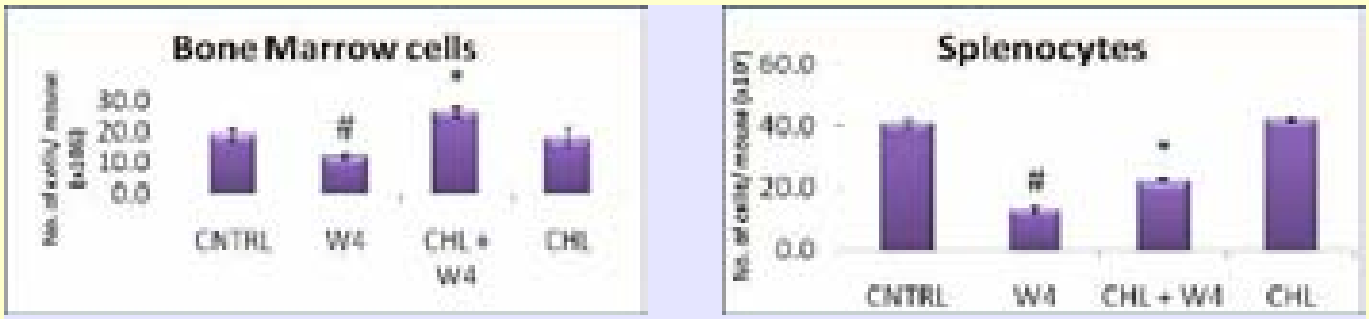


Chlorophyllin accelerated recovery from hematopoietic injury

use in mitigation of radiation injury. Cells were successfully cultured and morphology based characterization were carried out. Further study is going on to improve their yield and marker based characterization.

The bystander effect of medium obtained from the cultures of human tumour cells was studied on counterpart tumour cells in terms of increased clonogenic survival and proliferation, which depend on cell density and period of culture. Effect of radiation on invasive and metastatic behavior of human breast cancer cells was studied under in vitro conditions. Radiation induces dose-dependent changes in cell-cell interaction, cell adhesion and migration of breast cancer cells were observed. Results suggested the role of actin organization and filopodial/lamellipodial protrusions in radiation induced migratory phenotype of breast cancer cells. Results also showed involvement of p38-MAPK and JNK-MAPK pathways in radiation induced migration of breast cancer cells.

BARC researchers hypothesized that electrostatic attraction between the negatively charged cancer cells and positively charged amino acid Arginine (Arg) could selectively disrupt cancer cell.

Effects of thorium on proliferation of HepG2 cells were studied by thiozolyl blue tetrazolium reduction and H^3-thymidine incorporation assays.

In the field of Biology, following were the notable research activities at TIFR:

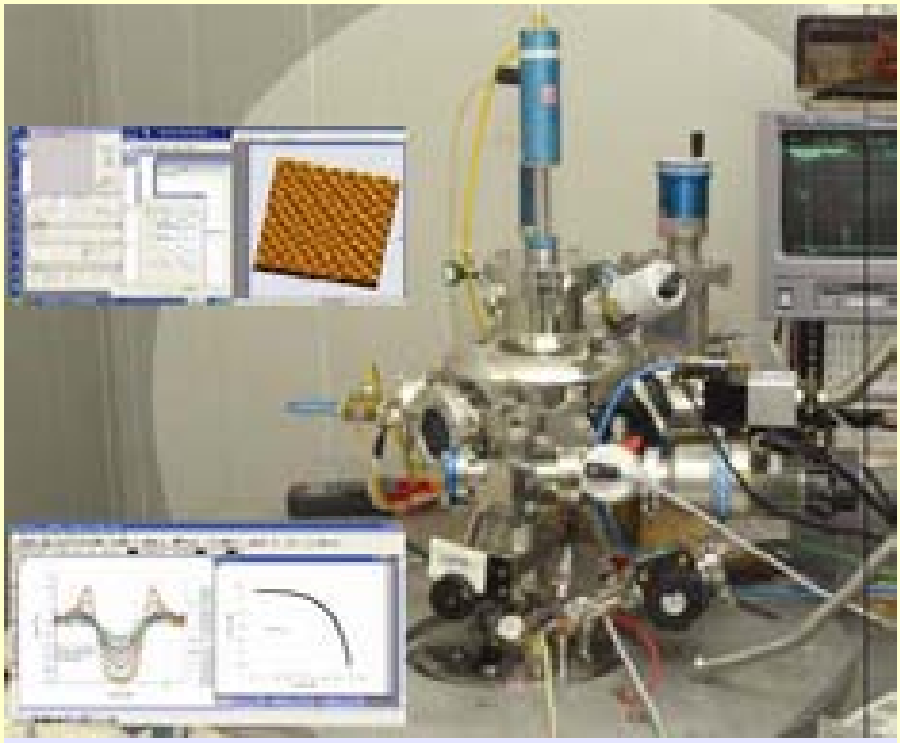
Plasmodium falciparum enolase undergo several post-translational modifications of relevance to its function. Using mass spectrometry, the researchers identified a tyrosine residue that gets phosphorylated.

Kinesin-2 subunits are essential for the bipartite olfactory cilia assembly and maturation. TIFR data provided an insight to the mechanism of generating sensory cilia diversity and established a new paradigm to study cilia assembly mechanisms.

ChAT binds directly to the KLP64D tail and the transport occurs in rapid intermittent bursts. Loss of ChAT activity is implicated in slow onset Alzheimers. The finding at TIFR explained the proposed slow transport of the molecule observed earlier and established that the process was actively controlled by kinesin-2.

TIFR researchers studied the role of mitochondrial remodeling during cell death using fluorescence microscopy and electron microscopy. It was found that mitochondria undergo hyper-fusion or fragmentation depending on the apoptotic stimulus and this morphological transformation influences progression of cell death. The study also revealed that apoptotic stimuli trigger cell death by two distinct molecular mechanisms that regulate mitochondrial morphology and calcium buffering function.

The single molecule studies on molecular motors and motor complexes led to a precise mechanistic understanding of how the activity of opposing microtubule motors is controlled at the nanoscale to generate useful and regulated motion inside cells. It was shown that Endosomes physically elongate along a microtubule during reversals in their motion. This established that opposing Dynein and Kinesin



Scanning Tunneling Microscopy Laboratory at TIFR

motors generate force against each other (as in a molecular tug-of-war) to effect reversals in motion and fission.

Under the genomics of QTLs (quantitative traits locus) in yeast, studies related to the effect of single nucleotide polymorphisms on quantitative traits, traits which are determined by multiple genes and their multiple alleles, like sporulation. It was found that there were definite sets of genes which get differentially regulated among various strains in this growth condition.

Transcriptional mechanisms that regulate cell identity in the developing brain were examined. In another project, a novel migratory stream of neurons was discovered that undertakes a route to the olfactory bulb, that is conserved in vertebrate evolution.

Key receptor based strategies were identified that significantly speed up the action of classical antidepressants in animal models that normally take 3-6 weeks. It was also shown that an animal model of depression based on a history of early life adverse experience results in aberrant serotonin2A receptor function in the prefrontal cortex.

To understand the metabolic regulation of sirtuins and microRNAs, it was demonstrated that Sirt1 is regulated in insulin secreting cells in vivo and its expression is controlled by microRNA mir-9 levels during glucose stimulated insulin secretion.

The salient research work carried out at the TIFR's National Centre for Biological Sciences at Bangalore during the report period was, as follows.

The work on the polypeptide folding and unfolding puzzle led to new results on landscape properties and its development. New protofibril mechanisms were found.

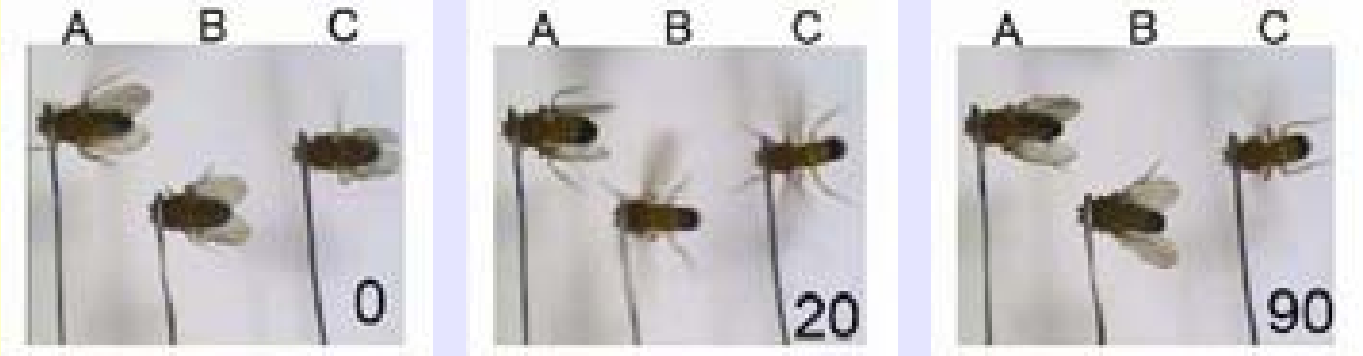
Mechanisms of cell survival using new Notch pathways were deciphered. A genome wide screen for endocytosis had yielded many new players.

Under the studies related to genetic analysis of neuronal function, muscle development, human neurological disease and Indian sub-continent wildlife, advances were made in studying animal movement, IP3 signaling, cell biology of the neuronal development and the genetic heritage of South Asia.

To understand the neural basis of brain function, work continued on the genetic analysis of chemosensory perception in Drosophila, the fragile X syndrome, computational neuroscience of the olfactory system, neurobiology of learning and memory, cargo transport within neurons and the physics and neurobiology of insect flight.

The development of the EM facility was completed. The sequencing and mass spectrometry facilities and computational facilities were made functional.

At SINP, the structural genomics and proteomics activities progressed further. The research objective was to carry out basic and applied research to understand the underlying mechanism of hematological



Snap shots of air-puff induced flight in Drosophila at approximately 0 secs, 20 secs and 90 secs after air puff delivery.
A) Drosophila mutants for the InsP3R are unable to fly (itprka1091/ug3).
B) The introduction of a dominant mutant for the endoplasmic reticulum Ca^{2+}-ATPAse reduces Ca^{2+} pumping into intracellular Ca^{2+} stores and raises cytosolic Ca^{2+} in neurons (dSERCAKum170/+; itprka1091/ug3). This leads to flight initiation.
C) Flight maintenance in addition requires store-operated Ca^{2+} entry which is restored by further introducing a mutant gain-of-function allele for the store-operated channel dOrai (dSERCAKum170/dOrai2; itprka1091/ug3).

disorders and neurodegenerative diseases. The research activities in the area of chemical biology, biomolecular spectroscopy, structural bioinformatics and computational biology were actively pursued. The research activities in the area of macromolecular crystallography, cellular and molecular biology for understanding biological processes in cancer and infectious diseases were actively pursued. Photophysical and photochemical studies were performed on inter- and intra-molecular electron/proton transfer and hydrogen abstraction reactions with small chemically and biologically important molecules.

The research activities in the area of chemical biology, biomolecular spectroscopy, structural bioinformatics and computational biology were actively pursued.

The research activities in the area of macromolecular crystallography, cellular and molecular biology for understanding biological processes in cancer, infectious diseases and Huntington's disease were actively pursued. Photophysical and photochemical studies were performed on (i) inter- and intra-molecular electron/proton transfer and hydrogen abstraction reactions with small chemically and biologically important molecules and (ii) interactions of small drug-like molecules e.g. NSAIDs with proteins and DNA bases in homogeneous and heterogeneous confined media.

The Structural Genomics and Proteomics activities were in full swing with objective to carry out basic and applied research to understand the underlying mechanism of human diseases. Currently, the activity is primarily carrying out research in two major areas - hematological disorders and neurodegenerative diseases. The widely prevalent disease of eastern India, í-Thalassemia, along with sickle cell anemia, hereditary spherocytosis and leukemia were under investigation as a model for hematological disorders while study on Alzheimer's and Huntington's diseases continued for the neurodegenerative diseases.

CANCER

At BARC, development of synthesis protocols and radiochemical evaluation were carried out for two ^{18}F containing diagnostic agents for cancer viz. ^{18}F-FLT for imaging cell-proliferation in cancers and ^{18}F-FMISO for imaging of hypoxic regions in tumours. The approval

of the radiopharmaceutical Committee was obtained and these Radiopharmaceuticals are commercially available for the first time in India.

The Medical Cyclotron Facility at VECC was almost fully operational. About 150 Ci of [F-18] FDG were produced and supplied to users. Two F-18 labelled radiopharmaceuticals, for imaging breast cancer and hypoxia imaging, were made and laboratory validation and biodistribution studies were completed. A long-term study has shown that multiple fractionated doses of [I-131] MIBG to neural crest tumours were as effective as a single high dose of the radiopharmaceutical in stabilizing the disease and improving the quality of life.

Installation and commissioning of a dual head gamma camera at the Radiation Medicine Centre was completed and it will improve patient throughput and their management.

At ACTREC, the multidisciplinary Clinical Research programmes grew exponentially during the report period. Over 2770 new patients referred from TMH underwent investigation or treatment at ACTREC. A 35% increase was observed in patients undergoing bone marrow transplant. The neurosurgery and tomotherapy programmes continued to run on target. Consolidation of various basic research programmes in particular, those on structural biology was carried out. Molecular profiling studies moved ahead with the identification of genes showing potential for clinical evaluation.

During 2010, several new protocols and clinical research programmes were initiated and the existing programmes were consolidated at the Clinical Research Centre of ACTREC.

There was an increase in the number of investigator-initiated projects in translational radiation oncology, to include areas such as evaluating HPV (human papillon virus) biology and outcomes following definitive chemo-radiation in head and neck and cervical cancers, genetics of prostate cancer, etc. The brachytherapy programme also expanded with a doubling in the number of intracavitory procedures, facilitating better resource utilization. In addition to soft tissue sarcomas, the interstitial brachytherapy programme was extended to breast and gynecological cancers. The existing external beam and brachytherapy planning software were upgraded to facilitate complex multimodality imaging based therapy.

ACTREC continued to provide advanced diagnostic services such as conventional radiography, ultrasonography, colour Doppler, diagnostic and planning computed tomography and magnetic resonance imaging scans and others. Biochemistry, haematology and cytology services were also provided.

At the Centre, the pharmacokinetic behaviour of anti-cancer drugs in Indian paediatric cancer patients was undertaken in collaboration with the University of Newcastle. Another focus was on early phase clinical development of indigenous plant derived compounds as well as chemical entities encompassing both pharmacokinetic and safety evaluation. A phase-I trial of a cdk inhibitor in solid tumours sponsored by the Piramal Life Sciences was underway. The Clinical Pharmacology lab was geared to provide therapeutic monitoring support for drugs used during bone marrow transplantation.

At the Cancer Research Institute, several programmes saw consolidation. The structural analysis of several molecules sped ahead, crystals for several molecules were ready for atomic level studies. Molecular profiling studies progressed with the identification of genes that show potential for clinical evaluation. In vivo roles are emerging for specific molecules that were identified earlier in cells/animals, and which regulate cell proliferation, differentiation and death.

Major inroads were made in identifying the genes present in chromosomal regions that are reported to be gained/lost during the transformation process in oral cancer. Microarray analyses identified prognostic markers of progression and response to treatment in cervical cancer. Expression of a set of genes was undergoing validation by quantitative real time PCR. Targeted exome capture followed

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Streamlining of the ethical and regulatory issues related to animal imaging as well as logistics involved in the setting up of the Gamma Medica Ideas Triumph microPET-SPECT-CT small animal imaging system were major achievements. Use of the system continued to study positron and gamma emitters in mouse and rat models of cancer.

Breast cancer diagnosis is limited from the absence or scarcity of early detection instruments. A project was taken up at VECC, to develop a low cost high resolution gamma imaging device for early detection of breast cancer. The design of pixilated detector, signal processing electronics and image processing software reached an advanced stage.

SYNCHROTRONS & THEIR UTILISATION

At the Raja Ramanna Centre for Advanced Technology (RRCAT), round the clock operation of both the sources Indus -1&2 was started on February 08, 2010 following successful completion of training of the first batch of operators and significant increase in beam availability had resulted. The training of the second batch of licensed Indus operators had commenced in May 2010 that will be completed in February 2011.

Indus-1 and Beamlines

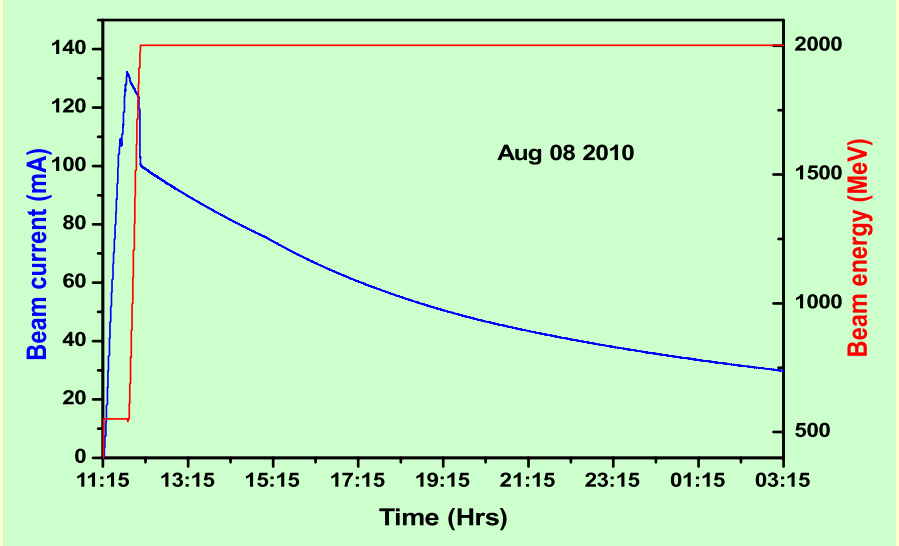
Indus-1 storage ring operated smoothly in user mode providing a total beam time on an average of 320 hrs per month. During this period, the beam lifetime was about 85 minute at 100 mA. The total beam availability from January to December 2010 was 3800 hrs as compared to 2800 hrs for the same time period last year.

Indus-1 is operating round the clock at 100 mA current

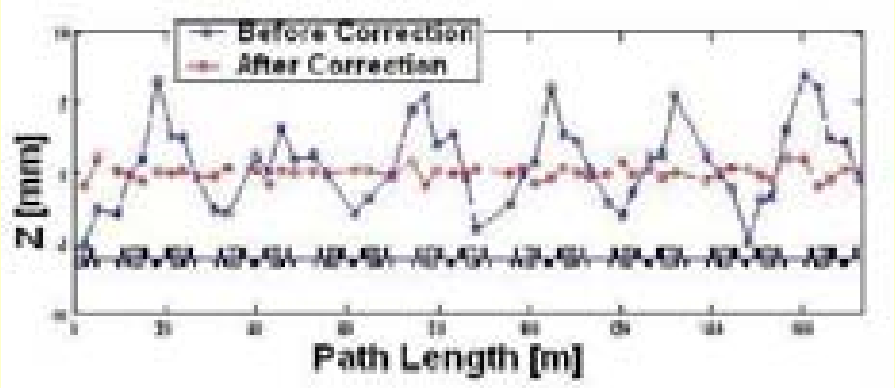
The beamlines on Indus-1 were in use by several user groups from IITs, Institutes, universities, UGC-DAE-CSR Indore, BARC and RRCAT.

Indus-2 and beamlines

In Indus-2, storage of 100 mA beam current at 2 GeV was



A typical operation cycle of Indus-2 at 2 GeV indicating beam lifetime of ~10 hours



Uncorrected and corrected vertical closed orbit distortion at 2GeV

achieved on March 6, 2010. The beam was stored for 2260 hrs at 2 GeV beam energy. The beam availability on Indus-2 i.e. beam storage time at all energies, improved from 3200 hrs from January to December 2010 to 620 hrs in the year 2009.

Experiments to reduce the closed orbit distortion, at 2 GeV, were carried out with Beam Position Indicators distributed all over the ring. In an experiment at 2 GeV with 51 beam position indicators using 48 steering magnets in horizontal and 40 in vertical plane, horizontal rms closed orbit distortion was brought down to ~1.0 mm from ~4.5 mm, and in the vertical plane the reduction was to ~0.6mm from ~2.9 mm.

Three beamlines on Indus-2 were commissioned and were fully operational. Five other Indus-2 beamlines were in advanced stages of installation. High pressure and low temperature facilities were under installation on ADXRD and EDXRD beamlines.

Energy-Dispersive X-Ray Diffraction beam line on Indus-2

Improvements in Indus accelerators

Upgraded beam position indicators were designed and fabricated at RRCAT and were ready for use. Ultrahigh vacuum compatible multi-functional beam diagnostic device for transfer line on Indus-1 were developed. Four BSMs for transfer line, were fabricated, assembled and were undergoing vacuum testing.

Equipment/systems pertaining to the power conditioning system for Indus-2 were inspected and delivered at site. The system was undergoing commissioning.

The Low Conductivity Water Plant for Indus-1 and Indus-2 can now be operated remotely from the control room. The process line was modified and provided with different sensors for monitoring various system parameters.

First result on the Angle Resolved Photo-Electron Spectroscopy Beamline on $CeAg_2Ge_2$ was published; the Reflectivity Beamline was extensively used and seven papers were also published. The Angle Integrated Photo-Electron Spectroscopy beamline was used by researchers from universities and other national institutes.

EXAFS beamline was used by the researchers from BARC,

Angle-Dispersive X-ray Beamline on Indus-2

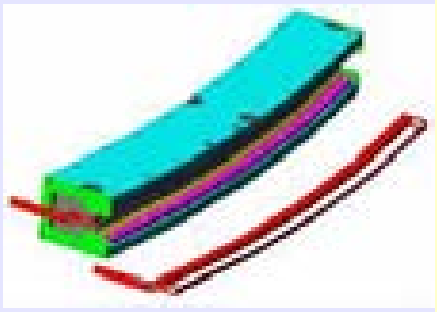
X-ray Lithography Beamline on Indus-2 under installation

X Ray Fluorescence Microprobe Beamline on Indus-2 under installation

Beam position indicator

Beam slit monitor under testing

The EDXRD beamline commissioned at Indus-2 synchrotron



The new alumina coated coil in the septum magnet and its schematic

Vikram University Ujjain, IGCAR Kalpakkam, Indian Institute of Science, Bangalore, Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore, VSR & NVR College, Guntur and Devi Ahilya Vishva Vidyalaya, Indore.

Septum magnets assembled with alumina coated coils and 0.1 mm thick Ni-Fe laminations were developed for use in the Indus-2 storage ring.

A diamond anvil cell was designed and fabricated at Trombay to carry out high pressure infrared (IR) absorption experiments at an IR beamline at Indus-1. The data showed the existence of pressure induced phase transformations in this compound.

The indigenously developed high resolution vacuum ultra-violet (HRVUV) beamline was commissioned at Indus-1 and performance testing of the beamline was carried out. Photophysics beamline on Indus-1 was utilized for spectroscopic investigations of molecules of atmospheric interest. High pressure experiments were carried out on Uranium-molybdenum alloys. Its equation of state was determined upto 70 Gpa.

A diamond anvil cell developed for IR absorption experiments at Indus-1 beamline

CYCLOTRONS & THEIR UTILISATION

Upgradation and Re-commissioning of K-130 Room Temperature Cyclotron (RTC)

The new magnet power supplies were installed at the newly renovated pit area at VECC. Various DC Power Supplies for biasing the RF tetrode tubes were developed and fabricated in house. The relay-based safety interlock system was renovated with the PLC-based safety interlock system that connects the entire RF system. The main diffusion pumps were equipped with new 36-inch gate valves and PLC based control of the entire vacuum system was incorporated, which improved the quality and reliability of the vacuum system.

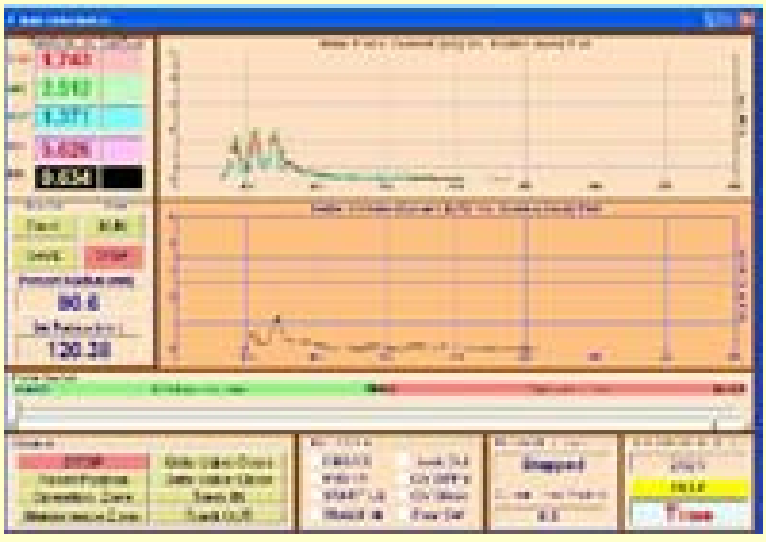
Following the up-gradation, the RTC was re-commissioned at VECC with 40 MeV alpha beam extracted from the machine. It continued to deliver alpha beam with energy ranging from 30 MeV

External beam in the first beam viewer on the external beamline

Superconducting Cyclotron at VECC

Beam Line Magnet power Supplies Interface

The operator interface of the Vacuum System



Graphical User Interface for Beam Diagnostic System

Control room of Superconducting Cyclotron

to 60 MeV and maximum extracted beam current of about 8 micro amp, and proton beam with energy ranging from 7.5 MeV to 15 MeV with maximum extracted beam current of about 20 µA for 10 MeV protons. The stability and the quality of the beam were improved tremendously after the modernization of the RTC. The machine has delivered beam for 3000 hours for conducting experiments in nuclear physics, radio-chemistry, material science as well as for pilot experiments for the production of radioactive beam.

Exploratory Studies towards Development of Electronic Tongue for Detection of Rare Earth Elements in Natural Surroundings

In collaboration with the C-DAC, VECC developed an electronic tongue, based on voltametric technique with sensor array made of gold, platinum etc., for detection and quantitative determination of different elements in aqueous solutions. Sample analysis using E-Tongue enabled accurate identification of various elements.

First Beam Acceleration Superconducting Cyclotron (SCC)

The beam trials were started after 45 kV dee voltage was attained on the three dees driven by independent amplifiers and their suitable phase stability was achieved for beam acceleration. All the diagnostics were made functional overcoming initial problems. Consequently operating at low power levels, Ne3+ beam was accelerated in second harmonic mode (at 3 Tesla magnetic field and 14 MHz RF).

Beams of nitrogen, neon, argon etc. were also accelerated in the cyclotron before taking a shutdown for installation of extraction system and major augmentation of cryogenic plant.

The 6 MV Folded Tandem Ion accelerator developed indigenously at BARC was in continuous operation for last ten years. The beam transmission was improved considerably and various beams with intensities upto 1 micro-ampere were available on target, which increased the scope of its utilization.

A high current (in micro amperes) negative ion facility was built and commissioned by the LEHIPA Team at BARC. The 50 keV beams of ions were extracted. The negative ion projectiles are specifically important for ion implantation on insulator targets as it circumvents the surface charging. The facility mainly consisted of a high intensity SNICS ion source developed in-house, high gradient accelerating tube, Einzel lens, and other components.

PLASMA & FUSION TECHNOLOGIES

The Institute for Plasma Research (IPR) carries out experimental and theoretical research in plasma physics with emphasis on the physics of magnetically confined hot plasmas and non-linear plasma phenomena.

Aditya Tokamak

At the Institute for Plasma

Research (IPR), experiments for upgrading the operational window of Aditya tokamak were continuing with different control systems. Negative converter operation made it possible to extend the plasma duration up to 250 msec. For boronization of Aditya vessel, procurement for shutters for diagnostics windows made progress. Charge exchange diagnostics was upgraded and charge exchange counts on all three channels could be realized. Estimated ion temperature from this diagnostics was found to be about 70 eV. The proposed Time of Flight Diagnostics system reached the final stage of fabrication. Infrared camera based diagnostics was deployed in Aditya to study inboard and outboard limiter.

During the report period, the vacuum ultra violet (VUV) spectrography remained operational collecting spectral data in the wide range of 100 A to 1700 A. A fast camera observing the total plasma light was installed and images with a time resolution of ~ 200 micro sec were obtained. Alignment and calibration for the Thomson Scattering System was completed. It became ready for regular operation. Detailed technical specifications were generated for a new 42GHz 500kW Electron Cyclotron Resonance Heating system for carrying out pre-ionization and start-up experiments.

Steady State Tokamak-1

During the report period, IPR's SST-1 Mission made rapid progress. Fourteen of the sixteen SST-1 TF (toroidal field) magnets were successfully tested. Bubble type cryostat 80 K bottom shield was prototyped, tested and cleared for manufacturing. All the cryostat panels were also successfully fabricated. The TF case cooling shields were fabricated successfully and were integrated on a TF magnet during the tests. All the 8 vacuum vessel modules with baking channels were baked and tested successfully. An octant of the machine comprising of the vessel module, Two TF magnets, 80 K vessel and sector panels, 5 K panels were successfully ground assembled. The LN2 booster system capable of providing single-phase nitrogen was designed and was under manufacturing.

Long duration operations of the SST-1 TF power supply with and without load in both local and remote modes were established. Through the development of Infrared Imaging Video Bolometer (IRVB) diagnostics, a new radiation sensing module was developed and a patent application was made for the same. Integrated testing of the System with central control and diagnostics signal conditioning systems continued for essential diagnostics channels. To address the integrated testing data handling requirements, a graphical user interface based Matlab data plotting platform was developed. Foronline matching of ion cyclotron resonance heating (ICRH) antenna impedance, a device called fast ferrite tuner was procured and put to testing. The works related to various RF Generators progressed well. Transmission line and automatic matching system of SST-1 were undergoing testing for cooling, pressurization and also for high power. The lower hybrid current drive (LHCD) System upgradation made progress. Waveguide assemblies were made for the high power water load. Dimensional tests, pressure tests and RF characterization continued. The procurement of the drive source was in progress. A collaborative work with CEA, Cadarache, France for high power LHCD experiments continued. For Electron Cyclotron Resonance Heating (ECRH) system, high power test of carbon vapour deposit diamond window was carried out. In order to operate the Gyrotron in pulsed condition, the work on a regulated high voltage power supply was initiated by commissioning with a 10-Joule wire test.

In the Large Volume Plasma Device, the experimental investigations were mainly focused towards pursuance of (i) realizing a control on electron temperature gradient in the plasma produced, (ii) characterization of the plasma produced, (iii) exploring high beta electron temperature gradient turbulence, (iv) excitation of double layer near filter region and study of turbulence in the region and

finally (vV) turbulence study in the Scrape-of-Layer of plasma produced with narrow source in the presence of a large floating circular ring limiter. Flow and fluctuation measurements in a simple magnetized current-less toroidal plasma were conducted in Basic Experiments in Toroidal Assembly (BETA) machine.

Improvisation of the plasma system and parameter optimization were pursued in the experimental system SYMPLE (SYstem for Microwave-PLasma Experiments). Major modifications on the plasma system included fabrication and installation of a pulse forming network in order to enhance the plasma pulse width to 100 micro sec and thus the axial extent of the plasma to about 1.5m. The initial phase of development of the VIRCATOR based HPM source was completed. A mini surface characterization facility was readied.

In the Plasma Wakefield Accelerator Experiment, the works pursued included (i) Running-in of excimer laser to stabilize output energy; (ii) Charging the heat pipe oven with Lithium and initiate study of neutral Li density using white-light absorption; (iii) Initiate generation of photo-ionized Lithium plasma; (iv) Design upgrade for the plasma chamber to incorporate more detailed temperature sensing, gas feed as well as optical ports for interferometric measurements.

For the Cesium plasma in a multi-cusp magnetic field experiment procurement of requisite equipment continued. The integration of the complete systems will start shortly. A few experiments were conducted in flowing plasma experimental setup.

Under the Eleventh Five Year Plan, development of various fusion related technologies were initiated. For the divertor technology development, tender document for fabrication of Divertor Cassette Body of ITER-like tokamak was prepared. Mechanical characterization and micro-structural studies of the joints made progress. The test mock-ups, developed by the National Aeronautical Laboratory (Bangalore) were subjected to high heat flux tests using EB-60 electron beam at Plasma Materials Test Facility at Sandia National Laboratories (USA).

Tungsten alloys and functionally graded materials using powder metallurgical processes were under development at the IIT-Kanpur. In Fusion Relevant Magnet Development, metallurgical characterization of the heat treated, indigenously developed strands of Nb_3Sn of 0.6 mm diameter was completed. In parallel, the cable-in-conduit-conductor fabrication line in a compact manner with the take-off spool was realized. MgB_2 strands capable of carrying a J_c in excess of 10^5 A cm^{-2} up to a length of 40 cm, was achieved on laboratory scale with additional doping and by self heating techniques.

A laboratory scale vacuum pressure impregnation facility was established at IPR, which is capable of impregnating laboratory size magnets up to 700 mm height and 500 mm diameter. In the Cryosorption Cryopump programme, for cryosorption pumps, a self-supporting, flexible adsorbent media such as activated carbon fabric was developed and characterized for adsorption of nitrogen at 77K. Work related to design analysis of Cryopump and welding analysis of a vacuum vessel sector were launched. For the development of megative ion source and technology, the experiments in ROBIN / BATMAN were continued with a refined Cesium oven design. The experiment shall be further advanced to carry out measurements using a multi-nozzle based distributor, to assess the feasibility of deploying a single oven for large area source. A mass flow controller based gas feed system was assembled and tested. The system became ready for integrated operation for the next experimental campaign on the plasma source. For the ROBIN experiment, fabrication of remaining parts of the accelerator was completed in the works of PVA-Tepla.

The completion of second phase of RF plasma experiments with the modified layout of matching network, MFC based gas feed system and acquisition software and commissioned CWS will be done. Design of Twin source will be completed for procurement.

For the Test Blanket Module (TBM) to be tested in ITER, IPR is collaborating with other DAE units (BARC and IGCAR) and is actively involved in the design and development of the TBMs. Indian team is developing Lead-Lithium cooled Ceramic Breeder (LLCB) (half-port size) which has the characteristics of both solid breeder and liquid breeder blanket concepts.

Thermo-fluid MHD studies using a 2-D MHD code was developed for rectangular straight channel and was successfully validated with the available analytical results. An MoU was signed between IPR and Institute of Physics, University of Latvia, to jointly carry out MHD and corrosion experiments with hot Pb-Li (~350 ^{o}C) as the working fluid.

In the Theoretical and Computational Plasma Physics front, numerical simulations of generalized electron magnetohydrodynamic (G-EMHD) equations and generalized hydrodynamics equations were continued with many interesting problems.

Works related to non-linear problems like lower hybrid oscillations in a cold plasma, Buneman instability using Lagrange variables, excitation of Nonlinear Wake-fields by an intense ultra-relativistic positron beam are leading to very exciting results. Vacuum acceleration of a charged particle was studied in 1D in the field of a relativistically intense short duration laser pulse and Multistage acceleration of ions by ultra-relativistic laser pulses incident on a solid target was studied using PIC simulations. Detailed electromagnetic particle-in-cell (EMPIC) simulations reproduced the experimental results from TIFR group in which biological targets were impinged by intense femto-second lasers.

Efforts included understanding of binary collision in the electromagnetic particle-in-cell code, which is at present collision-less. One-dimensional hydrodynamic simulation of a Hall thruster plasma in steady state was studied. Works relating to molecular dynamic simulations and Gyro-kinetic Simulations were also continued.

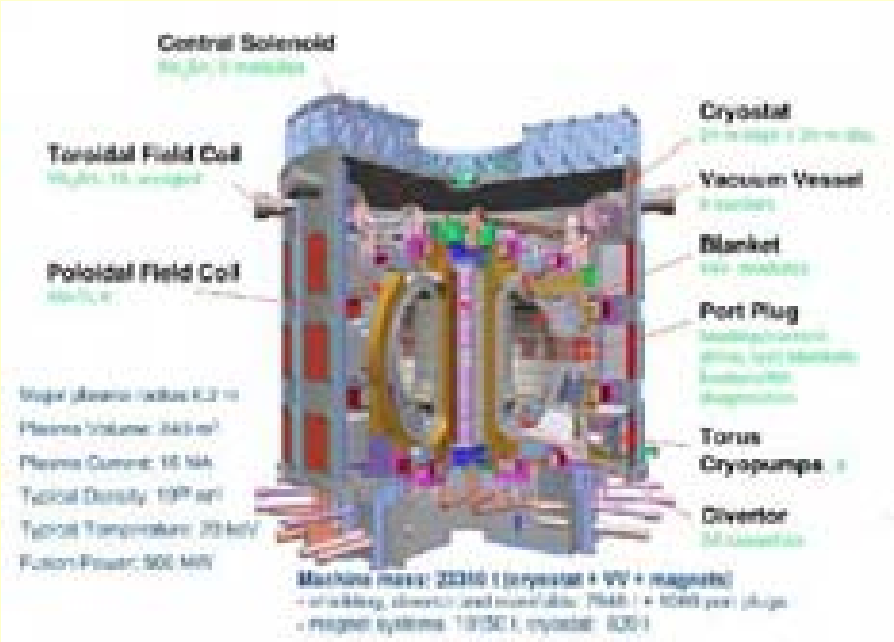
In collaboration with Princeton Plasma Physics Lab (PPPL), the role of ion temperature gradient driven turbulence in redistributing the hot ions in a fusion grade plasma confined in a tokamak was studied. Also the nature of transport of hot ions was studied in the presence of micro-turbulence generated by the pressure gradients of the trapped electrons in a tokamak using the Lagrangian stochastic model.

International Thermonuclear Experimental Reactor (ITER)

During the report period, IPR pursued the activities related to the International Thermonuclear Experimental Reactor (ITER).

Development of 180 kW, 1 MHz RF Generator for negative ion source for ITER-DNB Project progressed well. Conceptual design and calculations were completed.

For the 200 kW, 42.5 GHz DST



International Thermonuclear Experimental Reactor (ITER)

A 3-channel specimen of first wall of ITER TBM with a single bend fabricated through drilling and bending route

Gyrotron Project, the main responsibility of IPR includes the fabrication of all the magnets, thermal design of the gyrotron tube, components of the transmission line from gyrotron up to dummy load, required power supplies, as well as the development of a test set up.

For fulfilling the commitment of India to ITER project, 5 more Procurement Arrangements were signed and pre-procurement activities for the remaining ITER packages continued. Preparation of documents (technical, contractual, schedule, interfaces, SRDs etc.) related to Procurement Arrangement for the remaining procurement packages was in progress. First interim review of preliminary design was held and the comments were incorporated in the design basis documents. Various Design Change Requests (DCRs)/Project Change Requests (PCRs) were studied and comments were submitted to the ITER Organization. Construction of Laboratory building for ITER-INDIA approached completion and building utilities were in the process of procurement. Other works related to the infrastructure development continued.

BARC in collaboration with IPR, has been contributing to ITER Project. For the fusion neutronic design of the ITER\, computations and assessment was completed for heat generation rate in various components/systems of ITER, helium production rate in stainless steel, atom damage rate of the components and the radiation dose rate in various accessible areas.

At Trombay, a smaller sized specimen with less channels than the actual first wall of the ITER Test Blanket Module (TBM) was fabricated.

Studies were initiated on laser welding of ASTM A387 Grade 91 steel in large thicknesses required for use as a potential technique for the manufacture of the ITER test blanket module using an 8 kW CO_2 laser.

To determine a suitable post-weld heat treatment method, the laser weld joints were characterized.

Material Science

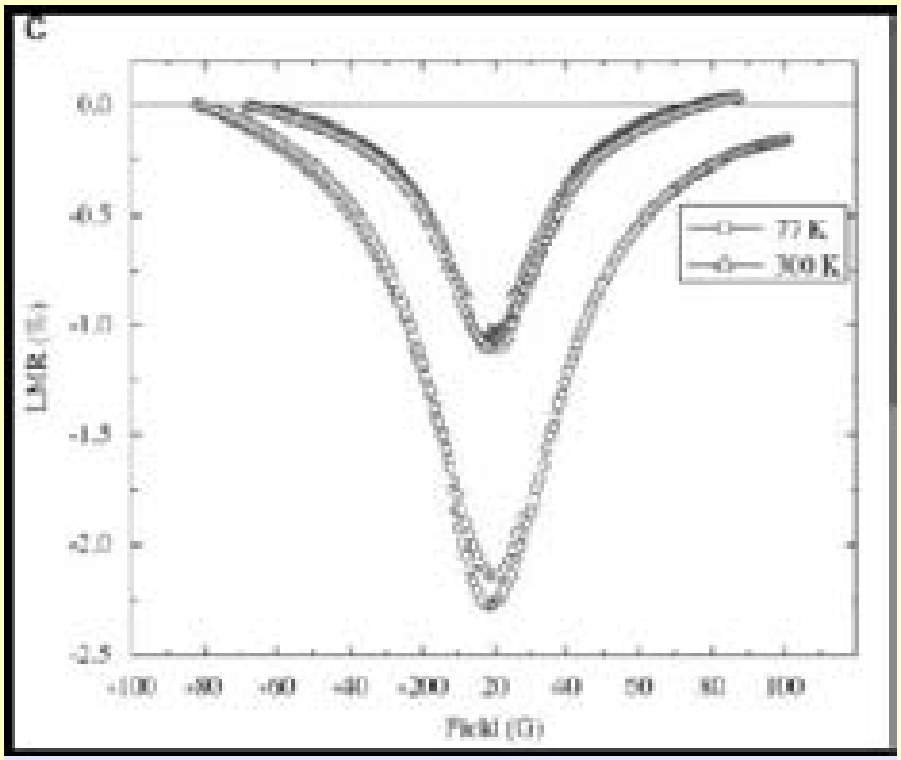
Binary structures of Au-Ni nano-wires were theoretically investigated at BARC for phase diagram and magnetic properties. Nano-structure phase diagram was simulated and magnetic properties of Au and Ni in the system are estimated. Nano structures of Au are found to be ferromagnetic as confirmed by experiments.

A new molecule DHTT was synthesized and DHTT monolayer exhibited a pronounced negative differential resistance in the currentvoltage characteristics.

$Ni_{83}Fe_{17}$ thin films are useful in magnetic sensor applications provided their magnetic properties are reversible as a function of field. Sputter-deposited $Ni_{83}Fe_{17}$ thin films prepared with very low oxygen partial pressure exhibited this property.

Ferromagnetic shape memory alloys based on Ni-Mn-Sn system are known to exhibit Inverse Magnetocaloric Effect in certain range of Sn-concentrations. Two different compositions namely, $Ni_{50}Mn_{37.5}Sn_{12.5}$ and $Ni_{50}Mn_{37}Sn_{13}$ were investigated.

The high-temperature DSC (differential scanning colorimetry) plots depict the incongruent melting nature of



Behavior of $Ni_{83}Fe_{17}$ Thin Film

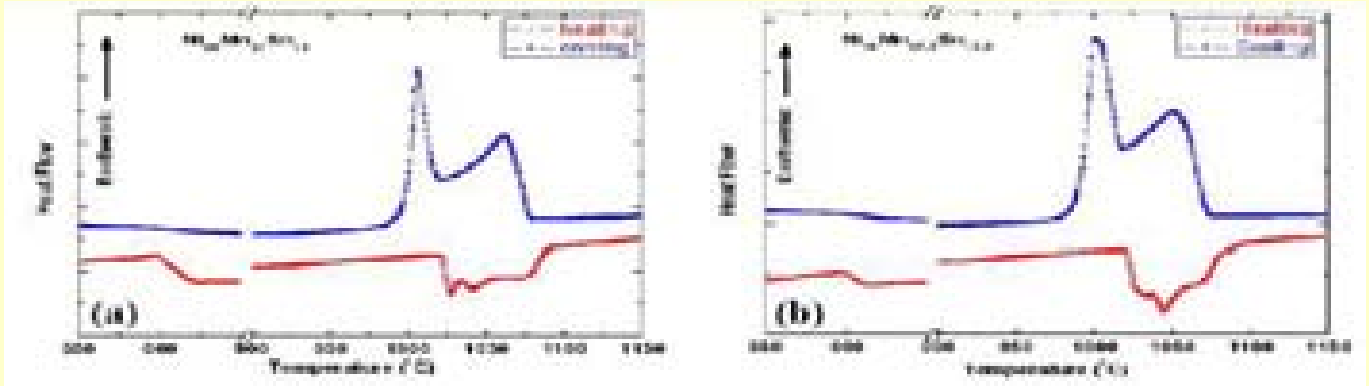
these two compositions.

These samples were subsequently solutionized at 1000 °C for 24 h and characterized by optical microscopy, X-ray diffraction and low-temperature differential scanning colorimetry.

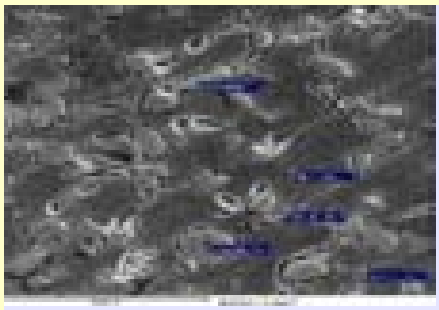
Hollow cylinders made by cold isostatic pressing of intimate mixtures of Y-123, 25wt%, Y-211 and 5.0 wt % Ag, were subjected to top seeded melt textured growth (TSMG) technique using MgO as the seed crystal for preferred texture orientation. The Y-211 phase was prepared by two routes namely, solid state as well as nitrate decomposition. The critical current density (J_c) was measured to be 838 A.sqcm for samples containing Y-211 from solid state route and 4032 A.sqcm for Y-211 from nitrate decomposition route. The five-fold increase in current density was due mainly to the finer size of the Y-211 phase obtained by the nitrate decomposition route.

New compositions with La_2O_3 additives in Ba- Zn/Sr-silicate system and Ba-Ca-AlB-silicate P_2O_5/Cr_2O_3 were optimized for high temperature sealant and seals were made. The integrity of seals under high temperature conditions was confirmed by microstructural studies and leak testing at 800 °C on an in-house designed and fabricated leak testing setup. Biocompatibility and antibacterial behaviour of iron doped calcium phospho-silicate glass-ceramics were also studied at BARC.

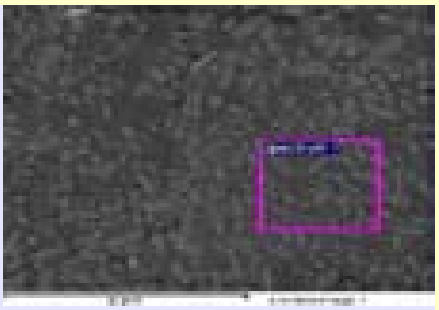
Submicron or nano-size powder of beta silicon carbide and alumina were evaluated for their dispersion characteristics in water using zeta-potential and rheological studies. Glass based



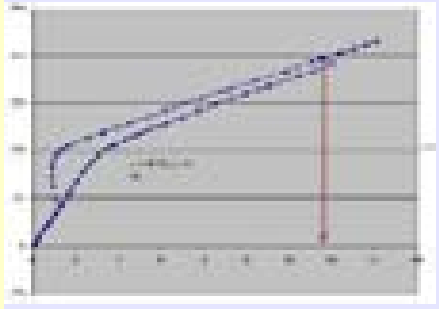
High-temperature DSC plots showing incongruent melting of (a) $Ni_{50}Mn_{37}Sn_{13}$ and (b) $Ni_{50}Mn_{37.5}Sn_{12.5}$ samples

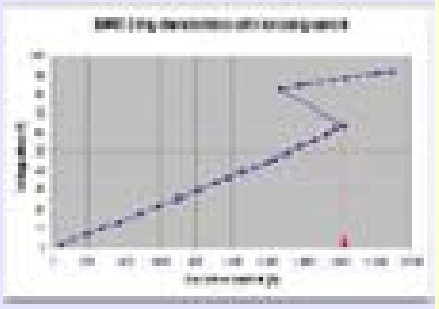


Y-211 by Solid State Route



Y-211 by Nitrate Decomposition Route





SEM images and Critical current density (Jc) plots of HT Superconducting Rings prepared by TSMG: Effect of Y-211 particle size

devices such as ionization vacuum gauge (BA Type) and various types of glass-to-metal and ceramic-to-metal seals were also produced as per users' requirements.

Plastic deformation of the materials is affected by the thermal aging or aging due to radiation. Mobile dislocations are responsible for the plastic deformation of materials. The defects (such as voids / loops / helium bubbles / precipitates) produced under irradiation conditions act as the barriers for mobile dislocations motion. Molecular dynamics simulations were used to study the effect of presence of 10% Cr and 1% He in pure iron on dislocation mobility. Analysis was further extended to address interaction of dislocation with irradiation induced voids and helium bubble.

A 3-D discrete dislocation dynamics simulations were carried out at IGCAR to investigate the plastic behaviour of model ODS system of Fe matrix containing 20 nm ytrria particles and irradiation induced loops.

Transition metal nitrides are technologically important materials having very high hardness in thin film forms. Metallic nitride films can be employed for tribological applications. However, in such applications their highly limited ductility is usually a problem. This can be overcome by adding a ductile metallic nano-crystalline second phase to form a nano-composite thin film. These composite thin films were synthesized at IGCAR.

The role of clustering of nanoparticles (aggregation) on thermal conductivity and rheology of nanofluids was studied from the time dependant thermal conductivity, average particle size, microstructure and viscosity of a 'stable' (non-aggregating) and an 'unstable' (aggregating) nanofluid. These results confirm the prominent role of agglomeration on thermal properties of nano-fluids and the importance of surface functionalization of nano-particles for improved stability.

Nonlinear ultrasonic technique was developed for non-destructive characterization of microstructural changes, mechanical properties and degradation in various structural steels. Nonlinear ultrasonic parameter determined from the second harmonic amplitude is found to have a good correlation with hardness of heat treated medium carbon steels, tensile and yield strength of cold worked AISI type 304 stainless steel and ageing degradation of heat treated M250 grade maraging steel.

At TIFR, a detailed study conducted related to the mechanism and application of metallic nanorod arrays to (i) the enhanced production of pulsed x-rays on exciting with a high energy laser beam, and (ii) electron emission at low turn-on fields.

Amino acid based ionic liquids were synthesized. In addition these were used for formation of

High temperature leak testing (upto 800°C) setup developed in-house

metal nanoparticles. The potential catalytic behavior of the ensuing metal NPs was studied.

A magneto-optical Kerr rotation spectroscopy setup was established and studies were made on epitaxial MnAs films. Integrated blue LED-visible blind organic photodetector. Transport measurements were made on doped organic semiconductors.

MOVPE growth and characterization of non-polar AlGaN and AlInN epitaxial layers was carried out. VLS growth of core-shell InAs/InP nanowire structures was also achieved.

Strategies were designed for the synthesis of Mn^{2+}-sensors, which can be used for in vivo Manganese imaging. Preliminary manganese toxicity studies in zebrafish embryos, to be used as animal models for in vivo Manganese imaging and identified possible manganese toxicity phenotypes, were completed.

INTERDISCIPLINARY AREAS

At Trombay, a supercritical test facility set up earlier to investigate heat transfer, pressure drop and stability behaviour of supercritical fluids, was modified for operation with Supercritical Water up to 250 bars and 400 ^{o}C.

Critical Heat Flux is an important design parameter for a boiling water reactor in which it is caused by the depletion of liquid film on the fuel. A computer code, FIDOM (FIlm DryOut Modeling) solves the conservation equations of mass and energy for the three fluid steam namely, liquid flim, entrained droplet and a central vapor core. Appropriate models for the entrainment and deposition of droplets relevant to BWR conditions were employed in FIDOM. The results indicated the appropriateness of these models under the BWR conditions.

At TIFR, a robust scheme was implemented for generation of intense laser pulses of 5 femtosecond duration, corresponding to two optical cycles. Such pulses were successfully utilized to study, for the first time, ultrafast dynamics of molecules and clusters in the strong field regime.

Researchers of TIFR-Bangalore centre characterized the voltage-dependence and pharmacological sensitivity of H+ transport across the Drosophila midgut epithelium. The hydraulic conductivity of the bovine retinal pigment epithelium and the demonstrated ion channel functions of some new synthetic antibiotic peptides were determined.

Beamlines in both the Linac user halls at TIFR were completed. The upgradation of the cryogenic system for the Pelletron Linac was underway. The low beta Nb cavity design was in progress.

For the Neutrinoless Double Beta decay Experiment at TIFR, the old He_3-H_4 dilution refrigerator was refurbished and a base temperature of 50mK was achieved.

A 3-m scale advanced optical interferometer as a Gravitational wave prototype detector and precision measurement platform was initiated. A method was devised to use such interferometers for better measurements of short-range gravity and the Casimir force.

Augmented Supercritical Water Loop

For the India based Neutrino Observatory, Large area Resistive Plate Chambers (RPC) was developed by TIFR. The Institute was in the process of transferring the knowhow to industry for developing various tools required for assembly line production of RPCs. An ASIC based 8 in 1 fast amplifier discriminator chip was fabricated. The Tamil Nadu Government identified lands for the INO Centre at Madurai as well as for the surface facilities at the INO underground site in Theni District of Tamil Nadu.

INTERNATIONAL RESEARCH COLLABORATIONS

A prototype solid state long pulse bouncer modulator was successfully designed, developed, tested and shipped to CERN by RRCAT under the Novel Accelerator Technology (NAT), Project under the DAE-CERN Collaboration.

Two 1.3 GHz prototype SCRF niobium cavities developed earlier were processed and successfully tested recently at Fermi National Accelerator Laboratory, USA under the DAE-Fermilab collaboration. A high value of 23MV/m was obtained for the acceleration gradient during these tests.

Vertical test stand

DAE (RRCAT) and Fermi National Accelerator Lab jointly designed a vertical test stand

performance of SCRF cryostat for evaluation cavities.

Under a collaborative programme between RRCAT and Fermilab, USA, development of cavity forming tooling for 650 MHz superconducting RF cavity was started. The first trial tooling was designed and manufactured at RRCAT. These cavities are required for accelerating medium energy protons for a high intensity proton accelerator application.

Superconducting cavities RF Niobium cavity under test

Vertical Test Stand Cryostat for performance evaluation of SCRF cavities at 2 K

India is participating and collaborating in the proposed Facility for Antiproton and Ion Research (FAIR) in Germany which, needs over 1400 magnet power supplies of various types. Preliminary design studies and simulations were carried out for these prototypes and were communicated to ECIL, Hyderabad for fabrication.

Under CEADAE collaboration scheme, IGCAR participated in the JANNUS facility for radiation damage studies, Joint seminars on the topics related to fast reactor safety and revision of French code RCC-MR. IGCAR also

participated in the IAEA-Technical Working Group on Fast Reactors annual meeting, technical meetings and coordinated research programmes. A sodium loop for irradiation tests of multiple specimens was designed for use in JHR.

The year 2010 brought a new era in the scientific world with the commissioning and successful year-long operation of the the Large Hadron Collider (LHC) built at CERN in Geneva (Switzerland). India played a major role in the construction of the accelerator and Indian scientists have made contributions to two of the large experimental systems named ALICE (A Large Ion Collider Experiment) and CMS in terms of detector hardware, electronics processing chips and data processing and analysis software.

ALICE is one of the four major experimental setup at the LHC and is dedicated to search for a novel state of matter, called quark gluon plasma that existed in the micro-second old universe according to the Big Bang model of Cosmology. The experiment has several subsystems, one of which is the photon multiplicity detector (PMD) built by Indian scientists under the leadership of VECC. It consists of a large array of tiny gas proportional counters whose signals are processed by Indian-built electronics chip.

The detector records signature of high energy photons and charged particles produced in the collision of nuclei and the data on the spatial distribution of these particles, after suitable reconstruction and analysis, is expected to reveal information about the nature of matter, which is produced for a very short time $\sim 10^{-23}$ sec. The ALICE experiment is expected to produce several peta-bytes of data each year. These are to be processed in several passes and the analysis will be done by the members of the collaboration to extract physics. Computing requirements for such processing being huge,

GRID computing (distributed computing over the internet) scheme was adopted to meet the demand of computing power and storage. The scheme is based on a hierarchical Tier scheme, with Tier-0 being at CERN providing storage for raw data and processing for early passes, six Tier-1 facilities set up at major computing centres and further down a number of Tier-2 facilities at many collaborating institutions around the world. At VECC, a Tier-2 facility, using latest computing hardware and software, was set up with a pledge to contribute about 3% of the computing resources required by the ALICE experiment. The presently installed system represents 40% of the pledged resources as per the plan till this year.

The system was running smoothly with availability and reliability figures in excess of 90% for the past couple of years. The facility is being used by all the scientists working for the ALICE experiment.

TIFR is setting up the International Centre for Theoretical Sciences (ICTS). The Government of Karnataka allotted 17.35 acres of land to TIFR to set up the ICTS permanent campus. DCSEM took up the co-ordination of the ICTS campus project at Bangalore.

In the Belle Experiment, Precision measurements of four B-meson decay modes were carried out by TIFR team, that demonstrated signal on both p-type and n-type strips (on opposite planes) of Double Sided Silicon Strip Detector developed in-house.

The Large Hadron Collider (LHC) at Geneva, started having proton-proton collision and the beam energy was consistently increasing. The current highest center-of-mass energy being 7 TeV. TIFR researcher continued taking data and carrying out physics analysis from CMS Experiment.

Saha Institute played a key role in ALICE Collaboration at Large Hadron Collider, CERN. The Institute is responsible for the run coordination of the Muon Spectrometer of ALICE. On the theoretical side, the photon spectra in anisotropic quark-gluon-plasma were calculated and

compared with the experimental data measured at RHIC, BNL. Work was also initiated on the search for WIMPs as cold dark matter candidates and superheated drop detector developed for radiation detection and dosimetry as part of PICASSO experiment stationed at the SNOLAB, Canada.

NISER became part of the Compact Muon Solenoid (CMS) experiment of CERN collaboration in May 2010, and worked on the data analysis from the CMS experiment at LHC, CERN. NISER remained involved in R&D in micropattern gaseous detectors which is a joint endevour by various international institutions.

CHAPTER : 6

RESEARCH EDUCATION LINKAGES

Headquarters of the Department of Atomic Energy at Mumbai

CHAPTER : 6

RESEARCH EDUCATION LINKAGES

HUMAN RESOURCE DEVELOPMENT AND KNOWLEDGE MANAGEMENT

Homi Bhabha National Institute

The Homi Bhabha National Institute (HBNI), that has now completed 5 years of its existence, remained engaged with its regular academic programmes.

During the report period, the Degrees and Diplomas (totaling 103) were awarded and a total of 328 results were declared. More than 120 Officers from DAE completed their MTech programme requirements. In the PhD programme of HBNI, 57 students completed all the programme requirements and were issued degrees/provisional certificates.

This number is expected to grow significantly every year with further additions from across engineering, and sciences disciplines.

The number of enrolments swelled to nearly 3000 since 2006, with PhD enrolment number alone being an impressive 1172. The enrolment number under the Post-Graduate Medical Programmes was also over 100.

An exhaustive review of the functioning of HBNI was conducted by the UGC Committee. Expressing its overall satisfaction on the functioning of HBNI in its report, the Committee particularly appreciated the unique research oriented nature of HBNI. While commending the large number of publications with good citations in International journals in basic sciences, it endorsed the research related to technological aspects as being of high quality. The Committee also appreciated the joint involvement of students and staff scientists in carrying out the research projects.

Training Schools

The recruitment and placement through the Training Schools is carried out under two schemes viz. Orientation Course for Engineering Graduates & Science Post-Graduates (OCES) and DAE Graduate Fellowship Scheme (DGFS). The task of advertising for the two schemes, inviting applications, conducting the written test for the science disciplines for screening purposes and conducting the interviews for the screened candidates were carried out. Meanwhile, the ongoing OCES/DGFS-2009 courses were completed and the placement of 137 Trainee Scientific Officers (TSOs) of OCES-2009 was completed.

The selections for admission to the PhD programme of BARC under the aegis of Homi Bhabha National Institute (HBNI) were conducted. Selection of candidates with Master's Degree in Science / Bachelor's Degree in Engineering was carried along with that for the OCES/DGFS selection process. A separate selection process was carried for admission to PhD programme on the basis of Master's degree in engineering.

The practical training (1 to 2 months) and project work (2 to 12 months) of BE/ BTech/ MTech/ Engg Diploma/ MSc/ MCA students from different universities were arranged. About 800 students from all over India had undergone practical training / project work in various Divisions of BARC during the year 2010.

Under the Continued Education Programme (CEP), advanced lecture courses were conducted for the benefit of the DAE employees. Seven courses were conducted during the year which was attended by 60 employees.

The One year post-M.Sc. Diploma in Radiological Physics course, affiliated to Homi Bhabha National Institute (Deemed University), was continued. Radiation Safety Officer (RSO) certification courses were conducted in the field of Medical Physics and Nuclear medicine. Sixty M.Sc. students from eight universities participated in Medical Physics discipline and 61 students participated in Nuclear medicine discipline. Four short term training courses were conducted on “Radiation Safety

Aspects in Nucleonic Gauges" and 2 training courses in "Radiation Safety Aspects in Research Applications of Ionizing Radiation" was conducted in collaboration with Indian Association for Radiation Protection. 10 short term training courses on "Radiography Testing Level 1 (RT-1) was conducted at Trichy (1), Pune (5), Mumbai (5) and New Delhi (1). Two training programs for Defence personnel was conducted at INS, Shivaji, Lonavala.

In order to comply with the requirement of licensing/authorization for operation of the variety of radiation installations in BARC, the BARC Safety Council Secretariat (BSCS) prepared and got approved a regulatory guidelines, which specify the requirements to be fulfilled for reauthorization of existing old facilities of BARC as well as it addresses the requirements for new radiation installations in BARC.

At IGCAR, Kalpakkam, the fourth batch of 48 trainee scientific officers, completed their training in six disciplines and were placed in various units of DAE. At the Training School, in the present academic year, 37 trainee scientific officers have been undergoing training. About 41 Research Scholars, inducted to pursue their doctoral programmes in the frontier areas of engineering and basic sciences under the aegis of HBNI, have also been undergoing coursework at the Training School. 26 employees pursuing their higher qualification are also undergoing coursework at the Training School.

A new facility - BARC Training School, AMD Campus, Hyderabad started in September, 2010. For Geology and Geophysics Trainee Scientific Officers, AMD studentship programme was continued, in which 34 M.Sc./M.Tech. students of different Universities completed their project work.

During the report period, NPCIL organized a number of training programmes encompassing 'Honing the Managerial Skills', 'Human Resource Management for Line Managers', 'Internal Auditors Certification Course on ISO-9001:2008", Awareness on Nuclear Security etc.

NPCIL conceptualized, designed, developed, deployed, implemented, managed and maintained 'web application' (fully in-house) for 'DAE Training Schools Selection Process (OCES/DGFS-2010 batch)'. The developed website was in public domain for around eight months and touched more than two million hits. The activity resulted in empanelment of 402 engineers and science post-graduates for various units of DAE including 122 Engineers and 18 Civil Engineers (to be trained at BARC training school, Mumbai) for NPCIL.

The Corporation also developed an online process for selection of experienced engineers for NPCIL. The activity resulted in the empanelment of 106 experienced engineering graduates/post graduates/PhDs.

After ensuring successful completion of one-year orientation training programme, final placement of engineers from OCES-2009 batch consisting of 94 from NPCIL NTCs, 7 engineers/scientific officers and 10 civil engineers from BARC Training School and 2 from IGCAR Training School was organized. This year 80 fresh NPCIL engineers were inducted through OCES 2010. Also one year orientation training of 30 fresh NTPC engineers 2 IOCL engineers along with fresh NPCIL engineers was undertaken.

Around 34,360 man-hours (around 859 man-weeks) of training were imparted with the faculty from NPCIL and outside Institutions. Training program includes 'Honing the Managerial Skills', 'Human Resource Management for Line Managers', 'Internal Auditors Certification Course on ISO-9001:2008', Awareness on Nuclear Security etc.

To meet the increasing demand of "Construction of NPPs" a "Qualification Programme for Construction" covering the administrative norms, subjects was developed. The training in "Construction Engineering" was completed at KAPS 3&4 and RAPP 7&8 to the experienced engineers working in construction.

During the report period, the members of the Mathematics group of HRI visited many

Institutes/Universities within India and abroad to attend conferences for giving invited talks and for collaborative research.

The Institute of Physics has been contributing in a significant way towards quality human resource development in the form of a one year pre-doctoral course followed by a Ph.D. programmme. By now, more than fifty students who have done their Ph.D. at the Institute, are occupying faculty positions in almost all the leading research centers, IITs, Central and State Universities in the country. Further, a good number of post-doctoral fellows have been attracted towards the research programs of the Institute. This year eight doctoral scholars received their Ph.D. degrees, while six scholars joined the pre-doctoral program.

The Institute actively promoted interactions with colleges, universities, academic institutions and laboratories by means of visitor programs, workshops, symposia and other academic events. The International Programme on Quantum Information was held at the Institute.

Since 2006, the Institute is involved in setting up of National Institute of Science Education and Research (NISER) and nurturing it in earlier years. Presently, NISER is operating from the Institute campus and sharing its resources.

At TMC, the intake capacities of M.Ch (Surgical Oncology) and DM (Medical Oncology) were increased to 16 and 10, respectively. The seats for MD (Anaesthesia, Pathology, Radiotherapy) were also increased. A total of 58 postgraduate students were registered during the year 2010.

A total of 58 new students were registered for various medical postgraduate courses. Various short-term and long-term training programmes were conducted for doctors, nurses and technicians, on continuing basis. In addition, short term observership and summer training was provided to 346 doctors, nurses, technicians and B.Sc/M.Sc. students. There were 143 international/national publications in indexed peer reviewed journals.

At ACTREC the Radiation Biology Lab was expanded and a clinical training programme in radiation biology was initiated for M.D. and M.Sc. students.

83 students are presently enrolled for the Ph.D. degree at the ACTREC. Besides these, five students were awarded the Ph.D. degree in 2010. ACTREC also provided short term / summer training to 161 M.Sc.students of the University of Mumbai as well as other universities / colleges from across the country.

The National Institute of Science Education and Research (NISER) continued with its activities in the fields of physical, chemical and biological sciences. NISER entered into strategic alliance in the field of scientific research and knowledge exchange programme during the report period, and signed two MoUs with the Institute of Life Sciences, Bhubaneswar and Kanungo Institute of Diabetes

Public Lecture by Prof. Sir. Michael Berry on 12.8.2010

Specialities, Bhubaneswar.

IMS remained engaged in its regular academic programme that includes selection of students at the graduate and postgraduate level each year through a joint entrance screening followed by an interview. These students undergo two years of course-work, followed by a doctoral thesis work for award of Ph.D. degree by the Bhabha National Institute.

For a few students during the summer vacation period, IMSc offers the opportunity of learning. These students spend up to six weeks doing their projects with faculty members. The faculty also supervises short-term projects during other periods.

Under its Visitors' Programme, IMS hosted a number of short and long term visits of scientists from all over the world. The Institute members are also involved in joint projects with colleagues from other national and international institutes.

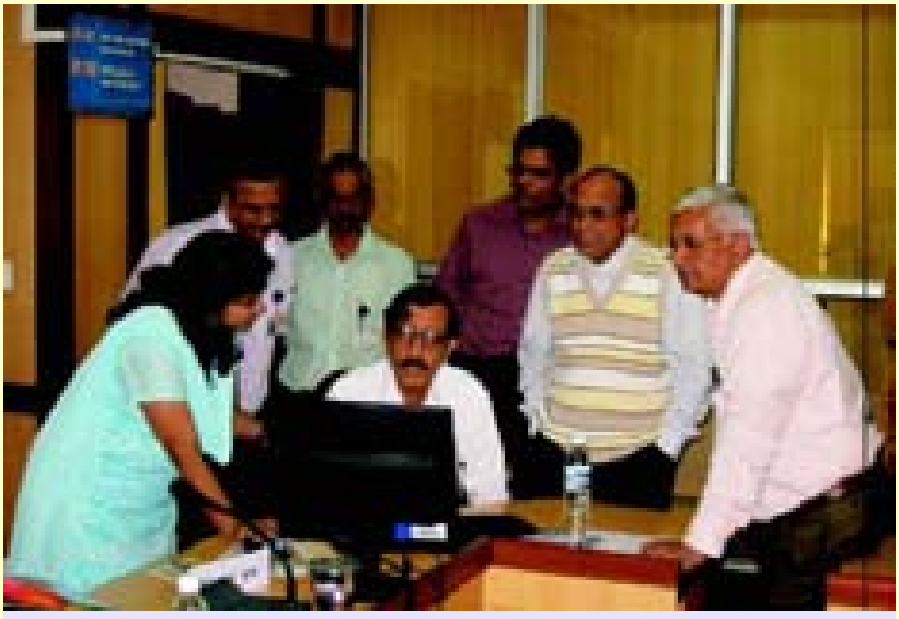
During the report period, the IMS faculty members had an active interaction with the researchers of other universities. This interaction took place via Associateship programme and Refresher Courses for college teachers.

Administrative Training Institute (ATI)

Administrative Training Institute (ATI) works towards the continued professional development of officials from various cadres of DAE. The programmes of ATI cater to a wide spectrum of training and management development programmes covering grass root levels to Unit Heads. These include induction programmes for the newly recruited UDCs, Stenographers, LDCs /Purchase /Stores Clerks etc; Refresher Programmes; Management Development Programmes;Art of Mentoring, Workshop on Communication Skills; Task Specific Areas; Computer applications; Advanced Information Tools Programmes; Preparatory workshop for departmental examinations; Experience Sharing Workshop on Industrial Relations, Official Language, RTI, Workshop on Import and Export Control Regulations, etc. In addition, officers are also sent for Short and Medium Term Management Development Programmes.

This year ATI organised five 1-week duration and one 3-week duration Management Development Programmes. The 3-week programme had a 2-week domestic component at Dr. MCR HRD Institute of AP and one week international component at RIPA International, London. The Institute also organized 74 Training Programmes that included long term stenography course and residential induction training programme for newly recruited Assistant Security Officers.

Most of the programmes are arranged in-house. Around 120 in-house faculty members within DAE have been developed. Wherever required external faculty is also invited. Some of the programmes are conducted with the help of professional



Inauguration of E-Procurement Software of DPS

Study Visit at GMRT, Narayangaon

agencies /State Administrative Training Institutes / premier Management Institutes like IIMs, MDI etc.

ATI uses a variety of methodologies in its training programmes. Apart from the conventional lecture method, highly participative methodologies are used.

SPONSORED RESEARCH

Board of Research in Nuclear Sciences (BRNS)

The Board of Research in Nuclear Science (BRNS) is an advisory body of DAE. Besides funding research projects, BRNS provides financial assistance to organize symposia / conferences / workshops on topics of relevance to the programmes of DAE. BRNS also awards projects to young scientists to initiate them in a career of research and Dr. K. S. Krishnan Research Associateship to identify and encourage highly talented young scientists and technologists. The DAE Graduate Fellowship Scheme (DGFS) is meant for inducting Graduate Level students doing M.Tech. at the IITs. While the Visiting Scientists programme of BRNS is meant for promoting short term in-house interactions amongst senior level experts, the Raja Ramanna Fellowship of BRNS is for reasonably long-term involvement of the eminent scientists and engineers in the various ongoing programmes of the Department. The Homi Bhabha Chair sponsored by BRNS is instituted to avail the honorable services of Scientists and Technologists who have distinguished themselves at national and international levels.

During the year 2010, 105 new research projects were sanctioned and some more R&D projects are likely to be approved shortly. Financial sanctions were also issued for the various on-going research projects. Nine fellowships were offered/awarded under the Raja Ramanna Fellowship Scheme (Senior Scientists Scheme) & Homi Bhabha Chair. Twentyone fellowships were awarded under the K.S. Krishnan Research Associateship Scheme and Twenty Five fellowships were offered/awarded under the DAE

Graduate Fellowship Scheme (15 for M.Tech. & 10 Ph.D.). Financial supports were extended to fully funded BRNS seminars as well as to partly funded seminars conducted by professional organizations on various topics of relevance to DAE, during the year 2010-11. Seventeen DAE-SRC were awarded for to outstanding research investigators by the Science Research Council (SRC) of DAE.

The "Prospective Research Funding (PRF) introduced under the Xlth Plan R&D proposals of the Department, was continued. The proposals funded through PRF facilitate new ideas in research that may accrue during the plan period. PRF will also help to cater to the proposals that may arise for filling critical gap areas of the main programmes of the Department during the course of the Xlth Plan. Processing of proposals and issue of financial sanctions under the PRF progressed. Five new projects were awarded under PRF, besides supporting nine ongoing projects. The proposed revised estimate of Budget for the BRNS activities for the year 2010-11 was RS.72.32 crore.

Promotion of Mathematics

The National Board for Higher Mathematics (NBHM) was established under the aegis of DAE in the year 1983 with the objective of promoting excellence in higher mathematics education and research in the country.

At the initiative of NBHM the prestigious International Congress of Mathematicians (ICM-2010) was held at Hyderabad during August 19-27, 2010. Over a thousand mathematicians from the country, including teachers and research scholars, were provided support for participation in the Congress. Many satellite conferences were also organized.

The Board has been promoting scholarship and proficiency in mathematics at advanced level through various programmes. During the report period, scholarships were awarded to talented students, selected through nationwide competitive tests, to pursue studies at masters and Ph.D. levels. Fellowships were also provided for the teachers at universities to undertake Ph.D. studies. NBHM continued to support a special programme called Mathematics Training and Talent Search (MTTS) at the undergraduate level. Under the programme, expert mathematicians provide supplementary training to the selected students from across the country during the vacation periods. Supplementary training activities were also undertaken for selected students at postgraduate level, in a coordinated fashion, under the Advanced Training in Mathematics (ATM) programme. Workshops were also held for college teachers, to refresh and strengthen their mathematical aptitude.

NBHM has been in charge of selecting the Indian Team to participate in the International Mathematics Olympiad (IMO). This is undertaken through an elaborate Mathematics Olympiad activity, with the help of the Homi Bhabha Centre for Science Education (HBCSE), targeting talented young students at higher secondary (the plus two) level. A team of six students was selected to participate in the 51st International Mathematics Olympiad (IMO-2010), held at Asthana, Kazagistan. The team secured 2 Silver, 1 Bronze Medals and 3 “Honorable Mention”.

A new competition was also started at the undergraduate level, in Pune and Mumbai as a pilot project, called Madhava Mathematical Competition to generate interest in mathematics in early years of college. NBHM is planning to hold this competition in about 30 centres all over the country. Suitable infrastructure, mainly in the form of human resources, would be built up for the purpose.

NBHM provided grants to mathematics libraries around the country for the purchase of the latest books and journals in mathematics. Around 80 such libraries took advantage of this scheme. Currently the support to the libraries was largely for hard copy material. Some support was also being provided for getting electronic access to some of the review journals. The Board plans to take up a comprehensive programme to create such a

facility nationwide. In the financial year, 2010-11, out of total allocated budget of Rs.20 crore, about Rs 5.50 crore were released to institutions as a support to libraries. NBHM also distributed selected books to various postgraduate institutions under its book distribution scheme.

NBHM gives grants to various special mathematical centers in the country, for carrying out their activities. The Chennai Mathematical Institute that runs a high quality undergraduate programme in mathematics has been a regular recipient of grants from NBHM. The Kerala School of Mathematics, Calicut is also being supported as under an MOU signed by DAE. During the review period, a supplementary MOU was signed between Kerala School of Mathematics and DAE to provide financial support for infrastructure development. The Institute of Mathematics and Applications, Bhubaneswar and the Bhaskaracharya Pratishthana, Pune, are two other centres that received substantial grant from NBHM based on various programme proposals. Rs 7.50 crore as a first installment were allocated to various centres mentioned above.

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, and for organizing conferences etc. Various institutions were also provided faculty support in the form of Visiting Professors, to strengthen the research and teaching potential at the institutions.

During the report period, financial support was provided to 44 national and international conferences held in India, and 14 Instructional Schools for advanced training in mathematics. Twelve research projects including ongoing as well as new ones, were funded by NBHM. Travel grants were provided to 56 mathematicians to enable them to participate in conferences held in India and abroad. 6 institutions were provided faculty support in the form of Visiting Professors, to strengthen the research and teaching potential at the institutions. Post Doctor Fellowships were awarded to 30 (including the ongoing ones) researchers for the period of 3 years.

NBHM is actively considering the proposal to create a web-based interactive system for communication, evaluation of proposals. This will help researchers obtain the prompt response from NBHM on their applications for grants.

Olympiad Programme

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

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

Every student representing India bagged a medal in the five science and astronomy Olympiads of the year 2010. The participants bagged 33 medals (14 gold, 15 silver and 4 bronze).

The Homi Bhabha Centre for Science Education produced 2 resource books on Olympiads for teachers and students and organized 11 resource and exposure camps for a large number of school and college teachers.

GRANTS-IN-AID

Grants to Aided Institutions

The aided institutions of the DAE are an integral part of it, in as much as there is a growing synergy between these institutions and the Research and Development Organisations of the Department. Several joint projects are undertaken between the DAE Organisations and Aided Institutions and there is frequent interaction between the academicians of the aided Institutions and scientists of the R&D Organisations. The Department has following nine aided institutions fully funded in terms of their recurring and non-

Sl. No.	Name of the Institutions	Budget Provision BE 2010 – 11 (Rs. in crore)
1.	Tata Institute of Fundamental Research (TIFR), Mumbai	423.50
2.	Tata Memorial Centre (TMC), Mumbai.	225.00
3.	Saha Institute of Nuclear Physics (SINP), Kolkata.	134.85
4.	Institute of Physics (IOP), Bhubaneswar	26.89
5.	Institute of Mathematical Sciences (IMS), Chennai	26.30
6.	Harish-Chandra Research Institute (HRI), Allahabad	23.00
7.	Institute for Plasma Research (IPR), Gandhinagar.	388.04
8.	Atomic Energy Education Society (AEES), Mumbai.	41.51
9.	National Institute of Science Education and Research (NISER), Bhubaneswar.	55.00

Funds (Plan & Non-Plan) allocated to Aided Institutions by DAE during the financial year 2010-2011

recurring expenditure. These institutions are growing at a faster pace in terms of the projects undertaken by them.

The funds (Plan & Non-Plan) allocated to these Aided Institutions by the DAE during the financial year 2010-2011 are as below.

Grants to Cancer Hospitals

DAE has extended the term of Third Tripartite Agreement (which was signed between DAE and the North-Eastern Council (NEC) and the Government of Assam) for another three years from 2009-10 to 2011-12 for the revitalization of the Dr. B. Barooah Cancer Institute (BBCI), Guwahati. This hospital is a Regional Cancer Centre (RCC) for cancer treatment and control in the North-Eastern Region (NER). The Department's total share as per the Tripartite agreement is approximately Rs. 2449.35 lakh for revitalization of the BBCI which includes the cost of construction for expansion of the hospital as well as the procurement of major radiation related equipment during its Revitalization Project-III which has been started during the year 2004-05.

The Department also extends financial assistance to cancer hospitals located in other parts of the country. The budget provision for the year 2010-11 for such partial financial assistance is to the tune of Rs. 18 crore.

An increasing need was also felt to use the expertise available in the DAE funded Tata Memorial Hospital for creating a better network between cancer institutions all over the country. This would include research & development, training and preparation of protocols for treatment as well as incentives for indigenization of much of the radiation related equipment for cancer treatment. For this

purpose, an Apex Committee was formed under the Chairpersonship of Director, TMC. The Apex Committee has met 18 times so far 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, and Brachytherapy etc.

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

CHAPTER : 7

TECHNOLOGY TRANSFER AND COLLABORATIVE PROGRAMMES

Study of fracture behaviour of pipe-elbow under different loading configurations by BARC at SERC, Chennai

CHAPTER : 7

TECHNOLOGY TRANSFER AND COLLABORATIVE PROGRAMMES

At DAE's research and development organizations, spin-off technologies are developed and transferred to public domain for further commercial proliferation.

TECHNOLOGY TRANSFER

Following technologies from BARC were transferred to industries :

Membrane Assisted Defluoridation process for safe drinking water

Domestic water purification device based on photocatalysis using solar light

Arsenic removal from drinking water ultrafiltration membrane assisted process

Backwashable Spiral Ultrafiltration Technology for Domestic & Industrial Water Purification

Domestic Water Purifier based on ultrafiltration polysulfone membrane

Preparation of Composite Polyamide Reverse Osmosis (RO) Membrane for Brackish Water Desalination (BWRO)

Non-Invasive Blood Pressure Module (Add-on)

Kitchen Waste Based Bio Gas Plant

UF Membrane Assisted Device for removal of Iron from contaminated water for drinking purposes

Licenses for the following technologies were renewed for a period of five years with different firms :

On-line domestic water purifier based on ultrafiltration polysulfone membrane

Non Invasive Blood Pressure Module & Oximeter Module

Dust respirators & Air-line respirators

The following technologies were in the process for transfer.

Quadropole Mass Spectrometer by VPID

8K USB-MCA technology (upgradation) by ED

Hand-held Tele-ECG instrument for rural healthcare.

The Agreement for Personnel Monitoring Services (PMS) of radiation workers using TLD badges, was renewed by BARC with M/s. Renentech Laboratories Pvt. Ltd., Mumbai.

A technology was developed at IGCAR using strong base fine resin (75-150 µm particle size) with the equilibration time to 12 months to get 65% of Boron-10. Both the technologies were transferred to Heavy Water Board for operation at Manuguru.

A Remote Terminal Unit (RTU) acquires signals inputs and sends digitized data packets over ethernet to the nearest local control centre. To cater various PFBR applications, seven different types of RTUs were designed & developed at IGCAR. The design technology of these Remote Terminal Units along with PCB fabrication details and supporting documents, were transferred by IGCAR to ECIL for bulk production.

As part of the technology transfer of the compact high average power Nitrogen Laser to a party in Pune, RRCAT helped to build a production version of the laser. This laser system will find use for hospitals where it will be used in the treatment of tuberculosis of the lung and the lymph node.

At the IPR's Facilitation Centre for Industrial Plasma Technology (FCIPT), the on-going activities included 40" long plasma based system for higher throughput of treated Angora wool, plasma aluminizing process for Inconel (IN718) alloys, 25 kW plasma torch system and others. Various kinds of material characterization

services were provided to external parties on commercial basis.

COLLABORATIVE PROGRAMMES

NPCIL has planned to augment nuclear power generation in a rapid manner and also to promote, other than nuclear sources, clean sources of energy as far as possible through partnerships and diversification.

In view of above objectives, various steps towards forming Joint Ventures were taken. These included signing of Joint Venture Agreement with Indian Oil Corporation Ltd. and signing of the Joint Venture Agreement between NPCIL and NTPC to incorporate a Joint Venture Company, for setting up nuclear power plants. A Joint Venture between Larson & Toubro (L&T) & NPCIL was also set up to manufacture special steels and large size forgings etc., to establish the supply chain for nuclear power projects.

In respect of other green power initiatives, in accordance with MoU between NPCIL and Tehri Hydroelectric Development Corporation Ltd., the work for Detailed Project Report (DPR) for Malshej Ghat (700 MW) hydroelectric Pump Storage Scheme was completed and a copy of DPR submitted to the Government of Maharashtra for formal clearance & allotment of project, to go ahead with the construction activities.

The collaborative MoUs signed by BARC with various parties included:

"Barge Mounted Sea Water Reverse Osmosis Plant for Production of Drinking Water" with IREL, Mumbai.

"Design & Development of Gigabit Networking Solutions for C&I Applications" with IIT-Bombay.

"Shake Table Tests and Pseudo Static Cyclic Tests on Shear Walls" with SERC, Chennai. "Seismic testing of pressured piping loops" with Centre Power Research Institute, Bangalore. "Technical consultancy for third party evaluation on Desalination and Water Purification" with Municipal Corporation of Greater Mumbai.

Tripartite Agreement between BARC, BRIT and MSAMB, Pune for commercial use of KRUSHAK Irradiator, Lasalgaon. w.e.f. 1-4-2009 till 31-3-2012. Extension of MoU with BHEL Trichi for Machining of Copper Gasket.

Extension of MoU between BARC and IOC-R&D Centre Faridabad on "Development of Process Tomography for Trickle Bed".

Development & Supply of MEMS based Pressure Sensors/Modules and other Modules for DAE application, with BEL Bangalore.

Development of Industrial Technology for production & supply of large sized PUF Blocks suitable for shock and heat shield for transportation packages of radioactive materials, with M/s. Pine Resins & Chemicals, Taloja.

The concept of Master Curve in fracture mechanics envisages a unique characterization of materials in terms of Reference Temperature.

As a part of BARC's collaborative project with Jadavpur University, Kolkata, tests were conducted towards investigation on Master Curve on Charpy, tensile, three point bend and compact tension specimens at temperatures ranging from -150oC to +25oC. The test data generated material J-R curve and associated reference temperature.

To demonstrate the ability of the piping in the nuclear power plants to tolerate defects, many elbows with different crack configurations were tested under combined loading of bending moment and internal pressure. The tests were conducted at SERC, Chennai. Apart from the demonstration of structural integrity, the extensive test data will be useful for studying fracture behaviour of elbow under different loading configurations.

SOCIETAL INITIATIVES

BARC signed AKRUTI Tech Pack Agreements with seven

Chairman, AEC & Secretary, DAE inaugurates AKRUTI-NIRMTEE

Innovation in Domestic Water Purifier (DWP)

AKRUTI activities

parties for deployment of technologies in rural sector.

BARC CENTRE FOR INCUBATION OF TECHNOLOGY

Infrastructure development work to convert old BARC Training school building at Trombay to BARC Centre for Incubation of Technology (BARCIT) was taken up.

INTELLECTUAL PROPERTY RIGHTS (IPR)

Any new technology developed in the R&D organisations, R&D teams of the Public Sector Undertakings and the Industrial organisations or the autonomous Grant-in-Aid institutions of DAE, that are directly relevant to the nuclear science & technology programme of the Department, are not patentable in India as per Section (4) of the Patent Act. Such inventions are filed as foreign patent applications in countries which allow patenting in this subject and also where there is a scope for commercialization of the patent. Those innovations that do not relate to the DAE's atomic energy programme such as the innovations relating to non-power applications of atomic energy and the spin-off technologies, are filed in India and abroad based on the scope for their commercialization.

The DAE-IPR Cell works as a nodal agency for all intellectual property rights related matters, including filing of patents within India and abroad, for all the DAE organisations including the public sector undertakings and the autonomous institutions under the aegis of Department. Besides the innovations resulting from the different organisations of DAE, intellectual properties also result from collaborative research/extramural funding wherein the principal research work is carried out in other universities or institutes. In such cases, the Department encourages the universities/institutes to file single or joint patent application as appropriate, to earn commercial benefits out of the intellectual properties generated. The following three Indian patents filed last year were the outcome of such collaborative research programmes.

1. Functional Clay filled LLDPE Nanocomposite film for modified atmospheric packaging with improved barrier properties for food applications. (BRNS project)

2. Fire Retardant Intumescent High Density Rigid Polyurethane Foam for Specialty Applications (BRNS project)

3. A Finishing Device (research carried out under an MoU with IIT-Kanpur)

The DAE-IPR cell takes care of review of patent proposal, and subsequently filing and prosecution of patent application, submit the mandatory information on the working of granted patents of all the organisations, to the Intellectual Property (IP) India. It also takes care of all post-grant maintenance including renewals and any opposition proceedings. Besides review of the patent proposals, the DAE-IPR cell also extends support to the organisations on developing guidelines for collaborative research programmes/MoUs covering the IP clause of the collaborations, non-disclosure agreements etc. Further, it also provides consultation services to the IPR cells in various organisations of the Department on IP and technology transfer-related matters.

During the calendar year 2010, five regular DAE-IPR cell meetings were held during which nine new inventions and five of the previously filed applications under the Patents Cooperation Treaty (PCT) applications were reviewed for the patentability and national phase entry respectively. Besides the regular meetings, special DAE-IPR cell meetings with the technical experts were also held often, to discuss specific IP-related issues of the Department. During the calendar year 2010, DAE filed 26 patent

applications resulting from both departmental as well as collaborative programmes. This includes 7 in India, 5 in European Union, 4 in USA, 3 in Japan, 1 each in Australia, Canada, South Africa, and Russia and 3 under PCT. During this period, 10 of the previously filed patents were granted to the Department. This included 6 patents granted by the Controller of Patents in India, 2 by the USPTO (US Patent & Trade Mark Office) and 1 each by the Japan and European Union. Some of the representative patents of the Department granted in India and abroad during the calendar year 2010 are:

1. Process for direct somatic embryogenesis from immature inflorescence segments of sugarcane (Indian patent no. 243371)

2. Zn fertilizer formulation and process for producing the same. (Indian patent no. 239929)

3. A P fertilizer formulation and a process of making it. (Indian patent no. 238485)

4. MET/FRET based method of target acid detection whereby the donar/acceptor moieties are on complementary stands. (Japanese patent no. 4457001)

5. Separation of No-carrier-added thallium radionuclides from No-carrier-added lead & mercury radionuclides by dialysis. (US patent no. 7799226)

6. Fluorescence correlation microscope with real time alignment readout. (US patent no. 7705987)

The inventors from various organisations of the Department take initiative towards commercialization of the inventions with the help of the Technology Transfer Cells existing in the respective organisations. The revenue earned by way of licensing was more than the expenditure incurred in filing, prosecution and maintenance of the IPs over the period FY 1998-2008.

During the calendar year 2010, the following technologies of the Department were licensed to different Indian companies.

1. Ammonia Flue Gas Conditioning System based on the patent titled “A method for treating exhaust gas emission produced during combustion of coal in a coal combustion plant for reducing suspended particulate matters” from Heavy Water Board, (Indian patent no. 194122). This patent has earned the highest revenue from licensing so far.

2. Domestic Water Purifier Technology from BARC based on the patent titled “Ultrafiltration Membrane water purification device” from BARC (Indian patent no. 195961).

3. Technology titled A spiral wound dry polyamide element for membrane filtration and a method of making the same from BARC (Indian patent nos. 194106, & 194101 combined).

4. Activated Flux Assisted TIG Welding Technology for Stainless Steel Components technology based on the Indian patent application “A penetration enhancing flux formulation for Tungsten Inert Gas welding of austenitic Stainless steel and its application” from IGCAR (Appl. No.1851 / MUMNP / 2007).

During the year, 24 patent applications were referred to the Department by the IP India, to screen for the applicability of section 20 (1) of Atomic Energy Act, 1962 and give its directions. Directions of the Department were communicated to the Controller of Patents in India.

On behalf of the Department, some members of the DAE-IPR cell participated in the round table discussion on "Government S&T organizations : Emerging IP challenges” held in New Delhi, on April 8, 2010, and gave a talk titled “Working in Consortium: IP due diligence”.

As a part of the IP Awareness Activities, lectures were given to the 53rd batch of the training school (OECS-2009) students covering all aspects of intellectual properties, protection and rights emanating thereof.

CHAPTER : 8

INFRASTRUCTURE

Integrated Facility for Radiation Technology Building at Vashi, Navi Mumbai

CHAPTER : 8

INFRASTRUCTURE

CONSTRUCTION, SERVICES & ESTATE MANAGEMENT

Directorate of Construction, Services & Estate Management (DCSEM) provides infrastructure support to various organisations of DAE including its aided institutions. DCSEM is involved in executing construction works for housing, schools, hospitals, laboratories, various public buildings and other infrastructure in support of science & technology programme of DAE. This Directorate is responsible for operation and maintenance of various services, estate management and security for the housing colonies of DAE at Mumbai. It also takes up project management consultancy for other government departments as deposit works.

Integrated Facility for Radiation Technology (IFRT)

During the year of the report, work orders for (i) Convention Centre/Sr. Officers' Guest House and Administrative Training Institute Complex, ii) Residential Quarters for CISF personnel, iii) Hostel for Trainees BARC/Homi Bhabha National Institute (HBNI), iv) Renovation of main gates of Anushaktinagar were issued and work continued. Financial sanction for proposed (i) 356 nos. residential quarters and (ii) Restoration/Renovation of Old Houses more than 20 years old Phase-I were received. Pre-qualification of contracting agencies for 356 houses was in process. Renovation of Canadian Bungalow at Old Yacht Club (OYC), various works under restoration/renovation of old houses and up-gradation of services under XI plan were in progress. Comprehensive master plan of Anushaktinagar was prepared and submitted to Statutory Authorities for environmental clearance.

In addition, DCSEM completed Expansion of PSI Laboratory for Variable Energy

Extension of PSI Lab. for VECC, Kolkata

Girls' Hostel for National Centre for Cell Science (NCCS) Pune

Cyclotron Centre at Kolkata, HVAC works of Institute Block Ph.II for National Brain Research Centre at Manesar, Haryana. Other activities included : development work for 96 flats for Tata Institute of Fundamental Research at New Mandala, construction of Physical Training & Aquatic facility for Atomic Energy Education Society at Anushaktinagar, construction of 24 flats of type B quarters for IIT Bombay at Powai, construction of Type V quarters temporary Girls Hostel for National Institute of Science Education and Research at Bhubaneswar, and construction of Girls Hostel and Cell Repository Building for National Centre of Cell Science at Pune. Construction of Housing for Atomic Mineral Directorate at Jaipur, and Integrated Facility for Radiation Technology for BRIT at Vashi were nearing completion. Pre-qualification of agencies for proposed Academic and Residential Township for NISER was also completed.

The DCSEM also took up works relating to Medical Cyclotron building, providing internal external works for Radioactive Ion Beam Building at VECC, Kolkata, Extension of School-VI, School-4 for AEES at Anushaktinagar, Construction of Computer Centre and Computer Science & Engineering Complex building, Type-C quarters, Type-B quarters and Apartment for QIP/DRDO for IIT-Bombay at Powai, Auditorium, Director's Bungalow, flat lets for Indian Institute of Geomagnetism at Panvel. Pre-qualification for proposed First Research and Teaching (FReT) Block for TIFR at Hyderabad was completed and construction of Training School, Core Library, hostel, guest house and staff quarters for AMD, Cherlapaly, Hyderabad was in progress.

Engineering Services Division of DCSEM maintained residential flats (over 9800) and public buildings of DAE in Mumbai, including execution of up-gradation works for the buildings which are of minor capital in nature.

This Directorate is also responsible for the operation & maintenance as well as up-gradation of electrical power

Auditorium Block for Indian Institute of Geomagnetism at Panvel

distribution, lifts, water supply distribution, sewer lines, sewage treatment plant, fire fighting system, rain water harvesting and energy conservation of the services in the large township at Anushaktinagar.

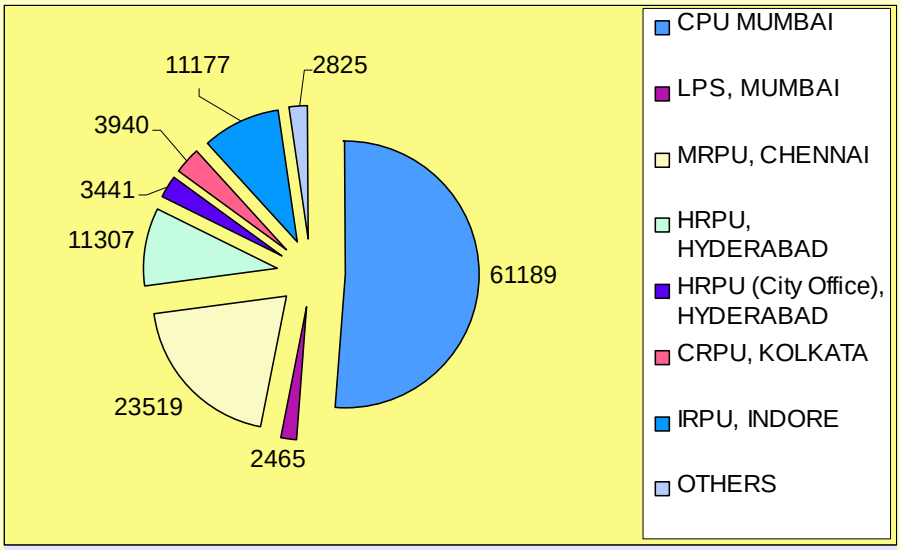
The Estate Management Section of DCSEM continued to manage the estate of DAE and allotment of residential flats, shops including public buildings and the security for the DAE Estate in Mumbai.

During the year of report, schemes worth Rs 120 crore were in the process of completion for various DAE organisations and other departments, including projects of DCSEM worth Rs. 38 crore.

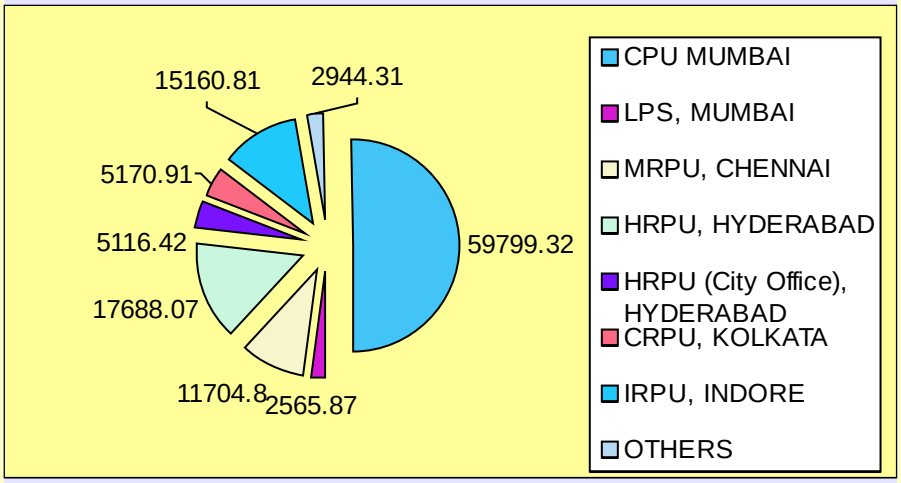
PURCHASE & STORES

The Directorate of Purchase & Stores (DPS), mandated with the responsibility of catering to procurement needs of various constituent units of DAE continued in its endeavour in exploring more possibilities, ways and means of rendering the procurement system more efficient, transparent and last but not the least bringing down the purchasing cycle time. The efforts towards leveraging Information Technology to achieve these objectives were continued with larger vigor and are likely to bear fruits by the launch of first e-tendering activity.

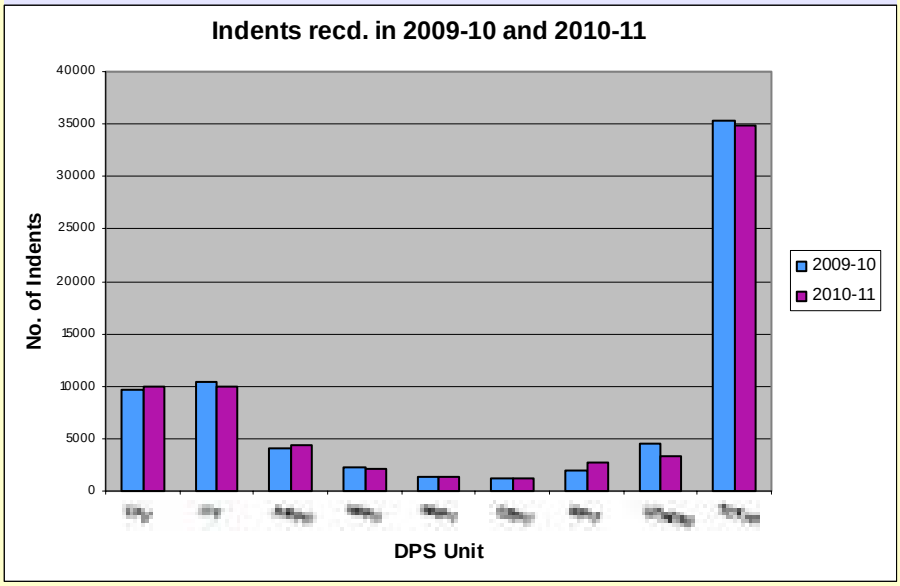
Quantum of work carried out during the financial year 2010-11 cab be seen in charts alongside.



Purchase statistics during the year 2009-10



Purchase statistics during the year 2010-11



During the period of report, following were the major activities of DPS :

Uranium fuel imports

DPS continued to contribute to meeting the fuel needs of NPCIL by directly handling the import of uranium in yellow-cake as well as in pellets form. Imports were successfully carried out from TVEL Russia and Kazatomprom, Kazakhstan. With the long term contracts already in place, additional supplements were signed with the respective governments to facilitate the import of the next fuel lots listed in the scheduled deliveries.

E-Procurement and other IT initiatives

I. Continuing with the steps initiated towards e-procurement launch, efforts were intensified to ensure first e-tender rollout within the targeted period. A roadmap set for the purpose was meticulously adhered to and the major milestones set out largely met.

Tender for item codification floated with the objective of codifying every item procured by DPS, which shall eventually lead to improved procurement practices by having in place a systematic and organized data base of items and vendors

Contract for DPS website facelift and maintenance are likely to be concluded shortly. This will make the site more informative and user friendly with enhanced security features.

II. Preparatory work carried out for STQC Audit

III. Plans to computerize T&C activities aimed at providing better service to user community by capturing all FE contract activities from the time shipment from foreign port was initiated upto the time of physical clearance and delivery to stores.

Stores Procedure

Stores Procedure were revisited with the intention of computerizing, maximum activities possible and finally dispensing with the manual mode of transactions.

GENERAL SERVICES ORGANISATION

The General Services Organisation (GSO), Kalpakkam takes care of the common facilities such as housing, medical, transport, water supply, civil and electrical maintenance in the Atomic Energy Townships at Kalpakkam and Anupuram, catering to the needs of various DAE Organisations located at Kalpakkam such as Indira Gandhi Centre, Madras Atomic Power Station, Bhabha Atomic Research Centre Facilities and Bharathiya Nabhikiya Vidhyut Nigam Limited.

GSO also renders administrative support to various common advisory committees like Kalpakkam Management Committee, Township Amenities Committee , Accommodation Allotment Advisory Committee that is common for both DAE and NPC Units at Kalpakkam.

GSO provides infrastructural facilities and support to Kendriya Vidyalayas, Atomic Energy Central School, Atomic Energy Central Higher Secondary School, Nuclear Employees

Development works in between bridges

Development of Parks

Sports and Cultural Organistion, and carries out the administrative work relating to Kalpakkam Nuclear Installation Local Authority. In addition, the Grant-in-Aid provided by DAE to the Atomic Energy Central Schools and Kendriya Vidyalayas is administered through GSO. This organisation is also involved in the various activities under the Neighbourhood Development Programme as part of social welfare in the village in and around Kalpakkam.

Kalpakkam Township consists of more than 5000 houses of various types, public buildings including 4 schools, guest house, hostels, hospital etc., Anupuram Township has more than 900 houses of various types, public buildings including school, guest house, hospital etc.,

During the report period, the Civil Engineering Division of GSO carried out the maintenance as well as construction activities pertaining to civil works at both Townships. Besides the civil engineering services, the essential auxiliary services viz., Sanitation and Horticulture services were also carried out.

The other activities of GSO included construction of 283 houses of various types, 240 Efficiency Plus Apartments, Hostel cum Guest house, 15 beds hospital, augmentation and refurbishment of the infrastructure facilities under XI plan projects, and construction of water treatment plant under Tsunami Relief works.

The other activities of GSO included maintenance of various electrical systems in DAE Township at Kalpakkam and Anupuram. Design, installation, testing and commissioning of electrical system for new buildings were also carried out.

The Estate Management activities of GSO related to allotment of residential quarters in Kalpakkam and Anupuram Townships numbering 4919 and 933 respectively, and 80 shops. GSO also maintained 3 Guest Houses and 4 Hostels consisting of about 439 rooms. GSO liaised with the State Government and law and order authorities for smooth functioning in both the Townships at Kalpakkam and Anupuram.

The DAE Hospital, that is administered by GSO, and is covered under Contributory Health Service Scheme of DAE, looked after the medical needs of DAE, NPCIL, CISF, AECS, and BHAVINI employees and their family members including retired staff numbering about 27,000 beneficiaries.

CHAPTER : 9

PUBLIC SECTOR UNDERTAKINGS
(FINANCIAL PERFORMANCE)

21 m Major Atmospheric Cerenkov Events (MACE) Telescope under construction for Gamma Ray Hanle Astronomy in Ladakh (ECIL)

CHAPTER : 9

PUBLIC SECTOR UNDERTAKINGS
(FINANCIAL PERFORMANCE)

The Nuclear Power Corporation of India Ltd., Bhartiya Nabhkiya Vidyut Nigam Ltd., Uranium Corporation of India Ltd., Indian Rare Earths Ltd., and the Electronics Corporation of India Ltd., are the five public sector undertakings of DAE.

The operational highlights of these organizations (except of ECIL) have been given under the related major programme heads. The financial performance of these undertakings (except BHAVINI which is yet to commence commercial operations) and the gist of performance of ECIL, are given here.

NUCLEAR POWER CORPORATION OF INDIA LTD.

NPCIL is a profit making, dividend paying company with the highest credit rating of its financial instruments.

NPCIL's provisional net profit (PAT) for the year 2010-11 (upto December 31, 2012) was Rs. 715 crore and the expected profit for the year is over Rs. 950 crore. The last year profit was Rs. 416 crore. The improvement in profit is due to better capacity utilization of the operating stations which in turn is due to improved fuel supply from both international as well as indigenous sources.

NPCIL bonds continued to be rated at AAA (highest safety) by CRISIL and CARE.

URANIUM CORPORATION OF INDIA LIMITED

The overall performance of the company during the year 2009-10 was recognised as Very Good. The total income of the company increased to Rs.545.38 crore as against Rs.397.29 crore in the previous year with a 37.27% rise. The profit after tax stood at Rs. 46.26 crore against Rs.18.01 crore in the previous year.

INDIAN RARE EARTHS LTD.

During the year 2009-10, IRE's Sales Turnover was Rs.337.10 crore against Rs.339.75 crore in 2008-09. Profit before tax in 2009-10 was Rs.47.81 crore against Rs. 82.88 crore in 2008-09. The company earned foreign exchange of Rs. 78.67 crore, and foreign exchange earnings for the current year (up to October'10) is Rs.45 crores.

The Company paid 20% dividend on the paid-up capital amounting to Rs.17.27 crore for both the financial year 2008-09 and 2009-10.

The actual sales turnover up to October, 2010 was Rs.203.00 crores against Rs. 176.00 crore achieved during the corresponding period of last year. Expected sales turnover for the year 2010-11 is around Rs.390.00 crore.

ELECTRONICS CORPORATION OF INDIA LTD.

Electronics Corporation of India Limited (ECIL) was originally established to be the electronics arm of DAE and meet the requirements of control and instrumentation, including detectors, required for the nuclear power generation programme. Over the years, ECIL has emerged as an important national asset in the field of strategic electronics catering to the needs of the Defence, Space, Aviation and Security sectors. It has also made singular contributions to the requirements of the industrial sector and other fields of economic significance, notably oil and petrochemicals, steel and non-nuclear power generation.

Performance in 2010-11

The performance effectiveness measures, specifically crafted by the management with customer in focus, resulted in significantly increasing the velocity of business operations and led to enhanced performance.

Against the annual MoU Target of Rs.1285 crore each of

Integrated Security System for Commonwealth Games 2010 (Jawaharlal Nehru Stadium)

Production and Sales for the year 2010-11, the company achieved a production of Rs.783 crore and a sales (net) of Rs.698 crore upto November 2010 as compared to Rs.524 crore and Rs.457 crore respectively for the corresponding period during 2009-10. The Company is confident of meeting its targets set for the year.

The Company successfully delivered the Integrated Security System(s) to Commonwealth Games-2010, New Delhi.

Important supplies made during the year 2010-11 in the strategic sectors were as follows :

i) Atomic Energy Sector :

- Control and Instrumentation Packages to PFBR Project
- Upgradation of DPHS-PCS to DCHS-PCS System
- 21M Telescopic Antenna for MACE Project of BARC
- I&C of 500 MW PFBR Simulator at Bhavini
- Access Control Systems to NPCIL, Kudankulam
- Reactor Trip Logic system and Proto-type Target Hardware to BARC
- Electronic Locks to BARC

ii) Defence Sector :

- Execution of Project Akash
- Gyro Stabilized Horizontal Bar Systems to GSL, NHQ
- Gyros to BEL
- Synchros to COD, Agra
- ET Assembly to Ordnance Factory, Trichy
- 11M Antennas for Project ICNS
- LP Antennas and Towers for Project Divyadrishti
- V/UHF and HF Transceivers and Speech Secrecy Equipment to Ministry of Defence (MoD).
- Civil Radar Display System (CRDS) to Indian Air Force
- Execution of Project Divyadrishti to MoD
- Solid State Cockpit Voice Recorders (SSCVR) to Air HQrs. and HAL

Indian Environmental Radiation Monitor (IERMON)

iii) Space Sector :

- Ship-borne VSAT terminals for ICNS
- 7.5M Full Motion Antenna to IRNSS project of ISTRAC

iv) Security Sector :

- Integrated Protection Systems to Commonwealth Games 2010, New Delhi
- Security Systems to Delhi Metro Rail Corporation
- Encryption Overlay for Satellite Communication for Indian Navy
- Surveillance Systems to Delhi Police
- Annual Maintenance for Integrated Security Systems at Parliament House, PM's Office and PM's Residence

v) Other Sectors :

- Execution of e-Governance Project KAVERI (Revenue Dept., Govt. of Karnataka)
- Execution of orders for Maharashtra Sales Tax Department and Kerala Road Transport Authority
- Electronic Energy Meters for West Bengal Electricity Board

vi) National Population Register Project :

The Government of India has decided to create National Population Register (NPR). The initiative is being carried out in phases. During the year ECIL received Rs. 57 crore worth order towards this project covering Andhra Pradesh, Orissa and West Bengal population.

R&D Achievements

The Vehicle Monitoring System developed for Radiation Detection (Gamma & Neutron) during 2009-10 is currently under-going product trials / evaluation / customer demonstration at JNPT. This is a precursor to receipt of a major order valued at Rs.120 crore from 12 major seaports for these systems.

The in-house R&D programme of the Corporation is well guided and supported by the Technology Development Council. The following projects are planned for completion during 2011-12 :

- Mount System for Satellite Tracking using 2.4m foldable Ku band
- 3D walkthrough for Power Plants
- Analog, Digital Input and Output System ADIOS-3000
- 1kW wide band power amplifiers and 1KW Filter Switching Unit in Frequency
- V/U Multi-couplers for use with 3060 Receivers
- R F Seekers for Missiles
- Multi-radar tracking and fusion for Air Defence
- Software Development for ECSCADA - IEC-870-104
- DNP3 Master Communication Protocol Development for RTU
- Development of Embedded Electronic Voting Systems for Preferential Voting Imaging System for Testing LINAC-Extension of LINAC Project
- Energy Monitoring & Control Systems - Automatic Power Factor Control System
- 3 Phase 4-wire AMR Trivector Meter
- Vehicle Monitoring System for SNM Detection
- Classroom Electronic Warfare Simulator (CREWS)
- Development of Indigenous Onboard Rugged Computer

Biometric Enrolment Kit for National Population Register

New Generation Bulk Encryption Unit for data streams from 2 Mb to 10 Gb

Infrastructure Projects

The Company, with the technical guidance and financial support of BARC took up the creation of following four infrastructure projects :

Radiation Detectors & Instrumentation, Characterisation Facility: The facility was inaugurated by Secretary, DAE on 31st May 2010.

High Density Interconnect Technology for Printed Circuit Boards: This facility was inaugurated by Director, BARC on 20th December 2010.

Electro-Magnetic Interference/Compatability (EMI/EMC): The facility is likely to be integrated by end March 2011.

Compact Antenna Test Facility (CATF) : The facility is likely to be integrated by end March 2011.

The Company has planned an investment of Rs. 31 crore from its own resources towards modernization and upgradation of Infrastructure with specific focus on attaining and maintaining global competitiveness in the area of strategic electronics with special emphasis on Nuclear Sector.

Certification of the applicable Quality Management Systems

Audits for ISO certification (ISO-9001, ISO 14001:2004, ISO 18001 OH&S) are being conducted and recommendations received for continuation of certificate(s) for Quality Management, Environmental Management and Occupational Health & Safety Management. Initiatives have been taken to integrate different Management Systems. Stage-I assessment for Information Security Management System Certification was completed and the final assessment leading to Certification is expected before March 2011.

Important Events

The Company made the following Strategic Tie-ups / ToTs / MoUs with reputed organizations in order to strengthen its activities :

MoU with NPCIL
ToT for Seekers (SRSAM, MRSAM)
ToT for Inertial Navigation Systems, Fibre Optic Gyros from DRDO
Localisation of Nuclear C&I Systems for Imported Reactors
Localization of Radiation Monitoring Systems for Imported Reactors
Power Converters for FAIR and ITER
On-board Electronics for Missiles (BDL)

Outlook for 2011-12

The performance measures put in place have equipped the Corporation to handle the following emerging business areas in the chosen Sectors of operation.

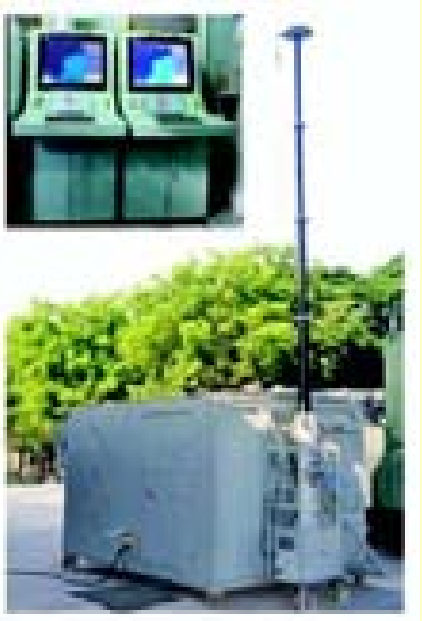
Atomic Energy :

A modern Control Room built by ECIL for PHWR

NPP Mega Projects (R7&8, K3&4)
Kudankulam Nuclear Power Project
PFBR & B1/B2 Projects
BARC Jobs
Process Control and Radiatiion Monitoring Systems for P3A Project of BARC
Process Control System for DFRP project of IGCAR
Projects for Bhavini
RDEs for Sea Ports

Defence :

M7 Radios to MoD
V/UHF Tx Rx 3060 Equipment to MoD
HF Tx Rx TR 2400 to MoD
MSRS-II to MoD
Universal Fuzes to MoD
Project BrahMos to BrahMos Aerospace Corporation
Project Akash (existing and new projects)
C4I Systems to MoD
CRDS for IAF
Autonomous Underwater Vehicle to NSTL



Command Control Centre for Akash Missile-Inset Squadron Control Console

Aerospace :

Integrated Communication Network System (ICNS) for ISRO
Weather Radars for IMD
MACE Telescope for Gamma Ray Astronomy
Creation of facility for Fibre Optic Gyros

Security :

CBRN Protection Systems for Parliament House
Security Systems for various establishments of DAE
Security Systems for Delhi Police
Security Systems for ASL, Nasik; Bakranangal Dam; Kolkata Metro Railway; Paradeep Port Trust; Southern and South Western Railways; Current Note Press, Nasik.
Scan Systems
Mobile Container Scanner (CaRDS)
X-ray Baggage Inspection Systems

CHAPTER : 10

OTHER ACTIVITIES

A view from a Science Park, setup by AEES

CHAPTER : 10

OTHER ACTIVITIES

NATIONAL SECURITY

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

CRISIS MANAGEMENT

The Crisis Management Group (CMG) is a standing committee of senior officials of the DAE who are responsible for coordinating the Department's response to a radiation emergency in the public domain. Such an emergency could be due to events taking place within any nuclear facility, due to an accident involving the transport of nuclear material, due to events at other facilities handling radioactive materials such as hospitals or industries, or even due to any deliberate attempt to cause disruption in public activities, by involving radioactive material.

Because of the inherent design features and deployment of multiple safety systems, the possibility of any accident in a nuclear facility or during transport which might lead to a radiation emergency in the public domain, is highly remote. However, in order to handle any unforeseen situation, formal emergency response systems are in place and are tested regularly to ensure that there would be no radiation hazard to the public. All these activities are overseen by an independent regulatory authority, which ensures that all radiological safety issues are adequately addressed. Further, in case such an unlikely event does occur and leads to a radiation emergency in the public domain, a response system is in place to tackle such situations, by mobilizing the expertise of DAE in the field of radiation measurement and protection and medical treatment of radiation injuries. The objective is to make these specialized technical support facilities available to public officials who would be handling various types of disasters or emergencies related to radiation/ radioactive materials in the public domain.

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. During the year 2010 the following exercises were carried out:

1. Communication Exercises - 305
2. Fire Emergency Exercises - 76
3. Plant Emergency Exercises - 58
4. Site Emergency Exercises - 11
5. Off-Site Emergency Exercises - 5

The Off-Site Emergency Exercises were carried out in the public domain in the vicinity of nuclear power stations at Kakarapar in Gujarat, Rawatbhatta in Rajasthan, Kalpakkam in Tamil Nadu, and of the heavy water plant at Manuguru, Andhra Pradesh. These Off-Site Exercises were conducted by the concerned district officials (the District Magistrate or Collector is the Off Site Emergency Director) and information flows were established to the CMG as well as to the National Crisis Management Committee of the Union Government.

The Emergency Response System of DAE is also available to respond to a request from any public official in the event of the reported presence or suspected presence of radioactive material. For this purpose, guidelines 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 communications rooms at Mumbai, which are manned on a round the clock basis throughout the year. These have multiple modes of communication and are in constant contact with various nuclear facilities in the country as

well as with IAEA in Vienna.

The CMG also provided its expertise in various forums in the field of disaster management at both National and International levels.

BARC SAFETY COUNCIL

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

To comply with the requirement of licensing /authorization for operation of the variety of radiation installations in BARC, the BARC-Safety Council Secretariat 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, consisting of eminent scientists, continued with the peer reviews of basic research to ensure that highest possible level of excellence is maintained.

INTERNATIONAL RELATIONS

The Bilateral Agreements signed during the year 2010 were as follows:

(i) Arrangements and Procedures agreed between India and the USA pursuant to Article 6

(iii) of their Agreement for Cooperation Concerning Peaceful Uses of Nuclear Energy, were signed on 30.7.2010

(ii) Joint Declaration by India and the United Kingdom on Civil Nuclear Cooperation was signed on 11.2.2010.

(iii) Agreement between India and the Russian Federation on Cooperation in the Use of Atomic Energy for Peaceful Purposes was signed on 12.3.2010

(iv) Agreement between India and Canada for Cooperation in Peaceful Uses of Nuclear Energy was signed on 27.6.2010.

(v) Agreement between India and Argentine Republic for Cooperation in the Peaceful Uses of Nuclear Energy was signed on 23.9.2010.

(vi) Agreement between the French Republic and India, concerning Intellectual Property Rights on the Development of the Peaceful Uses of Nuclear Energy, was signed on 6.12.2010 .

(vii) Agreement between India and the French Republic on the Protection of Confidentiality of Technical data and information relating to Cooperation in the Peaceful Uses of Nuclear Energy was signed on 6.12.2010.

(viii) Road Map for the Serial construction of the Russian Design Nuclear Power Plants in India was signed on 12.3.2010

(ix) Memorandum of Understanding between DAE and the State Atomic Energy Corporation "ROSATOM" concerning broader Scientific and Technological co-operation in the field of peaceful uses of nuclear energy was signed on 21.12.2010.

Civil Liability for Nuclear Damage Bill, 2010

The "Civil Liability for Nuclear Damage Bill, 2010" was passed by the Lok Sabha on August 25, 2010 and by the Rajya Sabha on August 30, 2010. After Hon'ble President's assent on September 21, 2010, the Bill has now become the "Civil Liability for Nuclear Damage Act, 2010".

Convention on Supplementary Compensation for Nuclear Damage

On October 27, 2010, India signed the Convention on Supplementary Compensation for Nuclear Damage in accordance with Article XVII of the Convention. At present there are 14 signatories to the Convention with 4 having ratified it. India has not yet ratified the Convention.

Donation of Bhabhatron

A Bhabhaton II teletherapy unit donated to Vietnam was installed in Can Tho General Hospital and was inaugurated in April 2010. At the IAEA General Conference in Vienna in September 2010, India announced the gift of a Bhabhatron Teletherapy Unit and one Radiotherapy Simulator to Srilanka.

Policy Guidelines

In order to encourage the development of commercial relations with any country in the area of atomic energy, under bilateral or multilateral agreements for cooperation, a Resolution on guidelines for implementation of arrangements for cooperation concerning peaceful uses of atomic energy with other Countries was published in the Gazette of India on 4.6.2010. The Government has also allowed supplies of nuclear material, non-nuclear material, equipment, components, information and technology listed in Schedule-I of the Resolution, from countries willing to trade with India without a formal bilateral agreement of cooperation with such countries. Supply of any scheduled item from such country shall be based on assurances from and agreed to by the Government of India.

A person in India who intends to enter into commercial relationship, collaboration, cooperation, or contract or has already entered into such an arrangement with persons in a cooperating country or a trading country, as the case may be, shall seek an authorization for such an arrangement.

Global Centre for Nuclear Energy Partnership

At the Nuclear Security Summit organized in Washington DC during 12 -13 April 2010, Hon'ble Prime Minister announced India's decision to set up a Global Centre for Nuclear Energy Partnership a state-of-the-art facility based on international participation from the International Atomic Energy Agency and other interested foreign partners, in India, in a phased manner. The Centre will be located in Haryana near Delhi which will have four schools :

a) School of Advanced Nuclear Energy System Studies : To pursue design studies and analysis of advanced nuclear energy systems with features to intrinsically enhance safety, security, proliferation resistance and sustainability.

b) School of Excellence in Nuclear Security : To pursue training and research in nuclear security.

c) School of Excellence in Radiation Safety : To develop radiation measurement and protection devices and provide training in their usage.

d) School for Applications of Radioisotopes and Radiation Technology : To pursue radiation technology applications in areas of health care, agriculture and food.

International Atomic Energy Agency (IAEA)

India is a designated member of the Board of Governors (BoG) of the International Atomic Energy Agency (IAEA) since its inception.

At the invitation from Chairman, AEC, Mr. Yukiya Amino, Director General, IAEA visited India during 16 -19 January 2011.

Besides the General Conference of IAEA in Vienna from 20 to 24 September 2010, India actively participated in other important meetings including Board of Governors, Programme and Budget Committee, Technical Assistance and Cooperation Committee etc. India was also represented in 31 committees of IAEA related to safety, safeguards, nuclear engineering and applications.

India continued to offer training facilities, fellowships, and scientific visits etc. to various countries, and also made available the services of 20 scientists as experts to various countries under the IAEA Technical Co-operation scheme in the field of peaceful uses of atomic energy.

Indo-German Bilateral Agreement

Under Indo-German Bilateral agreement 5 Indian scientists visited Germany and 6 German scientists visited India.

International Conferences, Symposia etc.

Around 2500 foreign scientists and a number of Indian scientists/engineers participated in the international symposia, workshops, conferences and meetings held in India under the auspices of the IAEA and various international/multinational organizations. India hosted 11 IAEA and 77 non-IAEA meetings/symposia on important issues such as National Cancer Control Programme, Combating Malicious Acts involving

Radioactive Materials at a Major Public Event, Advanced Techniques for Isotope and related Applications in Water Resources Management, Deterministic Best Estimate Safety Analysis for Advanced Nuclear Power Plants, Emerging Trends in Separation Science and Technology.

Deputations Abroad

Over 1050 scientists from India were deputed abroad to attend international symposia, workshops, conferences and meetings conducted by IAEA and non-IAEA organizations.

The Chairman, AEC visited Paris from March 8-9, 2010 to attend an International Conference on Access to Civil Nuclear Cooperation. He also visited the USA from 2 -12 May 2010 and attended the Pacific Rim Workshop on Nucleation, visited the Los Alamos National Laboratory, Jefferson Laboratory and University of Virgina.

World Nuclear Association

Three units of DAE i.e. NPCIL, NFC and AMD are members of the World Nuclear Association (WNA), a global non-governmental trade organization concerned with nuclear power generation and all other aspects of the nuclear fuel cycle. WNA also fosters commerce and co-operation within the nuclear industry in promoting the cause of nuclear energy in trans-national fora. DAE scientists take active part in various WNA activities including their Summer School.

International Co-operation in Civil Nuclear Energy

A meeting of the India-United States Civil Nuclear Energy Working Group (CNWG) was held in Mumbai on 3-4 February 2010. The meeting was co-chaired by Dr. R.B. Grover, Director, Strategic Planning Group, DAE and Dr. Warren "Pete" Miller, Assistant Secretary for Nuclear Energy, Department of Energy, USA. The co-chairs signed a U.S.- India Civil Nuclear Energy Action Plan which provides a path forward and timeline for execution of collaborative works in specific technical areas.

European Organization for Nuclear Research

India is an Observer in the European Organization for Nuclear Research (CERN) and continued to participate in collaborative work in the framework of the developments of computing and computational Grid technology for Large Hadron Collider Project (LHC) based on the 1991 agreement. India continued to be a part of the computing Grid Project of CERN upto 31st December 2010.

World Association of Nuclear Operators

NPCIL continued to be a member of various international organizations viz. World Association of Nuclear Operators (WANO), CANDU Owners Group (COG) and World Nuclear Association (WNA). NPCIL actively participated in various programmes of these organizations to enhance the safety and reliability of its nuclear power plants.

NPCIL, one of the founding members of WANO, is currently member of the two WANO Regional Centres at Tokyo and Moscow. All the nuclear power plants operating in over 30 countries of the world are its members. Dr. S.K. Jain, Chairman & Managing Director is on the worldwide WANO Governing Board.

In the current year NPCIL hosted WANO Peer Review of its plants which were carried out by teams consisting of experts from several countries representing global nuclear safety standards and found to be very useful in bringing in international perspective to our plants. Also, WANO organized Technical Support Missions (TSM) for NPCIL to achieve next higher level of safety and reliability. Several persons from NPCIL participated in the important meetings, seminars and peer reviews organized by WANO, and had the opportunity to discuss various issues related to improvement in plant performance with experts from other countries.

The CANDU Owners Group has installed a satellite server to replicate all the data available on main server of COG, for easy and fast access to the data available. The database has also been provided access to plant sites, so

that they remain connected with latest developments in safety of operating CANDU plants worldwide. NPCIL regularly participated in various programmes.

NPCIL also draws benefit from membership of WNA, especially it provides detailed worldwide report on all related issues of fuel like availability, utilization and forecast for future.

MANAGEMENT SERVICES

The Management Services Group (MSG) provides project monitoring, information services, computer network and systems support at the DAE Secretariat.

MSG maintained a comprehensive information system on the performance of all the operating units under DAE and based on the information periodic reports were prepared and sent to the Prime Minister and the Atomic Energy Commission. The information system to monitor the progress of major projects of the DAE organizations during the XI Plan, were updated periodically and reports highlighting the expected schedule of project completion and status of expenditure against plan budget were generated as and when required.

MSG continued to provide Information Technology (IT) facilities on a round-the-clock basis, to the DAE Headquarters. It also provided support in DAE Secretariat for video conferencing with all the organizations of DAE using its intranet and also with external organisations through public networks.

MSG maintained the Internet information portal for the Indian Atomic Energy Programme through the DAE web site ***(http://www.dae.gov.in)***. The website acts as a window to the public to communicate its activities. It is a repository of various acts, rules, agreements, publications, achievements of the Department, and provides downloadable forms for the benefit of the public. The IT infrastructure in DAE Secretariat was regularly upgraded and a Helpdesk continued to operate.

The Group continued to coordinate the functioning of the Computer Information and Security Audit Group (CISAG) constituted for the purpose of overseeing the security of the entire Department's IT infrastructure. The CISAG prepares periodic exception reports on IT security based on internal audit reports received from all the units for submission to Home Ministry and the Chairman, AEC.

Officers of the MSG participated in various committees and task forces of the department in the field of Information technology. It also continued to provide support to the Crisis Management Group (CMG) of DAE for carrying out its functions.

VIGILANCE

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

During the report period, the vigilance functions included timely transmission of various vigilance returns to the Central Bureau of Investigation (CBI), Department of Personnel and Training (DP&T)/Central Vigilance Commission (CVC), issuance of prosecution sanctions, processing of vigilance and disciplinary cases, monitoring of the progress of inquiry proceedings, investigation of complaints and others. In addition, an Annual Action Plan was worked out by all DAE units.

As advised by CVC, two specific areas prone to corruption (i.e. award of contracts, recruitment of personnel etc.) have been identified by each Unit of DAE and concerted action is being taken.

As per the directives of CVC, Vigilance Awareness Period was observed from October 25 to November 1, 2010 in the

Department as well as its Constituent Units, Public Sector Undertakings and Aided Institutions, by taking the vigilance pledge, arranging lectures, essay competitions, quiz competitions, drawings etc. on vigilance awareness. Seminar for promoting vigilance awareness with invited talks on 'Vigilance : An overview', 'Disciplinary proceedings' and 'Vigilance in PSU with Focus on Purchase Procedure' was arranged on November 16, 2010.

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 varied disciplines of Nuclear Science and Technology. Some of the efforts made in this direction are highlighted below :

- DAE is conducting 13th All India Rajbhasha Sammelan on 23rd - 24th November, 2011 at Homi Bhabha Centre for Science Education, Mumbai and various lectures and programmes are to be organized there.
- A bilingual (English-Hindi) Nuclear Glossary prepared by IGCAR with the collaboration of DAE as well as the Commission for Scientific and Technical Terminology, Ministry of Human Resource Development was widely circulated.
- 25 Seminars and 46 Talks in Hindi on diverse subjects, mostly related to Nuclear Science were organized and the Souvenirs in Hindi on the proceedings of the Seminars/Conferences were brought out.
- All Gazette Notifications, Cabinet Notes, Reports and other documents furnished to the various Committees of the Parliament, and the Agreements and MOUs were prepared bilingually.
- 2,502 Officials were imparted training in Hindi Noting and Drafting in Hindi Workshops. Cash awards were given to 604 Officials for writing original notes and drafts in Hindi.
- 291 Officials, 85 Typists and 36 Stenographers were imparted training in Hindi, Hindi Typing and Hindi Stenography respectively. 366 Officials, 72 Typists and 47 Stenographers are undergoing training in Hindi, Hindi Typing and Hindi Stenography respectively. 218 Officials, 76 Typists and 33 Stenographers were given cash awards and other incentives for successfully passing Hindi, Hindi Typing and Hindi Stenography examinations.
- Hindi books worth Rs. 11,60,583/- were purchased and books worth Rs. 2,11,222/- are proposed to be purchased.
- Quarterly meetings of OLICs held regularly and the progress of implementation of Hindi was monitored through OLIC meetings and review of the Quarterly Progress Reports.
- DAE and 19 of its establishments have their Websites in bilingual form. Presently, there are 17,731 bilingual computers and another 1,639 bilingual computers are proposed to be purchased.
- The Hindi Vigyan Sahitya Parishad, a voluntary organization of BARC continued to publish a popular Hindi quarterly bulletin "Vaigyanik". Pamphlets on various subjects related to DAE's activities were also prepared in bilingual form.
- 32 House Magazines and 04 News Letters were brought out by various establishments of DAE. In addition, One "Bulletin on Highlights" was also published by one of the constituent Units of DAE.
- Parliamentary Committee on Official Language inspected NPC, Noida; AMD, New Delhi and Shillong; ECIL, New Delhi and Mumbai and TAPS, Tarapur.
- The total strength of Hindi Staff in DAE and its constituent Units, PSUs, and Aided Institutions is 121.

SCIENTIFIC INFORMATION & RESOURCE MANAGEMENT

During the year, the information resource of Scientific Information Resource Centre (SIRC) of DAE was strengthened through procurement of new books, periodicals and audio-visual materials.

Services such as Circulation, News Clipping Service (News Watch), Interlibrary loans, Reprography, Referrals, and Internet Access etc. were catered uninterruptedly.

The Scientific Information Resource Division of BARC procured a total of 1220 books, 13 CD-ROMs/DVD-ROMs/ online databases of various standards, codes, patents and complete sets of standards such as IEC,ASHRAE, ASMEBPVC, AWS, ISO, ASTM.

BARC currently subscribes to 1797 periodicals. Approximately 2053 Science Direct (Elsevier Science Publishers) online journals not subscribed by BARC are either subscribed by other DAE units that are available to BARC under DAE Consortia, or are available on complimentary basis from Elsevier Science. The library is also having back files of the journals of the major publishers, e.g. American Chemical Society, American Institute of Physics, ASME, Cambridge University Press, Elsevier, IEL (IEEE/IET Electronic Library), INSPEC, IOP Science, Nature Publishing Group, Royal Society of Chemistry, Springer, Taylor & Francis, Wiley etc. The Library also purchased number of subjectwise back files such as Analytical Sciences, Biotechnology, Biochemistry and Biophysics, Chemistry and Materials Science, Engineering, Computing & Technology, Physics, Astronomy and Polymer. A total of 503 scientific and technical reports were added and1330 reports were digitized. In addition 5200 new bound periodicals were added to the collection.

Upgradation of network infrastructure including servers, switches and network was implemented. Re-structuring of switches/desktops to uniform campus wide scheme of 10 Network was carried out and BTS facility was provided to all the staff of SIRD. Digital resources on two fast Ethernet based networks for online resources and onsite resources were upgraded. Digital Portal Saraswati was upgraded for accessing, searching, downloading and printing of digital collection for higher speed and volume of digital resources from web browser interface at the desktop. Web enabling software Citrix MetaFrame was upgraded to Citrix XenApp Server with enhanced features of publishing /accessing the application /CDROM databases in a Network environment. Open source based digital repository E-Sangrahay consisting of full text peer-review articles, PhD theses and other scientific & technical information was developed and made available to BARC scientists and engineers. More than 180 PhD theses and 3650 journal articles are hosted in the repository. All the library activities such as acquisition of books, cataloging of documents, circulation of documents, subscription and renewal of journals and OPAC modules were upgraded to fully web based interface software known as LSPremia.

Library Circulation Unit continued to provide user friendly services to scientists and engineers of BARC and other DAE units. Trial runs are being made to provide online reservation and renewal of books/reports facility to the members through OPAC on SARASWATI. The new library members enrolled were 300.

Efforts to interact with other National and International organizations to identify and acquire the information which is not readily available in our library to satisfy the varied information requirements of BARC scientists and engineers continued. Publications of BARC scientists and engineers are displayed every month at the Display Unit of the Central Library. These publications are also listed in the monthly publication 'Scientific Information Resource Bulletin'. The full text of these publications are simultaneously made available on Saraswati. In order to meet the immediate photocopy needs of scientists and engineers, the library continued to provide

photocopy service and provided ten (10) self-operating photocopiers for the purpose.

Scientometric studies on various topics related to nuclear science and technology as well as major thrust areas continued and nine papers were published. Selective Dissemination of Information (SDI) is provided to Directors, Group Directors and Associate Directors of BARC on selected areas of research.

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 various divisions. Events like national and international conferences, public lectures as well as VIP visits were covered. Digitization of photographs of archival value was initiated.

Foreign Languages Unit carried out translations of various technical reports from Russian, German, French, Italian, Spanish Chinese, Korean and Japanese into English. Interpretation services were also provided in Russian for the ongoing projects. A short term course was conducted in Russian for the benefit of BARC scientists and engineers.

SIRD being an input centre to International Nuclear Information System (INIS) continued to send inputs on a regular basis to the INIS Central Secretariat, Vienna, Austria. A total of 2696 records were input to INIS database.

BARC Newsletter, Pulse and several internal and external reports, brochures etc., were published. A new publication Scientific Information Resource Bulletin was launched. This information bulletin covers new resources added to the collection, latest journal publications of BARC scientists and engineers, selected scientific translations, INIS activities, nuclear news, newspaper clippings, multimedia events and event calendar.

At IGCAR, as part of enhancement of digital resources nature materials, Nature archives, National Technical Reports Library, IEEE-E-Books were made available on the desktops of the users across the campus network.

Information up to Table of Contents of all the nuclear engineering holdings and full text of metallic fuel documents were digitized and integrated with the common metadata framework for efficient retrieval.

PUBLIC AWARENESS

DAE and its organisations continued their efforts towards creating mass awareness about the various programmes of the department and their societal impact. They organised exhibitions, seminars, workshops and essays and quiz contests, and brought out information literature on various aspects of nuclear energy, to keep the public abreast

Students at the DAE pavilion during the 98th Indian Science Congress 2011 at SRM university Tamilnadu

of the current trends and developments in the field.

During the year, DAE organised and participated in a host of events as follows :

The 98th session of the Indian Science Congress was held at the SRM University, Chennai, Tamil-Nadu during January 3-7, 2011. A Mega Expo, Pride of India was held parallel to the Science Congress. DAE participated in this exhibition and showcased all its major activities. Over 40,000 people including students, members of the general public, academicians gained from the event.

The 22nd All India Essay Contest on Nuclear Science & Technology was organised in October 2010. Essays were received in three languages and on three topics. The winners were shown various facilities of DAE. Certificates and cash prizes were awarded during the Founder's Day Celebrations.

DAE participated in Bangalore India Bio 2010 exhibition held at Bangalore during June 2-4, 2010. The department's activities in the area of healthcare, bio-technology, agriculture, food etc were brought out in this exhibition. More than 15000 visitors including farmers, rural public, students benefited from this exhibition.

The 16th All India National Expo 2010 was held at Nadia West Bengal during August 23 to 28, 2010. Information in Bengali about all the contributions of atomic energy towards peaceful purposes was exhibited. Members of the local public, students from schools and colleges, farmers visited this exhibition.

DAE took part in the 14th National Exhibition on the theme 'Striving towards a Glorious India' organised at Sodepur, Kolkata, West Bengal during September 3-7, 2010. The event was inaugurated by Chairman AEC. Over 40,000 people from varied backgrounds visited the exhibition.

A temporary exhibition on 'Science & Technology - Contributions of Indian Scientific Institutions' was held during the Common Wealth Games 2010 at the National Centre Delhi during October 2010. Students, members of the academic community benefited from this event.

The 30th India International Trade Fair, 2010 was held at Pragati Maidan, Delhi during November 14-27, 2010. DAE's

Participants of the 22nd All India Essay Contest in Nuclear Science and Technology

achievements in the area of nuclear power, applications of radioisotopes for societal development were showcased in this exhibition.

DAE participated in the 'India Energy 2010' organised by UBM India, at Mumbai during October 7-9, 2010. The departments activities in the area of Nuclear Power specifically and other applications in general were exhibited. Private Indian vendors exhibited their contributions to the Indian nuclear power programme. Several other countries also showcased their activities in the area of Nuclear Power Production.

The 2nd International Conference on Asian Nuclear Prospects, ANUP 2010, was organised at Mahabalipuram, Tamil Nadu during October 10-12, 2010. The event coincided with the completion of 25 years of the Fast Breeder Test Reactor, FBTR at IGCAR, Kalpakkam.

DAE participated in the 'Advances in Nuclear Technology - ADNUTECH 2010 exhibition and Conference held at the Nabhikiya Urja Bhavan, NUB, Anushaktinagar during December 2-3, 2010.

The Fifth International Conference NIC 2010, of NAARRI was held in Mumbai during December 13-15, 2010. DAE's achievements in the areas of applications of radioisotopes in Healthcare, Agriculture, Food, Bio-technology etc were exhibited.

The Swasraya Bharat 2010 was held at Kochi, Kerala during December 15-20, 2010. DAE participated in the Vigyan Mela and showcased its entire gamut of activities. Over 25000 people visited the exhibition.

DAE took part in the 11th International Conference on Public Communications of Science & Technology 11th PCST-2010, held at NASC, Pusa, New Delhi during December 2010. An exhibition on the Peaceful Uses of Atomic Energy and a skit depicting the exhibition theme were the highlights of the event.

DAE participated in the 5th Science Expo at the Nehru Science Centre, Mumbai during January 20-24, 2010. Several other government departments, academic institutions participated in this event. Over 30000 visitors mainly comprising students, teachers, general public benefited from this exercise.

The Science Fiesta-2011 was held at the Goa Science Centre, Goa during February 24-26, 2011. An exhibition on atomic energy, quiz contests etc were organised for students from schools and colleges.

An awareness programme on Radiation and Radioactivity, was held for scrap dealers at Mayapuri, Delhi during May 2010. The objective of the programme was to guide scrap dealers in being able to detect radioactive material that may have been accidentally discarded as scrap.

A one day National Seminar, on 'Applications of Radiation Technology in Medical Science (ARTMS)' was held at NEIGRIHMS, Shillong, Meghalaya in May 2010. DAE participated in the seminar on Peaceful Uses of Atomic Energy held by the United Schools Organisation, Jaipur during August 2010.A seminar on Awareness about the Progress in the Field of Modern Sciences was held at Jabalpur during September 2010. The 9th Asian Regional Seminar on Peaceful Uses of Atomic Energy was held in collaboration with the United Schools Organisation, USO, New Delhi during December 2010. A one day Seminar and Exhibition on Applications of Nuclear Energy for Societal Benefits was held at K C College Mumbai on February 5, 2011. The focus of the event was students and academia. The 2nd International Conference on 'Advances in Nuclear Materials, (ANM 2011) - Materials, Challenges for Future Reactors' was held at Anushaktinagar, Mumbai during February 9-11, 2011.

NPCIL carried out various communication activities for the dissemination of accurate and authentic information on nuclear power to different target groups on regular basis. The Company's website (www.npcil.nic.in) was updated regularly. News article repository system, an internal communication strategy implemented by NPCIL, was uploaded regularly to the company's intranet.

NPCIL organised exhibitions as a platform to directly communicate with the public,

industry experts, and students, etc. about nuclear power. The company setup pavilions in local, national and international level exhibitions to showcase its technical capabilities during the year. Some of the notable participations in the year were Atomexpo in Moscow and at the WANO BGM in New Delhi .

NPCIL set up a permanent exhibition on "Hall of Nuclear Power", at Nehru Science Centre, Mumbai. The aim of this innovative project is to communicate nuclear science in an interactive way to the general public.

The company has also taken up a structured programme on public awareness on nuclear power custom tailored for engineering college students and faculty members. The programme has been implemented in over twenty five colleges across the country including IIT-Bombay and IIT-Guwahati.

The company also carried out media interaction on regular basis and organized technical visits of media personnel to stations and projects. NPCIL produced short films and multimedia presentations to disseminate information about NPCIL and nuclear power. Interesting and interactive multimedia film on the company's profile and on the birds found in and around NPCIL plants has been produced.

Press releases (about 50) were issued from time to time about important events and the major milestones achieved. A mega press conference was organised for Kaiga-4 criticality event. Similar press meets were organised for the First Pour of Concrete at Kakrapar, MoEF clearance for JNPP, etc.

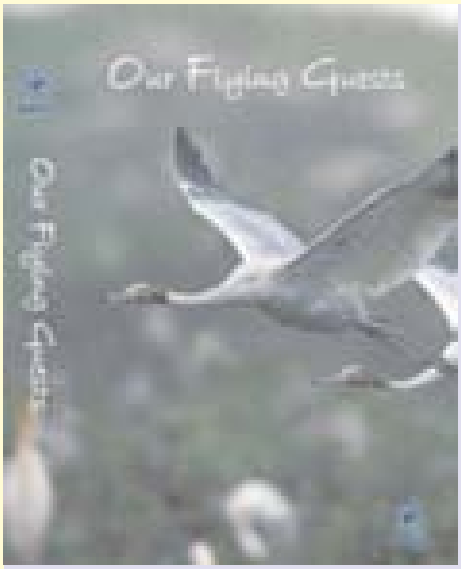
Company's profile, public awareness material, educational material, reports, promotional brochures are some the regular publications of NPCIL. Nu-Power - an International Journal of Nuclear Power is being published by the company in every quarter. The company provided financial assistance to several institutions and events.

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

During the year of this report, a coffee table book "Our Flying Guests" on the birds found within and around all the Indian nuclear power plants was published.

A study of wetlands and survey of birds in select districts of Tamil Nadu was conducted by the NPCIL volunteers. The information collected on water birds and wetlands during the survey as a basis for contributing to their conservations was submitted to Asian Waterbird Census (AWC) an Asia region programme to promote public participation to monitor the distribution and population of

Public Awareness programme at IIT-Bombay Techfest international exhibition



Coffee Table Book - 'Our Flying Guests' published by NPCIL

Butterfly garden at the Kakrapar Atomic Power Station

water birds and status of wetlands. The study on the breeding population of Indian Skimmer at Narora site is continuing since 2007. The volunteers from Rajasthan Atomic Power Station (RAPS) were campaigning under the Environment Stewardship Programme, for the discontinuation of diclofenac drug which was responsible for the drastic decline of three Gyps vulture species in India.

A survey of butterflies in the premises of Kakarapar Atomic Power Station was carried out to document the details of the species found in that region -- especially inside the exclusion zone. The study was done with the help of Nature Club, Surat, an NGO specialized in butterflies. A butterfly garden was also established at Kakrapar site.

BARC, conducted several public awareness programmes for the benefit of students, teachers and farmers. In all, 16 public awareness programmes were conducted. In addition, MRPAS provided media coverage to the various events organized at BARC.

An Exhibition on 'Thorium

Interaction with farmers at Barkachha, Mirzapur, Uttar Pradesh

Interaction with students of Tamil Nadu Agricultural University

Technologies' was held at Central Library during 17th May -18th June 2010. The exhibition displayed books, reports and multimedia resources related to thorium technologies

The IOP is actively involved in popularizing science. The national science day was celebrated on 28 February, 2010. A visit by Jawahar Navodaya Vidyalaya students was also arranged. The rural programme for scientific awareness through the Samanta Chandra Sekhar Amateur Astronomers' Association (SCAAA) formed an important part of the outreach programme. The physics open discussions for NISER students was also pursued actively this year.

The Institute of Mathematical Sciences (IMS) continued with its Science Popularisation programme.

SOCIAL WELFARE

NPCIL continued its corporate social responsibility initiatives, to support the community in and around its nuclear power plants, in three areas, health, education and infrastructure development. The support in health measures included organising regular medical check-ups and extending medical assistance in emergency cases, blood donation camps, eye camps, providing drinking water etc. The support in education comprised providing of educational infrastructure development essentially the school building, laboratory equipment, furniture, teaching aids, such as computer and study material to school etc. In addition to this, at the NPCIL sites, meritorious and needy children were adopted for their education. The company provided financial assistance to several institutions and events such as Blind Organisation of India, DAE Safety Meet, All India Association of Industries, and others.

EMPLOYEES' WELFARE

Employees' Health Care

The employees of DAE organizations, along with their family members, are beneficiaries of the Central Health Service Scheme (CHSS) of the Department. The healthcare facilities of CHSS are also extended to the retired employees and their families.

During the year of report, medical facilities under CHSS were extended to the DAE employees and their dependents, by the BARC Hospital through its 13 zonal dispensaries, 2 occupational health centres, pathology and radiology lab, pharmacy, and a 390 bed hospital.

Free Eye operation camp at NAPS

Foundation laying for Aganwadi at Ilayanarkuppam at MAPS

Work on setting up a new dispensary at Kharghar, Navi Mumbai commenced. Mammography facility, Radial Fluro X-ray machine and Computerized Radiography System were installed at the Medical Division of BARC.

Children's Education

The Atomic Energy Education Society (AEES), meets the educational needs of children of the employees of the Department and its constituent orgnisations. AEES currently administers 30 schools/Junior colleges at 15 centres located all over India, and provides education to over 27,000 students.

During the report period, AEES achieved remarkable success in its quest for excellence in academic as well as non-academic areas such as sports, NCC and arts. Several positive measures such as strengthening of infrastructure facilities, enrichment of the school libraries, computer-aided education and improvement of sports facilities and in-service training programmes for the teachers as well as enrichment and educational programmes for the students contributed significantly to the objective of providing quality education

Many students of AEES scored excellent marks in the All India Secondary School Examination-2010. Out of 28 schools, 21 schools produced 100% result, 27% of the students secured A1 Grade and 21% secured A2 Grade and the overall Excellence Index (those who scored more than 60% marks) is 84.53. The pass percentage was 99.46 as compared to 98.96 last year.

The AEES also started adopting the Continuous and Comprehensive Evaluation introduced by CBSE, from Classes I to VIII in all the AEC Schools.

In the All India Senior Secondary Certificate (AISSC) / HSC Examination, held in 2010, the pass percentage for Higher Secondary Examination was 89.21 and the Excellence Index was 66.27. Three schools produced 100% result. Several schools showed a pass percentage of above 90.

A large number of students secured admission in 2010 to professional courses all over the country. Several students bagged the National Talent Search Scholarship awards. One student of AEES emerged successful and attended the coaching camp for International Maths Olympiad. In the National Standard Examination also, the AEES students performed very well.

The 11th AEES Junior Science and Mathematics Olympiad was held in Mumbai in collaboration with the Homi Bhabha Centre for Science Education. The All India Inter AECS/AEJC Science, Social science, Mathematics and Teaching Aids Exhibition 2010 was held at AECS, Kudankulam.

AEES had launched the Talent

On the occasion of Teacher's Day, the Hon'ble President of India giving away the National Award to teachers of AEES for the year 2009-10

Nurture Programme in June 1999 for the benefit of the bright children belonging to socially and economically disadvantaged tribal communities, including rural children residing in the vicinity of AEC Schools. At present there are over 1000 children getting free education. These students also receive a monthly scholarship, medical facilities, school uniforms, books and notebooks.

Orientation programmes were organized to empower the teachers at Indore, Rawatbhata, Hyderabad, Mumbai and Oscom. AEES has decided to train its teachers and groom them to be special educators in order to provide the benefit of their services to those students from AEC Schools in Mumbai and Tarapur who are identified with various kinds of learning disabilities. AEES organized a Short Term Skill Enhancement Programme in 'Management of Learning Disability' to a select group of teachers.

Faculty Improvement Programme was launched to foster the professional development of its staff members through on-going training programmes. An orientation programme was organized for the PETs of all AEC schools and Junior colleges at Kaivalyadhama, Lonavla.

In order to update their knowledge and train them in handling the day-to day office matters efficiently, a five-day training programme for the administrative staff of AEES was planned with the help of the Administrative Training Institute, Mumbai.

AEES offered a two-year off campus programme leading to a Masters Degree in Educational Systems Management (MES) in collaboration with BITS, Pilani for 19 selected staff of AEES.

Six schools of AEES are part of the UK-India Education and Research Initiative (UKIERI) programme. Under this programme, four teachers from Silver Hill School and Village Primary School visited AEES Schools in Mumbai.

AEES has tie-up with the Global Indian Foundation which runs Global Indian International Schools in more than seven countries. 15 students who were the toppers in the Class X Board Examination-2009 from all AEC Schools, visited the Global Indian International Schools at Singapore.

Through Satellite and IT-Enabled Education (SITE), a major component of the ASTER project, AEES seeks to harness the tremendous potential of the multimedia to enhance the quality of education through e-learning. AEES schools are connected through satellite to have both non-interactive and interactive network. The goal of AEES is to eventually launch a state-of-the-art channel of international standards. AEES was allotted a separate bandwidth in the extended C-band by ISRO. The functionality of the ASTER studio and the connectivity to all the centres was established successfully.

Dr. Homi Bhabha Rolling Trophy was awarded to AECS-4, Mumbai for the best overall performance among schools and to AEJC, Mumbai for the best overall performance among junior colleges for the year 2008-2009. The Dr. Vikram Sarabhai Rolling Trophy was awarded to AECS, Indore for being the most progressive school of AEES and to AECS, Kakrapar for being the most progressive junior college of the AEES for the year 2008-2009.

The National Award to teachers for the year 2009-10 was conferred on two staff members of AEES in the primary and secondary categories respectively by the Department of School Education and Literacy, Ministry of Human Resource Development. The awards were given away by the President of India on 5th September 2010. A teacher of , AECS-1, Mumbai was conferred the Abha Goswami Memorial Award for the best Primary teacher among Atomic Energy Central Schools in Mumbai for the year 2009-2010.

The AEES proposed to participate for the Prime Minister's Award for excellence in public administration for the year 2009-2010. The 'Talent Nurture Programme for the underprivileged tribal and rural children: an educational initiative', has been the main focus for the presentation of this award.

The Atomic Energy Junior College, Mumbai received the ISO - 9001:2008 certificate for the year 2009.

A student of Class X, AECS-3, Mumbai was honoured with the prestigious post of Times NIE Star Correspondent, 2010. This is the second consecutive year she was given this prestigious award.

Four students from AECS, Narora, one student from AECS-4, Mumbai and two students from AECS, Kaiga secured ranks in the National Level Science Talent Search Examination organized by the Unified Council.

One student from AECS, Kudankulam secured 46th rank in the final round in the 12th National Science Olympiad in March, 2010. Six students from AECS, Narora, ten students from AECS, Indore and six students from AECS-4, Rawatbhata, secured All India ranks in Level II. One student from AECS, Kaiga, clinched 2nd rank in the National Science Olympiad.

Two students from AECS, Kudankulam, secured 57th & 72nd ranks and fourteen students from AECS-4, Mumbai secured international ranks in the final round in the 3rd International Mathematics Olympiad held in March, 2010 organized by the Science Olympiad Foundation.

Two students of Class X from AECS-4, Rawatbhata were awarded shields for securing 100% marks in the 13th National Mathematics Olympiad Contest 2010 organized by All India Schools Mathematics Teachers Association.

Three students from AECS-2, Mumbai won trophies and certificates in the Art Festival organized by the TIFR. AEES students participated in various sports events at the state and national levels and brought laurels to their respective schools. The Society, in collaboration with the DAE Sports & Cultural Council organized a Summer Sports Coaching Camp for school children.

AEES is planning to continue the Advance Coaching Camp for sports throughout the year. A Sports Complex with international standard sports facilities including swimming pool for aquatic sports, is coming up in Anushaktinagar.

AEES planned to set up Science Parks in all its schools. The first Science Park was set up at Hyderabad and setting up of the second Science Park at Kaiga is progressing. The process of setting up another science park at Turamdih has been initiated.

The broad vision of AEES has made it a committed supporter of special schools and rehabilitation centres for the differently abled. AEES provides financial assistance to SAUSHEELYA at Anushaktinagar, Mumbai, MEHATVA at Kalpakkam and to the special school run at AECS, Indore. AEES is also focusing on 'Community Schooling' and is providing material help to the underprivileged students of neighbouring schools.

DAE SPORTS & CULTURAL ACTIVITIES

The DAE Sports and Cultural Council (S & CC) looks after the promotion of sports and cultural activities among DAE employees and their families located at various units all over India.

During the year of report, the Council pursued its regular progrmmes of activities and introduced a few new initiatives towards achieving this objective.

The XXVI DAE sports & Cultural Meets were organized for twelve different sports and cultural events at twelve different units of DAE at various locations in the country.

A Fair Play Shield is awarded for each event to emphasize the basic objective of these meets. Around 1100 employees took part in the final meets and more than 2000 employees working at about 40 units all over India participated in the selection trials. These meets helped in creation as well as upgradation of playing facilities at host institutions. DAE-S&CC provided mementoes as a token of appreciation and remembrance to the participants and volunteers.

Teams to participate in the national events like bridge, Table Tennis, Badminton etc., were selected during the meet.

The Advanced Coaching Scholarship Scheme instituted for talented children from the summer camps, assisted more than 150 children in pursuing advanced training in various sports like badminton, table tennis, tennis, cricket and others.

The DAE-S&C Council, in association with AEES, conducted Annual Summer Sports Camps at various AEES centres, for promoting sporting

spirit and encouraging sporting talent amongst the school going children of DAE employees. During the report period, about 1500 children participated in the Sports Camps and a few children were selected for the DAE-Advanced Coaching Scholarship Scheme.

The Council also supported local sports meet and tournaments in the games such as table tennis, badminton, lawn tennis and others, to encourage these children.

A promotional Table Tennis Tournament was organized in collaboration with Mumbai District city and suburban TT Association. The tournament had about 500 entries. A number of Council's Scholarship awardees performed extremely well in the tournament. Two of the students won gold and silver medals in youth category.

Over the years, the Advanced Coaching Programme of DAE-S&CC has been instrumental in DAE-employees' children participating in the state and national level competitions. The recent examples are : Km Shammini winning a Silver Medal at the Indian National Women's Table Tennis Team at the Commonwealth Games-2010, and Surya Kumar Yadav selected for the Mumbai Ranji Trophy amd Mumbai Indian Teams.

Under its Health and Fitness activities, "Healthy Living" Programmes and regular yoga activities as well as camps, were organized at different centres at various levels as well as for their family members. Yoga Magazines were supplied to all the AEES schools and different units of DAE. To further encourage Yoga and Fitness, DAE organisations were encouraged and financially supported to set up Fitness Centers for their employees and family members. As a new initiative, DAE-S&CC, in collaboration with BARC Staff Club, organized its first National Yoga Workshop on "Self Discipline, the Key to Quality Life" during February 12-13, 2011 for DAE employees and their family members. A number of extremely eminent doctors and professionals participated in this workshop.

Every year, DAE-S&C Council organizes All India level Painting Competition for school going children of DAE employees. This year, the painting competition was held at AEES center at Mysore.

Under the Nature and Adventure Programme, DAE's Annual All India Trekking Programme "Girisanchar-22" was organized, with the approval of the Indian Mountaineering Federation, at Yana in the Western Ghats range of Uttar Kannada District, Karwar near the Kaiga Atomic Power Plant, Karnataka. About 250 participants in 9 batches with 25 volunteers from the entire DAE, covered a total distance of about 80 km.

To inculcate camaraderie and love for the mother earth, as well as develop awareness of natural environment amongst children (8-13 years) of DAE Employees, the 2nd Nature and Adventure Camp was held at Khireshwar, Harischandragad, Maharashtra during December, 17-20, 2010. The participating children were engaged in the activities like nature trail, rappelling, valley crossing, rock climbing, hiking, star gazing etc. The programme was conducted by the Nature and Adventure Circle, BARC Staff Club. Another popular programme, the Second Himalayan Trek for Beginners has been scheduled to start on March 31, 2011.

As a part of the infrastructural development and promotional activities, DAE S&CC supported various sports and cultural organizations by way of providing equipment.

Training and participation of the DAE teams in the All India National level Tournaments in Bridge, Table Tennis, Badminton and Ball Badminton, were also organized.

AWARDS & RECOGNITION

NPCIL units received several awards for performance in safety, environment protection and other areas as follows :

TAPS-1&2

- Industrial Safety Shield - 2009-10 of NPCIL
- National Safety Council of India Safety Award -2009 of Ministry of Labour

RAPS-1&2

- Industrial Safety Award-

2009 Jointly with KAPS (Category- Production Units-1) awarded by AERB
- Safety Innovation Award–2009 of Institution of Engineers (India)

RAPS-3&4
- Industrial Safety Runners-Up Shield for the Operating Plants-2008-09 & 2009-10 of NPCIL
- Excellent Performing Station Award -2009-10 of NPCIL

RR site
- ISBTI Appreciation Award-2009 of National Organization on Blood Transfusion Medicine (ISBTI), New Delhi

MAPS
- Good Green Governance Award-2010 (Runners Up) of Environmental Journal SHRISHTI National Safety Council - 2009 Certificate of Appreciation of the National Safety Council of India
- Green Site Award-2009 of AERB

KAPS
- Shreshtha Suraksha Puraskar-2009 of National Safety Council of India Industrial Safety Award for the year-2009 of AERB
- Fire Safety Award - 2009 of AERB
- Excellent Performing Station - 2009-10 of NPCIL
- Gujarat State Safety Award-2008 (Runners up) & Certificate of Honour for lowest disabling injury index, among category-v, group-a of industries in Gujarat State, and good performance, from Gujarat Safety Council

KGS-1&2
- Suraksha Puraskar-2009 of National Safety Council, Mumbai

KGS-3&4
- Industrial Safety Award - 2009 of AERB
- NPCIL's Award for Implementation of Official Language for the 12th consecutive year.

Heavy Water Plant

Heavy Water Plant-Manuguru has won the National Level Safety Award i.e 'Prashansa Patra" from National Safety Council of India for the year-2009.

Heavy Water Plant-Manuguru successfully adopted, implemented and re-certified for the EQMS in line with ISO-9001, ISO-14001 and IS -18001(2007)

Heavy Water Plant-Kota continued to remain certified as ISO 9001, ISO 14001 and IS 18001 company. Recently in June 2010, the plant got recertified for IS 18001 by M/s Bureau of Indian Standards.

HWP, Hazira has obtained IS: 18001 certification from M/s BIS

Two officers of AMD won 'Smt. Mantripragad Sita Devi-Sri Rama Rao Medal' and 'Dr. G. R. Udas -- Dr. K.K. Dwivedi Medal' for their contributions in the field of Geochemistry during the decade (2000-2009).

Two of the IMS's faculty members were elected Fellows of the Indian Academy of Sciences.

CHAPTER : 11

IMPLEMENTATION OF PERSONS WITH DISABILITIES (EQUAL OPPORTUNITIES, PROTECTION OF RIGHTS & FULL PARTICIPATION) ACT, 1995

The Department of Atomic Energy has a mandate to develop peaceful uses of nuclear energy in areas like power generation and basic research in frontier areas of science and technology. In view of the nature of activities carried out by the Scientific and Technical persons in various Research Centres, Public Sector Undertakings, Industrial Units and Aided Institutions of the Department, this Department is not in a position to implement the provisions of reservation of posts fully as required under the "Persons with Disabilities (Equal Opportunities, Protection of Rights and Full Participation) Act, 1995". Therefore, this Department has already sought exemption for the Units like Heavy Water Boards and Nuclear Power Corporation of India Ltd. From the provisions of the said Act. No specific scheme under plan projects for the benefit of persons with disabilities has been introduced in the Department. In-spite of the constraints, all the Units/PSUs/Aided Institutions have attempted to identify posts, where persons with disabilities could be employed without impairing the activities or causing inconvenience.

The sanctioned strength and number of persons with disabilities in various posts in Group A, B, C & D against 3% vacancies to be reserved for them under Section 33 of the said Act is indicated in the pages that follow.

ANNUAL STATEMENT FOR THE YEAR 2009-10 SHOWING THE REPRESENTATION OF THE PERSONS WITH DISABILITIES IN THE DEPARTMENT OF ATOMIC ENERGY AND ITS UNITS

GROUP	NUMBER OF EMPLOYEES				DIRECT RECRUITMENT							PROMOTION						
					No. of Vacancies reserved			No. of Appointments Made				No. of Vacancies reserved			No. of Appointments Made			
	Total	VH	HH	OH	VH	HH	OH	Total	VH	HH	OH	VH	HH	OH	Total	VH	HH	OH
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
GRP A	9259	0	1	22	0	1	5	235	0	0	5	0	0	0	91	0	0	0
GRP B	11902	30	8	38	0	7	10	212	0	0	7	0	0	0	162	1	0	0
GRP C	10785	50	18	73	2	8	9	234	0	2	2	0	1	1	423	0	2	5
GRP D	148	2	1	3	0	0	0	3	0	0	0	0	0	0	0	0	0	0
TOTAL	32094	82	28	136	2	16	24	684	0	2	14	0	1	1	676	1	2	5

Note: (i) VH stands for Visually Handicapped (Persons suffering from blindness or low vision)

(ii) HH stands for hearing handicapped (persons suffering from hearing impairment)

(iii) OH stands for Orthopadically Handicapped (Persons suffering from locomotor disability or cerebral palsy)

ANNUAL STATEMENT FOR THE YEAR 2009-10 SHOWING THE REPRESENTATION OF THE PERSONS WITH DISABILITIES IN THE PUBLIC SECTOR UNDERTAKINGS

GROUP	NUMBER OF EMPLOYEES				DIRECT RECRUITMENT							PROMOTION						
					No. of Vacancies reserved			No. of Appointments Made				No. of Vacancies reserved			No. of Appointments Made			
	Total	VH	HH	OH	VH	HH	OH	Total	VH	HH	OH	VH	HH	OH	Total	VH	HH	OH
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
GRP A	6783	5	1	29	5	4	2	241	1	0	2	0	0	0	12	0	0	1
GRP B	5842	4	3	29	2	0	3	170	1	0	2	0	0	0	13	0	0	0
GRP C	7618	6	13	42	1	0	0	87	0	0	0	0	0	1	45	0	0	1
GRP D	3278	1	1	8	1	1	0	4	0	0	0	0	0	0	1	0	0	0
TOTAL	23521	16	18	108	9	5	5	502	2	0	4	0	0	1	71	0	0	2

ANNUAL STATEMENT FOR THE YEAR 2009-10 SHOWING THE REPRESENTATION OF THE PERSONS WITH DISABILITIES IN THE AIDED INSTITUTIONS

GROUP	NUMBER OF EMPLOYEES				DIRECT RECRUITMENT							PROMOTION						
					No. of Vacancies reserved			No. of Appointments Made				No. of Vacancies reserved			No. of Appointments Made			
	Total	VH	HH	OH	VH	HH	OH	Total	VH	HH	OH	VH	HH	OH	Total	VH	HH	OH
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
GRP A	980	2	1	4	3	3	3	53	0	0	0	0	0	0	0	0	0	0
GRP B	2854	4	0	12	1	1	2	53	0	0	0	0	0	0	0	0	0	0
GRP C	1375	2	1	19	2	0	1	43	1	0	1	0	0	0	0	0	0	0
GRP D	1181	1	7	11	0	1	0	25	0	0	0	0	0	0	0	0	0	0

CHAPTER : 12

CITIZEN'S CHARTER

CHAPTER : 12

CITIZEN'S CHARTER

I) OUR VISION

The vision of the Department of Atomic Energy is to empower India through technology, creation of more wealth and providing better quality of life to its citizen. This is to be achieved by making India energy independent, contributing to provision of sufficient, safe and nutritious food and better health care to our people through development and deployment of nuclear and radiation technologies and their applications.

II) OUR CLIENTS

- User Ministries/Departments of Central Govt. and State Govt. dealing with energy, agriculture, food, health, education, oil and petroleum, industry, science and technology etc.
- Quasi Govt. Organisations, NGOs, industrial organizations, educational institutes.
- Electricity Boards, Hospitals, Research / Medical / Educational / Academic Institutions, agriculturists etc.

III) OUR ACTIVITIES

The Department is engaged in the design, construction and operation of nuclear power / research reactors and the supporting nuclear fuel cycle technologies covering exploration, mining and processing of nuclear minerals, production of heavy water, nuclear fuel fabrication, fuel reprocessing and nuclear waste management. It is also developing advanced technologies which contribute to the national prosperity. The human resource developed and technical services being rendered by the Department have been greatly helping the Indian industry.

The Department is also developing better crop varieties, techniques for control/eradication of insects thus protecting the crops, radiation based post harvest technologies, radiation based techniques for diagnosis and therapy of disease particularly cancer, technologies for safe drinking water, better environment and robust industry.

IV) MANDATE

The mandate of the Department, on which its programmes are based, covers :

- Increasing share of nuclear power through deployment of indigenous and other proven technologies, along with development of fast breeder reactors and thorium reactors with associated fuel cycle facilities ;
- Building and operation of research reactors for production of radioisotopes and carrying out radiation technology applications in the field of medicine, agriculture and industry;
- Developing advanced technologies such as accelerators, lasers, supercomputers, advanced materials and instrumentation, and encouraging transfer of technology to industry;
- Support to basic research in nuclear energy and related frontier areas of science; interaction with universities and academic institutions; Support to research and development projects having a bearing in DAE's programmes, and international cooperation in related advanced areas of research, and
- Contribution to national security.

V) DAE PROGRAMMES RELATING TO THE NATIONAL COMMON MINIMUM PROGRAMME

HIGH POTENTIAL DOMAINS FOR DEVELOPMENTAL APPLICATIONS

AGRICULTURE

Enhanced production of oilseeds and pulses

EDUCATION, HEALTH

- Homi Bhabha National Institute (HBNI)
- National Initiative on Undergraduate Science (NIUS)
- Countrywide Services in Cancer through Telemedicine

FOOD & NUTRITION SECURITY

Radiation Processing of Food & Agro Products

WATER RESOURCES

Desalination in water scarcity areas along the sea coast

ENERGY SECURITY

Electricity supply in near and long term ensuring long term sustainable development.
Rule of Nuclear Power as Primary Energy Source in the years to come.

VI) WHOM TO CONTACT

I. Public Grievance and complaints

Shri A.P. Joshi,
Additional Secretary, Public Grievances Officer & Chief Vigilance Officer, Department of Atomic Energy,
Anushakti Bhavan, C.S.M. Marg, Mumbai-400 001.

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apj@dae.gov.in

II. Public Relations

Shri S.K. Malhotra,
Head, Public Awareness Division, Department of Atomic Energy,
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Tel.No. 022-22823144
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Government of India
Department of Atomic Energy
Anushakti Bhavan, C.S.M. Marg,
Mumbai - 400 001

NOTICE

WE, THE PUBLIC SERVANTS OF INDIA DO HEREBY SOLEMNLY PLEDGE THAT WE SHALL CONTINUOUSLY STRIVE TO BRING ABOUT INTEGRITY AND TRANSPARENCY IN ALL SPHERES OF OUR ACTIVITIES. WE ALSO PLEDGE THAT WE SHALL WORK UNSTINTINGLY FOR ERADICATION OF CORRUPTION IN ALL SPHERES OF LIFE. WE SHALL REMAIN VIGILANT AND WORK TOWARDS THE GROWTH AND REPUTATION OF OUR ORGANISATION. THROUGH OUR COLLECTIVE EFFORTS, WE SHALL BRING PRIDE TO OUR ORGANISATIONS AND PROVIDE VALUE BASED SERVICE TO OUR COUNTRYMEN. WE SHALL DO OUR DUTY CONSCIENTIOUSLY AND ACT WITHOUT FEAR OR FAVOUR.

THIS OFFICE IS THUS COMMITTED TO MAINTAINING THE HIGHEST LEVEL OF ETHICS IN ITS WORKING TOWARDS ACHIEVING THE ABOVE OBJECTIVE, ALL ARE REQUESTED :

- NOT TO PAY BRIBE
- IF ANYBODY IN THIS DEPARTMENT OR ITS OFFICES ASKS FOR BRIBE OR
- IF YOU HAVE ANY INFORMATION ON CORRUPTION OR IF YOU ARE A VICTIM OF CORRUPTION IN ANY OF OUR OFFICES.

YOU MAY COMPLAIN TO :-

Shri A.P. Joshi,
Additional Secretary,
Public Grievances Officer & Chief Vigilance Officer,
Department of Atomic Energy,
Anushakti Bhavan, C.S.M. Marg,
Mumbai-400 001.

YOU MAY ALSO COMPLAIN TO THE :-

CENTRAL VIGILANCE COMMISSION,
SATARKTA BHAWAN, BLOCK 'A',
GPO COMPLEX, INA,
NEW DELHI 110 023.

ANNEXES

ANNEX-I

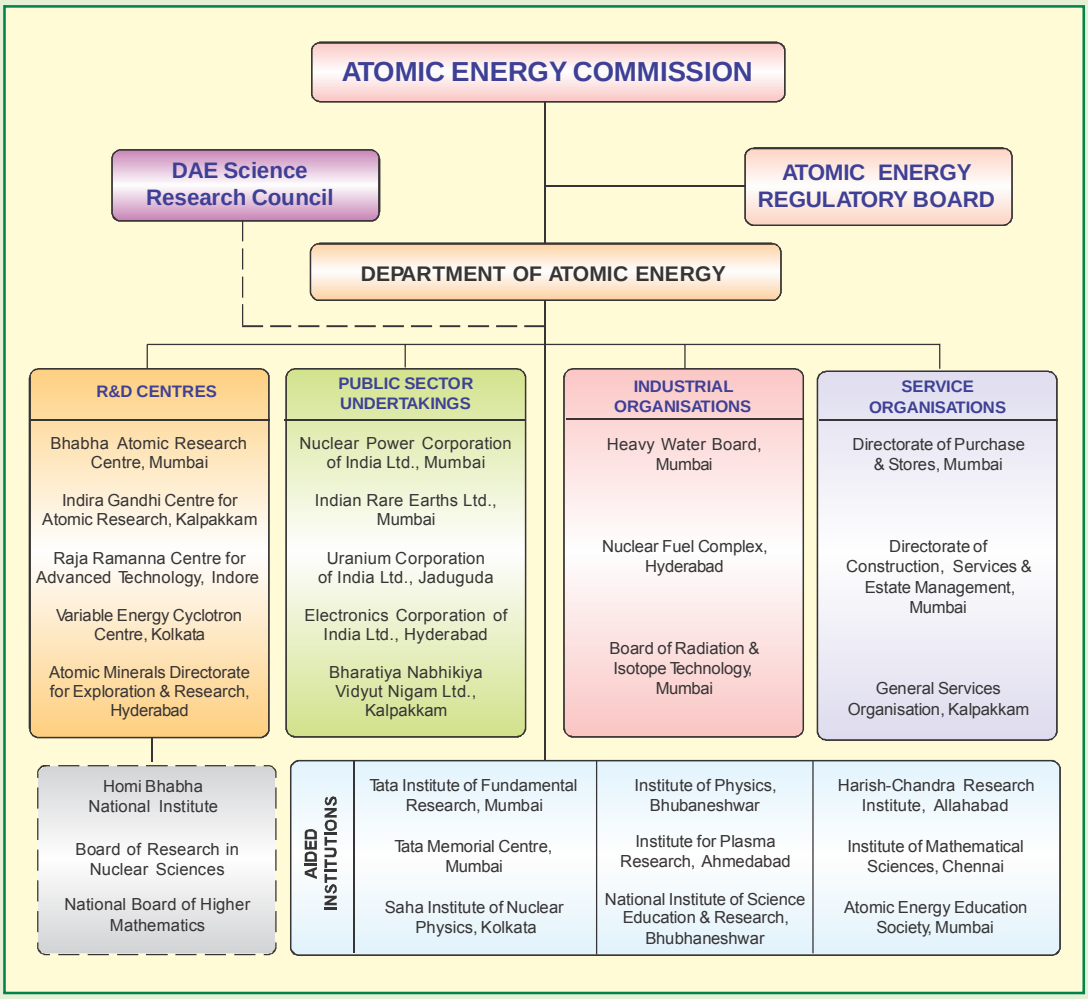
THE ORGANISATION

THE ORGANISATION

The Department of Atomic Energy (DAE), that came into being on August 3, 1954, has been engaged in the development of nuclear power technology, applications of radiation technologies in the fields of agriculture, medicine, industry, and basic research.

As integrated group of organizations, the Department comprises five Research Centres, three Industrial Organisations, five Public Sector Undertakings and three Service Organisations. It has under its aegis two Boards for promoting and funding extra-mural research in nuclear and allied fields, and mathematics, and a national institute (deemed university).

It also supports eight institutes of international repute engaged in research in basic sciences, astronomy, astrophysics, cancer research and education, etc., and a society that provides educational facilities to the children of DAE employees. The organizational structure of the Department is given below.



Major Programmes and Sub-Programmes

MP 1		MP 2		MP 3		MP 4		MP 5		MP 6		MP 7	
1.01	PHWR	2.01	Fast Reactors	3.01	Advanced Heavy Water Reactor	4.01	Research Reactors	5.01	Mathematics & Computational Sciences	6.01	Human Resource Development	7.01	Infrastructure
1.02	LWR	2.02	Materials	3.02	Thorium Fuel Cycle	4.02	Isotope Processing	5.02	Physics	6.02	Sponsored Research	7.02	Housing
1.03	Front End Fuel Cycle	2.03	FBR-Front End Fuel Cycle	3.03	Other Thorium Reactor Systems	4.03	Agriculture	5.03	Chemistry	6.03	Prospective Research Fund		
1.04	Back End Fuel Cycle	2.04	FBR-Back End Fuel Cycle	3.04	Accelerator Driven Sub-critical Systems	4.04	Food Processing	5.04	Biology	6.04	Homi Bhabha Centre for Science Education		
1.05	Health, Safety & Environment	2.05	Repair and Inspection Technologies	3.05	Materials	4.05	Health	5.05	Cancer	6.05	Information Technology Application Development		
1.06	PHWR	2.06	FBR-Health, Safety & Environment	3.06	Hydrogen Energy	4.06	Water	5.06	Synchrotrons & their Utilisation				
				3.07	Fusion Reactor	4.07	Industrial Applications	5.07	Cyclotrons & their Utilisation				
						4.08	Accelerators	5.08	Fusion & Other Plasma Technologies				
						4.09	Lasers	5.09	Material Science				
						4.10	Special Materials	5.10	Interdisciplinary Areas				
						4.11	Advanced Technologies	5.11	International Research Collaborations				
						4.12	Special Programmes						

MAJOR PROGRAMMES

MP-1 : Nuclear Power Programme-Stage-1
MP-2 : Nuclear Power Programme-Stage-2
MP-3 : Nuclear Power Programme-Stage-3 and beyond
MP-4 : Advanced Technologies and Radiation Technologies and their Applications
4A : Advanced Technologies and their Applications (Includes sub-programmes 4.01, 4.08 to 4.12)
4B : Radiation Technologies and their Applications (Includes sub programme 4.02 to 4.07)
MP-5 : Basic Research
MP-6 : Research Education Linkages
MP-7 : Infrastructure & Housing

Atomic Energy Establishments in India

ANNEX-II

REPLY TO AUDIT OBSERVATION

REPORT OF THE COMTROLLER AND AUDITOR GENERAL OF INDIA FOR THE YEAR ENDED 31 MARCH 2009-NO.13 OF 2010-11 (PERFORMANCE AUDIT) SCIENTIFIC DEPARTMENTS

Performance Audit of Procurements of Stores and Inventory Management in the Department of Atomic Energy

The major audit findings are as follows:

Computerization of purchase and Stores functions

Even after 10 years of decision to computerize the purchase, stores and accounting functions, DAE could not ensure implementation of a state-of-the-art e-procurement and material management system in its purchase and stores units. The computerization efforts made were not systematic and planned as it did not follow the normal stages of the System Development Life Cycle such as design phase, development/testing phase and delivery/transition phase. As a result the system developed suffered from many design and implementation deficiencies. The standalone systems implemented in various purchase and stores units were not integrated with each other, resulting in duplication of efforts and decreased effectiveness. DAE being in the forefront of technology, needs to take advantage of Information Technology tools in order to increase the efficiency of its procurement and inventory management functions.

Timeliness of procurement

We observed that no time frames were prescribed for single tender procurements less than Rs. 50 lakh. We further observed that around 11 per cent of the procurements were delayed beyond the prescribed timeframes and the delays in processing Purchase Orders ranged upto 54 months. The delays caused additional financial liability for DAE.

Planning for procurement

There was no system of preparation of annual procurement plans to make the planning for procurement more systematic and efficient. In 39 per cent of the cases test-checked, we observed that many purchase cases were processed in a routine manner without taking cognizance of the urgency of requirements of indentors. We also observed large variations between the costs projected in indents and the value of Purchase Orders and non-clubbing of requirements; all of which highlighted deficiencies in the planning process.

Competitiveness and objectivity in the tendering

As 94 percent of its procurements were based on restrictive mode of tendering (single/limited tenders), the procurement process of DAE could achieve only limited competition. Restrictive mode of tendering on grounds of urgency of requirement was resorted to without ensuring matching subsequent actions such as prompt processing of tenders, availability of site, effective coordination in ensuring timely installation/commissioning of equipment etc., which defeated the very purpose of adopting restrictive mode of tendering.

Contract management

Contract management in DPS was observed to be deficient as 17 percent of Purchase Orders had not

materialized ever after six years of their scheduled delivery dates and huge advance payments were lying unadjusted for long periods. Liquidated damages were not levied in spite of significant delays by the suppliers. There was no effective means of monitoring high value orders resulting in inordinate delays in execution of orders and additional financial burden.

Post contract management

Post contract management was lax as prompt and effective action was found wanting in 22 percent of cases amounting to Rs. 125.60 crore test checked in audit as there were delays in installation, commissioning and acceptance of machinery/equipment. Further, non installation / commissioning of machinery/equipment valuing Rs. 76,81 crore was due to non availability of site, improper site selection, non completion of certain functional tests etc., resulted in non-utilisation of equipment for the intended objectives apart from blockage of Government funds.

Inventory management

Inventory management was neither effective nor in adherence with the prescribed procedure. There were instance of excessive procurement which were not need based. Further, annual review of stock was not conducted regularly, surplus items were not being identified periodically and discrepancies in the stock verification reports were also not being promptly reconciled.

Purchase and Stores procedures

The Purchase and Stores procedures were not regularly updated. Piecemeal instructions were issued from time to time which were not consolidated and incorporated in the procurement procedure. This led to significant deviations from the prescribed procedures, arbitrariness / delays in procurement and inefficient inventory management.

As a result of Performance Audit, our major recommendations are given below:

Computerisation of purchase and stores functions

- Online connectivity may be provided across all DAE units to maintain uniformity among all purchase and stores units. All purchase and stores unit need to be integrated to achieve better control between purchase and stores activities.
- Inbuilt online checks and controls may be introduced to ensure accuracy and security of database.

Timeliness of procurement

- DAE must put in place a proper oversight mechanism to ensure that timeframe prescribed for processing and finalization of tenders is strictly adhered to by various procurement agencies of DAE.

Planning for procurement

- Annual procurement plans may be prepared and communicated to the purchase units consolidating requirements in advance to avoid delays and repetitive procurements thereby maximizing value for money.
- The POs should be placed in time to ensure supplies by the delivery schedules specified in the indents. Requirements raised on 'urgent', 'priority', 'immediate' basis etc., may be expressed in terms of specific timeframes for better procurement planning.

Competitiveness and objectivity in the tendering process and award of contracts

- Proposals seeking dispensation of normal mode of tendering on grounds of urgency could be backed by a

certificate of readiness of site or commitment for readiness of site by a specified date and other requirements to ensure justification of such an action.

Contract management

- DAE may discontinue the practice of granting interest free advances to suppliers in compliance to CVC guidelines and adopt a uniform policy across its various procurement units with regard rate of interest to be charged on such advances. Long outstanding advances against the suppliers may be reviewed and a time bound plan of action may be drawn up to settle them.
- DAE may like to revisit its provisions for refixing of delivery schedules as the new manual now gives legal sanction to refixing of delivery schedules due to purely departmental reasons. This will have a cascading effect not only on project schedules but also on financial implications of projects.

Post contract management

- Given the fact that installation /commissioning of a large number machinery/equipment get delayed due to reasons like non-readiness of site etc., DAE may direct its indenting officers to lay down specific timeframes for installation/commissioning of machinery/equipment.
- Provisions may also be incorporated in the purchase orders / contracts by making the suppliers responsible for defective/short supplies etc., in order to safeguard the Government interests.

Inventory management

- A mechanism may be put in place so that procurements are made only on the basis of assessed actual requirement.
- Annual review of all the stores units may be conducted to determine surplus items.
- Regular updating and posting of information on surplus items may be done in a way that the indentors are able to view them before raising the requirements.

Purchase and Stores procedures

- DAE procurement procedure may be reviewed and suitably amended/modified to address deficiencies and make it consistent with the provisions of the new General Financial Rules, 2005.

ANNEX-III

REPRESENTATION OF SCs, STs AND OBCs

ANNUAL STATEMENT FOR THE YEAR 2009-10 SHOWING THE REPRESENTATION OF SCs, STs AND OBCs IN THE DEPARTMENT OF ATOMIC ENERGY AND ITS UNITS

	Number of Employees				Number of appointments made during the previous calendar year									
					By Direct Recruitment				By Promotion			By other methods		
	Total	SCs	STs	OBCs	Total	SCs	STs	OBCs	Total	SCs	STs	Total	SCs	STs
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
GRP A	9259	453	75	376	334	5	1	35	373	35	10	19	1	1
GRP B	11902	2209	672	1422	241	45	14	98	418	91	21	10	2	0
GRP C	10785	2208	1181	2057	439	42	32	316	579	115	65	9	0	0
GRP D	101	40	8	27	7	3	1	2	0	0	0	0	0	0
GRP E	47	24	2	10	0	0	0	0	0	0	0	0	0	0
TOTAL	32094	4934	1938	3892	1021	95	48	451	1370	241	96	38	3	1

ANNUAL STATEMENT FOR THE YEAR 2009-10 SHOWING THE REPRESENTATION OF SCs, STs AND OBCs IN THE PUBLIC SECTOR UNDERTAKINGS

	Number of Employees				Number of appointments made during the previous calendar year									
					By Direct Recruitment				By Promotion			By other methods		
	Total	SCs	STs	OBCs	Total	SCs	STs	OBCs	Total	SCs	STs	Total	SCs	STs
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
GRP A	6783	659	162	585	270	30	7	51	726	114	26	13	1	0
GRP B	5842	984	356	946	173	26	20	55	670	158	59	1	0	0
GRP C	7618	1387	1010	1789	141	33	12	79	1266	189	50	0	0	0
GRP D	3093	317	1136	575	16	2	0	10	21	5	3	0	0	0
GRP E	185	117	1	16	0	0	0	0	15	5	0	0	0	0
TOTAL	23521	3464	2665	3911	600	91	39	195	2698	471	138	14	1	0

ANNUAL STATEMENT FOR THE YEAR 2009-10 SHOWING THE REPRESENTATION OF SCs, STs AND OBCs IN THE AIDED INSTITUTIONS

	Number of Employees				Number of appointments made during the previous calendar year									
					By Direct Recruitment				By Promotion			By other methods		
	Total	SCs	STs	OBCs	Total	SCs	STs	OBCs	Total	SCs	STs	Total	SCs	STs
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
GRP A	980	31	5	59	90	1	1	10	6	1	0	0	0	0
GRP B	2854	358	78	381	131	19	6	52	21	3	0	0	0	0
GRP C	1375	279	74	242	52	8	3	12	1	0	1	1	1	0
GRP D	945	210	35	141	17	11	1	2	0	0	0	0	0	0
GRP E	236	215	3	7	8	7	0	0	0	0	0	2	0	0
TOTAL	6390	1093	195	830	298	46	11	76	28	4	1	3	1	0

ABBREVIATIONS

ADS	Accelerator Driven Sub-critical System
AES	Atomic Emission Spectrometer
AGRS	Air-borne Gamma-Ray Spectrometry
AGSS	Aerial Gamma Spectrometric System
ALARA	As Low As Reasonably Achievable
CCCM	Centre for Compositional Characterisation of Materials
CCRM	Coolant Channel Replacement Machine
CERN	Organisation Européenne pour la Recherche Nucléaire
CHTR	Compact High Temperature Reactor
CORAL	COmpact Reprocessing facility for Advanced fuels in Lead cells
CWMF	Central Waste Management Facility
DFRP	Demonstration Fast Reactor Reprocessing Plant
DSRDM	Diverse Safety Rod Drive Mechanism
ECCS	Emergency Core Cooling System
ECR	Electron Cyclotron Resonance
ECRH	Electron Cyclotron Resonance Heating
EMF	Electro-motive force
ERDS	Emergency Response Data System
ESL	Environmental Survey Laboratory
FBTR	Fast Breeder Test Reactor
FDG	Fluoro deoxy glucose
FFLM	Failed Fuel Location Module
FRFCF	Fast Reactor Fuel Cycle Facility
HPU	Health Physics Unit
HWP	Heavy Water Plant
IAEA	International Atomic Energy Agency
ICP-MS	Inductively Coupled Plasma Mass Spectrometer
ICRH	Ion Cyclotron Resonance Heating
ICRP	International Commission on Radiological Protection
IERMON	Indian Environmental Radiation Monitoring Network
IPIG	Instrumented Pipe-line Inspection Gauge
IRMA	Immunoradiometric Assay
ISI	Inservice Inspection
ITER	International Thermo-nuclear Experimental Reactor
KARP	Kalpakkam Fuel Reprocessing Plant
keV	Kilo Electron Volt
kV	Kilo Volt
LBS	Laser Blow-off System
LCTR	Large Component Test Rig
LHC	Large Hadron Collider
LINAC	Linear Accelerator
LTVE	Low Temperature Vacuum Evaporation
mCi	Million Curies
MeV	Million Electron Volt
MIBG	Meta Iodo-Benzyl Guanidine
MoU	Memorandum of Understanding
MOX	Mixed Oxide Fuel
MSF-RO	Multi-Stage Flash Reverse Osmosis
MWD/Te	Mega watt day per tonne
MWe	Mega Watt (electrical)
MWt	Mega Watt (thermal)
NDT	Non-Destructive Technique
PCS	Process Control System
PHWR	Pressurised Heavy Water Reactor
PREFRE	Power Reactor Fuel Reprocessing Plant
PDSC	Project Design & Safety Committee
QC/QA	Quality Control / Quality Assurance
QGP	Quark Gluon Plasma
QMS	Quadrupole Mass Spectrometer
R&M	Renovation & Maintenance
RAPS/P	Rajashtan Atomic Power Station / Project
REE	Rare Earth Elements
RFQ	Radio Frequency Quadrupole
RFID	Radio Frequency Identification
RIA	Radioimmuno-assay
RIB	Radioactive Ion Beam
RIMS	Resonance Ionisation Mass Spectroscopy
RIP	Repository for Immobilised Waste Product
RMC	Radiation Medicine Centre
RO	Reverse Osmosis
RRMC	Regional Radiation Medicine Centre
RRS	Reactor Regulating System
SCADA	Supervision Control & Data Acquisition System
SECC	Site Emergency Control Centre
SODAR	Sound Detection and Ranging
SQUID	Super-conduction Quantum Interference Device
SRS	Synchrotron Radiation Source
SSMS	Spark Source Mass Spectrometry
TAPS	Tarapur Atomic Power Station
TBP	Tributyl Phosphate
TDEM	Time Domain Electromagnetic
Th,Pu	Thorium, Plutonium
TLD	Thermo Luminescence Detector
tpd	Tonnes Per Day
U/Th-Mo-O	Uranium/Thorium-Molybdenum-Oxygen
UHF	Ultra High Frequency
U-Zr-O	Uranium Zinconium Oxygen
VSAT	Very Small Aperature Terminal
WDXRF	Wave Dispersion X-Ray Fluorescence
XRF	X-ray Radio Frequency

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