MILESTONE 2004-2005

During the year 2004-05, the Department of Atomic Energy (DAE), that came into being on August 3, 1954, set many landmarks in the domain of its mandate that focuses on the development of nuclear power technology, applications of radiation technologies in the fields of agriculture, medicine, industry and research.

NUCLEAR POWER PROGRAMME – STAGE-1: PRESSURISED HEAVY WATER REACTOR & LIGHT WATER REACTOR

The Nuclear Power Corporation of India Ltd.(NPCIL), a public sector undertaking of DAE, is responsible for the design, construction and operation of nuclear power reactors. The Company operates fourteen reactors (two boiling water reactors and twelve pressurised heavy water reactors) with a total capacity of 2770 MWe. In addition, NPCIL is also engaged in construction of eight nuclear power reactors including six pressurised heavy water reactors and two light water reactors, totaling 3960 MWe capacity.

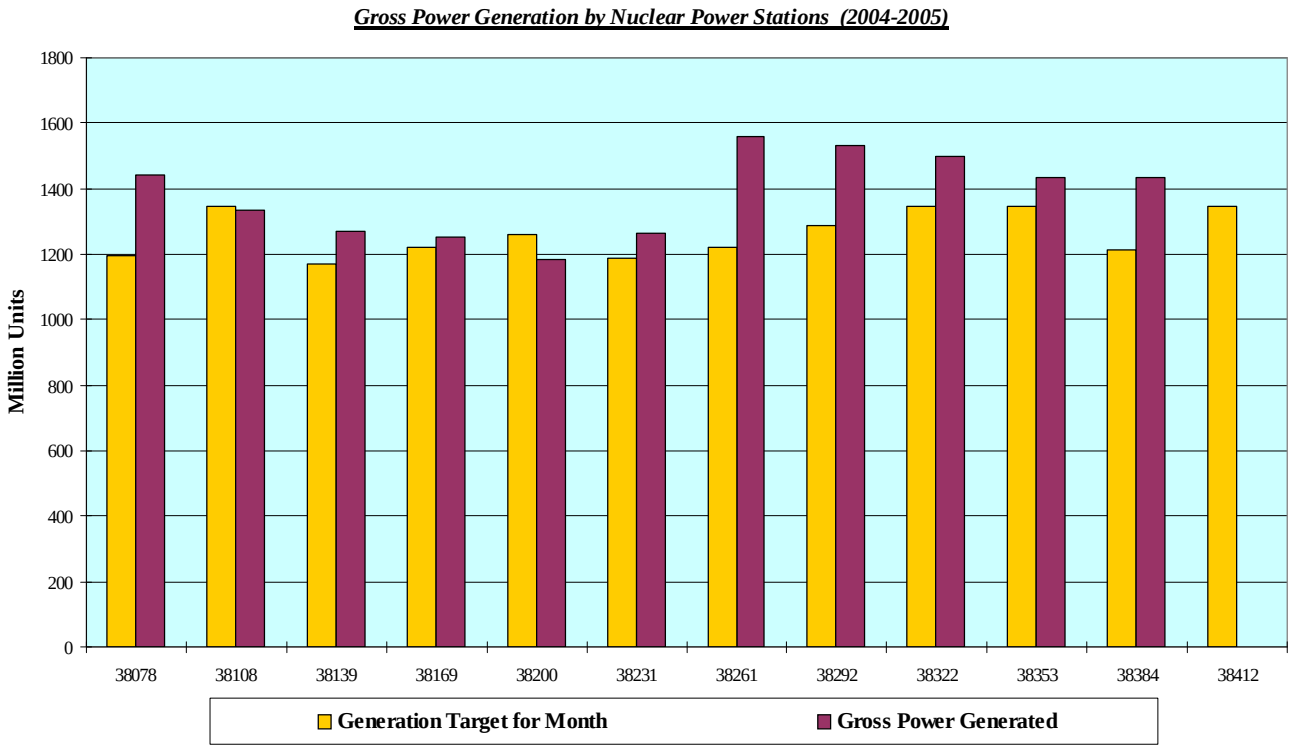
Nuclear Power Generation

Generation of electricity from nuclear power plants was 16,531 million units (MUs) during the calendar year 2004, and during the financial year 2004-05, till December 2004, it was 12,147 MUs as compared to a target of 11,235 MUs. In addition, 303 MUs were generated from the first unit of Rajasthan Atomic Power Station, which is owned by DAE and operated by NPCIL. The generation for the full year 2004-05 is expected to be about 16,500 MUs.

Unit-2 of Narora Atomic Power Station (NAPS) established record of 'Longest Continuous Operation' of 272 days. Continuous operation of 238 days was also achieved for the Units 1&2 of NAPS. Refueling of Unit 1 of Tarapur Atomic Power Station was accomplished in 26 days.

Nuclear Power Projects under construction

The construction work on two units of 540 MWe each (TAPP-3&4) PHWRs at Tarapur, Maharashtra reached advanced stage. This is the largest indigenously designed



Total Gross Generation target for year is 15143 Million Units (MUs)
Actual Generation to date is about 15201 MUs

and built nuclear power reactor in the country. The unit TAPP-4 achieved criticality on March 6, 2005. The gestation period of about 50 months from the first pour of concrete is now comparable to the best in the world. The TAPP-3 unit is expected to be commissioned during 2005-06.

The work on Kudankulam Nuclear Power Project (KKNPP-1&2) was in full swing. A total of 6.3 lakh cu.m of concreting out of a total of 9.5 lakh cu.m was completed for the project upto December 2004. The receipt of Reactor Pressure Vessel for Unit-1 at site on January 13, 2005 signified achievement of a major milestone of the project. Other major equipment were also received at site. The work is progressing fast for completion of the first and second units in the year 2007/ 2008.

The construction work on the two units of 220 MWe each (Kaiga-3&4) PHWRs at Kaiga, Karnataka was progressing well. The overall physical progress was 57% as on December-2004.

The construction work on the two units of 220 MWe each (RAPP-5&6) PHWRs at Rawatbhata, Rajasthan, was also progressing well. The project work reached an overall physical progress of 48% as of December-2004.

Research and technology development relating to PHWR

BARC continued with its R&D support to the nuclear power programme. During the report period, it developed a number of equipment, tools and techniques that included:

- Commissioning of Fault Tolerant Process Control System for 540 MWe PHWRs at Tarapur, Liquid Zone Control System and Channel Temperature Monitoring System for PHWRs;
- Development of Sludge Lancing Equipment, and Full Bore Leak Arresting Device that was supplied to Narora Atomic Power Station and Rajasthan Atomic Power Station as part of contingency preparedness during inspection of coolant channels using BARCIS;
- Development and commissioning of fuelling machine

Tarapur Atomic Power Project-3&4

Reactor Building of Kaiga Atomic Power Project-3&4

Reactor Building of Unit-1 of Kudankulam Atomic Power Project

Unit-5 of Rajasthan Atomic Power Project-5&6

test facility control system, PHWR fuel handling system training simulator at Nuclear Training Centre, Kaiga, and - Modification of channel health monitoring system BARCIS (BARC Channel Inspection System) to include remote operation and control, that was supplied to KAPS, and modification of ROHYTAM device to include remote wireless control facility.

A flux mapping system for TAPS-3&4 has already been shipped to the site.

The control mechanisms for Adjuster Rods, Control Rods and Shut-off Rods of TAPP-3&4 based on BARC design, were manufactured. These have recorded satisfactory performance.

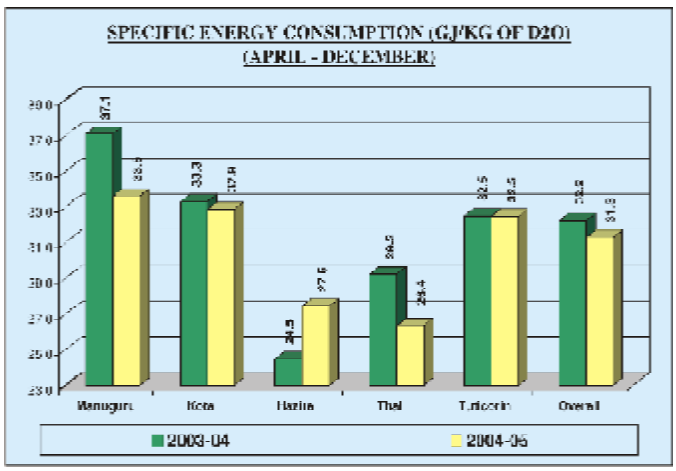
The pilot plant facility for production of detector grade enriched Boron (^{10}B) at Talcher was running satisfactorily and the enrichment of ^{10}B above 90% was achieved from second column. More than 2500 gms of enriched ether complex and 700 gms of BF_3-CaF_2 complex was already produced. 350 gms of the complex was delivered to BARC for using as a source material for neutron detectors.

FRONT END FUEL CYCLE

The Front-End Fuel Cycle of the Nuclear Power Programme constitutes the operations that range from mining, milling and processing of ore, and fabrication of fuel. Heavy water production is an important component of PHWR programme. In a pressurized heavy water reactor, heavy water is used as moderator and coolant.

Heavy Water Production

The **Heavy Water Board**, Mumbai is responsible for design, construction and operation of heavy water plants (HWPs) in the country. The Board operates six heavy water plants. The production, specific energy consumption and safety record of all the operating heavy water plants during the report period were excellent with production



Vapour Absorption Refrigeration

exceeding the scheduled target, and achieving further reduction in production cost.

The commissioning of HWP (Baroda) with Ammonia Water Exchange Front end, as a technology demonstration, was successfully completed. The Plant is producing nuclear grade heavy water. Presently it is operating at about 80% of design capacity. Further optimization to achieve design capacity and energy optimization is in progress.

Implementation of various Energy Conservation (ENCON) Schemes in the heavy water plants at Manuguru, Kota, Hazira, Thal and Tuticorin resulted in a saving of 50 kWh/kg of heavy water.

Mineral Exploration and Mining

The **Atomic Minerals Directorate for Exploration and Research** (AMD) carries out surveys and exploration for the mineral resources.

Exploration activities, for uranium in Proterozoic & Phenorozoic basins, for rare metals in pegmatite belts of eastern and central India and for beach sand heavy minerals in coastal areas, were carried out for augmentation of resources of raw materials required for the atomic energy programmes of the country.

New uranium anomalies were identified and additional uranium reserves were established. Exploratory and evaluation drilling resulted in augmentation of additional resources of uranium at Rohil-Ghateshwar, Sikar district, Rajasthan; Wahkyn, West Khasi Hills district, Meghalaya; Gogi, Gulbarga district, Karnataka; and Koppunuru, Guntur district, Andhra Pradesh.

Uranium Corporation of India Ltd. (UCIL) uses the state-of-the-art technology for mining and processing uranium ore to produce uranium concentrate. During the report period, all the operating units of the company

Northern Arm of Chitrial outlier, to be taken up shortly for subsurface exploration for locating unconformity type uranium deposit, Nalgonda district, Andhra Pradesh.

showed better capacity utilization, and uranium output has gone up. Narwapahar mine produced more than its installed capacity. Turamdih mine was commissioned ahead of schedule. The performance of Jaduguda and Bhatin mines and the Jaduguda processing plant also improved substantially.

UCIL has taken up a massive expansion programme to construct several new mines and plants in different parts of the country.

Fabrication of nuclear fuel and structural components

Nuclear Fuel Complex (NFC), an ISO 9001 organization of DAE, manufactures natural uranium oxide fuel for PHWRs, enriched fuel for PWRs, reactor core structurals, and special materials such as tantalum, niobium, etc.. In addition, NFC produces seamless stainless steel tubes, hexcans and other structurals for fast reactor core assemblies and special alloy tubes. NFC also caters to the demand of high quality stainless tubes and pipes for critical and strategic applications.

NFC successfully completed the fabrication of 37 element fuel bundles for the initial core of 540 MWe PHWR at Tarapur (Tarapur-4). In addition to meeting re-load requirements of the 8 operating PHWRs and 2 BWRs, fuel bundles with depleted uranium were fabricated here. It also manufactured and supplied Zr 2.5% Nb pressure tubes for the 540 MWe PHWR (TAPP-3).

BACK END OF NUCLEAR FUEL CYCLE

The programmes relating to fuel reprocessing and nuclear waste management form the Back-End of the Nuclear Fuel Cycle. BARC and IGCAR are contributing to this segment.

Fuel Reprocessing and Nuclear Waste Management

The report period saw the revamping of PREFRE, Tarapur and spent fuel storage facilities construction at Tarapur and Kalpakkam nearing completion. Various ongoing projects at Tarapur, and, Waste Immobilisation Project at Kalpakkam recorded good progress.

The reprocessing facilities at Trombay, Tarapur and Kalpakkam for spent fuel from research/power reactors were operated. The reprocessing capacities continued to be augmented to meet increasing demands for plutonium as a fuel for fast breeder reactor.

Waste management facilities at the sites operated satisfactorily. Release of radioactivity to the environment was well below the stipulated limits. The high level radioactive liquid waste at Trombay and Tarapur is being processed by vitrification and concentration.

The Tri-Butyl Phosphate (TBP) plant at Talcher was stabilised and successfully synthesized 65 batches of product since its commissioning in mid-2003 meeting international quality standards. The plant has already supplied 35 MT of TBP to the users.

NUCLEAR POWER PROGRAMME – STAGE -2

FAST REACTORS PROGRAMME

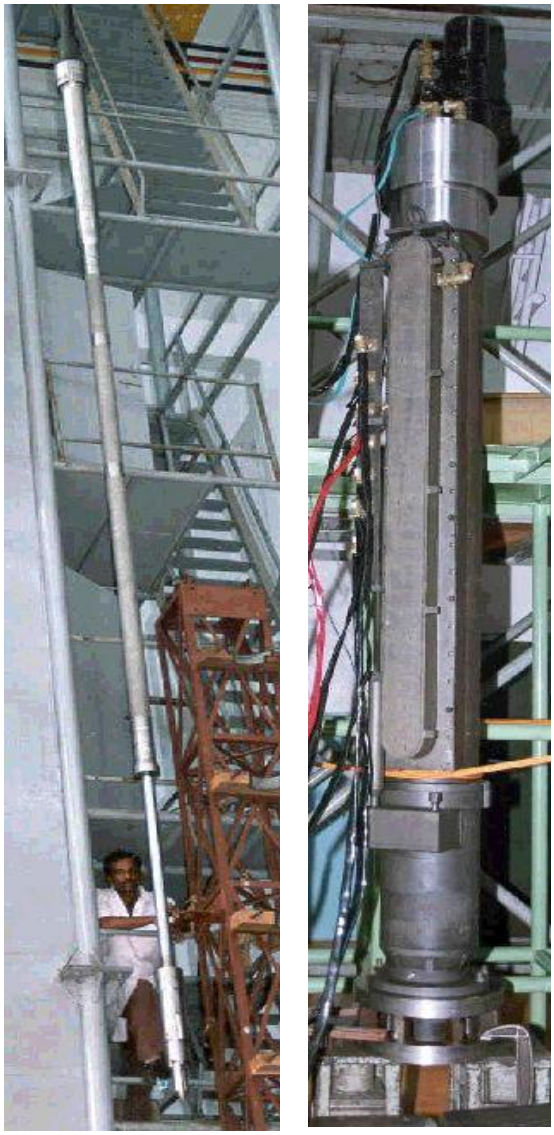
With the aim to meet the growing demand for electricity, the Indira Gandhi Centre for Atomic Research (IGCAR), engaged in the design, development, construction and operation of liquid sodium cooled fast breeder reactors (FBR), has successfully developed the breeder technology and designed 500MWe prototype fast breeder reactor (PFBR). A new public sector company BHAVINI embarked on the construction of this reactor.

Fast Breeder Test Reactor

Fast Breeder Test Reactor (FBTR) has been in operation with indigenously developed U-Pu carbide fuel. The reactor has also generated about 1.2 million units of electricity during the last irradiation campaign, which ended in December 2003. It achieved a fuel burn up of 133,570 MWd/t. Studies have revealed the excellent performance of the fuel and of the high temperature sodium systems.

Prototype Fast Breeder Reactor

From the experience gained in the successful operation of FBTR and the R&D efforts carried out in various disciplines of FBR technology, the Centre designed a pool type, liquid sodium cooled, oxide fuelled 500 MWe



Lower and Upper part of Control and Safety Rod Drive Mechanism

Prototype Fast Breeder Reactor (PFBR), and completed the detailed design of the Nuclear Steam Supply Systems (NSSS) and the Balance of Plant.

The Government of India accorded administrative approval and financial sanction for the construction of the PFBR at Kalpakkam and a new company named "Bharatiya Nabhikiya Vidyut Nigam Limited" (BHAVINI) was formed.

A function to commemorate the launching of the commercial phase of the India's Fast Breeder Programme and the golden jubilee of DAE was held at IGCAR on October 23, 2004.

Site excavation works for the reactor were completed. Specifications and drawings for the manufacture of most of the major reactor components were finalised.

At Trombay, design and development of Inclined Fuel Transfer Machine for PFBR was completed. Shielding experiments (PFBR-Phase III) continued. The periscope for viewing core internals of FBTR was completed.

Fast Reactor Fuel Cycle

Fast Reactor Fuel

Neutron radiography of the fuel pins irradiated to 100,000 MWd/t was completed in the KAMINI reactor. Clearance was obtained to enhance the fuel burn up to 146,500 mega watt day/tonne (MWd/t).

A test fuel subassembly of PFBR composition was fabricated and assembled, and was loaded into FBTR for irradiation. Recently it touched a burn up of 36,560 MWd/t.

Fuel Reprocessing

The Lead Mini Cell, a pilot plant facility for reprocessing of FBTR carbide fuel on lab scale, was commissioned.

The experience thus gained is being utilised for the design of fast reactor fuel reprocessing plant for FBTR fuel and also for demonstration of reprocessing of PFBR oxide fuel.

NUCLEAR POWER PROGRAMME – STAGE -3

BARC, with the aim of utilizing thorium for power generation, is engaged in the development of a 300 MWe Advanced Heavy Water Reactor (AHWR).

Advanced Heavy Water Reactor (AHWR)

At Trombay, the core monitoring system for AHWR was designed. Advanced operator information system for AHWR was under development. Work on the various control instrumentation systems and devices including the software packages for the AHWR progressed as scheduled.

Safety systems for AHWR including control and instrumentation for shut down and emergency core cooling systems were developed.

AHWR thermal hydraulic studies progressed in a scaled up model of advanced accumulator. Design and development work on the fuel transfer machine as well as various channel components for AHWR made progress. Further studies on the thorium fuel studies were being carried out.

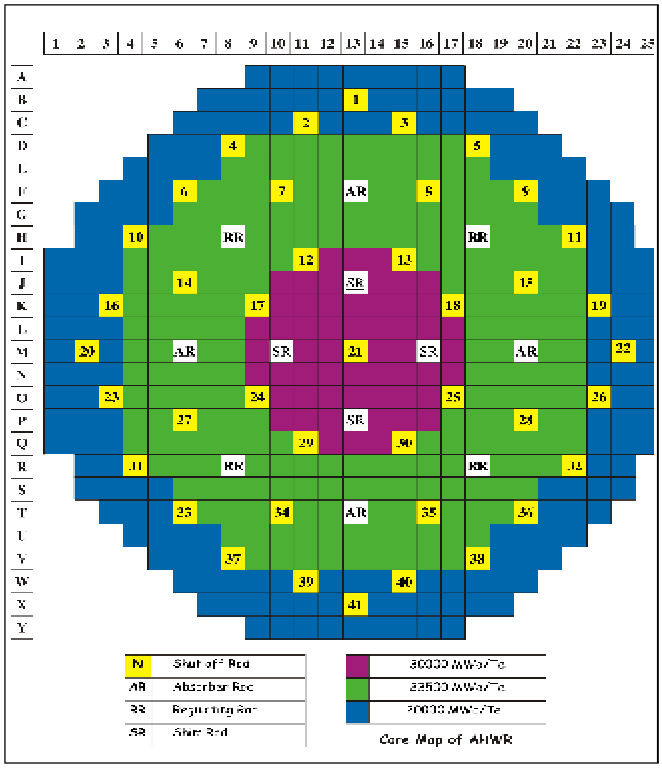
Advanced Reactor Development Programme

Development of a Compact High Temperature Reactor (CHTR) was taken up by BARC. Such system is a compact power pack that can be used in remote

locations. During the report period, thermoelectric devices for CHTR were developed at Trombay.

Accelerator Driven Sub-critical System (ADS) can provide external neutron source to sustain power level in a sub-critical blanket. Such a system can be used to produce several times more electrical energy than that required to run the accelerator. The Department has taken up a long term programme to develop ADS.

Setting up of a Critical Facility for reactor physics experiments of Advanced Heavy Water Reactor (AHWR) and 540MWe PHWR has progressed satisfactorily.



Core Map of AHWR

Critical Facility at BARC

HEALTH, SAFETY AND ENVIRONMENT PROGRAMME

During the report period, all the nuclear power plants and heavy water plants operated safely. All the operating nuclear power plants and heavy water plants now have the ISO environment certificate.

Radiation Protection & Environmental Surveillance

Radiation protection, industrial hygiene services and environmental surveillance activities were carried out by BARC, in and around the operating nuclear fuel cycle facilities of DAE.

Whole Body Monitoring Services to all the radiation workers of nuclear fuel cycle facilities were provided on a regular basis. Radiological safety assessments at the design stage, and Environmental Impact Assessments (EIAs) were carried out for various DAE projects.

A new solar powered Environmental Radiation Monitor system developed at Trombay, will be deployed at all the stations of the Indian Environment Radiation Monitoring Network (IERMON) stations.

CaSO4:Dy based thermo-luminescence dosimeter (TLDs) was modified for environmental radiation dosimetry and a fully automatic TLD reader was developed for reading these dosimeters. An optical fiber based remote radiation dosimeter was made using indigenously developed Optically Simulated Luminescence phosphor.

Quality assurance programme for medical and industrial applications of radiation and radioisotopes, and TLD personnel monitoring service were continued.

The Coordinated Research Project on thermal ecological studies, initiated under the aegis of the Board of Research in Nuclear Sciences (BRNS) during 1999-2000, to generate data in respect of site specific issues pertaining to the nuclear power stations, concluded. The studies showed that the nuclear power plants on coastal sites pose no threat to the thermal ecology.

The Nisarga-Runa technology developed at BARC converts biodegradable solid waste into useful manure and methane. One such plant of 1 tonne/day capacity was installed at Colaba, Mumbai for Indian Navy. Technology for the Biogas plants has been transferred to 12 entrepreneurs.

The Sludge Hygienization Research Irradiator (SHRI) facility at Vadodara produced about 75 tonnes of dry hygienized sludge that underwent assessment under field conditions.

NAPS and Kaiga Generating Station (KGS) won Shreshtha Suraksha Puraskar from the National Safety Council of India. TAPS and NAPS also won the "Green-

tech Safety Gold Award" whereas KAPS, RAPS, KGS and KKNPP-1&2 bagged the "Green-tech Safety Silver Award" by Green-tech Foundation of India, for performance in the field of industrial safety.

RADIATION TECHNOLOGIES AND APPLICATIONS

BARC, BRIT, CAT and VECC are the organisations of DAE engaged in the development of radiation technologies and their applications in the areas of health, agriculture, industry and research. DAE is working in close co-operation with other organisations of the Government of India to widen the reach of these technologies for the benefit of the common man.

Research Reactors

During the report period, research reactors Apsara, Cirus and Dhruva operated satisfactorily with high level of safety and availability. The reactors were well utilized for isotope production, research, material testing and human resource development.

Radioisotopes Production

Isotope production and processing to meet the requirements from various end users continued.

The focus of BARC and BRIT remained on developing new technologies using sealed sources and radiotracers for non-destructive-testing applications, industrial troubleshooting, process optimization, using environmental (stable & radioactive) isotopes for water resources development and management and environmental control; offering consultancy; conducting training courses for human resources development, and carrying out hot cell operations for fabricating high activity Cobalt-60 sources for use in various types of irradiators.

Nuclear Agriculture

The nuclear agriculture programme of BARC covers development of high yielding crop seeds, using nuclear techniques, radiation processing of food items, fertilizer and pesticide related studies, and other areas.

A new Trombay Groundnut variety, TG 37A was released and Gazette notified by the Ministry of Agriculture for commercial cultivation in agro-climatic zone-I and confectionery groundnut variety TPG-41 was released for all India commercial cultivation under *rabi*/ summer situation. The total number of Trombay crop varieties released and notified for commercial cultivation so far has reached 24. The State Seed Committee of

New Groundnut TG 37A variety released for Rajasthan, Punjab, Haryana and Uttar Pradesh

Maharashtra has released a soyabean variety TAMS-38 developed at Trombay for commercial cultivation for Vidharbha region.

Preservation of Food and Hygienization

Work relating to radiation processing of food and agricultural commodities with emphasis on development of new products and applications, was continued. This included developing microbiologically safe meat and fish products with improved shelf-life and quality, preparation of ready-to-eat Indian preparations and hygenization of fresh precut fruits, vegetables and sprouts.

Radiation processing was found to reduce spongy tissue development in Alphonso mango and in controlling caking in tea leaves during storage. Radiation in combination with modified atmosphere storage extended shelf life of cut flowers and florets without affecting their freshness.

KRUSHAK (Krushi Utpadan Sanrakshan Kendra), a technology demonstration unit of BARC, set up at Lasalgaon, near Nashik, Maharashtra, for low dose applications of radiation for food preservation, processes onion, pulses, rawa and turmeric. This facility was operated to process rabi crop of onion.

The capacity utilization and sales performance of BRIT's Radiation Processing Plant at Vashi improved significantly. It is expected to process more than 1500 metric tonnes of spices and allied products during the year 2004-05.

BRIT signed a number of Memorandum of Understandings (MoUs) with private agencies for setting up of Gamma Radiation Processing plants.

The first private sector commercial Gamma Irradiation Plant in the eastern region of the country set up by

M/s Organic Green Foods Ltd, Kolkata was commissioned in August, 2004. Apart from supplying 100kCi Cobalt-60 source, BRIT provided requisite technical guidance and facilitation services to the party from conception stage to the commissioning of the plant. Civil construction work of the plant being set up by M/s Varadan Agrotech at Sonipat, Haryana is nearing completion and M/s A.V.Processors Pvt Ltd have already started civil construction work for their plant at Ambernath, Maharashtra and foundation stone was laid for the plant being set up by M/s Universal Medicap Ltd at Baroda, Gujarat.

Radiation Plant setup at Kolkata by M/s Organic Green Foods

Water Desalination

1.8 million litres/day of potable water from seawater is being produced from the Reverse Osmosis based plant set up by BARC at Kalpakkam. Construction of BARC's another facility here using multi-stage flash distillation process, to produce 4.5 million litres/day, progressed.

To demonstrate seawater desalination using waste heat from a nuclear reactor, the 30 cubic metre/day low temperature evaporation desalination plant was commissioned with Cirus research reactor at Trombay. It is planned to integrate a 500 cubic metre/day seawater desalination plant with AHWR.

The 30,000 litres/day brackish water RO plant installed by BARC in Satlana Village of Jodhpur district, continued to provide safe drinking water to villagers. The technology for online domestic water purifier based on ultrafiltration polysulfone membrane for producing bacteria free safe drinking water was transferred to twelve parties, of which five parties launched their product in the market.

4500 m^3/day Multi-Stage Flash (MSF) Plant under construction at Kalpakkam

BARC is a member of the International Nuclear Desalination Advisory Group (INDAG) of International Atomic Energy Agency (IAEA) for providing advice and guidance on IAEA activities on nuclear desalination and participating in Coordinated Research Projects of IAEA and sharing the expertise with other Member States.

Radioisotopes in health care

Radioisotopes and their formulations find wide applications in diagnosis, therapy and healthcare. BARC supplies reactor produced radioisotopes to BRIT, that produces and supplies radioisotope products including radiopharmaceuticals, immunoassay kits, technetium-99m generators, radiochemicals, labeled compounds, labeled nucleotides, and luminous compounds.

Production and supply of about 40,000 consignments of various types of radioisotopes, equipment and allied products, valued at about Rs. 27 crore is expected by BRIT during 2004-2005.

The Board produced and supplied radioisotope products including radiopharmaceuticals, immunoassay kits, radiochemicals, labeled compounds, labeled nucleotides, luminous compounds, and ^{99m}Tc generators for cancer diagnosis and treatment and also for use as nuclear & biological tools in research institutions. It also produced and supplied sealed radiation sources of ^{60}Co and ^{192}Ir and Blood Irradiator units for use in cancer hospitals. Over 15,300 consignments of radiopharmaceutical and associated products and over 44,500 vials of cold kits of different formulations were supplied to various nuclear medicine centers for diagnostic investigations and therapeutic use.

More than 7500 kits of radioimmunoassay (RIA) and immunoradiometric assay (IRMA) were supplied to about 300 immunoassay laboratories in the country. Supply of ready to use ^{99m}Tc formulations and RIA services were continued at the regional centres for radiopharmaceuticals of BRIT located at Delhi, Bangalore and Dibrugarh. ^{131}I-Hippuran (a radiopharmaceutical product) was produced by the Radiopharmaceutical Laboratory in Kolkata and supplied to medical and biological research institutions there.

The work on development of FT4 RIA based on antibody coated tubes was completed and was ready for supply.

Radiation Equipment

Three units of new Blood Irradiator (BI 2000) were supplied by BRIT for use in hospitals and research institutions.

Prototype units of ^{137}Cs and ^{60}Co based compact and economical model of blood irradiators were under fabrication at BRIT for demonstration and field trials and certification from AERB.

19 nos of teletherapy sources of total activity of about 170 kCi of ^{60}Co and about 50 metres ^{192}Ir-Pt medical wire were prepared and supplied to various hospitals and medical research centres for treatment of cancer. 12 nos. of ^{137}Cs manual after loading brachytherapy kits were fabricated for supply to cancer treatment centres after requisite regulatory approval from AERB.

Radiation sources of total activity of about 650 kCi were fabricated, processed and supplied.

An order for export of 100kCi ^{60}Co source for radiation processing applications, to Vietnam is expected to be executed shortly.

More than 750 nos of ^{192}Ir and ^{60}Co sources were fabricated and supplied for use in industrial gamma radiography, and about 120 sources of ^{137}Cs, ^{60}Co, ^{170}Tm, ^{46}Sc, ^{124}Sb were fabricated and supplied for other industrial applications.

BRIT produced and supplied a large number of sealed sources of ^{60}Co, ^{192}Ir, ^{137}Cs and other radiation sources for industrial applications, and research institutions.

Processing of about 120 kCi of ^{60}Co activity was carried out at RAPPCOF (Cobalt Facility) of BRIT at Kota, Rajasthan. ^{3}H light sources and ^{3}H - Titanium suspension were processed and supplied for various applications.

Radiotherapy

Radiation Medicine Centre (RMC) of BARC in Mumbai, diagnosed more than 7500 patients and delivered radiotherapy for various ailments. Cyclotron and Positron Emission Tomography (PET) facility at the Centre was extensively used for diagnosis.

At the Regional Radiation Medicine Centre (RRMC) of VECC at Thakurpukur, Kolkata, scintiscan studies were performed and radio immunoassays of thyroid hormones (T-3 and T-4), and thyroid stimulating hormone (TSH), were carried out regularly. Annually about 7000 patient exposures are delivered here.

The Advanced Centre for Treatment, Research and Education in Cancer (ACTREC) of TMC, at Kharghar, Navi Mumbai, continued research relating to cancers prevalent in the Indian sub-continent. Research groups at ACTREC investigated molecular aspects of oral cancer – the predominant cancer in India.

Radiation Sterilisation of Medical Products

ISOMED plant of BRIT continued to provide efficient gamma sterilization services to a number of institutions involved in the production and supply of medical and surgical products. The plant has been providing services of radiation processing of medical products, to over 1500 clients. During the report period, a revenue of about Rs. 6 crore was generated from gamma sterilization.

Industrial Applications of Radioisotopes

A working model for the Install and Operate Irradiator was made. Design approval was received from AERB for ISOMED type, 4+4 pass high efficiency wet source storage gamma irradiation plant for offer as an off-the-shelf product to prospective clients. Conceptual design drawings for radiation processing plants meant for sewage treatment were also prepared.

Sixteen new ROLI-1 radiography cameras were supplied to users and 20 ROLI-1 cameras were in the advanced stages of fabrication as per ISO 3999 specifications.

Three units of new Gamma Chamber 5000 units each loaded with 12,000 curies of ^{60}Co source, were fabricated.

Industrial Accelerators

Electron beam accelerator (ILU-6) of BARC was refurbished to its full operating power, and commercial as well as research and development activities were resumed. Radiation curable formulations for surface coatings on wooden substrates were successfully developed. Radiation processed hydrogel dressings were produced to meet requirements of hospitals.

The 500keV Industrial Accelerator located at BRIT, was in operation for the process development applications. This accelerator was used by the Ship Building Centre, Vishakhapatnam for grafting of rubber tiles. Reliance Industries Ltd. used it for crosslinking of polythene sheets/granule. Hindustan Lever Ltd. & Mahindra Engineering & Chemical Products also made use of this facility for irradiation of their polythene and rubber products.

The 10 MeV, 10 kW RF LINAC was installed at the Electron Beam Centre at Navi Mumbai. The subsystems of 3 MeV, 30kW, DC industrial accelerator were fabricated, tested at sub-system level.

KALI 5000 single shot pulse accelerator, was commissioned at Trombay and experiments for using this accelerator were under planning.

Laser Applications

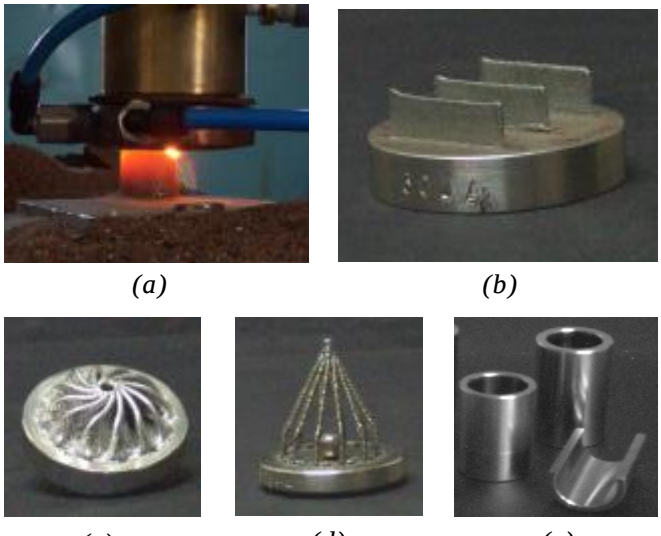
CAT developed a number of laser systems for industrial applications. These included a fibre coupled Nd:YAG laser system for cutting a coolant channel in a nuclear reactor core that decreases the cutting time nearly fifty fold; Carbon dioxide (CO_2) laser based rapid manufacturing system used in the fabrication of a number of components with various alloys, and novel CO_2 laser based multi-pass cavity for laser isotope separation of carbon-13.

A compact portable laser fluorimeter for uranium detection was developed for use in exploration, mining, reactor chemistry, health physics, effluent monitoring and environmental survey applications. A laser based phosphor thermometry set-up was made for non-contact surface temperature measurement, especially in high temperature measurement in rotating and sensitive environment.

The successes of the laser technology development efforts of CAT included the development of a diode pumped Nd:YAG laser delivering 60W of power at 532nm, a HyBrID CVL (copper vapour laser) with an output power of 25 W, and a compact spark pre-ionised Pulser Sustainer TE CO_2 Laser.

At CAT, generalised Self Filtering Unstable Resonator was successfully used to improve the beam quality of excimer laser without any loss in energy.

The output power of ~0.6 W was achieved in the Supersonic Chemical Oxygen Iodine Laser. A unique data acquisition and control system was also developed here for this laser.



(a) *(b)* *(c)* *(d)* *(e)*

Laser based rapid manufacturing at CAT using CO_2 laser (a) On-line process (b) SS316L walls of different thicknesses (c) Impeller (d) Cage (e) Colmonoy bushes

All optical switching experiments were performed with metalloporphyrins. These are an attractive candidate for all-optical molecular devices for information processing and storage, due to their large nonlinearity.

Self-rotation of red blood cells (RBCs) in optical tweezers was observed and its potential for the detection of RBCs from malaria-infected samples was demonstrated.

Synchrotron Radiation Sources

CAT has been setting up Synchrotron Radiation Sources Indus-1 and Indus-2 in Indore, Madhya Pradesh. Indus-1, already in operation, is used by researchers from various institutes and universities. Indus-2 is under construction.

Indus-1 vacuum ultraviolet/soft x-ray reflectivity beamline was used for the characterization of x-ray multilayer mirrors and super smooth glass substrates.

To supplement Indus-1 and Indus-2 utilization programme, an ultra high vacuum electron beam deposition system, an ion beam sputtering system, a grazing incidence x-ray diffractometer/ reflectometer and a total external reflection x-ray fluorescence spectrometer were developed. High-resolution transmission electron microscopy/scanning electron microscopy facilities were set up.

The work on evaluation of major components and subsystems of Indus-2 was completed and most of the hardware was installed in the storage ring tunnel. Precision alignment of the components and final integration of the storage ring has reached final stage.

A view of part of the 172m circumference, 2.5 GeV electron Indus-2 storage ring

For installation of beamlines on Indus-2, various front-end components were designed and developed. A prototype front end was assembled and detailed testing of its safety features progressed.

Prototype front end assembled in the Indus-2 experimental hall

Supercomputer & Grid Computing

At BARC, the 128 node supercomputer of ANUPAM series giving 365 giga floating point operations (Flops) provided high computing platform to increasing number of applications.

The work on 512 processor system with 1 Tera Flops computational power reached advanced stage. A software "ANUNETRA" was developed for monitoring performance of ANUPAM supercomputer while in operation.

Under DAE-CERN collaboration for Grid Computing, a problem tracking system, SHIVA was developed at Trombay. A 4x4 tiled display graphics cluster offering resolution of 20 million pixels was developed alongwith a postprocessor for visualization of data generated in computational fluid dynamics applications.

A postprocessor (AnuVI) supporting large tiled display graphics cluster for visualization of data generated in Computational Fluid Dynamics applications

Gamma Ray Telescope

The gamma ray telescope **TACTIC** installed at Mt. Abu by BARC, was deployed for observation of candidate cosmic gamma ray sources in the very high energy range. The analysis techniques for the imaging data were optimized resulting in an improvement in the overall sensitivity of the telescope which is now comparable to similar systems operating in other countries.

Seismic Studies

BARC's medium aperture array at Gauribidanur, Karnataka and tripartite array at Delhi functioned smoothly and recorded local, regional and tele-seismic events. In collaboration with Konkan Railways, a remote seismic monitoring station at Ratnagiri for hazard monitoring along railway line was set up.

Cancer Treatment & Research

The Tata Memorial Centre (TMC) pursued its programmes in comprehensive care of cancer patients, research, and education.

India's first bone marrow transplantation (BMT) for chronic granulomatous disease, haploidentical BMT (with patient's father as the donor), and BMT with 'in the bag' T cell depletion were done at the Tata Memorial Hospital (TMH). The Hospital also developed first Indian recombinant antibody based therapeutic immunotoxin that is effective on certain category of cancers, especially the carcinoma of breast.

For bio-imaging, a PET-CT Scanner, the first in India, was commissioned at TMH, and its pathology wing was equipped with state-of-the-art equipment.

Rural Out-reach Programme

The TMC Rural Outreach Programme (TMC-ROP) for the Districts Ratnagiri and Sindhudurg of Maharashtra, based at the B.K.L.Walawalkar Hospital at Dervan, Chiplun, Maharashtra, completed over 1,30,000 household surveys and screened over 25,500 persons.

Telemedicine

Towards networking of all the Regional Cancer Centres (RCCs) through telemedicine, the activities covered installation of hardware and software for the communications and the videoconferencing. In the first phase, TMH and Dr. B. Borooah Cancer Institute, Guwahati and the TMC's Rural Outreach Programme for the Ratnagiri and Sindhudurg areas at Walavalkar Hospital, Dervan, Chiplun were linked. In the second phase, six Hospitals from the Northeast were connected and established linkages with other Centres.

Teletherapy Machine

A world class Teletherapy Machine for treatment of cancer was indigenously developed at BARC and commissioned at ACTREC, Navi Mumbai.

Cancer Research

ACTREC continued with its research programmes relating to cancers prevalent in the Indian sub-continent. Basic research groups at the Centre investigated molecular aspects of oral cancer – the predominant cancer in India.

Studies in the area of carcinogenesis encompassed chemical analyses, evaluation of mutagenicity, genotoxicity and carcinogenicity of tobacco products, identifying their mechanism/s of action, and establishing biomarkers of exposure in habitués.

Accelerators

At Kolkata, the Variable Energy Cyclotron was used for research in nuclear physics and nuclear chemistry, and produced radioisotopes for various applications. Superconducting Cyclotron and Radioactive Ion Beam Facility are the major ongoing projects of VECC.

For the Superconducting Cyclotron Utilisation Project, VECC completed design of beam lines, and design & procurement of its components progressed. The building was occupied, and the assembly work of main magnet frame along with its ancillary systems was completed.

For Heavy Ion Acceleration with VEC, main magnet power supply was installed which improved the beam stability considerably and the Calcium Beam was developed. Several experiments were conducted on the Indian National Gamma Array installed at VECC, using the beam from cyclotron.

For the Radioactive Ion Beams Facility, full scale 1.7 m diameter LINAC-1 Al cavity fabricated for various studies, was approaching completion.

Fusion & Other Plasma Technologies

At the Institute for Plasma Research, the operation of ADITYA tokamak became much more consistent. Presently, 70 to 80 kA discharges with a total duration of about 80-100 ms were routinely obtained.

The Steady State Tokamak (SST-1) experiment remained focused to address the related physics and technology issues. Erection of SST-1 at site has begun.

Steady State Tokamak (SST-1) setup at Institute for Plasma Research

Research Education Linkage

DAE organisations have been collaborating with national laboratories and the university systems through Consortium for Scientific Research, and by funding of extra-mural research.

The UGC-DAE Consortium for Scientific Research, in Indore, functioning under the control of UGC, aims at utilization of the research facilities set up at various DAE research centres. The scope of cooperation includes all the programmes pursued by DAE in the areas of physical, chemical, life and engineering sciences.

The research centres of DAE are recognized by the universities of their regions, as the centres for research leading to postgraduate degrees. A number of scientists and engineers are recognized as post-graduate teachers by the respective unversities. The employees are encouraged to register and obtain research degrees based on the work done in these research centres.

FUNDING OF EXTRA-MURAL RESEARCH

DAE encourages and promotes scientific research in universities, institutes and laboratories in the areas of relevance to the Department, through the Board of Research in Nuclear Sciences (BRNS) and the National Board for Higher Mathematics (NBHM) both at Mumbai.

During the period of report, 136 new research projects were sanctioned by BRNS. Financial sanctions were issued for the various on-going research projects. One fellowship was awarded under the Homi Bhabha Chair Scheme, five fellowships were offered under the Senior Scientists Scheme, eight fellowships were awarded under the K.S.Krishnan Research Associateship Scheme and thirty-two fellowships were offered under the DAE Graduate Fellowship Scheme.

DAE, through the National Board for Higher Mathematics (NBHM) promotes excellence in higher mathematics, education and research in the country.

A major portion of the budget of Rs. 7.50 crore for NBHM, was released to the mathematics departments of 87 universities/institutions towards library support, to enable them to purchase the latest mathematical books and journals. In collaboration with the International Mathematical Union, NBHM also initiated schemes for making mathematical literature accessible through electronic-communication. NBHM provided 9 new fellowships at doctoral and 16 at post-doctoral levels.

NBHM conducts Olympiad contests among the young talents at plus two (+2) level. The Board is also responsible for selecting the Indian Team for participation in the International Mathematical Olympiad (IMO).

Grant-in-Aid to institutions

DAE has eight aided Institutions, including one education society, that are fully funded in terms of their recurring and non-recurring expenditure. There is a growing synergy between these institutions and the Research and Development centres of DAE.

The non-recurring and recurring funds allocated to these Institutions by the department during the financial year 2004-2005 are as under:-

1) Tata Institute of Fundamental Research (TIFR), Mumbai	Rs.130.50 crore
2) Tata Memorial Centre (TMC), Mumbai	Rs. 102.75 crore
3) Saha Institute of Nuclear Physics (SINP), Kolkata	Rs. 46.75 crore
4) Institute of Physics (IOP), Bhubaneswar	Rs.12.15 crore
5) Institute of Mathematical Sciences (IMS), Chennai	Rs. 9.50 crore
6) Harish-Chandra Research Institute (HRI), Allahabad	Rs.10.25 crore
7) Institute for Plasma Research (IPR), Gandhinagar	Rs.69.00 crore

Grants to Cancer Hospitals

DAE has signed a Tripartite Agreement with the North-Eastern Council (NEC) and the Government of Assam, for the revitalization of the Dr. B. Barooah Cancer Institute, Guwahati. The Department's share as per this agreement is about Rs.10.44 crore.

The department also released grants to some cancer hospitals for procurement of equipment.

A national centre for clinical trials to be called "DAE-Clinical Trial Centre (DAE-CTC) has been established at a cost of Rs.1.98 crore to act as a centralised facility providing services, both to the public and private Sector. Education and Training are the important activities of DAE-CTC.

INTERNATIONAL RESEARCH COLLABORATION

Under a cooperation agreement, signed in March 1996, DAE, through its units, is required to develop and supply some of the sophisticated components of Large Hadron Collider (LHC), a particle accelerator under construction by European Centre for Nuclear Research (CERN) at Geneva, Switzerland.

Supply of 616 superconducting Decapole-Octupole corrector magnets to CERN was completed by CAT in June 2004. About 6000 jacks out of a total of 6800 jacks were also shipped to CERN in December 2004.

A full custom mixed application specific integrated circuit Indiplex for ALICE experiment was fully designed at Trombay and was sent to Belgium for fabrication.

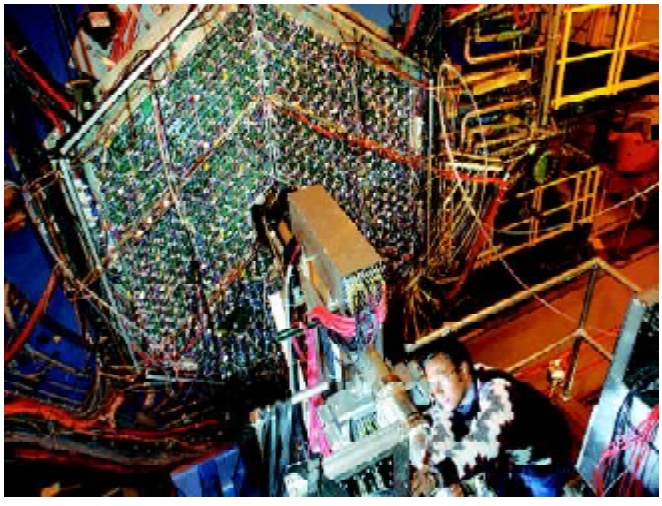
The STAR Photon Multiplicity Detector (PMD) developed at VECC started taking physics data. The first set of data, on analysis produced exciting results on photon production at Relativistic Heavy Ion Collider (RHIC) energy and on limiting fragmentation. Construction of the PMD for ALICE experiment at LHC was under construction at various collaborating laboratories in India.

SINP completed the MEGHNAD Array - a multi element detector system for the study the properties of a wide variety of particles. For the *LHC and GRID project*, the detector production is nearly complete and mass production of the MANAS chips was initiated.

The Institute of Physics participated in the Photon Multiplicity Detector collaboration experiment at the Relativistic Heavy Ion Collider (RHIC) and Large Hadron Collider (LHC) accelerator facilities in USA and CERN, Geneva respectively. The photon multiplicity detectors fabricated at the Institute were undergoing installation and testing as part of the STAR experiment of the RHIC accelerator.

Under DAE-CERN collaboration for Grid Comput-

MEGHNAD setup at SINP



STAR Photo Multiplicity Detector (PMD) manufactured at VECC and set up at the Brooke Haven National Lab, USA

ing, a problem tracking system, SHIVA was developed at Trombay. This 4x4 tiled display graphics cluster offering resolution of 20 million pixels was developed alongwith a postprocessor for visualization of data generated in computational fluid dynamics applications.

A plastic scintillator detector, ENSTAR with state-of-the-art fibre optic readout has been designed and built by BARC for studies of a new and exotic form of matter. The construction and setup of this detector containing 204 scintillator elements was completed and a test run was conducted at the COSY accelerator, Julich, Germany.

VECC is setting up a Grid Computing Facility for ALICE Experimental Data. As a first step towards building the Tier-2 Centre for ALICE Grid Project, it commissioned a 8-node dual processing cluster system.

Setting up of the mirror web-site for Asian Region for Nuclear Data Services of Nuclear Data Centre of International Atomic Energy Agency continued at BARC.

PUBLIC SECTOR UNDERTAKING (FINANCIAL PERFORMANCE)

The financial performance of the DAE public sector undertaking namely, Nuclear Power Corporation of India Ltd., Uranium Corporation of India Ltd. and Indian Rare Earth Ltd. and the Electronics Corporation of India Ltd., are as follows:

NPCIL registered a net profit of Rs. 2604 crore for the financial year 2003-04. It paid a dividend at the rate of Rs. 63 per share amounting to Rs. 521 crore to Government of India for the financial year 2003-04. The net profit for the year 2004-05 upto December 2004 was Rs.1120 crore (Provisional). NPCIL's bonds were rated at AAA by CRISIL and CARE.

The overall performance of UCIL during the year 2003-2004 was satisfactory in terms of production and profit. During this year, the turnover of the company increased from Rs.177.07 crore to Rs.197.68 crore, posting a 11.6% rise. The net profit stood at Rs.9.79 crore against Rs.4.81 crore in the previous year registering an excellent growth of about 203%.

For the year 2004-05, IREL is expecting a turnover of Rs.277 crore and the foreign exchange earning of Rs.85 crore. Its profit before tax is likely to be Rs.39 crore. The company paid a dividend of 30% of profit after tax for the year 2003-04.

During the report period, till December 2004, ECIL achieved a production of Rs. 412 crore and a sale of Rs.419 crore, and booked orders worth around Rs.200 crore. Major supplies have been to the two strategic sectors of Nuclear and Defence and other sectors. Also, ECIL exported equipment to Russia, South Africa, Nepal, USA and Switzerland. A high power delegation from Nigeria visited ECIL to see the performance of Electronic Voting machine. The satisfactory order book position and the prospects augur well for ECIL for the next few years.

OTHER ACTIVITIES

Crisis Management

The Crisis Management Group, a standing committee of senior officials of DAE, coordinates the response of the department, to a nuclear or radiological emergency in the public domain.

To ensure that the emergency plans are in high state of readiness, major nuclear facilities such as nuclear power stations and hydrogen sulphide based heavy water plants carried out a variety of emergency exercises.

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.

Technology Transfer

During the report period, several technologies from BARC were transferred to industry. These included On-line Domestic Water Purifier based on Ultra-Filtration Polysulfone membrane, Nisarg-runa, a bio-gas plant based on biodegradable waste, FDK-Fluoride Detection Kit for Groundwater, Lascan Dia Gauge technology, Production of nano-size Ceria Powder for optical polishing applications, and Acceleration –Deceleration control valve and circuit for hydraulic lift.

At the Facilitation Centre for Industrial Plasma Technologies, Ahemdabad, plasma pyrolysis technology for medical and plastic waste was developed and demonstrated.

Technical Services

The Technical Services offered by DAE research centres to industry related to non-destructive testing, stress measurements, acoustic topography, material characterisation and others.

BARC accredited one laboratory for carrying out thermo-luminescence detector (TLD) based personnel monitoring services. A blade diagnostic system was developed in this centre. The technique was implemented and validated in Nuclear and Thermal Power Plants.

Collaborative Programme

A total of 25 MoU's were signed by BARC. These included Channel Heat-up Experiments, Technical Consultancy on Low Temperature Evaporation Desalination, Setting up demonstration unit for Electron Beam Welding applications, Supply of nuclear/breeder seed of groundnut, Manufacture of Alarm Annunciation System, and Bulk Encryption Unit.

Intellectual Property Protection

During the year 2004-05 the IPR Cell of DAE filed 14 patent applications including 6 in India, 4 under Patent Cooperation Treaty (PCT), 2 in Europe, and 1 each in USA and Japan. The Controller of Patents in India has granted patents on 9 previously filed applications while 1 patent was granted by the USPTO and 1 by Australian patent office. Cumulatively till date, DAE has filed 151 patent applications including PCT and national phase applications, out of which 61 patents have been granted so far of which 24 are in force. This year 49 Trade marks applications were also filed with the Trade marks registry.

International Relations

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

India continued to offer training facilities, fellowships, scientific visits, etc. to foreign scientists and provided the services of its scientists for expert assignments to other countries both through IAEA and to the countries with which we have entered into bilateral agreements for co-operation in the field of peaceful uses of atomic energy. Around 753 Indian scientists/engineers and 490 foreign scientists participated in international symposia, workshops, conferences and meetings held in India under the auspices of the IAEA and various international organisations.