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MILESTONE : 2005 - 06

Department of Atomic Energy, Government of India

MILESTONES OF 2005-2006

For the Department of Atomic Energy (DAE), the year 2005-06 was eventful. The Department set many milestones, achieved a number of successes, and took confident strides towards its long term goals. Present here is a gist of achievements and activities of DAE in its programmes.

NUCLEAR POWER PROGRAMME-STAGE-1

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 15 reactors (2 boiling water reactors and 13 pressurised heavy water reactors).

During the calendar year 2005, generation of electricity from nuclear power plants was 17831 million units.

The Unit-4 of the 540 MWe Tarapur Atomic Power Project TAPP-3&4, was made critical on March 6, 2005, in less than 5 years. The Unit went commercial on September 12, 2005.

Unit-1 of Kakrapar Atomic Power Station (KAPS-1) operated uninterrupted for 372 days, setting a record for an operating pressurised heavy water reactor in India.

The shutdown period for a reactor was successfully brought down by NPCIL to an average of 26 days.

The World Association of Nuclear Operators (WANO) peer-reviews atomic power stations and peer-reviews at Kakrapar, Narora, Kaiga, Rawatbhatta and Tarapur have been completed. These reviews indicated that condition and performance of the stations matched the world level.

The civil construction works for Kudankulam Nuclear Power Project-1&2 reached advanced stage of completion. The project achieved a physical progress of 61% upto December 2005. The Kudankulam reactor units are expected to be completed in the years 2007 and 2008 respectively.

The construction of Kaiga-3&4 reached advanced stage and commissioning activities of Kaiga-3 have commenced. These Units are scheduled to be completed by the year 2007.

Civil structural works of Rajasthan Atomic Power Project-5 (RAPP-5) and common buildings were nearly completed. Unit-5 and Unit-6 are scheduled to be completed by August 2007 and February 2008 respectively.

The in-principle approval of the Government of India was obtained in respect of sites for four new power stations at Kudankulam, Kakrapar, Rawatbhata and Jaitapur (Maharashtra), totalling a capacity of 6800 MWe. NPCIL is also developing a 700 MWe pressurised heavy water reactor. Detailed design work for this reactor progressed.

At Kalpakkam, upgradation jobs for Unit-1 of Madras Atomic Power Station were completed and the unit attained criticality on January 4, 2006. The Enmasse Coolant Channel Replacement and upgadation jobs for Unit-1 of Narora Atomic Power station commenced.

Nuclear Fuel Cycle

The Nuclear Power Programme has a number of ancillary operations which form Nuclear Fuel Cycle. The Front-End of the Cycle includes mineral exploration, mining and processing of ore, and fabrication of fuel. The

Tarapur Atomic Power Station-3&4

Back-End of the Cycle covers reprocessing of spent uranium fuel and management of nuclear waste. Production of heavy water that is used as moderator and coolant in PHWRs, is also an important ancillary operation associated with Nuclear Fuel Cycle. During the report period, the major accomplishments in these ancillary programmes were as follows:

Heavy Water Production

The Heavy Water Board (HWB) of DAE operates six heavy water plants at Baroda (Gujarat), Tuticorin (Tamil Nadu), Hazira (Gujarat), Thal (Maharashtra), Kota (Rajasthan) and Manuguru (Andhra Pradesh).

The production of heavy water and specific energy consumption of the operating heavy water plants was excellent, with production exceeding the scheduled target, and achieving further reduction in production cost. The plants maintained excellent safety performance and achieved accident free continuous run of all the operating plants.

This year also, the Heavy Water Board executed an export order of 6 MT of heavy water to South Korea.

The Board has diversified into production of solvents required for DAE's programmes. Organo-Phosphorous solvents for the back end of the fuel cycle are being produced at Talcher facility for the captive needs of the Department.

The Board also took up research and development activities essential for nuclear power programme. These include production of enriched Boron and development of solvent extraction facility for production of uranium from phosphoric acid at Talcher and Centralised Uranium Conversion facility at Tarapur and Kalpakkam with recyclable uranium oxide powder manufacturing capability. A Technology Demonstration Plant for recovery of uranium from secondary sources especially from phosphoric acid manufactured using rock phosphate, is being set up. The Board also embarked on distillation route for production of $H_2{}^{18}O$ at 99.8% purity.

Civil works for Boric acid enrichment plant through ion chromatographic route at HWP, Manuguru was completed

Exploration and Mining

For augmentation of atomic mineral resources required for the atomic energy programme of the country, the Atomic Minerals Directorate for Exploration & Research continued survey and exploration. Following were the major achievements :

· 1186 tonnes of additional uranium (U_3O_8) resources were established at Rohil, Sikar district, Rajasthan and Wahkyn, West Khasi Hills district, Meghalaya.

· Significant uranium mineralisation was intercepted in the bore holes in Mahendragarh district, Haryana; Bastar district, Chhattisgarh; Kadapa and Nalgonda districts, Andhra Pradesh.

· The promising uranium anomalies were located in the Proterozoic and Phenerozoic basins: Pur-Banera basin, Rajasthan; Kaladgi - Badami basins, Karnataka; Satpura Gondwana basin, Madhya Pradesh; Mahadek basin, Meghalaya and Pakhal Basin, Andhra Pradesh

· Comprehensive process flow sheet was developed for extraction of uranium from dolostone hosted Tummalapapple ore, Kadapa district (Andhra Pradesh).

Uranium Corporation of India (UCIL) adopted the latest state-of-the-art technology for mining and processing uranium ore to produce uranium concentrate. The capacity

Uranium Processing Plant under construction at Turamdih, Jharkhand

utilization of all the operating units of UCIL improved substantially. Narwapahar mine and Processing Plant produced more than their installed capacity and Turamdih mine improved its capacity utilization.

To meet the enhanced requirement of nuclear fuel, the expansion programme of UCIL continued. Construction works of Banduhurang Opencast mine, Processing Plant at Turamdih and Bagjata mine progressed satisfactorily. Pre-project activities for Lambapur-Peddagattu in Andhra Pradesh and KPM Project in Meghalaya progressed.

Pre-project activities at Tummalapalle in Cuddapa district of Andhra Pradesh were initiated.

Fabrication of Nuclear Fuel & Structural Components

During the report period, NFC met the regular re-load fuel requirement of all the operating pressurised heavy water reactors and boiling water reactors. It will soon meet the entire core fuel requirement of the 540 MWe Unit-3 of the Tarapur Atomic Power Station-3&4. It supplied the full core requirement of zirconium alloy calandria tubes for Kaiga-3 and RAPP- 5.

NFC continued setting up of the New Zirconium Oxide and Sponge Plant at Palayakayal to meet the increasing Zirconium Sponge requirements for the nuclear power programme. The plant will produce annually 500 tons of hafnium-free zirconium oxide and 250 tons of reactor grade zirconium sponge.

Several critical process equipment were developed and fabricated.

A process was developed for the preparation of certain uranium alloy fuels. Technology for synthesis of trialkyl phosphine oxide (TAPO) and di (nonylphenyl) phosphoric acid (DNPPA) — solvents for the extraction of uranium from phosphoric acid- was developed.

Fuel Reprocessing

Plutonium Plant at Trombay was operated satisfactorily and PREFRE at Tarapur continued processing of spent fuel from power reactors. For Power Reactor Thoria Reprocessing Facility, design work for major systems was completed.

For nuclear waste extraction, various exotic organic ligands were synthesized at Trombay.

Sealed Type Three-Piece Manipulator of 20-kg payload capacity, an advanced version of mechanical master slave manipulator, was an important development.

A facility for recovery of major portion of Plutonium from process waste was set up at Trombay.

Waste Management

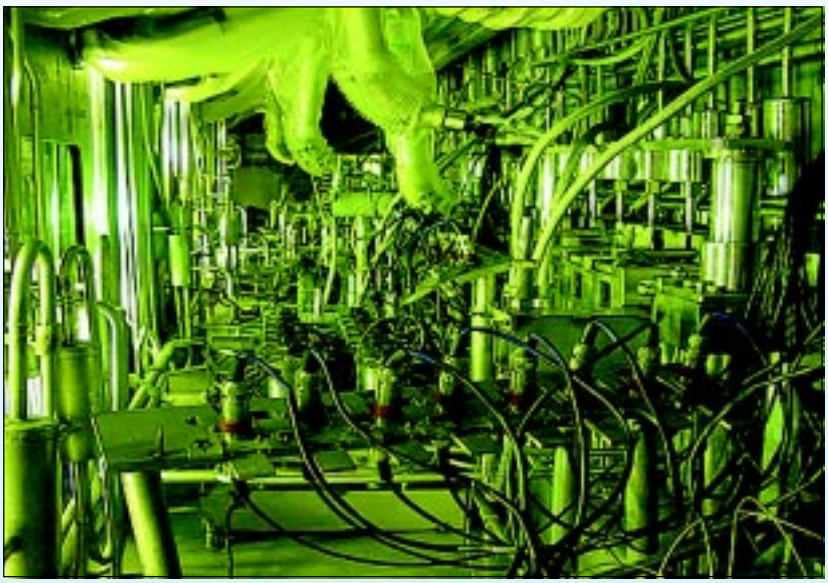
Waste management facilities at Trombay, Tarapur and Kalpakkam were operated safely. Waste Immobilisation Plant (WIP), Trombay carried out remote welding of the 100th canister containing vitrified high level radioactive waste.

Processes for bulk separation of actinides and lanthanides from high-level waste using indigenously developed novel solvents, were demonstrated. All the works related to the Advanced Vitrification System at Tarapur were completed.

Research and Development Inputs

At BARC, testing of First Fuelling Machine Head of 540 MWe for its reactor worthiness and the Emergency drive system of Ram Assembly were carried out. Ultrasonic sensor based non-contact creep measuring technique was developed and implemented in TAPS-4 and KAPS-1.

Facility for Integral System Behaviour Experiments



Lead Mini Cell at Indira Gandhi Centre for Atomic Research

(FISBE) was set up at Trombay to generate data related to Indian PHWRs. A Flux Mapping System was successfully developed and commissioned.

The Centre also provided fuel management service for TAPS-1&2, and fabricated Boron carbide control blade assemblies and channel fastener assemblies for TAPS.

A laser-based system for cutting and welding the bellow-lip for the en-masse coolant channel replacement in old pressurized heavy water nuclear reactors was developed at RRCAT. With this system, there will be an enormous time saving for en-masse coolant channel replacement work that is due to start at Narora shortly.

Health, Safety & Environment

NPCIL registered about 245 reactor years of safe and radiation accident free experience of operation. The atomic power stations at Narora and Kakrapar bagged the Industrial Safety Awards of the Ministry of Labour and National Safety Council.

Complete automation of personnel monitoring service was achieved and network connectivity between various TLD and Health Physics Units of BARC was completed through ANUNET and NPCNET.

Carbon doped alumina sensor having high sensitivity for beta and gamma radiations for personnel dosimetry and Ion-implanted photo diode coupled to Cs(Tl) detector for alpha particles, were developed. The technology for portable X-ray baggage inspection unit was transferred to ECIL.

To meet nuclear emergencies at nuclear power plants, real-time as well as predictive calculation of dispersion of radioactive releases with operating domain 150x150 square km around Nuclear Power Plant (NPP) site was developed.

BARC continued to provide radiation protection, industrial hygiene and environmental safety surveillance to all the nuclear fuel cycle facilities of DAE. The BARC Safety Council Secretariat conducted regulatory inspection of several facilities of BARC.

For maintenance planning at nuclear power plants and other facilities, probabilistic safety analysis techniques were developed.

A radiological monitor for vehicle loads, a portable compact gamma spectrometry system with navigational aid, a fast responding tritium-in-air monitor were developed at Trombay.

An Environmental Surveillance Laboratory of Health Physics Unit of BARC located at Jaduguda monitors the environment for the radiation levels in and around the plants. UCIL accords utmost importance to the occupational safety and health of the persons working in the company. It is committed to environmental protection and maintaining the ecological balance.

NUCLEAR POWER PROGRAMME-STAGE-2

Fast Reactors

The second stage of nuclear power generation envisages setting up of fast breeder reactors (FBR) backed by reprocessing plants so as to achieve the closed fuel cycle. FBR can increase Uranium utilisation by about sixty times of what is possible with Pressurised Heavy water Reactor.

Fast Breeder Test Reactor

At the Indira Gandhi Centre for Atomic Research, Fast Breeder Test Reactor (FBTR), operated successfully with over 80% availability. The fuel reached a peak burn-up of 154,000 MWd/t. For extension of the operating life of FBTR beyond 20 years, a systematic analysis of various components was undertaken.

Activities related to refurbishment of the facilities for

Fast Breeder Test Reactor at Kalpakkam

fabrication of fuel pins for FBTR, were under execution by BARC.

Prototype Fast Breeder Reactor

Bharatiya Nabhikiya Vidyut Nigam Ltd., (BHAVINI), is constructing the Prototype Fast Breeder Reactor (PFBR) of 500MWe capacity. The project work achieved an overall physical progress of 14 % as on December-2005. Fabrication of large sized reactor components such as safety vessel and main vessel progressed. Preliminary Safety Analysis Report was updated and the plant layout with emphasis on safety, constructability and compactness was finalised. Prototype Diverse Rod Drive Mechanism had undergone testing in hot sodium, representative of reactor conditions.

At Trombay, mixed oxide fuel pins containing 44% PuO_2 for making the hybrid core of FBTR, were fabricated, and installation of a new fuel fabrication line for fabrication of MOX fuel pins for PFBR was completed. A new line having a total of 14 boxes for FBTR Fuel fabrication was undergoing commissioning.

At IGCAR, the PFBR test fuel subassembly reached a burn-up of 59,200 MWd/t.

Fast Reactor Fuel Reprocessing

IGCAR created a new international bench-mark by successfully reprocessing the mixed carbide FBTR fuel, which had undergone a burn up of 100,000 MWd/t, in the Lead Mini Cell (LMC).

The Demonstration Fast Reactor Fuel Reprocessing Plant (DFRP), which will reprocess fuel from FBTR on a regular basis and some oxide subassemblies from the first core of PFBR, reached an advanced stage of construction.

Materials

At IGCAR, development of new indigenous variants of structural alloys for fast breeder reactors and fast reactor reprocessing plants, were completed.

Boron Enrichment Plant (BEP) at Kalpakkam achieved an enrichment above 65% in Boron-10, which is the requirement for PFBR. Some enriched boric acid was produced for conversion to elemental boron. Based on the technology demonstrated, a plant is being set up at Manuguru to produce enriched boron for PFBR.

NUCLEAR POWER PROGRAMME STAGE-3

Thorium utilisation is the long term core objective of the Indian Nuclear Power Programme for providing energy security on sustainable basis. The third stage of the Indian Nuclear Power Programme is based on the Thorium-Uranium-233 cycle. Following were the major activities in this programme segment :

Advanced Heavy Water Reactor

BARC is engaged in developing 300MWe Advanced Heavy Water Reactor (AHWR). This R&D endeavour aims at developing expertise for thorium utilization and demonstrating advanced safety concepts.

BARC completed fabrication of reactor tank for AHWR Critical Facility, and design and stress analysis of fuelling machine assembly. Design of passive concrete cooling system and Emergency Core Cooling System (ECCS) was also completed**.**

Integral Test Loop simulating Primary Heat Transport system and Safety Systems of AHWR were commissioned at Trombay.

PFBR Safety vessel fabrication under progress

A prototype fuel pin gamma scanner for scanning of AHWR fuel pins was designed and developed.

Fabrication of metallic uranium fuel cluster assemblies for reference core, and fabrication of thorium oxide fuel pellets for thorium oxide fuel clusters for AHWR critical facility were completed.

Kamini (Kalpakkam Mini Reactor)

The Kamini reactor at Kalpakkam was utilised for the neutron radiography of pyrodevices and activation analysis of samples.

Other Thorium Reactor Systems

BARC has been developing other thorium reactor systems also. These endeavours include Compact High Temperature Reactor (CHTR), Accelerator Driven Sub-Critical Systems (ADS), and others.

The physics design of the 100 kWt CHTR was completed. Preparation of dense amorphous carbon shapes, isotropic, high density graphite as well as C-C Composite blocks and tubes of various shapes and sizes for the CHTR and fabrication of one piece of graphite hot channel having 75mm OD and length of 1400mm with intricate bores, was achieved.

BARC also started the work on physics design of high temperature reactor for hydrogen production.

Physics design of Low Energy High Intensity Proton Accelerator (LEHIPA) for Accelerator Driven Sub-Critical System (ADS) project was completed at Trombay.

Mining and Processing for Thorium

The mining operations of the Indian Rare Earths Ltd.'s (IRE) southern plants at Chavara and Manavalakurichi were affected by Tsunami. The production of ilmenite and associated minerals during the current financial year recovered from the impact of Tsunami disaster. IREL rendered necessary assistance to the affected areas and has recommenced mining.

IREL commissioned THRUST project and commenced regular operations. The capacity expansion of the projects in mineral units at Chavara, Manavalakurichi and OSCOM continued.

RADIATION TECHNOLOGIES AND APPLICATIONS

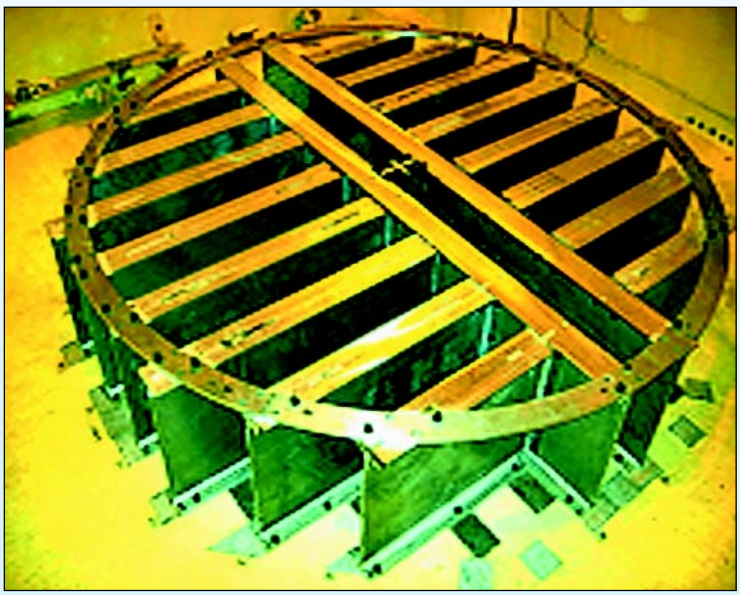
DAE's programme relating to radiation technologies and applications, covers building and operation of research reactors for production of radioisotopes, setting up of other sources of radiation such as accelerators and lasers, and developing and deploying radiation technology applications in the fields of medicine, agriculture and industry.

India is one of the leading producers of radioisotopes in the world. Radioisotopes are produced in the research reactors at Trombay, atomic power reactors of NPCIL and the cyclotron of VECC at Kolkata.

The radioisotopes produced at Trombay find wide applications in the fields of agriculture and food, medicine and healthcare, industry, and research. Based on these applications, following programmes have been established in India.

Research Reactors

At Trombay, the research reactors Apsara, Cirus and Dhruva operated satisfactorily and were utilized for basic and applied research, radioisotope production, material testing and human resource training and development. The design of Multi-Purpose Research Reactor was under upgradation.



Reactor Vessel of Advanced Heavy Water Reactor

Isotope Processing

Radiochemicals and Sealed Sources

A large number or radioisotopes such as Molybdenum-99, Iodine-131, Samarium-153, Chromium-51 and others were produced at Trombay and procedures for production and assay of the gaseous radiotracers Argon-41 and Krypton-41 used in industrial applications were standardized.

Nuclear Agriculture

The Nuclear Agriculture Programme of DAE focuses on the use of radiation technology for the development of high yielding mutants of pulses, oil seeds and cereals, post-harvest radiation processing of food items, fertilizer and pesticide related studies, and other areas.

High yielding and disease resistant varieties of Soybean (TAMS-38) and Mungbean (TMB-37) were released for commercial cultivation. So far 26 crop varieties have been released for regular use. Six more varieties were getting ready for release. Micropropagated tissue cultured plants of high yielding Banana and giant Cavendish and somatic embryo derived plants were undergoing evaluation studies at different centres.

Food Processing

The Radiation Processing Plant at Vashi processed about 1,500 mt of spices and other allied products to reach a turnover of Rs.1.5 crore.

Onion and other agricultural commodities (130 tonnes) were radiation processed at the Radiation Processing Plant Krushak, Nasik, Maharashtra.

Considerable progress was achieved in setting up of radiation processing in private sector. Three new radiation processing plants were completed in Sonepat, Ambernath and Vadodara. During the report period, four more private agencies signed MoU with BRIT for setting up radiation processing plants.

The research studies related to radiation processing of food, progressed well. Radiation processing was found to extend the shelf life of French beans.

Electron beam accelerators at Vashi, Navi Mumbai and Indore were used for food irradiation studies.

Environment Friendly Technologies

BARC has installed at various places bio-gas plants "Nisarg-Runa", that are operating satisfactorily. A few more gas plants are planned for installation.

Sludge hygienisation research irradiator (SHRI) processed dry hygienised sludge and supplied to farmers.

HEALTH CARE

Radioisotopes and their formulations find wide applications in diagnosis, therapy and healthcare. BARC and BRIT are the main centres of this activity.

Radiopharmaceuticals

During the report period, BRIT supplied ready-to-use radiopharmaceuticals of Iodine-131, Phosphorous-32, Chromium-51and Samarium-153 (total 5250 consignments), and Cold Kits (48,000 nos.) for formulation of Technetium-99m (Tc-99m) radiopharmaceuticals to various nuclear medicine centres. It also supplied 500 Curies of Molybdenum-99 (TCM-2) (2526 consignments) to user hospitals for extraction of Technetium-99m.

Samarium ^{32}P Phosphate colloid-injection developed at BRIT, was under clinical trials. This product is very useful in treatment of disease of joints. Also, a Technetium-

Soybean TAMS-38

Mungbean TMB-37

99m Column Generator Production Facility (TcGPF) was successfully completed.

Radiation Sterilization of Medical Products

The Plant for Radiation Sterilization of Medical Products (ISOMED) continued to offer gamma sterilization services to customers spread all over the country. About 14,000 cubic metres of different types of products were sterilized. ISOMED also carried out radiation stability testing of materials and equipment for various DAE units.

BRIT extended expert services for plant commissioning dosimetry to private parties, during the commissioning of their new gamma irradiation plants.

Radiodiagnosis & Treatment Services

At BARC Brachy therapy sources were fabricated to meet the hospital requirements. Iodine-125 doped tiny sources for the treatment of ophthalmic cancer were produced and supplied for clinical studies. Search for new and safe anti-oxidants and radioprotectants from plants and herbs continued.

Technology for bio-medical instruments such as Cardiac Output Meter, Anu-photo Rheograph, noninvasive Blood Pressure Monitor were developed and transferred to private domain for commercial production.

The Radiation Medicine Centre of BARC provided quality services to cancer patients by way of advanced diagnostic investigations and radiotherapies, besides carrying out advanced research studies in the field of nuclear medicine.

BRIT supplied nearly 9250 kits of radioimmunoassay (RIA) and immunoradiometric assay (IRMA) to 300 immunoassay laboratories in the country.

Free T_4 kits (based on coated tubes) and HCG IRMA kits (based on magnetizable particles) will be launched in the market shortly.

The Regional Radiopharmaceutical Centres of BRIT located at Bangalore and Delhi processed ready-to-use ^{99m}Tc radiopharmaceuticals for use in the host medical centres.

The RIA centre of Dibrugarh continued to provide RIA and IRMA diagnostic investigations to the poor and needy patients in the region.

Apart from carrying out R & D work related to PET radiopharmaceuticals, the Radiopharmaceutical Lab of BRIT at VECC, Kolkata remained involved in setting up of radiopharmaceutical production facility of the DAE Medical Cyclotron project.

The Regional Radiation Medicine Centre at Kolkata offered various diagnostic services. During the year 2005, 1100 patients underwent imaging studies and around 3,000 patients underwent thyroid hormone profile assays. The Iodine-131 therapy for cancer thyroid patients continued.

VECC aims to establish a 30 MeV Medical Cyclotron Facility for production of radio-pharmaceuticals for medical applications, and for experiments related to the development of Accelerator Driven Subcritical System (ADS), and Material Science. AERB has given the site clearance to install the Medical Cyclotron for radio-pharmaceuticals production.

Raja Ramanna Centre for Advanced Technology developed India's first solid-state green laser based photo-coagulator to treat diabetic retinopathy of the eye.

A method based on polar-decomposition of Mueller matrix was also developed here which may find application *in-vivo* determination of optically active (chiral) substances in turbid media, like for example glucose in human tissue.

A patient undergoing treatment with Bhabhatron at ACTREC

At the Tata Memorial Hospital (TMH), about 38,800 cases were registered, over 16,500 patients were admitted in the Hospital, over 8,28,900 pathological investigations and about 83,700 radiological investigations were made.

To offer patients, without an HLA-matched sibling, a reasonable chance for transplant, a bone marrow registry of unrelated voluntary marrow donors - Marrow Donor Registry (India) - was established.

The Advanced Centre for Treatment, Research and Education in Cancer (ACTREC) is now functional. All the diagnostic and therapeutic facilities of the Clinical Research Centre of ACTRC were commissioned and the 50-bedded state-of-the-art clinical facility devoted to translational and clinical research was inaugurated. A state-of-the-art Cobalt Teletherapy Machine 'Bhabhatron', developed through coordinated efforts of BARC and the TMC and an industrial partner, was in regular use.

TMC, under its *Urban Outreach Programme* covered over 75,000 women. Over 100,000 persons were covered under its *Rural Outreach Programme* in the districts of Ratnagiri and Sindhudurg of Maharashtra.

TMC is linking cancer centres through a nationwide network. Under the second phase of the Telemedicine Project of TMC, 7 hospitals were added to the tally of 19 nodes.

DESALINATION OF WATER

BARC has developed a number of desalination technologies such as multi-stage flash (MSF) evaporation, reverse osmosis (RO) and low temperature evaporation (LTE). Based on these desalination plants have been developed for providing potable water in rural areas and on ships, and water for industrial uses.

During the report period, the nuclear desalination plant at CIRUS reactor worked well. Three desalination plants were supplied and installed at the Tsunami affected areas in Tamil Nadu. Ultra Filtration Pre-Treatment System was incorporated in the sea water reverse osmosis plant at Trombay. Work on nano-filtration technology was taken up.

INDUSTRIAL APPLICATIONS

Radiotracer investigations connected with isotope hydrology continued at BARC. An Automated Gamma Scanning System was developed for on-line inspection, trouble shooting and process optimization of industrial process plants. One such unit was installed at Heavy Water Plant, Manuguru.

At Trombay, proton, lithium and carbon beams from FOTIA accelerator were made available to users.

At RRCAT, wood polymer composites were successfully formed from mango and palash and significant improvements in density, compressive strength and anti-shrink efficiency were observed.

Accelerators Development

VECC at Kolkata is engaged in setting up of Superconducting Cyclotron, Heavy Ion Acceleration with the Variable Energy Cyclotron and a Radioactive Ion Beam facility.

During the year of report, the excitation current in the superconducting coils for the main magnet of the Superconducting Cyclotron reached very close to the design

A view of Out Reach Programme of Tata Memorial Hospital

RO Unit at General Hospital, Nagapattinum, Tamil Nadu

value. Majority of the components reached advanced stage of fabrication.

To obtain heavy ion acceleration with VEC, upgradations incorporated in the power supplies of beam lines resulted in very stable beams on targets. Also Dee voltage stability was improved. Sophisticated experiments using Indian National Gamma Array detectors were done and heavy ion beams of neon, oxygen, nitrogen were provided. VECC plans to obtain Argon and Sulphur beams.

At VECC, work continued on the development of Radioactive Ion Beam facility. This facility will provide accelerated beams of short-lived nuclei for accelerator based research in India.

An important milestone achieved at VECC was the commissioning and successful testing of the RFQ. Oxygen and nitrogen beams were accelerated upto 30 keV/u using this indigenously made first heavy ion RFQ. This success has put India in the elite group of countries possessing this technology.

Lasers & Applications

BARC and RRCAT are engaged in the research and development in the fields of lasers and their applications. Many devices and techniques based on lasers have been developed at these centres.

BARC developed a helium free TEA CO_2 laser that is superior to the conventional TEA CO_2 laser. The centre has also obtained a US patent for the same.

Laser welding of various automobile components was established with the indigenously developed high power carbon dioxide lasers.

The centre also developed a laser based compact fuel metrology system for quality assurance of uranium oxide fuel pellets being produced at NFC.

A technology was demonstrated At RRCAT for sol-gel based anti-reflection coatings on end faces of Nd:glass laser rods. A highly stable operation of regenerative Nd:glass laser amplifier was accomplished and a high sensitivity second order auto-correlator was set up for measurement of pulse duration of femtosecond laser pulses.

BASIC RESEARCH

The research centres of DAE are engaged in basic research in the areas relevant to the programmes they are pursuing. In addition, the autonomous research institutes, supported by grant-in-aid by DAE, are also the centres of excellence in basic research that ranges from mathematics to computers, physics to astronomy, and biology to cancers.

Mathematics, Computation and Basic Sciences

Highly significant results were obtained in the study of surfaces, in TIFR. The institute also designed a novel efficient micro-payment scheme called *e-coupons*, and developed a text-to-speech system for the blind. The efficacy of String Theory was demonstrated to smoothen the classical singularity in a class of (supersymmetric) black holes by including quantum gravity corrections.

At the Harish-Chandra Research Institute, classification of Irreducible Integrable modules for Twisted Toridal Lie algebras with finite dimensional weight spaces was done.

The 512 node Anupam-Ameya supercomputer systems developed at BARC were in regular use by various national agencies for high end scientific calculations and data generations. A high-resolution tiled display system and a high-end parallel processing software

BARC's supercomputing facility : Tera Flop Class 512 node Anupam-Ameya supercomputer

ANU-view were also developed at Trombay.

At VECC, for the Grid Computing Facility for ALICE Experimental Data, the 8-node dual processing cluster system are operational.

Exit Slit Assembly for use on PASS Beamline (Indus-I) and all the six modules of experimental station for EDXD Beamline (Indus-II), were designed, fabricated and delivered by BARC. The Centre also developed a Microcontroller based control and data acquisition system for the Inductively Coupled Plasma spectrometer and integrated to the system.

Very low noice-high gain ASICs were developed at BARC for front-end signal processing for the nuclear detectors. INDIPLEX is designed for its use in ALICE experiment at CERN. A new, high-performance 8 k MCA was also designed and developed with many advanced features.

Theoretical studies to understand the spin polarization in oxide semiconductors such as SnO_2 and ZnO etc on doping with magnetic ions were carried out at Trombay.

Investigations on scattering of laser light from argon-gas clusters were carried out at RRCAT to study the processes of laser-cluster plasma interaction.

At TIFR, work covered Spectroscopic Studies and Device Physics; Ultrafast Processes in semiconductor nanostructures, devices and other materials, and Synthesis and Study of Local Properties of Nanoscale Materials

The 3MV pelletron accelerator at the Institute of Physics was used for a variety of experimental research programmes and users from universities and other research institutions utilized the beam time of this accelerator.

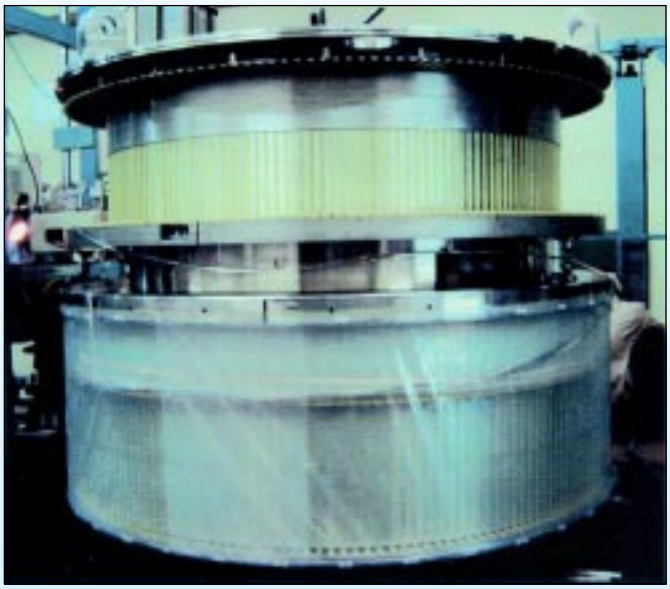
The 50-element BaF_2 array for high-energy gamma-ray measurements was commissioned at VECC.

At BARC, astrophysics studies in collaboration with other institutes continued. The 349-pixel Imaging Element of the TACTIC gamma-ray telescope at Mt. Abu Observatory was deployed for observing Active Galactic Nuclei (AGN).

BARC catered to the chemical analysis needs of national institutes/laboratories. A soft donor metal extractant namely aza amides was synthesized at Trombay for selective extraction of micro quantities of actinides from bulk amounts of trivalent lanthanides.Bio-active elemental selenium nanoparticles were also developed. New methods for halogenation of aromatic ring, silicon, and sulphur-mediated reactions were developed for their application in the syntheses of target compounds. Novel metallo-organic molecular precursors for metal chalcogenides were designed and developed. Selective separation of americium and curium was accomplished by supported liquid membrane (SLM) methods. New techniques were commissioned for carrying out chemical quality control of nuclear fuel and other materials.

At BARC-Kalpakkam, a novel specimen holder assembly was designed, fabricated, installed and tested in the high temperature high pressure loop for studying the flow assisted corrosion.

During the report period, at Trombay, the research in bio-sciences remained directed towards evolving high yielding, biotic and abiotic stress resistant food crops, delaying or preventing post-harvest losses by increasing shelf



Superconducting Cyclotron Magnet Coil

Meghnad-I

life, developing modalities for low dose cancer radiotherapy and employing molecular and isotope techniques in basic biology. Here, anti-tumour compounds were successfully synthesized.

RRCAT has developed India's first laser photo-coagulator for the treatment of diabetic retinopathy of the eye. An optical tweezers based efficient and controlled manipulation of neuronal growth cones was demonstrated at RRCAT. Induction of artificial growth cones from neuronal cell body and enhancement of the growth rate of the natural growth cones was achieved.

Under the MEDIP Project of VECC, a hardware-based system was developed for real-time de-noising and enhancement of medical ultrasound images, and an experimental set-up was evolved for precise quantitative imaging of a known scatterer embedded in human soft tissue.

At TIFR, the studies related to the development of functional neural networks in the brain of Drosophila. Other studies related to Metabolic Pathways of Plasmodium falciparum during asexual & sexual growth stages; Protein-DNA interactions, and Manipulation of Biological Molecules. At the National Centre for Biological Sciences of TIFR, programmes were developed in the area of membrane organization and cancer biology of HPV induced cancer.

At SINP, several target proteins implicated in blood disorders and neurodegenerative diseases were cloned, expressed and purified to homogeneity.

Synchrotrons

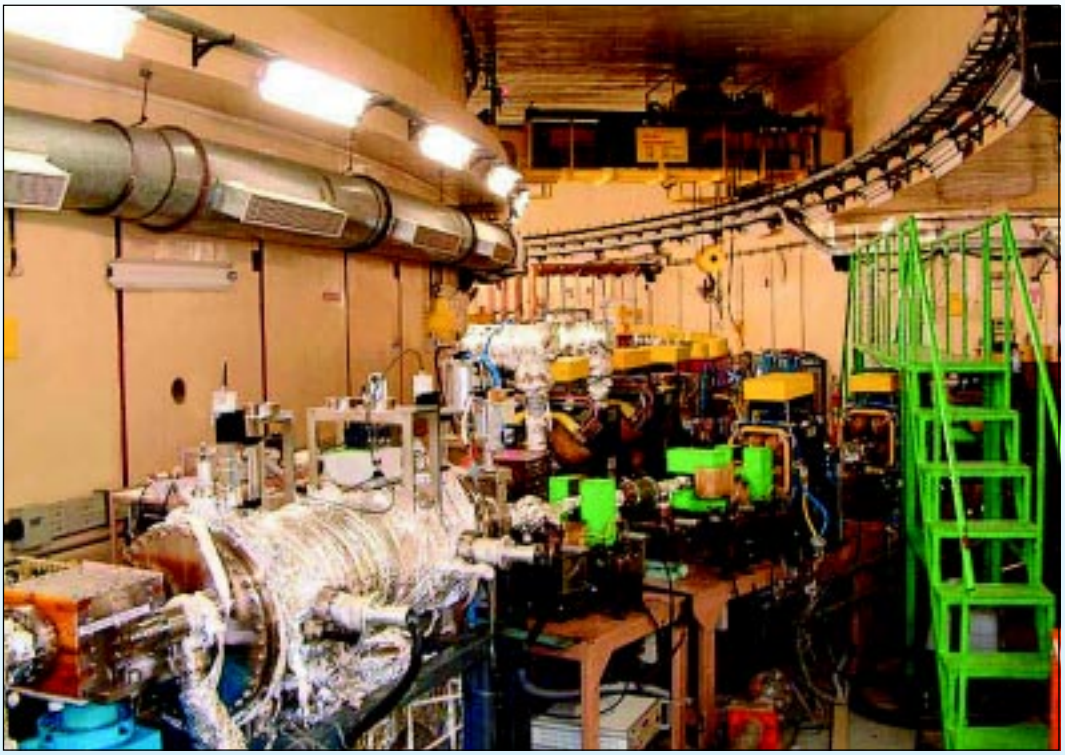
The 2.5 GeV Synchrotron Radiation Source Indus-2 was fully assembled and integrated at RRCAT. All subsystems were made operational and initial experiments to store electrons in the ring have commenced. Indus-2 was dedicated to the nation on November 15, 2005 by the Prime Minister Dr. Manmohan Singh.

RRCAT completed the last stage of evaluation of various components and sub-systems of Indus-2 ring and transport line-3 (TL-3). The electron beam was transported through TL-3 and successfully injected into storage ring. 450 MeV electron bunches were circulated in Indus-2 lasting several seconds and the synchrotron light was recorded. First front-end of high-resolution X-ray diffraction beamline was installed on Indus-2 bending magnet and tested. Work on the installation of this Indus-2 beamline also progressed. An experimental station for photo fragmentation studies was setup on Indus-1 vacuum ultraviolet/soft x-ray reflectivity beamline.

Cyclotron

In Superconducting Cyclotron the excitation current in the coils reached very near to the designed value.

For Heavy Ion Acceleration with VEC, upgradations of the Heavy Ion Acceleration were incorporated in the power supplies of beam lines leading to experimental stations. This resulted in very stable beams on targets. Also Dee voltage stability was improved.



Synchrotron Radiation Source Indus-2 setup at Indore

At VECC, another important achievement was the commissioning and successful testing of the Radio Frequency Quadrupole (RFQ). Oxygen and Nitrogen beams were accelerated using this heavy ion RFQ.

Fusion & Other Plasma Technologies

At the Institute for Plasma Research tokamak ADITYA was operated to study experimentally, density limit under various operating conditions.

The new experiment Steady State Superconducting Tokamak (SST-1) in the field of steady state operation of tokamaks is the main experimental effort at the Institute. SST-1 is nearing completion. International fusion community accepted Indian expertise in fusion science and technology and accepted India as a full participating country in the International Thermonuclear Experimental Reactor (ITER) venture.

International Research Collaborations

The contributions of DAE organisations to the CERN kept pace with programmes of building Large Hadron Collider, along with its detectors CMS and ALICE.

Under the DAE-CERN collaboration in large hadron collider (LHC), RRCAT completed the supply of 6800 precision movement alignment jacks to CERN, and dispatched last batch of superconducting sextupole corrector magnets for the LHC main dipole.

Under the VECC project "Search for Quark Gluon Plasma", the fabrication and assembly of half of the detector modules for the PMD of the ALICE experiment at CERN LHC was completed.

The international research collaboration of TIFR included Study of PP Collisions using CMS detector at LHC; Search for New Particles in the Large Hadron Collider (LHC) at CERN, and Maintenance & Operation of CMS Detector and Grid Computing.

At SINP, the 8 Muon chambers were successfully fabricated, and the first production of MANAS chips was completed. This first batch of chips was delivered to the PMD Collaboration in ALICE.

The Photon Multiplicity Detectors fabricated at the Institute of Physics were under installation at the Relativistic Heavy Ion Collider (RHIC) accelerator as part of the STAR experiment. Experiments were also carried out by IoP at the Electra synchrotron facility in Trieste and ALPI Linear accelerator at LNL, Italy through the medium of research students.

Homi Bhabha National Institute

Government approved setting up of Homi Bhabha National Institute (HBNI) under the aegis of DAE, with the status of a 'deemed-to-be-university' under the UGC Act. This landmark will help in accelerating the pace of basic research as well translation of basic research into technology development.

TECHNOLOGY TRANSFER AND COLLABORATIVE PROGRAMME

For the commercial exploitation of the spin off technology based developments, BARC transferred a number of technical know-hows to various institutions (both private and public), and signed several MoUs with entrepreneurs.

Plasma pyrolysis technology for medical waste disposal was commercialised by IPR. The plasma pyrolysis systems for non-chlorinated plastic waste were installed in Goa, Sikkim and Himachal Pradesh as well.

Dipole assembly weighing 32 tons being installed on jacks supplied by Raja Ramanna Centre for Advanced Technology for the Large Hadron Collider at CERN, Geneva

PATENTS

To protect the intellectual property created during this process, DAE-IPR Cell works as a nodal agency for intellectual property right related matters including filing of patents within India and abroad for all constituent units and grant-in-aid institutions.

During the report period, DAE filed 7 patent applications and 13 patents (11 patents granted by Indian Patent Office and 2 by United States Patent and Trademark Office) were granted to the Department.

Till date, DAE has filed 156 patent applications including PCT and national phase applications, out of which 76 patents were granted so far of which 45 are in force.

RESEARCH EDUCATION LINKAGES

In the areas of relevance to its programmes, DAE promotes scientific research, in collaboration with universities, educational/research institutes and laboratories. This is done through the Board of Research in Nuclear Sciences (BRNS) and the National Board for Higher Mathematics (NBHM).

During the report period, 105 new research projects were sanctioned by BRNS and 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/awarded under the Senior Scientists Scheme, eight fellowships were awarded under the K.S. Krishnan Research Associateship Scheme and thirty-two fellowships were offered/awarded under the DAE Graduate Fellowship Scheme. Financial supports were extended to fully funded BRNS seminars as well as to partly funded seminars conducted by professional organisations on various topics of relevance to DAE.

During the Golden Jubilee Year, the Science Research Council (SRC) of DAE had launched a unique programme to encourage exceptionally innovative research and development activities named as DAE-SRC Outstanding Research Investigator Award. Twelve recipients were selected for this award during this year.

NBHM extended financial support to 87 universities/ institutions to enable them to purchase the latest mathematical books and journals. In collaboration with the International Mathematics Union, the Board also initiated schemes for making mathematical literature accessible through electronic-communication. NBHM has provided 9 new fellowships at doctoral level and 16 at post-doctoral level. In addition, 20 national and 11 international conferences relating to mathematics were partially supported.

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

A recurring grant of Rs.1.56 crore was released in favour of the Chennai Mathematical Institute.

The Department has 8 aided institutions (including an educational society) fully funded in terms of their recurring and non-recurring expenditure. Several joint projects were undertaken amongst the DAE organisations and its Aided Institutions.

The funds (Plan & Non-Plan) allocated to these institutions by DAE during the report period were: Tata Institute of Fundamental Research (Rs.141.46 cr), Tata Memorial Centre (Rs.102.30cr), Saha Institute of Nuclear Physics (Rs.41.85cr), Institute of Physics (Rs.13.70cr), Institute of Mathematical Sciences (Rs.10.50cr), Harish-Chandra Research Institute (Rs.10.42cr), Institute for Plasma Research (Rs.93.70cr), and Atomic Energy Education Society (Rs.27.82).

DAE signed a Third Tripartite Agreement with the

Testing on flexural elements of Fibre Reinforced Composites, an emerging material for repairing and re-strengthening of the reinforced concrete structures. The project that aims at exploring Fibre Reinforced Composites as retrofitting and repair of reinforced concrete framed structures, is sponsored by DAE.

North-Eastern Council (NEC) and the Government of Assam, for the revitalization of the Dr. B. Barooah Cancer Institute, Guwahati, by way of financial support of Rs. 10.44 crore.

The Department also extended financial assistance to the tune of Rs.6 crore to Cancer hospitals located in other parts of the country.

An Apex Committee formed for creating a better network between cancer institutions all over the country deliberated on indigenous development and manufacturing of the equipment related to radiation oncology.

The Department also approved a collaborative project titled "Nuclear & Biotechnological Tools in Coastal System Research – Phase-II" undertaken by M S Swaminathan Research Foundation at an estimated cost of Rs.4.40 crore spread over for four years.

National Security

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

Financial Performances of Public Sector Undertakings

NPCIL registered a net profit of Rs. 1705 crore, and earning per share of Rs.180, and paid dividend of Rs. 342 crore to Government of India for the financial year 2004-05. The net profit for the year 2005-06 upto December 2005 was Rs.1257 crore (Provisional). NPCIL's bonds continued to be rated at AAA by CRISIL and CARE.

During the year 2004-05, UCIL recorded excellent performance. Its turnover was Rs.235 crore and the net profit stood at Rs.29 crore. The turnover of IRE for the said period was Rs.295 crore with foreign exchange earnings of Rs.91 crore. Profit before tax was Rs.61 crore, and the Company paid a dividend of 30%. For the financial year 2004-05, ECIL recorded a turnover of Rs. 771 crore and its profit before tax and Rs. 51 crore.

Noteworthy achievements of ECIL included completion of Control & Instrumentation supplies to unit-4 of Tarapur Atomic Power Station-3&4 and development of Special Nuclear Material Detection System for Vehicle Monitoring. Special purpose systems were supplied and commissioned for surveillance applications in the Ministry of Defence, as part of several Electronic Warfare Projects. ECIL was selected by the Department of Space for the supply of a 32 metre dia Deep Space Network (DSN) Antenna for India's prestigious Chandrayaan Project.

The success of the Electronic Voting Machines (EVMs) in the National Elections resulted in generation of lot of interest for the EVM in various countries in the African continent as well as in other developing countries.

OTHER ACTIVITIES

Crisis Management

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

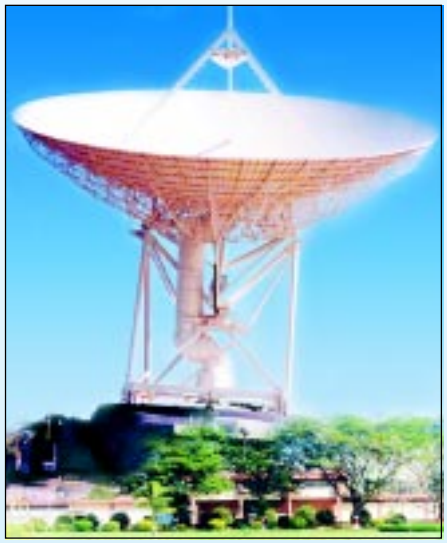
BARC Safety Council

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

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.

Electronic Voting Machine at Rajya Sabha, developed by ECIL



Chandrayaan Antenna

Vigilance

Annual Action Plan relating to vigilance was carried out in the Department as well as its constituent Units.

Information Dissemination

DAE publishes reports, documents and information material for departmental use, employees' enrichment and public awareness in English, Hindi and other Indian languages.

During the report period, various publications brought out by DAE included periodicals, and documents on various programme activities of DAE. A set of compilation of 3 volumes, describing the saga of Atomic Energy Programme in India covering a period of five decades, was released by the Prime Minister Dr. Manmohan Singh.

Under the employees' enrichment programme, information monographs/documents relating to DAE's programmes and objectives were produced in various Indian languages.

The information data was also hosted on DAE website. Various e-documents were produced for DAE library reference.

In tune with the emergence of digital library systems for information management and data retrieval, the libraries of various DAE organisation have taken up the task of converting paper documents into electronic formats. The libraries also subscribe to a number of on-line data bases such as Science-direct, INIS, Medline, and others.

Right To Information Act

The 'Right To Information' Act of Government of India, which came into force on October 12, 2005, was implemented in DAE organisations.

International Relations

India has been designated member of the Board of Governors (BoG) of the International Atomic Energy Agency (IAEA) since its inception and has been taking active part in policy management and programmes of the agency. India continued to offer training facilities, fellowships, scientific visits, etc. to foreign scientists and provided the services of its scientists for expert assignments to other countries both through IAEA and to countries with which we have entered into bilateral agreements for cooperation in the field of peaceful uses of atomic energy.

The set of three books on Saga of Atomic Energy Programme in India covering a period of five decades

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