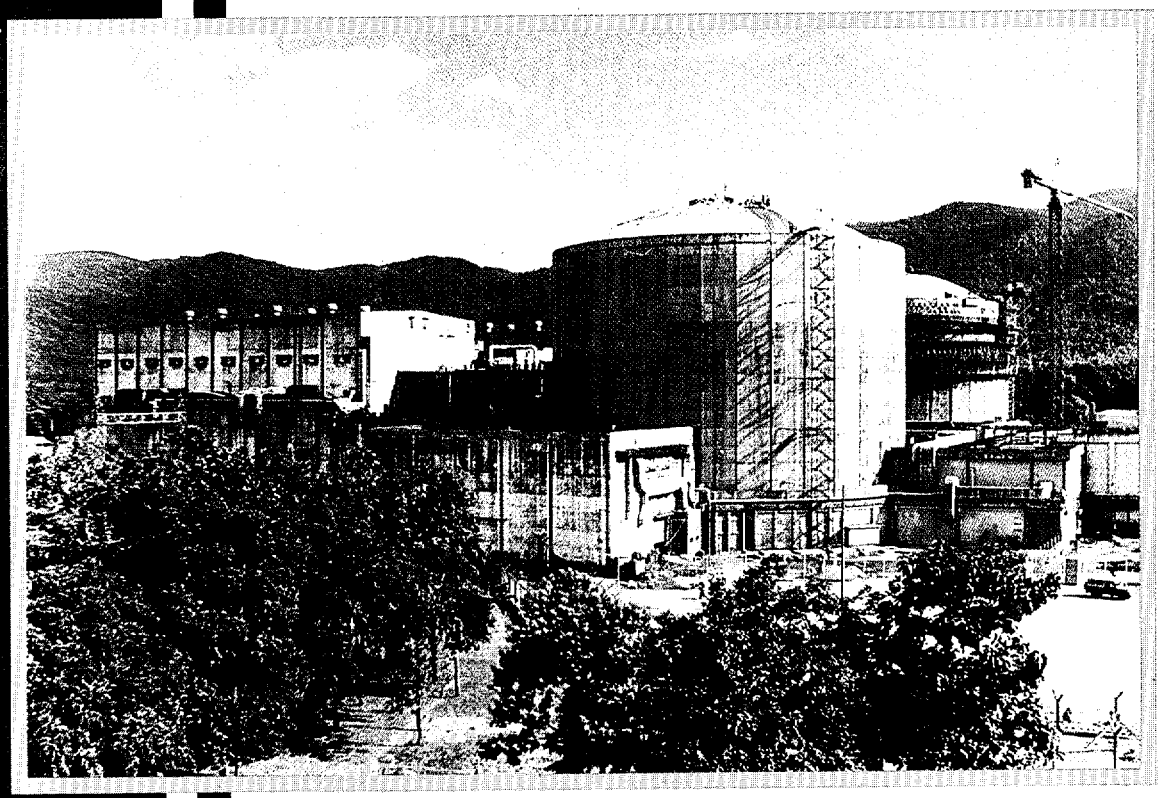
# ANNUAL REPORT
# 1999-2000



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**GOVERNMENT OF INDIA**
**DEPARTMENT OF ATOMIC ENERGY**

31/30

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**GOVERNMENT OF INDIA**
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# C O N T E N T S



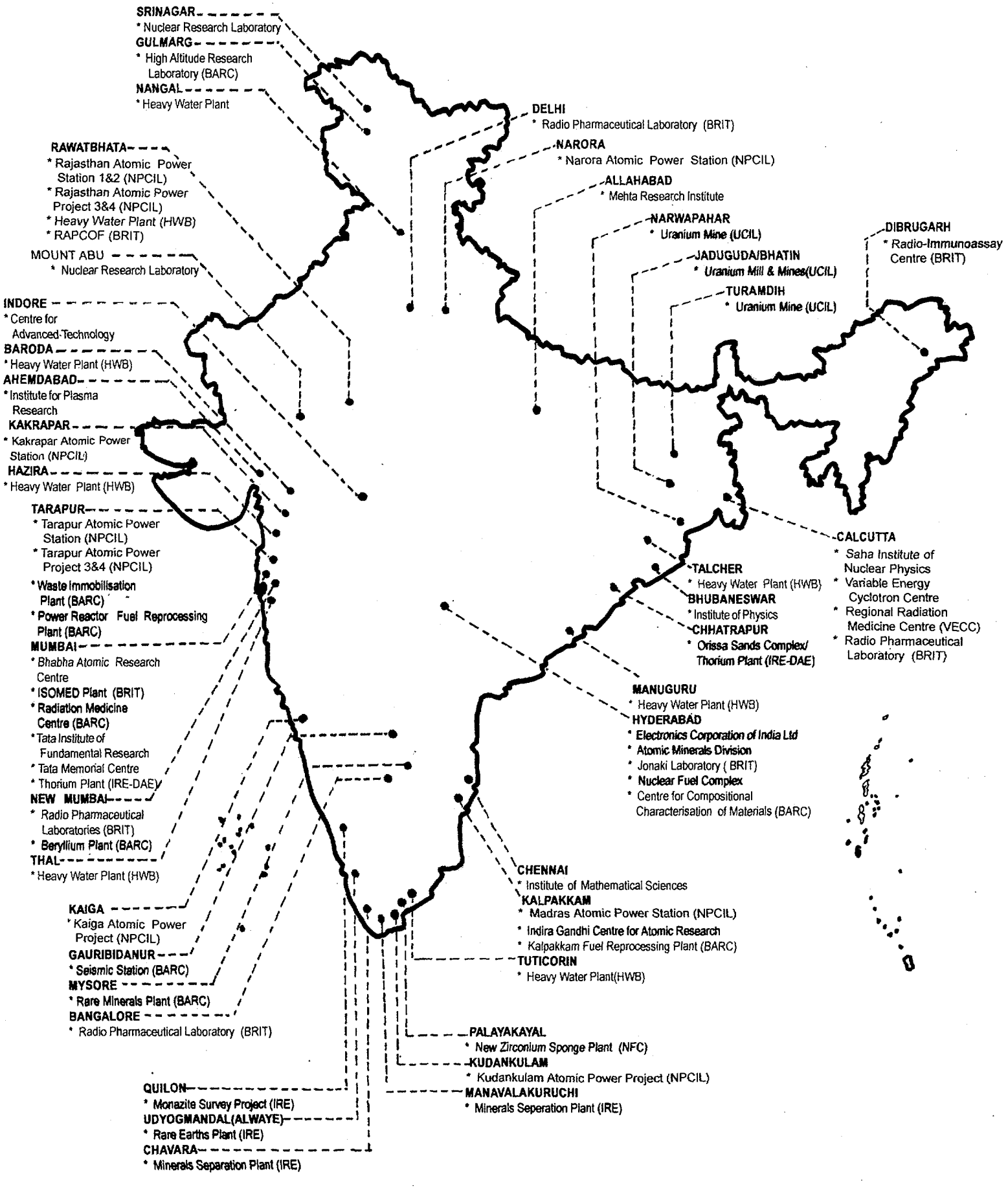
***Cover:***

*The state-of-the-art indigenously designed 220MWe pressurised heavy water reactor of the Kaiga Atomic Power Station which attained criticality on September 24, 1999. The reactor was synchronised to,the grid on December 2, 1999.*

***Back Cover :***

*INDUS-1 , the first Synchrotron Radiation Source (SRS) at Indore, which reached a beam current well above its design value.*

# Atomic Energy Installations in India



# *EXECUTIVE SUMMARY*

The Department of Atomic Energy (DAE) in India is a broad based multi-disciplinary organisation engaged in basic research, applied research, technology development and translation of the latter to industrial applications. As a result, the Department today builds its own nuclear reactors and associated nuclear fuel cycle facilities, is one of the leading producers of radioisotopes for use in industry, medicine, agriculture and research, and has established itself in hi-tech areas relating to accelerators, lasers, supercomputers, advanced materials, and sophisticated instrumentation. The stringent quality needs of nuclear technology have helped in upgrading the quality levels of the Indian industry. Besides all this, a pool of quality manpower has also been developed. Today, DAE is marching ahead with the mission enshrined in its mandate.

For DAE, the year 1999-2000 was an epoch making period. The Department crossed a number of milestones, registered significant achievements, and took long strides in all its programmes. The highlights are :

Two state-of-the-art indigenously designed 220 megawatt(e) pressurised heavy water power reactors attained criticality one each at Kaiga (Karnataka) and Rawatbhatta (Rajasthan). The Kaiga Unit was synchronised to the grid. Both these Units will soon become commercial.

INDUS-I, the first Synchrotron Radiation Source in India, reached a beam current well above its design value.

The country's first Solid Storage Surveillance Facility (S3F) at Tarapur was inaugurated, making India fourth nation in the world to have such a facility.

The Commercial Demonstration Plant for Radiation Processing of Spices set up at Vashi, Navi Mumbai by BRIT, became operational and regular processing of spices commenced. Radiation processed spices have large export market.

NFC commissioned its new projects for the manufacture of Uranium Oxide Fuel, Uranium Fuel Assembly, and Zircaloy Fabrication.

A supercomputer consisting of eight Pentium-III nodes, developed at BARC, reached a sustained speed of 2 giga flops (floating points per second).

With a power generation of about 11,950 million units during April 1, 1999 to February 29, 2000, the operating atomic power stations achieved an overall capacity factor of nearly 80%. The safety record of all the plants was also very satisfactory.

The mixed carbide fuel for the Fast Breeder Test Reactor at Kalpakkam crossed a burnup of over 50,000 megawatt day/tonne.

The overall performance and safety record of the operating Heavy Water Plants were excellent. The Fuel Reprocessing Plants at Trombay, Tarapur and Kalpakkam operated satisfactorily.

In the field of mineral exploration, additional resources of uranium oxide were located at Wahkyn (Meghalaya).

At Talcher, a pilot plant for production of D2EHPA was commissioned. The quality of the product was found to be better than that of the imported one.

Design, construction and development of a Remotely Operated Power MANipulator (ROPMAN) with six degrees of freedom, along with a gripper, was completed for hot cell

applications at IGCAR.

The farmer friendly nuclear research achieved the following : The groundnut variety TAG-24 was included in 'Package of Practices' for summer cultivation for Rajasthan by the Rajasthan Agricultural University, Udaipur; Several insect pheromones were synthesized, and trace element finger print pattern technique for determination of nutrients in soils was developed.

In the field of environment, ISO-14001 certificate was awarded to the Narora Atomic Power Station while the Rajasthan Atomic Power Station got the Golden Peacock Award-1999 for its efforts in conservation of environment. To study the effects of low level radiation on human population living in the high background radiation areas, a new building for Low Level Radiation Research Laboratory (LLRRL) was inaugurated at Kollam, Kerala. The in-plant and environmental surveillance carried out at the uranium mines and mill of Uranium Corporation of India Ltd. (UCIL), minerals and monazite processing plants of the Indian Rare Earth Ltd. (IRE), and different fuel fabrication and related plants of the Nuclear Fuel Complex (NFC), Hyderabad found all the parameters well within their regulatory limits.

The scientists from BARC analysed the data from the measurements carried out at the time of the Pokhran tests in 1998 as well the radioactivity in the rock samples obtained by post-shot drilling and by bore hole logging at the test sites. These studies confirmed fully the initially declared yields and other design parameters for all the devices.

Following is the summary of DAE's activities during the period of report :

## NUCLEAR POWER PROGRAMME

The Nuclear Power Programme of DAE comprises building of pressurised heavy water reactors, fast breeder reactors and thorium reactors on commercial scale. Technology development relating to operation and maintenance of the reactors, waste management, safety and environment monitoring also forms part of the programme.

### Power Generation

The Nuclear Power Corporation of India Ltd. (NPCIL) has 10 atomic power reactors in operation -- two reactors each at Tarapur, Rawatbhata, Kalpakkam, Narora, and Kakrapar. Of these, Unit-1 of the Rajasthan Atomic Power Station at Rawatbhata is operated on behalf of the Government of India.

For over five years, NPCIL has been showing consistent improvement in its operations. During April 1, 1999 to February 29, 2000, NPCIL increased the overall capacity factor of its atomic power stations to nearly 80% from a capacity factor of 75% during 1998-99 (excluding Rajasthan Atomic Power Station-1). It registered a gross electricity generation of about 11,950 million units during this period.

The company achieved a net profit of nearly Rs.450 crore (Provisional) during the financial year 1999-2000 up to February 2000 and paid Rs. 50.44 crore as maiden dividend to the Government.

Based on the targets set in memorandum for understanding (MoU) for the financial year 1998-99, the performance appraisal of NPCIL was rated as "Very Good". CRISIL upgraded its rating to "AA" from A+.

**Power Projects under Construction**

Kaiga Atomic Power Project-1&2 (2x220 MWe PHWRs), Rajasthan Atomic Power Project-3&4 (2x220 MWe PHWRs) and Tarapur Atomic Power Project-3&4 (2x500 MWe PHWRs) are the ongoing projects of NPCIL.

One 220 megawatt(e) reactor each at Kaiga and Rawatbhatta attained criticality on September 24 and December 24, 1999 respectively. The Kaiga unit was synchronised to the Southern grid on December 2, 1999 and the Rajasthan unit will follow suit soon.

The main plant civil contracts of TAPP-3&4 Project were awarded and the works have progressed.

**New Projects**

The Kudankulam Atomic Power Project (2x1000 MWe VVER) and Kaiga-3&4 (2x220 MWe PHWRs) are the new projects of NPCIL.

Good progress has been made on the preparation of the Detailed Project Report (DPR) for Kudankulam Project and NPCIL has taken up pre-project activities relating to Kaiga-3&4 Project.

**Fast Breeder Programme**

The Indira Gandhi Centre for Atomic Research (IGCAR) has been engaged in the development of sodium cooled fast breeder reactors. Over the years, the Centre has established comprehensive R & D facilities in the field of fast breeders. Fast Breeder Test Reactor (FBTR) is its major research facility built indigenously.

During the year, the Fast Breeder Test Reactor (FBTR), with its small core, was successfully operated at 8 MWt with indigenously developed plutonium-uranium carbide fuel. The fuel reached a burnup level of 50,500 megawatt day/tonne by November 1999. Several experiments related to reactor safety, surveillance activities and others, were carried out.

With this expertise, IGCAR has embarked on the design and development of 500 MWe Prototype Fast Breeder Reactor (PFBR) which will be the forerunner in the series of fast breeder reactors. Significant progress has been made in the design & development of components and systems of PFBR.

The major engineering development activities carried out by IGCAR, in support of PFBR, included the experimental studies on Large Component Test Rig (LCTR), component hydraulics, sodium pump and reactor instrumentation.

The construction of PFBR is scheduled to commence during the last year of the IX Plan.

NUCLEAR FUEL CYCLE

Nuclear Fuel Cycle covers the entire range of programmes which support the nuclear power generation, and comprises mineral exploration, mining, heavy water production, fuel fabrication, fuel reprocessing and waste management.

DAE has achieved self-reliance in all the nuclear fuel cycle activities.

The DAE organisations engaged in the activities relating to Nuclear Fuel Cycle are : Atomic Minerals Directorate for Exploration and Research, Uranium Corporation of India Ltd., Indian Rare Earths Ltd, Heavy Water Board, Nuclear Fuel Complex, BARC and IGCAR.

The activities under the Nuclear Fuel Cycle are described as follows.

### Mineral Exploration

Exploration of mineral resources for the Nuclear Power programme of the country are carried out by the Atomic Minerals Directorate for Exploration and Research (AMD). Salient achievements and activities of AMD during the year were the following :

- Additional resources of uranium oxide were located Wahkyn (Meghalaya), and inferred reserves of Yellapur Peddagattu blocks (Andhra Pradesh) were converted to indicated category by drilling in filling boreholes.

-Continuity of ore grade uranium mineralisation (>0.10%) was established over considerable strike length at Gogi (Karnataka) and Koppunuru (Andhra Pradesh). Mineralised intercepts with better grade were also met in boreholes drilled at Ghateshwar in Rajasthan.

-Noteworthy uranium occurrences were located by ground radiometric surveys in parts of West Khasi Hills district (Meghalaya); Solan and Sirmour districts (Himachal Pradesh) and Cuddapah district (Andhra Pradesh).

-Airborne Gamma Ray Spectrometric and Aero-Magnetic surveys were carried out over 23,900 line km in parts of Bhima basin (Karnataka) and Vindhyan basin (Uttar Pradesh and Bihar).

-Ground geophysical surveys narrowed down target areas and helped in deciphering mineralisation trends in parts of Karnataka and Andhra Pradesh.

-New heavy mineral potential areas with significant heavy mineral content were identified along the coastal tracts of Andhra Pradesh and Kerala.

-Additional resources of about 220 tonnes of xenotime bearing polymineralic concentrate were estimated from riverine placers of Bihar.

-The four recovery units located in Bihar, Madhya Pradesh and Orissa produced 41.80 tonnes of xenotime bearing polymineralic concentrate, 3.37 tonnes of columbite-tantalite and 3.40 tonnes of beryl.

### Mining

Mining and ore processing of uranium ores and mineral sands are done by the Uranium Corporation of India Ltd. (UCIL) and the Indian Rare Earths Ltd. (IRE). Their functions and organisational set up are given under "DAE Organisations" at Annex-1. Both UCIL and IRE are public sector undertakings and their activities and achievements have been covered in this chapter under the section Public Sector Undertakings.

### Heavy Water Production

Heavy Water Board produces heavy water which is used in the pressurised heavy water reactors as moderator and coolant.

During the year, the overall performance and safety record of the operating Heavy Water Plants were excellent. The cumulative production achieved exceeded the target scheduled for the period.

The plants at Tuticorin, Baroda and Kota completed more than 8.6, 9.6 and 5.3 million manhours of continuous operation respectively. Due to the closure of old ammonia plants of Gujarat State Fertilizer Corporation (GSFC), Baroda, the Heavy Water Plant, Baroda has been stopped since December 1998. A major modification for reviving operation of Baroda Plant was initiated by the HWB.

Implementation of ISO-9002 quality system was carried out at Heavy Water Plant, Tuticorin.

As a part of future diversification, an R&D Pilot Plant facility for production of D2EHPA

solvent was successfully commissioned. The Process chemistry was provided by BARC.

**Nuclear Fuel Fabrication**

The Nuclear Fuel Complex (NFC), Hyderabad meets the fuel and zircaloy requirements of all the nuclear power reactors in the country. In addition, NFC manufactures stainless steel tubes for other industrial applications. The projects commissioned during 1999-2000 were : New Uranium Oxide Fuel Project, New Uranium Fuel Assembly Project, and New Zircaloy Fabrication Project. Also, augmentation of Uranium Metal Production at Trombay reached its completion stage.

**Nuclear Fuels Development**

With a burnup reaching over 50,000 MWd/tonne, the mixed carbide fuel in Fast Breeder Test Reactor (FBTR) performed extremely well. As a part of mixed carbide fuel development, samples of carbide fuels were fabricated for various studies.

Progressive introduction of mixed oxide (MOX) fuel in reactors at Tarapur continued.

Significant progress was made in the developments of fuel for Prototype Fast Breeder Reactor (PFBR). This included fabrication and characterisation of mixed uranium-plutonium oxide fuel pellets of different compositions.

After the successful demonstration of Sol-gel microsphere pelletisation technique for production of good quality high-density pellets suitable for PHWR fuel, a large-scale uranium-oxide microspheres preparation was undertaken at Trombay.

**Fuel Reprocessing**

The Fuel Reprocessing Plants at Trombay, Tarapur and Kalpakkam operated satisfactorily. A facility for the separation of uranium-233 from thorium rods irradiated at CIRUS and DHRUVA reactors approached completion and revamping of PREFRE Plant at Tarapur continued.

IGCAR's Lead Mini Cell (LMC), a demonstration facility for reprocessing of FBTR fuel on laboratory scale, reached advanced stage of completion. The safety and commissioning reports have been under review by the AERB's Safety Review Committee for Operating Plants (SARCOP). Work on Fast Reactor Fuel Reprocessing Plant (FRFRP) also progressed. Various equipment reached the site. The process vessels, which are under fabrication, are expected soon.

At Uranium-233 Extraction Plant, hot commissioning works related to the second campaign of uranium-233 extraction from thorium rods, were completed. Uranium-233 was extracted and converted to oxide form successfully.

**Waste Management**

Work on revamping of the Waste Management Facilities at Tarapur, Trombay and Kalpakkam progressed. A major milestone of the radioactive waste management programme was the inauguration of country's first Solid Storage Surveillance Facility (S3F) at Tarapur. Solid Storage Surveillance is an important stage prior to the disposal of higher level wastes in deep geological repository. India is the fourth nation in the world to have such a hi-tech facility.

At the Waste Immobilisation Project, Trombay an indigenously designed and manufactured vitrification furnace for immobilisation of highly active radioactive wastes in glass matrix was successfully commissioned. The furnace system has a unique design.

The construction of the WIP-Trombay is expected to be completed soon. The construction of Waste Immobilisation Plant, Kalpakkam also made good progress.

**R&D Support to Nuclear Power**

The improved INGRESS for garter spring relocation in wet channels of PHWRs reached an advanced stage of testing at Trombay.

At IGCAR, the PFBR core physics design codes were approved by the Validation Committee and safety analysis codes were also reviewed. The document on incident / accident analysis of PFBR was under review. Probabilistic safety analysis of the shutdown and decay heat removal systems made progress.

**Quality Assurance**

ISO-9001 and ISO-14001 certificates were awarded to the Engineering Directorate at Head Quarters of NPCIL and the Narora Atomic Power Station respectively. Assessors from the Confederation of Indian Industry (CII) commended NPCIL's strong commitment to the Total Quality Management (TQM).

At Kalpakkam, Quality Assurance, Non-Destructive Testing and Quality Audit were conducted for various projects of IGCAR. These services were also provided to other units such as Heavy Water Plant (Manuguru), Tarapur Atomic Power Station etc. To cater to the needs of R & D and other engineering projects related to PFBR, a Quality Engineering Services and Testing Facility was under augmentation.

**Safety**

At Trombay, under the safety related technology development, work continued on augmentation of Facility for Accident Scenarios and Operational Transients. For the project Nuclear Aerosol Test Facility (NATE), civil construction on the building has been completed.

The radiological safety support to various nuclear power plants and other fuel cycle facilities was continued by BARC. This included assessment of the radiological status of the plant areas, safety reviews and other allied activities. The analysis of the data showed that the doses received within the exclusion zone (1.6 kilo metres) are much less than the limit prescribed by AERB. At Kaiga and RAPP 3&4, health physics laboratories and facilities were set up to meet the operation schedules.

Countrywide personnel monitoring was conducted for 32,000 radiation workers of about 3000 industrial, medical, research and DAE institutions.

Safety surveillance inspections were carried out in IGCAR and BARC Facilities at Kalpakkam, and programmes on safety education, first aid training, fire squad training etc., were also organised.

The operating DAE units have drawn up comprehensive Emergency Preparedness and Response Plans to handle postulated emergency scenarios like Plant and Site Emergencies.

A total of 245 exercises of different types were conducted during the year 1999 by the major DAE facilities. The Off Site Emergency Exercises were carried out in the public domain surrounding the nuclear power stations at Tarapur, Kalpakkam and Kaiga and the heavy water plants at Rawatbhatta and Manuguru. Guidelines were circulated to the State Governments and Union Territories for handling the presence or suspected presence of nuclear materials in the public domain.

During the year, various organisations of DAE ensured Y2K readiness with respect to their functions. The Action Group at DAE monitored the implementation of Y2K resolution by all the DAE organisations. Particular attention was paid to both computer based systems and embedded components at the nuclear power stations, research reactors and other nuclear facilities. While continued safety in operations had been ensured, contingency plans, to handle any unanticipated

Y2K related problem, had also been drawn up by the various units. All these efforts helped in smooth transition to the year 2000.

**Environment**

Environmental surveillance for radioactivity was conducted at the various nuclear power stations by the Environmental Survey Laboratories (ESL) of BARC.

To study the effects of low level radiation on human population living in the high background radiation areas, a Low Level Radiation Research Laboratory (LLRRL) building (a part of Monazite Survey Project at Kollam, Kerala) was inaugurated.

For dispersion estimates, 3-dimensional meteorological model ADOCT (Atmospheric Dispersion over Complex Terrain) was developed at Trombay.

The efforts of Environmental Survey Laboratory, Rawatbhata led RAPS to win the coveted Golden Peacock Award -1999 instituted by the World Environment Foundation.

At IGCAR, the work on the environmental impact assessment study for PFBR was completed. A 30 metre meteorological tower was installed for carrying out coastal atmospheric studies.

One environmental gamma dose logger, an atmospheric sampler and a gamma tracer were designed, fabricated and tested by IGCAR, and environmental gamma dose was archived and analysed.

*Environmental Surveys*

All the parameters were found to be well within their regulatory limits by the in-plant and environmental surveillance carried at the uranium mines and mill of UCIL at Jaduguda, Bhatin and Narwapahar, mineral and monazite processing plants of IRE at Udyogamandal, Chavara, Manavalakurichi and OSCOM (Chhatrapur), and in different fuel fabrication and related plants of NFC, Hyderabad.

Environmental radiation monitoring was carried out in the coastal villages in the naturally high background areas of Kerala, Tamil Nadu and Chhatrapur in Orissa. Also, for carrying out countrywide radon mapping, radon calibration facility was set up at Kalpakkam.

## NON-POWER PROGRAMME

The radiation and isotope technology programme is oriented to meet the growing demand of radioisotopes & radiation technology in industries, health care services, agriculture and research. BARC has been producing radioisotopes for over four decades, and today the Centre is a leading manufacturer of radioisotopes.

The radioisotopes produced at Trombay have been in use in various industrial processes, testing and services. In the field of agriculture, high yielding mutant varieties of various crops have been developed, nuclear technology has been established in reducing post-harvest losses by preventing damage from insect and microbial contamination and extension of shelf life. The Government of India have approved irradiation of a number of food items. The indigenous technology of radiation processing of food items has entered the commercial domain. Radioisotopes have also been used to improve fertilizer use efficiency, monitoring the fate and persistence of pesticides in soil, and ground water.

## Research Reactors

BARC's reactor programme provides R&D support to operating / under construction nuclear power plants, in meeting the growing demand of radioisotopes, and to provide facilities for basic and applied research, development of advanced reactors and associated technologies.

The research reactors DHRUVA, CIRUS and APSARA at Trombay have been used for the production of radioisotopes besides their use in basic and applied research, irradiation testing of fuels & materials, and training.

DHRUVA, which completed 14 years of successful operation, continued to be a major facility for radioisotope production, and served as a national facility for neutron beam research programmes. APSARA also functioned satisfactorily. To extend the useful life, refurbishing work on CIRUS continued.

To enhance safety in operation & maintenance activities for the research reactors, internal regulatory inspections for the research reactors were introduced. Probabilistic Safety Analysis studies for DHRUVA reactor was also completed.

The KAMINI reactor -- a uranium-233 based system designed by BARC and set up at Kalpakkam, continued to perform well. It operated upto its rated power level of 30kW and was utilised for irradiation, activation analysis of samples and neutron radiography of specimens.

The design and engineering development of Advanced Heavy Water Reactor (AHWR) progressed and its physics and thermal hydraulics design was further optimised.

## Radioisotope Technology

During the year 1999, more than 50,000 consignments of radioisotope products valued at Rs. 17.84 crore were supplied for use in industry, research, agriculture and health care.

Radioisotope products and equipment valued about Rs. 1.5 crore were exported to countries such as United Kingdom, Germany, Sri Lanka, Syria, Myanmar, Bangladesh and Tanzania. The items exported included 1.85 PBq cobalt-60 source (Atomic Energy Research Establishment, Bangladesh), G amma Chamber 5000 Unit (Atomic Energy Department of Myanmar), Fume Hood with accessories (Sri Lanka), and Laboratory Equipment and accessories of Tc-99m generator (Syria). An export order from Japan Radioisotope Association is under execution.

BRIT fabricated and supplied a total of 12.95 PBq ( 350 kilocuries ) of *radiation sources* for use in industry, medicine, agriculture and research, and processed about 70.6 TBq ( 1910 curies ) of reactor produced *radioisotopes* for supply to various users and for formulation of a variety of radiopharmaceuticals.

BRIT supplied over 900 consignments of carbon-14 and tritium *labelled compounds* and 1900 consignments of various *labelled biomolecules* to about 250 research institutions. The JONAKI laboratory at Hyderabad produced P-32 and P-33 *labelled nucleotides* meeting the indigenous research needs.

### *Radiation Sterilisation*

The ISOMED Plant, the facility operated by BRIT at Trombay, has been providing sterilisation service to the medical industries for over 25 years. ISOMED operated at 85% capacity factor and approx. 10,000 cu. metres (1,16,000 cartons ) of various medical products were radiation sterilised. A few million dai kits were sterilized at the plant by different manufacturers for supply to rural heath programme funded by WHO. ISOMED also continued production and supply of

items relevant to gamma radiation processing and health care programme. ISO-9002 certification process for ISOMED Services reached final stages of completion.

*Industrial Applications*

Gamma scanning of 12 types of columns ( 2 to 9.1 metres in diameter and 40 to 60 metres high) was carried out for chemical and petrochemical industry.

As a result of BARC's studies on sediment transport in the Hooghly estuary, Calcutta Port could effect substantial financial savings.

Under the programme of radiation processing of natural polymers, the electron-beam-irradiation of polyethylene films blended with rice husk and bagasse was carried out by BARC. These radiation processed films were found to possess good mechanical strength and pronounced biodegradability.

To promote radiation processing using industrial electron accelerators, BARC is setting up at Khargar, a new Electron Beam Centre housing two industrial accelerators.

### Radiation Medicine

BRIT supplied over 45,000 consignments of different radiopharmaceuticals, cold kits and radioimmunoassay kits to various nuclear medicine centres and RIA laboratories for diagnostic and therapeutic uses. The Regional Centres at Bangalore and Delhi processed ready-to-use Tc-99m radiopharmaceuticals for use in their region, and the Dibrugarh and Bangalore centres offered radioimmunoassay service to local hospitals. New products introduced included MIBG Iodine-131 injection (IOM-50) and production of a kit for preparation of Tc-99m ECD injection ( TCK-42 ).

At Trombay, the hydrogel preparations, developed for healing burn injuries, underwent clinical tests successfully. An indigenously assembled radiochromatography system for validation of labelled radiopharmaceutical preparations proved to be a good import substitute. BARC developed a process for preparation of Iodine-125 source for use in the treatment of ocular tumours and prostate cancer.

The Radiation Medicine Centre (RMC) of BARC continued to serve as a regional referral centre of the World Health Organisation (WHO) for the South East Asia.

At the Regional Radiation Medicine Centre at Calcutta the medical LINAC benefitted more than 7000 patients during the year 1999. More than 1000 patients were provided with therapy and scanning facility. Radioimmuno-Assay serviced about 5000 patients.

## HIGH TECHNOLOGY

The research organisation of DAE are also engaged in the development of high technologies such as accelerators, lasers, cryogenics, pulse power, supercomputers and others. Many successes have been achieved under these programmes as follows:

### Accelerators

The accelerator programme of DAE is geared towards the development of accelerators to meet the needs of modern research and applications in the fields of medicine, agriculture and industry. The Variable Energy Cyclotron Centre (VECC), Calcutta; Centre for Advanced Technology (CAT), Indore, and BARC are the centres engaged in the research and development relating to accelerators.

The Variable Energy Cyclotron, a national research facility, has been in operation for over 25 years. The facility was undergoing upgradation for acceleration of heavy ions. The work for the upgradation of the VEC with Electron-Cyclotron-Resonance (ECR) heavy ion source developed in-house, almost reached completion. First beams of 115 MeV Oxygen and 150 MeV Neon were extracted with currents over 50 nano-ampere. The Centre continued to work on setting up a Superconducting Cyclotron and a Radioactive Ion Beam (RIB) facility.

Construction of the Superconducting Cyclotron building and fabrication of the major components of the accelerator progressed and ultrasonic testing of all the forgings for the main magnet frame was over. The Radioactive Ion Beam (RIB) facility, which is technologically very challenging, is a collaboration project of VECC, SINP and RIKEN, Japan. Most of the systems / subsystems were either in the fabrication stage or ready for the start of assembly. The R&D activities on some of the systems were underway.

*Synchrotron Radiation Source*

At CAT, Indore, INDUS-1, the first Synchrotron Radiation Source (SRS) in India, reached a current of 160 milli ampere on 28 July 1999, which was well above its design value. Only a dozen countries have the capability in designing and construction of such complex accelerators. INDUS-1 consists of three indigenously designed and developed accelerators namely a 20 MeV microtron, a 450 MeV booster synchrotron and 450MeV storage ring. To use the synchrotron radiation, five beamlines were designed and constructed by CAT, BARC and Inter-University Consortium for DAE facilities (IUC-DAEF). Theoretical design for INDUS-2 was also completed.

At Trombay, the Folded Tandem Ion Accelerator (FOTIA), an indigenously designed and fabricated system reached final stages of commissioning. The accelerator is one of the few of its kind operating accelerators in the world. FOTIA will deliver light and heavy ion beams for use in basic and applied research in nuclear, atomic and material sciences. The BARC-TIFR Pelletron Accelerator Facility completed 11 years of successful operation. The research programme conducted at this facility have already made an impact on the international scene.

The 500 KeV Industrial Accelerator was tested successfully upto a beam energy of 400 KeV. The Linear Accelerator (LINAC) facility at Trombay remained in continuous operation. It was also used by some universities.

Lasers

CAT has been working on the development of biomedical laser applications. Applications of nitrogen lasers in diagnosis of certain cancers, yielded confirmatory results. For clinical use two prototype equipment were built and one was installed at the Cancer Screening Centre at Indore.

A Pulsed Laser Deposition (PLD) facility was set up at Indore. It was used for growing thin films of wide band gap semiconductors. On PLD collaborative research on materials continued with the Inter-University Consortium (IUC), Indore; IIT-Madras and IIT-Bombay.

Under the Development of Laser Materials Programme, CAT completed fabrication of a facility for making ferroelectric oxide thin films. It also established an indigenous facility for developing transparent ceramic plates of strategically important material.

A number of lasers/instruments were developed and supplied to users. These were: a 300 mJ pulsed Nd:YAG laser, installed at the Syrian Atomic Energy Commission, IIT-Madras, IGCAR and Nagpur University; Surgical carbon dioxide laser systems supplied to a hospital at Guwahati

and AIIMS, New Delhi; a high power 2.5 kW carbon dioxide laser system for material processing delivered to Jadhavpur University, and one 500W multi-beam carbon dioxide laser system supplied to the Hindusthan Laser Ltd., Kodaikanal for sealing thermometer tubes. Two laser fluorimeters were installed at AMD, Tata Nagar and Health Physics Unit of RAPP, Kota, respectively.

At IGCAR, a new laser heating method was found to be useful in causing localised de-sensitisation of austenitic stainless steels.

### Cryogenics

R&D work in cryogenics is mainly conducted at CAT and VECC.

At CAT, the development work on a three stage closed cycle cryocooler, capable of producing a lowest temperature of 6.5 Kelvin, progressed . Two cryocoolers -- a two-stage and a single-stage cryocoolers, producing lowest temperatures of 10 Kelvin and 30 Kelvin respectively, were undergoing testing.

VECC fabricated and set up a portable helium extraction system at Bhabanipur (West Bengal) where large scale helium escape was noticed. Efforts were directed to enhance the scale of separation.

### Pulse Power Research

The KALI-5000 pulse power system, being developed at Trombay, reached an advanced stage of assembly. The pulsed electron beam produced from the facility will be used for applications in high power microwave generation, pulsed intense neutron source etc..

### Supercomputer

BARC's ANUPAM Super computer commissioned at the National Centre for Medium Range Weather Forecasting, Delhi, resulted in considerable savings by the NCMRW. Another supercomputer consisting of eight Pentium-III nodes, developed at BARC, reached a sustained speed of 2 giga flops (floating points per second).

To meet the increasing computing needs, work on setting up a centralised computing facility continued.

### Robotics

Design, construction and development of a Remotely Operated Power MANipulator (ROPMAN) with six degrees of freedom, along with a gripper, was completed for hot cell applications at IGCAR. The servomotor controlled motion of the ROPMAN facilitates its upgradation to a full-fledged robotic arm.

### Materials

In the field of Material Sciences, efforts of BARC were focused on upgradation of technology for production of uranium compounds, rare earths, nuclear grade thorium, and setting up of a Lithium Metal Pilot Plant and Advanced Material Processing Centre.

Technology demonstration of fabrication of low temperature niobium-titanium multifilament superconducting cables was taken up. Heat shrinkable shape memory alloy sleeves were also developed for supply to the Light Combat Aircraft (LCA) Project.

At Kalpakkam, for production of enriched Boron-10, the Isotope Separation Plant reached

advanced stage of construction. The commissioning of the plant will be taken up shortly.

Special sensitive sensor materials were developed by IGCAR, and the experimental setup for the production of sodium, was operated successfully.

**Instrumentation**

At BARC the Pipe Inspection Gauge (PIG) system developed earlier was successfully tried at the test facility of the Indian Oil Corporation, Faridabad. It was ready for field trials in Barauni-Patna pipeline. With the success of PIG, plans were drawn up for building pipe inspection gauges for larger diameter pipelines.

Other notable developments in field of instrumentation included :

- A portable bedside Veno Screen for periodic screening of venous circulation of patients;
- Enhancement in the capability of Inductively Coupled Plasma Source - Mass Spectrometer (ICP-MS) developed at the Centre;
- Fabrication and commissioning of a DC Arc Power Supply for emission spectroscopy work which is an import substitute;
- A fatigue-creep monitoring system (FCMS) which converts the power plant transients to temperature/stress responses. India joined worldwide technical information network FAMONET (Fatigue Monitoring System Network).
- Fabrication and testing of a combined ion gauge and convectron gauge control unit for the measurement of vacuum from atmosphere to $10^{-10}$ Torr;
- Process for preparing borosilicate glass having coefficient of expansion matching to Kovar metal;
- The indigenously designed and fabricated Time of Flight Mass Spectrometer for photochemical investigations of atmospherically important molecules;
- A new pocket dosimeter (DIGIDOSE) with selectable integrated dose alarm levels, and
- A Soft-X-ray Reflectometer was designed for measuring the reflectivity of multilayer coatings.

The technology contributions from BARC to the reactor units at Kaiga and Rawatbhatta covered a number of computerised control and instrumentation systems for plant protection, control of processes and operator support. The SCADA system developed at Trombay attracted agencies for technology transfer.

A compact single wire arc-plasma spray torch was developed at Trombay and used to spray coat copper and stainless steel wires. A number of such systems were developed for neutron tomography, two phase flow visualization, void fraction measurement and others. The techniques developed at BARC was used for applications such as CCD based gamma tomography, X-ray diffraction imaging and medical imaging.

At Kalpakkam, an argon atmosphere glove box assembly was commissioned for carrying out various measurements on radioactive and air sensitive compounds. A Temperature Monitoring System for FBTR reactor vessel was successfully developed. A low field SQUID magnetometer was also assembled and tested successfully. This paved the way for the development of systems for SQUID applications in materials technology including NDT. A process for producing electro-catalytic coatings on titanium meant for nitric acid application was developed and a patent was filed.

**Seismology**

The seismic monitoring and data processing facilities of BARC located at Mumbai, Gauribidanur and Delhi continued to function satisfactorily. With the commissioning of five digitally communicating stations at the Seismic Array, Gauribidanur, the Data Acquisition and Processing Facilities got upgraded. Two wide band systems were also commissioned at Gauribidanur and Delhi.

The seismograms generated at various distances by the Indian explosions at Pokhran in 1998, were analysed which gave the yield in the range 52-63 kT. This agreed well with the announced yield and the post-shot radiochemical yield.

**National Security**

Following the successful nuclear tests in May 1998 at Pokharan, implementation of the programme to meet the national policy of credible minimum nuclear deterrence in terms of necessary research and development as well as manufacture, is being pursued.

**Nuclear Agriculture & Biosciences**

BARC's activities in the area of nuclear agriculture remained focused on developing improved crop varieties, use of radiotracers in the study of fertilizers and behaviour of agrochemicals in the environment, and use of radiations in the control of insect pests.

The groundnut variety TAG-24 was included in 'Package of Practices' for summer cultivation for Rajasthan by the Rajasthan Agricultural University, Udaipur. Nineteen new groundnut cultures were in different stages of evaluation in the coordinated trials of the Indian Council of Agricultural Research (ICAR).

The ongoing studies in nuclear agriculture related to field trials for standardising a protocol for the trapping of red palm Weevil by using its pheromone; experiments using sterile insect technique (SIT) on diamond backmoth, and bioremediation technology for the treatment of radionuclide, heavy metal and organic waste.

At Trombay, a simple method was developed for the bulk purification of horse radish peroxidase. This enzyme has a number of applications in industry and diagnostics. BARC also provided more than 1200 tissue cultured plants to seven research stations/universities.

Several insect pheromones, pharmaceutical intermediates and ligands for actinide extraction were synthesised. A synthesised pheromone for the control of sweet potato Weevil pests, and an insect growth regulator formulation developed at Trombay were found to be very effective in all India trials. A cheaper and highly efficient pheromone dispenser was also developed at BARC.

The farmer-friendly nuclear research resulted in the trace element finger print pattern technique for determination of macro and micro nutrients present in different soils, and estimation of trace level of arsenic in ground water using proton-induced-X-ray emission.

The BARC has established linkages with agricultural universities for extension of the research efforts.

The rDNA from groundnut was cloned to detect polymorphism and develop fingerprints for Trombay groundnut varieties.

Four blackgram varieties (urid) developed at Trombay and two national check varieties were analysed for developing DNA fingerprints.

Yield trial of Trombay mustard cultures at Nagpur Agricultural College showed TM-1 to be superior to the check variety in seed yield.

Seventy five quintals of breeder seed of four Trombay groundnut varieties worth Rs.2.85 lakh

was produced by BARC under contract farming at Kolhapur.

The *in vitro* methodology for clonal propagation of pineapple and grapes, reached the stage of field evaluation, after its standardisation.

Biotechnological applications covered micropropagation of economically important crops and production of bioactive compounds using plant cell culture and enzyme and microbial technology. BARC transferred several technologies which included release of genetically improved crop varieties, transfer of protocols for large scale multiplication of tissue culture raised banana, transfer of bio-reactor technology for large scale production of plant biomass and transfer of biopesticide development technology.

For the World Bank aided Projects at Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, a model watershed was developed by BARC. The system was found to be effective in soil and water conservation.

**Food Technology**

In the field of Food Technology, the research and development work related to preservation of food by gamma radiation as well as by the conventional and emerging methods.

The Commercial Demonstration Plant for Radiation Processing of Spices set up at Vashi, Navi Mumbai by BRIT, became operational and regular processing of spices in this plant commenced. The plant is designed for a maximum capacity of 1000 kilocuries of cobalt-60 source.

To demonstrate the feasibility of increasing the shelf life of potatoes and onions on commercial scale, the construction of POTON Irradiator at Lasalgaon near Nashik (Maharashtra) made further progress.

At Trombay, the Food Package Irradiator and other experimental facilities for irradiation were used for irradiation of food and experimental samples. Various fruits and vegetables were studied for their amenability to preservation and hygienization by gamma radiation.

Storage studies on fish and ready-to-eat meat kababs established the effectiveness of radiation processing in enhancing their shelf-life.

A nondestructive method for sorting of mangoes infested with stone weevil and spongy tissue; increase in the utilization efficiency of wheat straw for mushroom cultivation, and isolation of a new antioxidant from Jawala fish, were other developments.

Radiation processing of potato, onion and mango was carried out by BARC for a firm in Mumbai.

The patent applied by Centre for the process of isolation of a polysaccharide -- a good immuno-modulator--from the Indian medicinal p*lant, Tinospora cordifolia*, was accepted.

**Desalination of Water**

BARC has developed various processes for desalination plants. Based on these processes, the Centre has developed desalination plants for rural areas, ship-borne plants, and for other uses. To demonstrate the feasibility, safety and economic viability of coupling nuclear reactor for desalination of sea water, BARC has been setting up a 6300 cubic metre/day capacity Desalination Plant at Kalpakkam. The construction of this plant progressed during the year of report.

**Basic & Applied Research**

DAE research centres have also been engaged in basic and applied research in frontier areas of sciences. Basic research is also carried out in nuclear energy and basic sciences at seven national

institutes under the aegis of DAE.

BARC has been setting up world-class astronomical facilities under the Gamma Ray Astrophysics Coordinated Experiments (GRACE) Project at Gurushikhar Mt. Abu. (Rajasthan). As part of phase-II of the Project, design and development of telescope facilities MACE, MYSTIQUE and BEST made progress.

The major efforts of B5 ARC studies at Trombay focused on the physics problems of design, safety and operation of nuclear reactors. Research and development covered activities in allied areas of reactor theory, neutron transport theory, applied mathematics and numerical methods.

A code was developed at BARC for Evaluation of Magnetic Dipole and Electric Quadrapole Interaction Constants in the analysis and Simulation of Atomic Hyperfine Structure. As a spin-off of developing charge-coupled-device (CCD) based X-ray diffraction imaging systems, a prototype x-ray imaging system suited for medical diagnostic purpose was designed at the Centre. Test runs on the system gave quality images suitable for medical diagnostics. A three dimensional neutron tomography technique using CCD based detectors was also developed at Trombay.

A 40 kV/ 280 kJ, capacitor bank consisting of 48 energy storage capacitors was used for experimental studies on matter at high energy densities. Two plasma focus devices -- one for high neutron yield and another a small neutron source, and a vacuum spark plasma device based on the concept of passive triggering was also developed.

The studies conducted at VECC related to the isovector response for finite nuclei; understanding the temperature dependence of observables; formulation concerning asymptotic expansion of the Fokker-Planck equation; neutron multiplicities and mean kinetic energies of the evaporated neutrons, variance of the total kinetic energies of the fission fragments. Calculation of low-lying excitation spectra of $^{11}$Be and $^{19}$O; description of nuclear fission dynamics at high excitation energies; the effect of dissipation and noise on the domain formation; formation and evolution of disoriented chiral condensates, and Propagation of heavy quarks in equilibrating quark gluon plasma were some other major investigations made at VECC. Also, studies made covered radiation of single photons from relativistic heavy ion collisions; High spin states of odd-odd $^{142}$Pm and odd-A $^{143}$Pm, and Decay mechanism of light hot composite nuclei produced by heavy ion collision.

VECC pursued R&D activities on high temperature cuperate superconductors based on YBaCuO and Bi-Sr-Ca-Cu-O systems. Radiation Damage Studies of Nuclear Structural Materials like Zircaloy, Zr-2.5%Nb, Zirlo and SS-316 with charged particles from cyclotron were undertaken with the purpose of simulation of reactor damage.

## PUBLIC SECTOR UNDERTAKINGS

DAE has under its aegis four public sector undertakings namely the Nuclear Power Corporation of India (NPCIL), Uranium Corporation of India (UCIL), Indian Rare Earths Ltd. (IRE) and Electronics Corporation of India (ECIL).

Activities of NPCIL have already been covered under nuclear power generation. Following are the major activities of the remaining Public Sector Undertakings :

### Uranium Corporation of India (UCIL)

During the year 1998-99, improved efficiency in all fields of operations of UCIL resulted in higher production of uranium concentrate and rise in net income of the company.

The Narwapahar mine became fully operational with modern mining equipment and technology, the expanded Jaduguda Mill with high levels of instrumentation and automation was commissioned, and the works of deepening of Jaduguda and Bhatin mines progressed.

High safety standards were maintained in the units of UCIL and implementation of its ecology and environmental protection programme continued.

A medical survey conducted by a team of doctors and radiation experts in the villages around Jaduguda, could not find any linkage of disease pattern with the operations of the UCIL.

**Indian Rare Earths Ltd. (IRE)**

The Indian Rare Earths Ltd. (IRE) has been engaged in mining and production of beach sand minerals and rare earths compounds.

During the year 1998-99 IRE's performance was impressive. It registered an all-time-high turnover of Rs.178 crore, earned foreign exchange of Rs. 61.84 crore and received Capexil's Export Award. It bagged an order of USD 2.33 million from Egypt, for setting up a mini-pilot plant for monazite processing.

The company expects to achieve sales turnover of Rs. 200 crore during 1999-2000 with export touching Rs.70 crore.

Efforts of IRE continued to improve production at Chavara which was affected by the non-availability of raw sand. It completed Microzir project for production of fine zircon powder and obtained ISO-9002 certificate for its Manavakuruchi Unit. At Manavakuruchi unit, collection of raw sand from beach washing has restarted. OSCOM, in spite of a shut down of its plant due to cyclone, attained a production of 80% of its installed capacity.

For setting up a Synthetic Rutile Plant at OSCOM, IRE signed a joint venture with an Australian company.

**Electronics Corporation of India (ECIL)**

During the year 1998-99 the production of the ECIL was about 238 crore and the gross income was about Rs. 251 crore and it booked orders worth Rs.198 crore. The company introduced a number of new products needed by the thermal power plants, space, defence, and crucial sectors. The export from the company included X-ray generators, notch indicators, gyros and synchros.

For the year 1999-2000 , the corporation has drawn up a sales plan of Rs. 440 crore.

**Promotion of Research & Development**

DAE through its Board of Research in Nuclear Sciences (BRNS), promotes research and development activities in Indian universities and other institutions of higher learning for the growth of nuclear and allied sciences. BRNS also sponsors conferences, symposia, workshops and seminars on topics of relevance to DAE programmes.

During the period of report, BRNS offered Dr. K.S. Krishnan Research Associateship (5nos.) and initiated a Visiting Scientist Scheme for university scientists. The Board also approved financial assistance for 83 new projects including conducting a coordinated study on thermal ecology (8nos.), renewed 128 ongoing projects and supported 70 symposia/conferences.

As a part of DAE-University Collaboration BRNS approved setting up a Centre for Formal Design and Verification of Software at IIT-Bombay, a National Centre for Fast Reaction Kinetics at the University of Pune, and a LOCA Environment simulation and Aging Test Facility for large components.

**University Interaction**

Under the Inter-University Consortium for DAE Facilities (IUC-DAEF), the research facilities at DAE's research centres were regularly utilised by universities/institutes for research & training. Practical training/ project work for BTech/ MSc/ MTech students of Indian Universities were also coordinated by BARC. The Centre continued its assistance in strengthening MSc (Radiation Physics) course at the Mangalore University, and in setting up Electron Beam Centre at SAMEER.

**International Research Collaborations**

Research centres of DAE such as BARC, CAT, VECC have been engaged in International Research Collaborations.

BARC continued participating in the international collaborative research project on Micronuclei in Human Populations, and in the development of CMS detector & detector frames for PHENIX. The Centre took up follow up actions for various projects under Indo-German and other schemes.

VECC has been collaborating in the International Research Projects namely WA98 experiment at CERN SPS accelerator in Geneva (Switzerland) and ALICE experiment at the Large Hadron Colliders (LHC). The Centre analysed the data of the WA98 experiment. For the consideration of the LHC Experiments Committee, VECC submitted a design report relating to Photon Multiplying Detector (PMD) which will be a special type of gas detector based on honeycomb proportional chambers.

**Technology Transfer & Collaborative Programmes**

The DAE organisations have been contributing to augmenting scientific capability of the nation through their linkages with academic institutions and national laboratories.

Some new initiatives in this regard included BARC's Collaboration with Agricultural Universities in Maharashtra and Large Scale Component Test Work continuing at institutions such as the Structural Engineering Research Centre, Chennai. Taking shape at IIT-Bombay is the BARC's joint activity on thermal hydraulics studies related to Advanced Heavy Water Reactor (AHWR).

The technologies transferred by BARC included Foldable Solar Dryer, Lascan Dia Gauge, Triode Sputter Ion Pumps, TLD Reader, Mini-Micro Stepping Control Drive, ANUDAQ-20, sputter ion pumps and 100 MSPS Transient Digitiser. A local company was accredited to provide Personnel Monitoring Services to radiation workers in India.

The technology for the sodium level sensors developed in-house at IGCAR was also transferred to industry.

Various hi-tech products such as X-Ray Proportional Counter, Anugami PC interface Card, Virtual Reality Software, Titanium anodes duly plated with enriched uranium, Boron Carbide, Gamma Scanning Equipment, Machined Uranium Pellets, Fuel Tube head, Lithium Carbonate and Hexamethyl Propylene Oxime (HMPAO) were supplied to Indian parties/companies.

A number of MoUs signed by BARC included Process Design Consultancy and Technical Backup for setting-up of large sized Thermal Desalination Plant; Supply, installation & commissioning of Fluorine Purification System; Use of radiation and radioisotopes in agriculture; Technology for diamond polishing scaives; Setting up of National Single Crystal X-Ray Diffraction Facility; Development of indigenous technology for manufacture of irradiation Cross Linked Cables and heat shrinkable accessories; and Acoustic and RF Technology, and Development &

modification of Solvent Extraction process for refining of ammonium diuranate.

Items exported by BARC included thoria buttons (USA), TLD cards & cassettes and TLD Personnel Monitoring System (Saudi Arabia) and TLDATE Software ( Hongkong).

*Technical Services:* Consultancy services in the field of Stress Analysis, Failure Analysis, Gamma Scanning, Welding, Powders Classification, Vibration Diagnostics, Radio Isotope applications were provided by BARC.

Apart from meeting the captive needs, the Centre provided analytical service support to organisations, hospitals and academic institutions.

As a part of life extension programme, methodologies for evaluation of structural integrity of tail rotor blades of helicopters were developed and standardised .

**Support to Research & Development**

For promotion of research in the frontier areas of nuclear science, mathematics and cancer, DAE provides grants-in-aid to seven institutes of national eminence.

For the year 1999-2000, grants provided by the Department were as follows :

Tata Institute of Fundamental Research (Rs.85.95 crore), Tata Memorial Centre (Rs.68.50 crore), Saha Institute of Nuclear Physics (Rs. 28crore), Institute of Physics (Rs. 6.4crore), Institute of Mathematical Sciences (Rs.5.55 crore), Mehta Research Institute (Rs. 5.43crore), and Institute for Plasma Research (Rs. 30.80crore) .

The Giant Metre-wave Radio-Telescope (GMRT) set up by the TIFR near Pune, Maharashtra, and the Laboratory for Computational Mathematics, also set up at Pune by TIFR in collaboration with BARC, became operational. The objective of the laboratory is to develop symbolic and numerical computation paradigm. TIFR's National Centre for Biological Sciences at Bangalore moved to its new building.

The Tata Memorial Centre, which is engaged in the field of comprehensive diagnosis and treatment for cancers and allied diseases, cancer research, patient care services, and professional education and training, has been setting up a new Advanced Centre for Treatment, Research and Education in Cancer (ACTREC) at Navi Mumbai. During the year of report, work on ACTREC progressed. Also, TMC renovated its patient wards and procured medical equipment of the state-of-the-art technology.

The Saha Institute of Nuclear Physics (SINP) is engaged in teaching of higher learning and research in nuclear and biophysical sciences. SINP's programmes of setting up a National Facility for High Current Isotope Separation and Ion Implantation, and Multi-element Gamma, Heavy-Ion and Neutron Array Detectors (Meghnad) continued. Work on setting up a Radioactive Ion Beam Facility, another major project of SINP, also made progress.

The Institute of Physics (IOP) remained engages in setting up a laboratory for producing atomic clusters and cluster assembled materials which could guide future technology.

The Institute of Mathematical Sciences (IMSc) fosters fundamental research in frontier areas of mathematical sciences. IMSc continued with the research in physics, mathematics and theoretical computer science.

The Mehta Research Institute for Mathematics & Mathematical Physics (MRI), remained actively involved with its teaching and research programmes and other allied activities.

The major activities of the Institute for Plasma Research (IPR) focused on the development of tokamak reactor concept, fusion related technologies, theoretical and experimental work relating

to fundamental plasma physics, and plasma technologies for industrial applications. The Institute has been working on the development of Steady State Super Conducting Tokamak-1 (SST-1).

For improving cancer control measures in the country, the Department provides financial assistance to some of the leading cancer centres in the country. The Department approved six new research projects for the Cancer Institute, Adyar, Chennai.

The Department also provided grant-in-aid of Rs.7.75 crore to the Atomic Energy Education Society which manages the atomic energy schools at various sites for the education of children of employees of the DAE organisations.

**International Relations**

India, a designated member of the Board of Governors of the International Atomic Energy Agency (IAEA) since inception of the Agency, continued to offer training facilities, fellowships, scientific visits etc. to countries, through IAEA or under bilateral agreements. It also made available services of its scientists for expert assignments in the field of peaceful uses of atomic energy. Over 470 scientists/engineers participated in international symposia, workshops and conferences. Under IAEA fellowship-programmes and bilateral agreements, 58 foreign scientists were trained. India also hosted 16 IAEA meetings/symposia and 10 other international meetings during 1999-2000.

Chairman, Atomic Energy Commission (AEC) led the Indian delegation to the Regular Session of the IAEA General Conference held in Vienna, Austria during September 1999. Bilateral discussions were held with a number of other delegations participating in the Conference.

An agreement between the Atomic Energy Regulatory Board (AERB) and the Nuclear Installation Safety Directorate (DSIN) of French Republic for the exchange of information and cooperation in the regulation of Nuclear Safety, was signed.

**Public Awareness and Welfare**

DAE and its organisations continued their endeavour in disseminating awareness on the peaceful applications of atomic energy and India's progress in this field. Media, educational domain and public at large were the main focus of these efforts which included information literature, exhibitions, multimedia presentations, seminars and symposia. Quiz /essay competitions, and lectures were the other efforts made. Welfare programmes covering health care, education, community service and others, continued for the benefit of people.

Major DAE organisations launched their Web-Sites with a view to make information readily available to public. The Indian RCA National Home Page was also put on Web by BARC.

**Human Resources Development**

For developing managerial skill among senior officers sharing substantial administrative responsibility, BARC continued to coordinate and organise Management Development Courses. During the period of report, 156 trainee scientific officers of the Orientation Course for Engineering Graduates and Science Post-Graduates (OCES) and Orientation Course for Engineering Post-Graduates (OCEP) graduated and absorbed in different DAE organisations. About 1400 students completed training/ project work. Training facilities were provided to 24 IAEA fellows. A new scheme commenced in collaboration with IIT-Kanpur. The scheme offers regular appointment in DAE to those candidates who will be completing MTech in nuclear engineering & tech-

nology at IIT- Kanpur.

Homi Bhabha Young Scientist Award Scheme, instituted earlier by BARC to motivate excellence in research, continued. NPCIL has also introduced award schemes for technical excellence and meritorious service, and "NPCIL Millennium Award Scheme".

**Employees' Welfare**

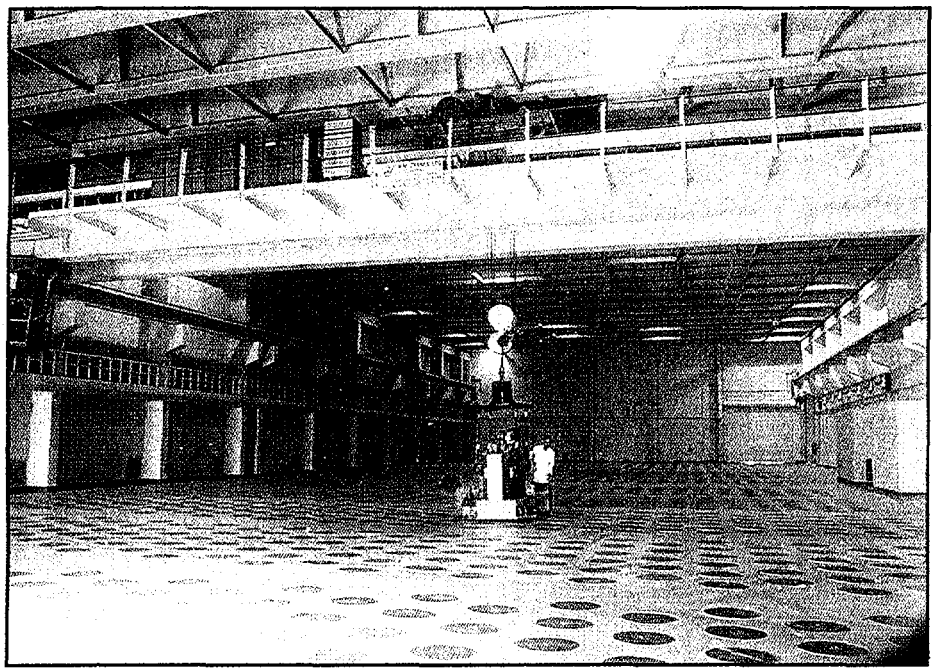
Under the Central Health Service Scheme (CHSS), which covers over 72,000 beneficiaries, over 4.80 lakh patients were treated, while the Audiology and Speech Therapy Unit extended treatment to 3800 patients. As a part of social service activity, assistance was provided to about 12,000 patients.

The morbidity patterns of the prime population were compiled under WHO codes for determining prevalence rates of various ailments.

# BHABHA ATOMIC RESEARCH CENTRE

The Bhabha Atomic Research Centre's research and development efforts are concentrated towards fulfilling its mandate of indigenous nuclear power programme and other peaceful uses of nuclear energy. The technology to design, build and operate nuclear power reactors has been mastered and a blue print is being made ready for the development of next generation of nuclear reactors for exploiting vast reserves of thorium. Considerable self reliance has been achieved in the field of nuclear materials which go into the making of a reactor and fuels which run it. An indigenous capability has been built over the years to reprocess the spent fuel and recycle the valuable fertile and fissile material and to manage the nuclear wastes by isolating it from environment to minimise the risks for future generations. BARC has contributed significantly by supplying radioisotopes, which find extensive use in the fields of agriculture, medicine and industries. Ensuring health and safety of personnel against radiation and protection of environment has been the primary concern in all its endeavors. The Centre also aims to provide R&D support for Nuclear power generation programme.

The Research Centre is executing many programmes in the IX Plan to meet the short term / long term goals in the fields of Reactors, Reprocessing & Waste Management, Nuclear Materials, Nuclear Fuels, Health &Safety, Bio-Sciences, Radioisotope Applications, Chemical & Physical Sciences and Desalination. Enhancement of existing infrastructures becomes essential to successfully implement the aforesaid programmes. Strong linkages exist among all the cited programmes.



*The storage vault of Solid Storage Surveillance Facility, Tarapur designed and constructed indigenously. The Facility which has become operational, is a major achievement*

Suitable mechanisms and strategies were adopted to monitor progress and achieve high performance in meeting physical and financial targets utilising available resources. Project reviews have been undertaken at various levels as project monitoring activity on a continuous basis as part of Management services.

The highlights of some of the major activities, initiatives and achievements made during this year are enumerated as follows:

## Reactor Programme

Development of Reactor technology is at the core of comprehensive R&D program being pursued in BARC. All other programmes are linked with reactor programme overtly or covertly. BARC reactor program is mainly geared towards R&D support to operating / under construction nuclear power plants, to meet the growing demand of radioisotopes for use in agriculture, medicines and industries, to provide facilities for basic and applied research, development of Advanced Heavy Water Reactor and Light Water Reactor technologies.

## Research Reactors

Research reactors DHRUVA and APSARA are operating well. The refurbishing of CIRUS Research Reactor is in full swing to extend the useful life of the reactor and a desalination plant is also planned to be coupled with this reactor. These reactors provide facilities for basic and applied research, irradiation testing of fuels & materials, production of radioisotopes and training of scientific and technical staff.

### APSARA

The reactor completed 43 years of successful operation and continues to be used in several research applications which include, neutron activation analysis; environmental, biological and geological studies; trace element characteristic studies; radiation damage studies and neutron detector testing. Over 500 samples were irradiated during the year for research & radioisotope production. Neutron radiography facility was used for testing of nuclear fuel assemblies and some real time applications. Preparations have been completed for starting the experiments for testing of bulk shielding assembly models proposed to be used in the Prototype Fast Breeder Reactor. These included installation of a especially designed aluminium box in the pool between the core and the shielding corner cave in order to provide the required incident thermal neutron flux on the flux converter assemblies and engineering modifications to the shield trolley and converter assembly trolley. Reactivity worth measurements of Burnable Poison Rod (BPR) assembly consisting of Gadolinium Aluminate as neutron absorber are also being carried out in Apsara.

Work related to planned core conversion and refurbishment of Apsara is in progress. The conversion aims to provide a demonstration of the design concept and technological features of 10 MWt Multi Purpose pool type Research Reactor whose basic design has been recently worked out . The detailed design of Process systems, Core components and Control & Instrumentation systems is in an advanced stage of completion. The Project Design Safety Committee constituted by AERB has completed design safety review of the proposal.

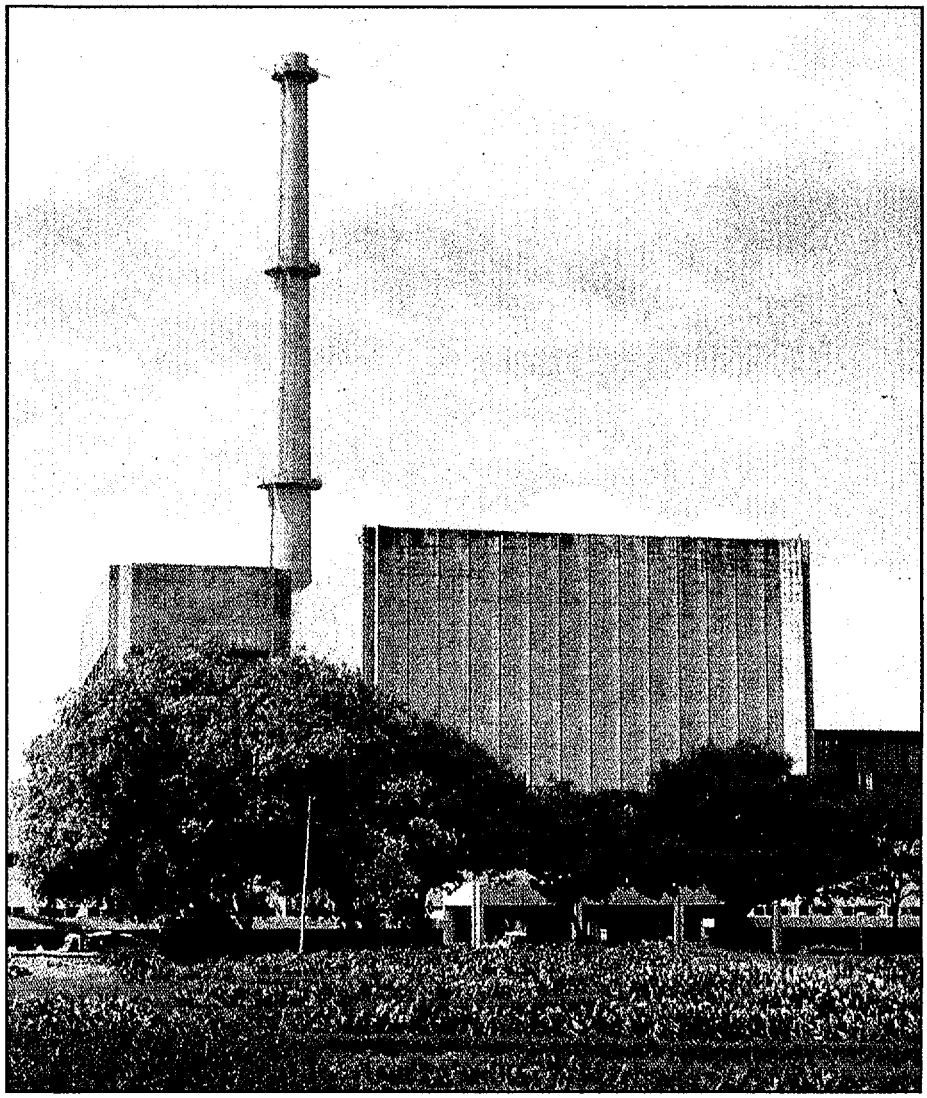
### CIRUS

The complete core of the reactor remains unloaded to facilitate refurbishing activities and various safety and process systems are being maintained and monitored in the preserved state.

### DHRUVA

The reactor completed 14 years of successful operation and was operated at near rated power level. Dhruva continues to be the major facility for radioisotope production and serves as a national facility for neutron beam research programmes. During the year, about 850 samples were irradiated for radioisotope production. A number of research scholars from various academic institutions utilised the facility under DAE-IUC programme.

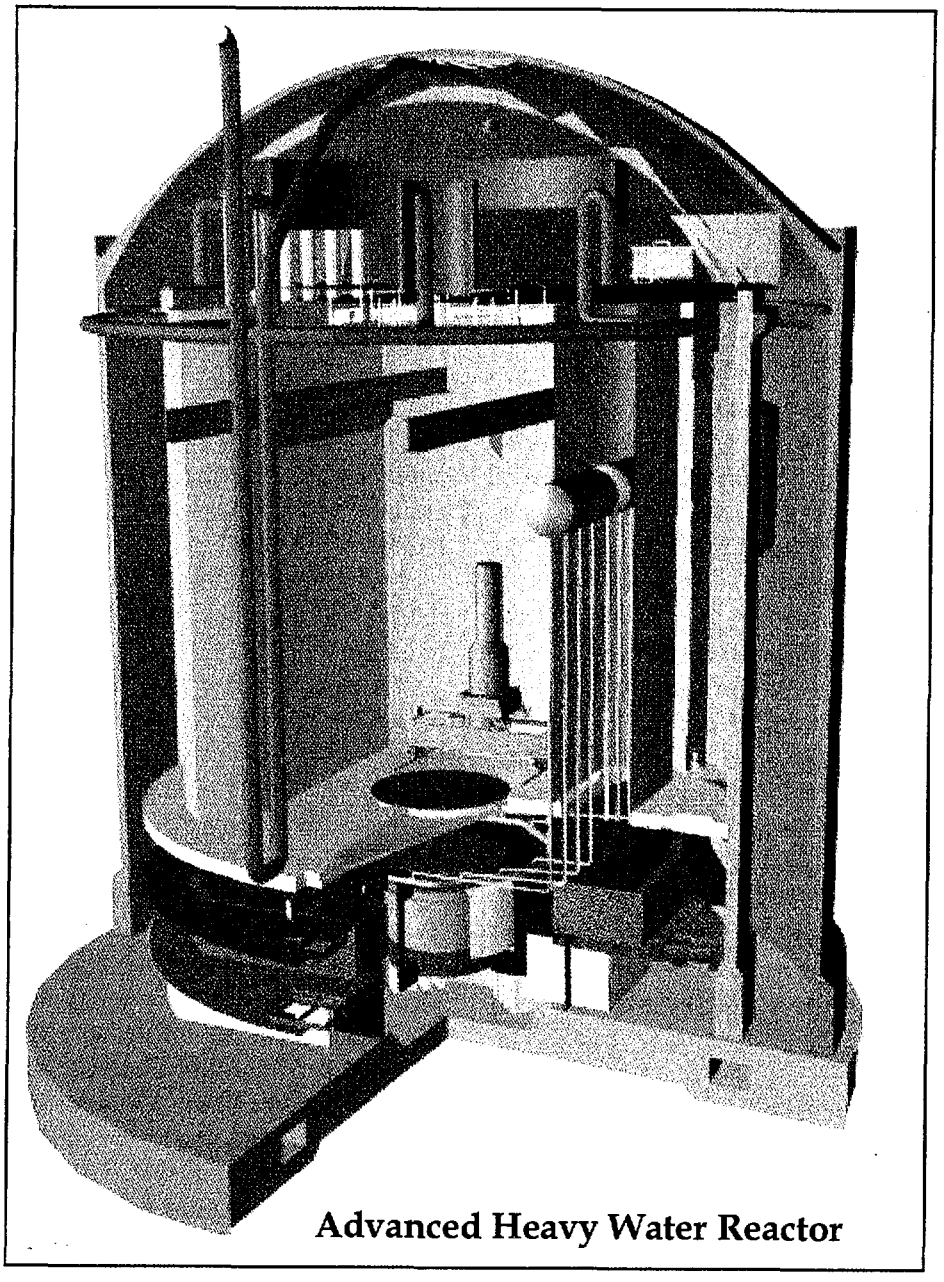
*Research Reactor DHRUVA at Trombay*



Two dedicated Diesel Generator sets of 125 kVA each were commissioned for further improving the reliability of power supply to the overhead storage tank make-up pump units. The overhead storage tank supplies gravity assisted power water flow to the turbines coupled to the shutdown cooling pumps of the reactor.

A pneumatic carrier rod assembly was installed in pile after necessary piping modifications. A relay based new control console was designed, fabricated and commissioned for the Pneumatic Carrier Facility. Shooting of empty and weighted capsules was carried out successfully during reactor shutdown. This facility will now be put to regular use for short-term irradiation of materials.

Event based Emergency Operating Procedures to cater to several postulated off-normal conditions were developed for use by operating staff. A document for In-service Inspection program for Dhruva was also prepared. Relining of 100 M3 capacity Main Outside Sump with Stainless Steel-316L plates was completed as the earlier lining had developed defects. Preparatory work and installation trials were carried out towards commissioning of the controlled temperature irradiation facility at one of the beam holes.




*Advanced Heavy Water Reactor*

Activities related to the design and construction of a new Critical Facility for carrying out Reactor Physics experiments for Advanced Heavy Water Reactor and 500MWe Pressurized Heavy Water Reactors is progressing well. With due considerations to the requirements of the experimenters, the basic design features of the Critical Facility were finalized. Core physics and shielding design, geo-technical investigation of the site and building layout drawings were finalized. Detailed engineering design of the Reactor block, Core components, Process systems, Control & Instrumentation systems and other auxiliary systems like air conditioning and ventilation, Power supply and distribution, Compressed air system etc. are in advanced stages of completion. Procurement of various equipment/components/materials is in progress. Detailed safety analysis report of the Critical Facility has been prepared and will shortly be submitted to Atomic Energy Regulatory Board for review and approval.

Work related to integration of a desalination unit based on Low Temperature Vacuum Evaporation Process with CIRUS reactor is in progress.

Engineering feasibility study of a 12 pin fuel cluster for the proposed New High Flux Research Reactor was carried out and engineering design was also evolved. A conceptual design of a fast neutron irradiation facility was also developed.

Quality Assurance (QA) programme was augmented towards enhanced safety in operation & main-

tenance activities for the research reactors. As part of this program internal regulatory inspections for the three research reactors have been introduced.

As part of on-going PSA studies for Dhruva reactor, reliability analysis of Shut-off rod system and containment isolation and emergency exhaust system was completed.

Over 20,000 samples of light water, heavy water, helium gas and ion exchange resins were analysed during the year. Technical and analytical services, e.g. for analysis of silica gel, lithium hydroxide etc., carrying out analytical work at Kaiga-2 project site during first criticality, analysis of heavy water samples for uranium content, preparation and supply of heavy water standard to Nuclear Power Stations, evaluation of hot conditioning of PHT systems of Kaiga-2 & RAPP-3, decontamination of moderator systems of NAPS-2 etc. were provided to NPCIL, as required.

A computational model for the calculation of reactivity worth of shut-off rods in Cirus and Dhruva was developed

**Reactor Engineering**

The design and engineering development of Advanced Heavy Water Reactor (AHWR) is progressing well. The natural circulation loop set up specifically for purpose of studying the phenomena and its stability in AHWR has provided experimental validation of models in this area. The physics and thermal hydraulics design of AHWR has been further optimised. Design of various other engineering systems and procurement/fabrication of components of these systems are in progress. Flow sheet and specifications for major equipment and piping layout of integral test facility are nearing completion. Spacer design optimisation for fuel assembly development and commissioning of test facility for separate effects test have made significant progress. Design of fuelling machine head and carriage is in progress.

The design work of various systems for setting up a Critical Facility to conduct reactor physics experiments of various fuel configurations of AHWR has made good progress.

The important landmarks in the development of Pressurised Heavy Water Reactor systems this year include commissioning of the first phase of the Facility for Integral System Behaviour Experiments (FISBE). This facility permits experimental simulation of accident scenarios and operational transients in Pressurised Heavy Water Reactors, thereby improving our understanding of the physical phenomena that occur under such conditions and also enable tests on relevant recovery methods and operational procedures.

This year has also seen major gains in terms of data generation on fatigue and fracture behaviour of primary systems piping as a part of our effort to realise leak before break capability in Primary Heat Transport System of 500 MWe PHWR.

Development of catalytic recombiners, a system meant for mitigating the hydrogen related risks in an accident situation has also reached an advanced stage. Different techniques for physical/chemical deposition of catalyst on substrates have been tried out with very encouraging results.

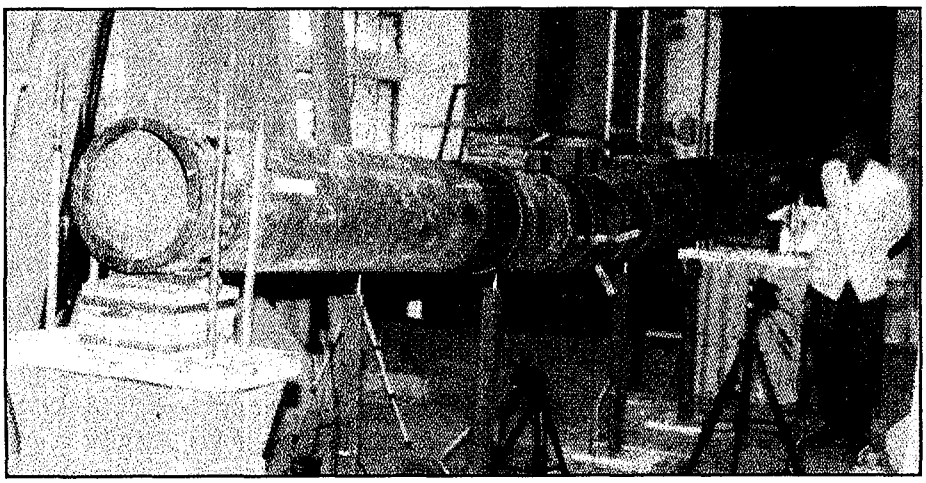
In support of operating power stations, recently the vibration diagnostic technique was tried out with a larger shaker enabling further improvements. The improved INGRESS with its delivery system, which can carry out garter spring relocation in wet channels of PHWRs as well as improved scrape sampling tool, is in an advanced stage of testing. Fifth campaign of decontamination using BARC developed process was successfully carried out recently at Kalpakkam.

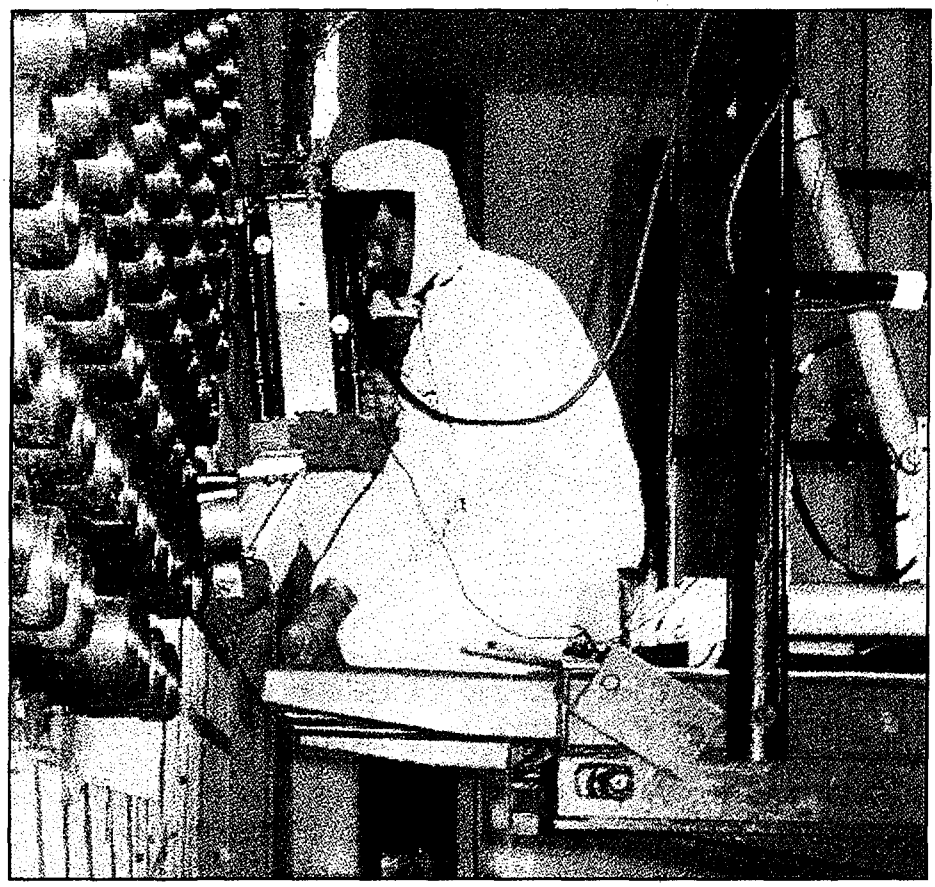
Development of advanced inspection and diagnostic tools and techniques for assessing structural integrity of critical components of NPPs is an ongoing activity of the centre.

Design of equipment and instrumentation towards augmenting test facility for accident scenarios & operational transients is in progress. The fabrication of 19 rod FRS for phase-I test is going on. Design and development of containment model, PHT model, process and special instruments (like $H_2$ monitors, blowdown flow monitors and aerosol monitors) has made good progress. Experimental studies at various nuclear facilities for corrosion and mechanical properties are in progress.

An endurance test in the investiga-

*Leak Before Break Testing of PHT system piping of PHWR*





*Vibration Diagnostic Technique for Cooling Channels of PHWR*

tion study of wear in the inner spacers of upstream bundle is very important. Vibration measurements of 500 MWe fuel and in-channel components were carried out in a specially engineered experimental setup in Hall-7. The flow induced vibration of fuel bundle, fuel locator and liner tube under simulated reactor condition was measured by remote Electro-optical and laser Vibrometer through specially designed optical windows.

A fatigue-creep monitoring system (FCMS) has been developed which converts the power plant transients to temperature/stress responses using finite element method (FEM) and transfer function approach. India is a member of the recently established worldwide technical information network FAMONET (FAtigue MOnitoring system NETwork) to facilitate the exchange of information between research organisations and industries dealing with the development of fatigue monitoring systems for integrity assessment and maintenance of power plant components.

**Reactor Safety**

Under safety related technology development, work continued for Augmentation of Facility for Accident Scenarios and Operational Transients. An experimental set-up was installed to determine the safe distance from the electrical live (up to 25 kV) parts for the purpose of fire fighting. The experiment for safe current as per Bureau of Indian Standard has been completed. A number of tasks connected with Containment Studies Test Facility (CSTF) instrumentation were completed. A detailed methodology, for using Kaiga Simulator for collection of data on operator performance, under post-event conditions in simulated scenarios, was worked out.

As a part of seismic re-evaluation of CIRUS containment, the dynamic analysis of the 3D model of the superstructure of the CIRUS containment is completed. A design check has been carried out for the embedded parts of the radiation shielding doors of "New hot cell facility for PIE of Nuclear fuels and reactor components" subjected to horizontal and vertical earthquake loads. The embedded parts as well as the hinge plates are found to be safe for the dead load and earthquake load.

A design basis transient analysis for sizing of the Over Pressure Relief system of Primary Heat Transport (PHT) system of 500 MWe PHWR power plant was carried out. The analysis was done using the process dynamics code DINA500 developed in-house.

The system dynamics code DINA220 developed to study the operational transients of a 220 MWe PHWR power plant was used to study the different mitigation schemes for avoiding low-pressure during transients in a 220 MWe PHWR system.

For the multidivisional project on Nuclear Aerosol Test Facility (NATF), civil construction of the building has been completed. The test vessel has been erected. The Code HYRECAT has been augmented for box type recombiners with convective gas flow model.

Finite Element Analysis was done for international benchmark exercise "Determination of the ultimate load capacity of Pre-stressed Concrete Containment Vessel (PCCV.) test model (1:4 size of a Japanese PWR containment) sponsored by USNRC and NLTPEC" The analysis was completed with in-house finite element code ULCA. It was demonstrated that PCCV test model would fail by bulging in the membrane region due to through thickness cracking of cylindrical wall that is followed by the steel liner tearing at a pressure 2.36 times

the design pressure. For life extension of Heavy Water Plant Kota, seismic re-evaluation of process tanks, dump tanks and their supporting structures have been completed. LOCA Analysis for the ECC header break for AHWR. Reliability analysis of multi-pin connector from TAPS has been carried out under combined environment of accelerated temperature, humidity and radiation in the synergism simulator facility. Guidelines for reliability assessment/long-term performance evaluation of cables, elastomers, process instruments, electronic/electrical components and materials have been prepared and distributed to the various units of DAE.

BARC has been participating in the IAEA CRP on "Management of Ageing of I&C cables". Large number of cable samples received from IAEA have been tested and test results have been communicated to IAEA.

Investigations were carried out into various HRA methodologies with focus on the application of expert estimation methods in HRA of Indian nuclear plants. A methodology was developed for using the Kaiga Nuclear Power Plant Training Simulator for HRA.

An in-house 2/3-D damage mechanics code 'MADAM' has been developed and successfully applied to analyses many fracture specimens. The code has been validated against experimental results of standard tensile and CT specimen of two different materials.

**Nuclear Fuels**

The programme of progressive introduction of MOX fuel in reactors at Tarapur is continued. KAMINI reactor at Kalpakkam, a Uranium-233 based system designed in BARC has continued to perform well. The mixed carbide fuel in Fast Breeder Test Reactor (FBTR) continues to perform extremely well. The year has also seen significant developments for the fuel for Prototype Fast Breeder Reactor (PFBR).

Laser material processing facility has been equipped with laser machines and is being used for surface engineering studies and feasibility study of dismantling of fuel bundles and under water cutting applications.

Augmentation of Uranium metal production by adding new equipment and mechanising operations is in advanced stages of completion.

During the fabrication of MOX fuel rods for Boiling Water Reactors at AFFF of BARC at Tarapur, Gamma-auto-radiography was successfully used to evaluate composition of MOX pellets and to detect presence of $PuO_2$ agglomerates in the peripheral region. Experiments were made to standardize the conditions for distinguishing fuel pellets of different composition by gamma-auto-radiography of fuel pins loaded with pellets of different composition.

As a part of mixed carbide fuel development, samples of appropriate dimensions of $(U_{0.8}Pu_{0.2})C$ and $(U_{0.45}Pu_{0.55})C$ were fabricated for thermal conductivity, thermal toughness, coefficient of thermal expansion and carbon potential measurements. A modified fabrication route has been developed for fabrication of fresh $ThO_2$ pellet which will remove excess sulphur present in the thoria feed powder received from IRE. Fabrication of 2 Tons of $ThO_2$ pellets is in progress following the modified route. As part of mixed $(U\text{-}Pu)O_2$ fuel development for PFBR work, fuel pellets of different compositions were fabricated and characterised in terms of density, (O/M ) ratio and solid solution formation.

As part of the activities of Task Force for thoria based fuels, grain growth studies on sintered $ThO_2$ pellets were done by heating the pellets isothermally at 1650°C for 8 Hours, 12 Hours & 24 Hours. Grain size measured was in the range of 24.7 to 33.9 microns which is the average of measurement on 64 fields.

Nuclear Fuel Development Programme envisages Construction of shielded hot cell facility, revamping and augmentation of fuel fabrication facilities, development of Prototype Fast Breeder Reactor (PFBR) fuel, development of process for plutonium based fuels and their characterisation, augmentation of MOX fuel fabrication facility at Tarapur, development of telerobots, telemanipulators and high speed rotor.

**Nuclear Recycle**

*Fuel Reprocessing*

At present three reprocessing plants are in operation catering to the requirements of research & power reactors. All the three Reprocessing Plants and a number of other plants are operating well. To meet the reprocessing demand of the spent fuel arising from Kaiga, Narora and RAPP-3&4, reprocessing plants are being set up at Tarapur & Kalpakkam under New Technology Development programme.

A facility for the separation of U-233 from thorium rods irradiated at CIRUS and Dhruva reactors isexpected to be completed shortly. PREFRE Plant at Tarapur is being revamped and the civil works for revamping of PREFRE-1 have commenced and basic design of various systems is nearly completed and detailed design of systems is in progress.

Removal of $^{137}Cs$ activity from the spent fuel solution before it is processed for the recovery of plutonium and uranium can considerably reduce the radiation hazard. Laboratory scale studies with dissolved fuel solution have demonstrated the possibility of sorption of $^{137}Cs$ on selected inorganic sorbants, rendering it safer for further processing. Specific sorbent for the

removal of $^{137}Cs$ from highly alkaline waste with high solid content has been developed.

Uranous nitrate solution is employed for the reductive stripping and separation of plutonium in Purex process. Laboratory studies have established the feasibility for its preparation by catalytic reduction of uranyl nitrtate solution with hydrogen gas. This method will serve as an alternative to the currently vogue electrolytic reduction of uranyl nitrate solution which has certain limitations. Equipment for a pilot plant scale unit has been designed, fabricated and is being installed.

Studies are in progress for co-processing and recovery of uranium and plutonium together from spent uranium fuel solution instead of their individual separation for their direct use in MOX fuel fabrication, thereby reducing the number of steps involved in fuel fabrication.

*Waste Management*

A major milestone was achieved in the radioactive waste management programme with the inauguration of country's first Solid Storage Surveillance Facility (S3F) at Tarapur. India has thus become the fourth nation in the world to have such a hi-tech facility. This is an important step prior to disposal of higher level wastes in deep geological repository.

Waste Management facilities are in operation for many decades at Tarapur, Trombay and CWMF Kalpakkam to handle low level wastes originating from nuclear plants/labs. These facilities are being revamped to enhance the overall performance of existing facilities by replacing aged equipment and installing latest safety features.

Waste Immobilisation Project, Trombay has achieved the distinction of successful commissioning of Vitrification furnace using induction heating system for immobilisation of highly active radioactive wastes in glass matrix. The furnace system has a unique design and has been indigenously designed and manufactured within the country for the first time. These systems have been earlier imported for the plant at Tarapur. Several successful trials have been taken to prove the cell worthiness of the furnace. Apart from the provision of the independent controls for the selective zonal heating of the furnace, new designs of the freeze valves and feeding arrangement have been successfully implemented.

For the first time a new concept based on Servo Manipulator technology has been used for all incell operations. The complete system has been indigenously designed and manufactured.

Construction of Waste Immobilistion Project at Trombay is expected to be completed by March 2000 and full commissioning trials are expected to begin thereafter. The high and low level liquid wastes generated from Plutonium plant at Trombay are going to be treated and immobilised in this plant after it becomes fully operational.

A centralised component decontamination and conditioning facility being constructed at Trombay has made good progress.

Construction of Waste Immobilistion Plant at Kalpakkam to immobilise and store in a solid form of high and intermediate level waste being generated from Kalpakkam Reprocessing Plant (KARP) has made good progress.

Stage-II investigations to select a few candidate sites for ultimate disposal of high level radioactive wastes generated from reprocessing nuclear fuels is completed. Further studies to completely characterise the site and rock mass with view to assess its suitability for a pilot repository in future are in progress.

Work on development of radiation shielding windows is progressing as per plan. A few radiation shielding windows which turned cloudy and opaque have been successfully refurbished.

A pilot scale facility for alkaline hydrolysis treatment of waste solvent TBP and a continuous calciner for HLW treatment studies are in advanced stages of construction. Laboratory scale investigations for destruction of used ion exchange resins by wet oxidation followed by photochemical oxidation have been successfully tried out.

Design and procurement action for the disposal of beryllium waste at Gamma Garden site, BARC is nearing completion. Pilot plant scale runs for immobilization of beryllium waste in vitreous matrices have also been carried out.

**Health, Safety and Environment**

*Health Physics & Radiation Standards*

Environmental surveillance for radioactivity is conducted continuously at the various Nuclear Power Stations by Environmental Survey Laboratory (ESL) operated by Health Physics Division of Bhabha Atomic Research Centre. The estimation of intake of radionuclides by the population around the plant is made by measurements of concentrations of radionuclides in air, water, vegetables, cereals, milk, meat, fish, egg etc. and the dose to population is computed. The analysis of 1998 data shows that the doses received at 1.6 kms are much less than the limit prescribed by the Atomic Energy Regulatory Board (AERB). At farther distances the doses are observed to be still less.

Radiological safety support function to various nuclear power plants and other fuel cycle facilities was continued by the Health Physics Units (HPUs) located at the these DAE facilities. This includes assessment of the radiological status of the plant

areas, safety reviews and participation in O&M activities during normal and special operations, towards exposure control. Health physics coverage was also provided to (i) creep adjustment of 30 coolant channels in unit #1, RAPS, (ii) the repair works inside process cells of PREFRE plant at Tarapur, (iii) treatment of intermediate level waste from PREFRE plant at WIP, Tarapur, (iv) transfer of alkaline waste from waste tank farm of PREFRE to trenches in Solid Waste Management facility in Tarapur.

Health physics instruments were installed and commissioned, standard procedures for operation were formulated by the HPU of WIP for the storage vault of Solid Storage Surveillance Facility at Tarapur. A few vitrified waste canisters have since been transferred to this facility from WIP and health physics services were provided during this operation.

At Kaiga and RAPP 3&4, health physics laboratories and facilities were set-up with requisite radiation measuring instruments, sampling equipment, counting systems and data processing systems to meet the operation schedules. Ventilation duct radiation monitors, iodine activity monitors, particulate activity monitors, fission product noble gas monitors, tritium-in–air monitors, heavy water loss monitors, area radiation monitors, shutdown area radiation monitors and wide range radiation monitors have been installed.

A new pocket dosimeter (DIGIDOSE) with selectable integrated dose alarm levels has been designed using a silicon diode as the radiation detector. Countrywide personnel monitoring was conducted for 32,000 radiation workers from about 3000 industrial, medical, research and DAE institutions.

A computerised machine with a provision to manipulate the sample along the 3 axes and with a positional accuracy better than that available in the market was designed and fabricated as an import substitute for calibration of Radiation Equipment against Radiation Standards.

*Low Level Radiation Research Laboratory, at Kollam, Kerala*

Hardware and software for Aerial Gamma monitoring are being developed. Setting up site emergency control centre at Tarapur, Development of tritium in air monitor and connection of HP units to BARC are at various stages of progress. Characterisation of Radon / Thoron calibration facility unit and country wide survey programme is in progress. Development of Therapy cassettes for electron beam dosimetry, in-vivo dosimetry in radiotherapy, plane parallel chamber for electron dosimetry was continued.

Several polymeric materials in the form of thin films like radiochromic dye films, clear perspex HX, and cellulose triacetate find a wide application in radiation processing dosimetry. A work was carried out in BARC to investigate the dosimetric properties of locally manufactured Garfilm-EM to determine its suitability as a high dose dosimeter.

Analytical services for radiochemical analysis (Gross alpha Gross beta, Cs-137, Ra-226 and Ra-228) were provided to Pharmaceutical companies, e.g. Mediorals, Cipla Ltd., Okasa Ltd., and to Marine Export Development Authority (for Cs-137). Samples of export and import origin were analysed for radioactivity content by ESL, Kalpakkam and test certificates were issued. These services resulted in revenue earnings of Rs. 21 lakhs during this year.

Environmental Radiological Laboratory, Kaiga has been recognised as a centre for pursuing research in radiation physics and environmental chemistry by Manglore University, Manglore.

The efforts of Environmental Survey Laboratory, Rawatbhata led RAPS to win the coveted Golden Peacock Award (for the year 1999) under large scale enterprises category instituted by the World Environment Foundation.

### Environmental Assessment and Research

Studies on indoor pollution assume importance since an average person spends more than 80% time of the day in the indoor environment, either in the home or in the office premises. A number of indoor sources such as emission

from the building material, furniture, painted surfaces, smoking, releases through cooking are responsible for enhanced level of air pollutants in indoor environment. Volatile hydrocarbons such as hexane, benzene, toluene, xylenes etc. were estimated in indoor and outdoor air samples using cryogenic pre-concentration and a gas chromatograph with a flame ionization detector. The study revealed that the indoor concentration of the pollutants are higher in the presence of indoor sources. Polycyclic aromatic hydrocarbons (PAH) such as, acenaphthylene, fluorene, phenanthrene, anthracene, pyrene, etc., generated by indoor activities like cooking, smoking etc were estimated in indoor and outdoor air samples using high pressure liquid chromatography equipped with UV detector. PAH concentrations were significantly high in indoor air particularly where the kerosene is the domestic fuel.

Exposure assessment due to toxic heavy metals were carried out for Mumbai adult population. Ingestion is the predominant route for metals like Cu, Mn, As, Cr and Fe while inhalation is the significant route for Pb and Cd for Mumbai adult population. The daily intake of toxic metals was less than the permissible intake. However, the intake of essential metals was also lower than the recommended levels. The intake of Mn through milk and milk products for Mumbai children was calculated. Estimation of exposure of Pb in school children of Mumbai , nutritional status studies through determination of trace elements in colostrum milk and intake of toxic metals by anemic children were also studied. 17.3% of the children tested had blood lead levels exceeding the permissible value of 15mg/dl . The levels of essential elements like Cu, Zn, Fe in colostrum milk was 2-5 times more than those in breast milk.

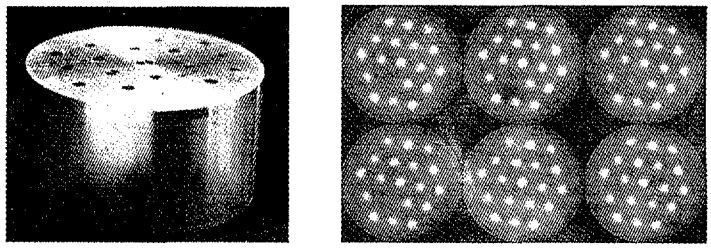
IRSL based techniques are widely used for dating the geological samples containing feldspar. During the course of analysis of the geopogical samples collected from Thar desert under a DST project, it was found that the age estimates based on IRSL measurements at elevated temperatures were consistently higher than those at room temperatures. There exist two possible explanation for this phenomenon, viz., thermally assisted increase in the charge transfer giving rise to increase in the recombination efficiency and the availability of additional traps at elevated temperatures. Studies were carried out in EAD to find out the relevant mechanism in the present context and optimize measurement parameters. Three sets of experiments were conducted with feldspar using an indigenously designed and fabricated IRSL system. These experiments supported the theory of increased charge transfer due to local heating of the sample by IR stimulation. Based on these results, a revised protocol has been proposed in which the paleodose in geolological samples is determined by first partially bleaching the samples by IR at room temperatures and then recording IRSL at 70 °C .

Studies on the electrical behaviour of radon progeny aerosols in electric fields have received fresh attention in view of new pathways of increased risks being hypothesised for populations exposed to AC fields from high tension powerlines. In this context, a study was undertaken to examine the charged fraction, neutralization rate and electrical mobilities of radon progeny. A new technique using a combination of AC and DC fields in a modified scintillation cell was developed and used to estimate these parameters. A series of experiments conducted with this system yielded charge lifetimes of 0.02s and mobilities of 1.14 $cm^2/V/s$, for $^{218}Po$ under high humidity conditions. In order to understand the mechanisms of charge neutralization, a theory based on the columnar track recombination process has been developed. The solutions for the fraction of the progeny species escaping recombination with columnar ions has been derived as a function of track and ion parameters. The results yielded an escape fraction to the extent of about 60% in low humidity atmospheres. The theory also suggests that the rapid recombination observed at high humidities are very likely to be due to drastically lowered ion mobilities attributable to transient ion-induced clustering effects.

A three-dimensional convective heat transport model is developed to predict the temperature distribution in the vicinity of a thermal discharge outfall located in coastal sea. The flow velocity distributions are obtained from the governing momentum and continuity equations with wind stress on the sea surface as the forcing function. The temperature distribution is evaluated using the energy equation. The equations are solved numerically by assuming a temperature rise of $10^0$ C over the ambient near the discharge outfall. Gradient boundary condition for temperature is applied at all boundaries and constant eddy exchange coefficients are used in the simulation. The model is initialized using a southwesterly wind with speed ranging between 3 and 6 m/s. The resultant horizontal velocities range between 1 and 8 cm/s. The results shows that the eddy diffusion process overrides the convection process due to low flow velocities. After 12 hr of thermal discharge, the affected area with at leàst $1^0$C rise in temperature, lies within 1.2 km east (offshore) and 1.4 km north. After 24 hr of discharge, this area marginally increases upto 1.7 km east and 2.3 km north. It is observed that the iso-contour of $10^0$C rise covers a very small area around the outfall.

The non-homogeneous and non-

stationary nature of meteorological parameters makes the simplified models such as Gaussian plume, puff models inapplicable in realistic situations for dispersion estimates. To overcome this problem, the meteorological model ADOCT (Atmospheric Dispersion over Complex Terrain) was developed. ADOCT is a 3-dimensional meteorological model in terrain following co-ordinate system for incompressible fluid with hydrostatic assumption and is coupled to particle trajectory model for impact assessment. The flow model solves the momentum equations, conservation equations for heat and specific humidity. A new methodology is also developed to estimate plume gamma dose using particle trajectory model and is an integral part of the ADOCT code. Model needs the initial profiles of wind velocity, temperature and specific humidity as input. The complete validation of the model will be carried out in the IXth plan validation experiment, presently the model validation is carried out for a typical sea-breeze condition observed at Kalpakkam. The predicted dose-rate values agreed reasonably well with the dose-rate values normally observed.

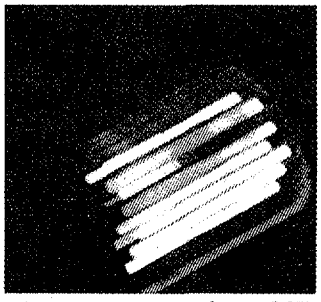


Simulation of fuel bundle



Multiple two dimensional Neutron CT images

Three Dimensional neutron CT



A cut away portion of 3D CT showing broken rod

*Two & three dimensional neutrons*

In plant and environmental surveillance for radiological and conventional constituents were carried out in the front end of the nuclear fuel cycle at the uranium mines and mill of UCIL at Jaduguda, Bhatin and Narwapahar, mineral and monazite processing plants of IREL at Udyogamandal, Chavara, Manavalakurichi and OSCOM (Chhatrapur), and in different fuel fabrication and related plants of NFC, Hyderabad.

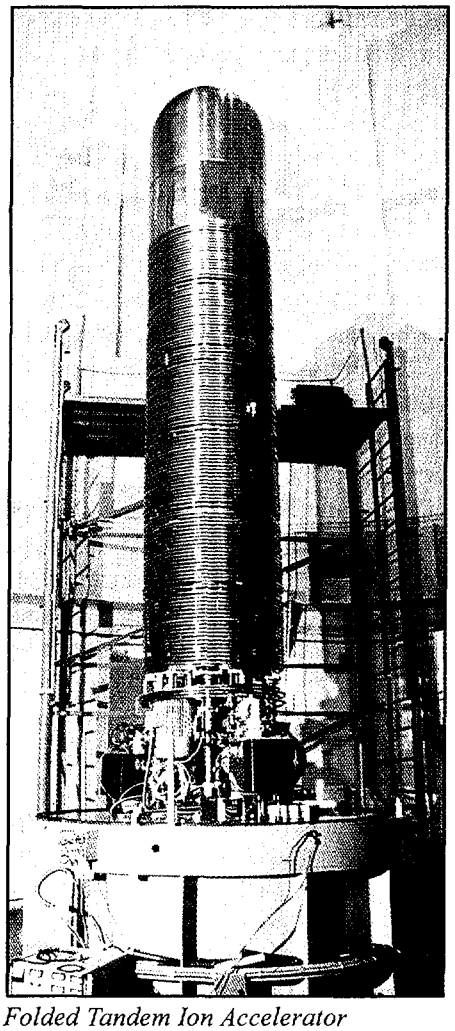
Depending on the Facility, Monitoring is carried out for some of the following to ensure compliance with the regulatory limits: radiation dosimetry for operating personnel, radon/thoron in exhaled breath of workers, long lived alpha activity, Environmental radiation especially due to radon and thoron and their daughter products, and radioactivity in effluents, surface & ground water & soil. Results indicated that all parameters were well within the respective regulatory limits. Environmental radiation monitoring was also carried out in the coastal villages in the naturally high background areas of Kerala, Tamilnadu as well as in the villages with naturally elevated radiation levels near Chatrapur in Orissa.

Concentrations of some non-radioactive pollutants specific to a Facility such as siliceous dust and noise levels at UCIL, Jaduguda were also determined. The monitoring has ensured that the regulatory limits are not exceeded for any constituent. The number of samples collected and analysed varies from plant to plant. For example, at NFC facilities about 25,000 samples of work place air, stack emissions and ambient air were collected and analysed for uranium and chemical constituents like $Cl_2$, $NO_2$, $NH_3$, $ZrO_2$ and CO.

**Physical Sciences**

In order to promote radiation processing using industrial electron accelerators, 2 MeV Electron Accelerator is being shifted to Vashi, Navi Mumbai and a new Electron Beam Centre housing two industrial accèlerators is being set up at Khargar in collaboration with SAMEER.

Folded Tandem Ion Accelerator, an indigenously designed and fabricated system is one of the few of its kind operating accelerators in the world. FOTIA is in final stages of commissioning. FOTIA will deliver light and heavy ion beams with a terminal voltage of 6 MV to be used in basic and



*Folded Tandem Ion Accelerator*

applied research in Nuclear, Atomic and Material Science. The BARC-TIFR Pelletron Accelerator Facility, which has now completed 11 years of successful operation, has already made a large impact on the international scene by the research programme conducted at this facility. For adding a Super conducting Linac Booster to the Pelletron, 15 quarter wave resonators which are high technology items have been successfully fabricated in our Central Workshops. Work on the RF and control electronics towards realisation of Super conducting Linac Accelerators is also in progress at this Centre. Two Thermal Ionisation mass spectrometers have been built and are ready for delivery to the users. The 500 KeV Industrial Accelerator has been tested successfully upto a beam energy of 400 KeV with beam current of 7.5 mA.

As part of phase-II of project GRACE, design and development of MACE, BEST and MYSTIQUE telescope facilities are in progress and procurement and installation of various sub-systems of these facilities are also in progress.

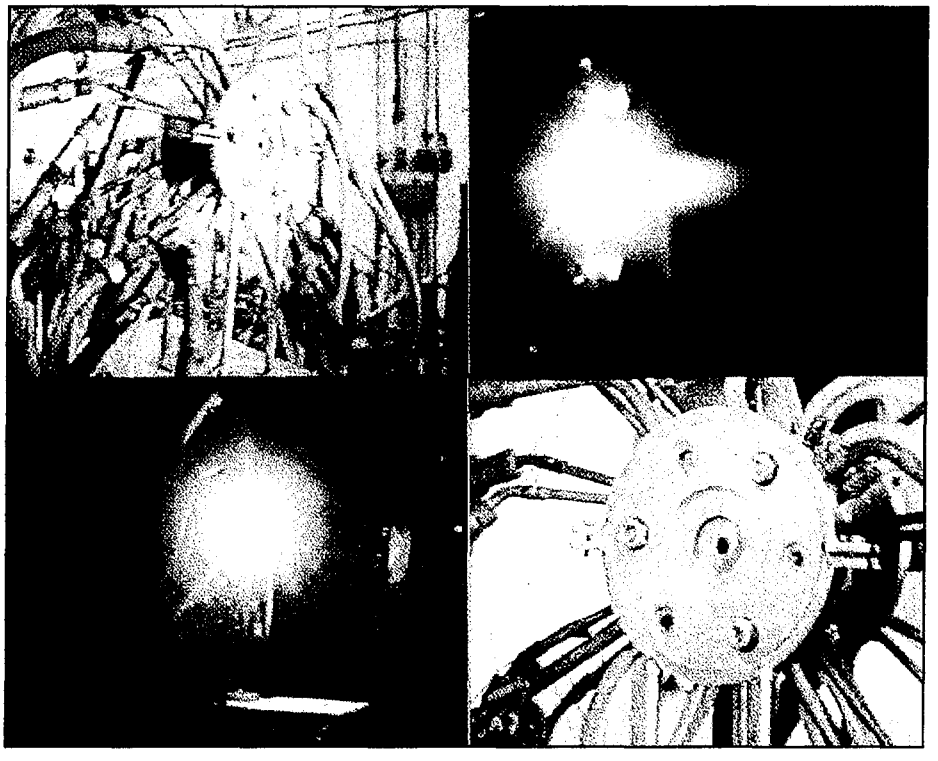
Design and fabrication of mirror chambers and high temperature absorption cell for high resolution beam line at Indus-I and target chamber for Beam foil spectroscopy beam line at FOTIA made good progress. Optical design of the beam line for XAS Beam line at Indus-2 is completed. The installation of Material characterisation setup using FT-IR facility is nearly completed. Design of Two Beam Accelerator (TBA) and development of pulsed neutron sources, heavy ion beams is in progress. Good progress has been achieved in fabrication of Relativistic Klystron Amplifier and development of non-linear computer code.

The first phase of the constricted arc plasma generator program worked out in collaboration with the Propulsion group at VSSC was successfully completed. A compact single wire arc-plasma spray torch has been developed and used to spray coat copper and stainless steel wires.

The Linear Accelerator (LINAC) facility was in continuous operation. The facility is regularly used not only in BARC but also by some universities such as Pune University and Mahatma Gandhi University.

Neutron imaging finds applications in many branches of science and industry such as in nondestructive testing, material science etc. Scientists at BARC have been working on digital imaging of neutrons for various applications using Charge Coupled Device (CCD) based detectors. A number of such systems have been developed at BARC for applications like two and three dimensional neutron tomography, two phase flow visualization and void fraction measurement inside metallic pipes, neutron radiography with non reactor sources etc. The techniques

*Constrictor Arc Plasma Generator*



developed at BARC have been used for applications such as CCD based gamma tomography, x-ray diffraction imaging and medical imaging.

**Theoretical Physics**

The major efforts in this field are to study the physics problems of design, safety and operation of nuclear reactors. It also carries out research and development activities in allied areas of reactor theory, neutron transport theory, applied mathematics and numerical methods. In addition many areas of physics and such as radiation hydodynamics, non-linear equations, classical and quantum chaos, and quantum optics.

The introduction of a few MOX fuel bundles in TAPS reactors has necessitated the development of a new core-simulator for these reactors. The new simulator based on multigroup diffusion theory, as against one group model of the old simulator, slightly improves the agreement between theory and TIP measurements. The interpretation of TIP measurements is being looked into afresh. This is because the quarter core symmetry assumed in their location is usually absent in the core configurations.

Reactivity worth for regulating, shim and absorber rods were measured during the phase-B commissioning of Kaiga 1 and 2 reactors. The worths of primary and secondary shut down systems were also measured. These experiments were analysed and there was excellant agreement between the experimental values and theoretical predictions.

A program to efficiently solve the neutronics equations of power reactors is underway, in collaboration with computational mathematics laboratory, TIFR, Pune. It is found that the use of ILU pre-conditioned, stabilised bi-conjugate gradient method results in time savings by a factor of 3 for large problems.

One-way coupled fast and thermal subcritical, accelarator driven systems are being studied using multigroup tranport theoretic methods for realistic geometries.

The problem of engineering the motional state of an atom in a laser cooled harmonic trap by coupling its internal state to an externally applied electromagnetic field is being investigated. This problem is of interest for producing the non-classical states of motion. An exactly solvable many-body Hamiltonian has been found that relates itself to metal-insulator transition in three-dimensional Anderson model, Bose-Einstein condensation and pseudointegrable billiards. It is also the first example of a one-dimensional statistical mechanical system to support quantum phases. A theory for understanding dissipation in finite Fermi systems, like nuclei and metallic clusters, has been developed. An extensive study of the nonlinear dynamics of circuits has been done. Computer codes for numerical study of a class of nonlinear dynamical systems have been developed. Relations between the correlations between the Husimi zeros and the random matrices was studied. Indispensability of closed, almost periodic orbits, of polygonal billiards for semi classical quantization was established.

**Spectroscopy**

High resolution studies of uranium spectra has been initiated on the newly installed Fourier Transform Spectrometer (FTS). As a test case, emission spectrum of uranium was recorded on FTS. These studies would enable to evaluate isotope shift and hyperfine structure in selected transitions and the energy levels of uranium atom.

A code has been developed for Evaluation of Magnetic Dipole and Electric Quadrapole Interaction Constants (A- and B-factor) in the analysis and Simulation of Atomic Hyperfine Structure. Two UHV laser alignment boxes have been designed, fabricated and tested to be incorporated in photo physics and Photo-Electron Spectroscopy (PES) beam lines at INDUS-I synchrotron at Indore.

A Soft-X ray Reflectometer has been designed for measuring the reflectivity of multilayer coatings, to be prepared by R.F. Sputtering technique, in the wavelength range of 30-100 using the laser plasma source. The laser plasma source is a very bright and continuous source of Soft X-ray and UV radiation. It was shown it theoretically that it is possible to extract a narrow wavelength band from the continuum using a combination of a transmission foil and grazing incidence mirror. An optical lay out of the reflectometer set up has also been prepared where it would be possible to measure two soft X-ray signals simultaneously, viz., the original signal and the signal reflected from the sample and thus reflectivity of the sample would be measured at each laser pulse. A method was developed to analyse aluminium content in percentage levels in Niobium Alloys using ICP-AE spectrometric technique.

**High Pressure Physics**

BARC is engaged in the study of materials using static and dynamic methods. State-of-the-art static diamond anvil cell and dynamic gas gun facilities are set up to study condensed matter at ultra high pressures. First principles theoretical methods are used for the prediction and interpretation of experimental data. High Energy Density Physics (HEDP) phenomena such as mega Kelvin plasmas, mega-bar shocks and mega-gauss magnetic fields are being studied using a multi-mega ampere current source and a variety of diagnostics systems. Currents upto 2.3 MA have already been generated. This facility is expected to serve as a test bed for experimental bench mark-

ing of computer simulation of high energy density phenomena as well as for design and demonstration of novel high energy density objects such as Z-pinch driven dynamic hohlraums. The techniques for the development of digital imaging of radiation are vigorously pursued with an aim to utilize them for basic and applied sciences. This includes real time x-ray imaging for studying kinetics of phase transitions under pressure, imaging spatial and temporal behaviour of high density plasmas. The applications include development of new technologies for CCD based two phase flow visualization and void fraction measurement inside metallic pipes for nuclear power programme, electronic imaging techniques for neutrons and x-rays, imaging techniques for portable neutron sources etc. A 400 kV neutron generator based on the T(d,n) a fusion reaction, has been installed at Purnima Laboratory. This facility will be used to carry out integral benchmark experiments to verify the neutron cross-section data sets and to check the reliability of calculational methods for neutron transport in fusion blanket design. A collaborative experimental programme with Centre for Advanced Technology, Indore and Laser & Plasma Technology Division of BARC is in progress to study the properties of laser produced high density matter and to verify the reliability of computational methods.

The self shorting shock arrival time transducer which detects the arrival time of the shock wave at the known position, can be used for both shock and particle velocity measurements in a material, thus characterising the complete equation of state. Transducers for this purpose have been developed in-house. The transducers were tested in a few shock wave experiments, along with the manganin gauge technique, on SS304 and rock samples.

To examine the behaviour of c-$AlPO_4$ (cristobalite $AlPO_4$) and $Ca(OH)_2$ under shock compression and to compare it with static high pressure experiments, shock recovery experiments were carried out on these materials at different pressures.

Zr and Zr-Nb20 are important nuclear materials. (to understand the mechanism of $\alpha \rightarrow \omega$ and $\beta \rightarrow \omega$ transformation) respectively, which requires the investigation of the nature of the interface between the two phases and the derivation of their habit plane. Static and dynamic, compression experiments were carried out on Zr and Zr-Nb20 samples. A dynamic experiment on two Zr-Nb20 samples with different oxygen contents was carried out at a pressure of 15.5 GPa. The XRD pattern of shock retrieved sample does not show any new reflection but changes in the relative intensities of various Bragg reflections were observed. Electronic structure calculations with generalized gradient approximation (GGA) have been carried out on Fe, Zn and Nb. In order to confirm the role played by the glue atoms to stabilize the quasicrystalline structure, additional calculations were performed on crystalline $Mn_{13}Al_{54}$.

High pressure angle dispersive x-ray diffraction measurements were carried out on adamantane at BL10XU beamline of Spring-8 to confirm the earlier Raman measurements which indicated possibility of various phase transitions with pressure.

The alloy $Sn_{0.75}In_{0.25}$ was investigated for its high pressure behaviour by ADXRD measurements, using the CCD based detector system to obtain quick signature of structural transitions. The measurements were then repeated using imaging plate area detector for accurate structural analysis. The analysis showed a phase transition around 2.75 GPa.

High pressure ADXRD experiment on the intermetallic compound $AuIn_2$ was carried out at the Elettra synchrotron source The high pressure data collected at Elettra confirmed the structural phase transition observed earlier.

High pressure behaviour of berlinite $AlPO_4$ ($\alpha$-$AlPO_4$) was reinvestigated with x-ray diffraction using a powerful synchrotron x-ray source SPring-8. The results show that it transforms to a crystalline Cmcm phase beyond ~ 13 GPa.

High pressure behaviour of $\alpha$-cristobalite has been investigated with extensive molecular dynamics calculations. To represent shock loading, pressure and temperature were simultaneously and instantaneously increased to the calculated Hugoniot values appropriate for porous cristobalite.

To understand the mechanism of pressure induced phase transitions in $\alpha$-$GeO_2$ at atomistic level, a classical molecular dynamical simulation was carried out. In these simulations, a first order phase transition is observed at 9 GPa, which causes a drastic reduction in intensities of Bragg peaks in the calculated diffraction pattern. This is in agreement with the experimental results.

Medical diagnostic imaging is fast developing from conventional analog screen film technique to digital technique. There are several advantages in switching from analog to digital medical imaging such as filmless radiography, reduced dose, online display and enhancement of images which eliminates the need for multiple exposures, easy archival and teleradiology. As a spin-off of developing CCD based x-ray diffraction imaging systems, a prototype x-ray imaging system suited for medical diagnostic purpose was designed. Feasibility study using this system with isotopic source such as 125I and a dental x-ray tube supplied by BEL were carried out. Good quality images suitable for medical purposes have been obtained. Further work on developing a user friendly

prototype medical imaging system is under progress.

A three dimensional neutron tomography technique based on CCD based detectors was developed. Further work in this area for 3D visualization of an object and for performing operations such as slicing at any angle, peeling off some portions of it nondestructively, were carried out. This work is being further extended for CCD based three dimensional x-ray tomography for industrial purposes. Various components and systems required for such a work are being fabricated and assembled.

Neutron diffraction studies are currently being carried out using gas filled detectors. A feasibility study of using CCD based neutron detectors for neutron diffraction work has been carried out and some initial results using standard powder samples were obtained. These experiments have helped in identifying the design features required in the development of CCD based neutron detectors suited for neutron diffraction experiments. Further improvements in the setup are being planned.

A 40 kV/ 280 kJ, capacitor bank has been made operational for experimental studies on matter at high energy densities. The bank consists of 48 energy storage capacitors with pressurized air spark gaps. Simultaneous triggering of all the capacitors well within a transit time isolation limit of 100 ns is achieved by means of a master and two sub-master trigger generators, each generating 24 trigger outputs.

A compact, high neutron yield, low energy (1.6 kJ) Mather type plasma focus device of squirrel cage geometry was developed. In an attempt to make a small neutron source for various applications, another mini plasma focus device was designed and developed. The device was a Mather type co-axial gun of length 70 mm and 38 mm diameter.

A vacuum spark plasma device based on the concept of passive triggering has been developed. This device is driven by a single capacitor (7.2mF, 26kV, 160 kA) with an integrally mounted sparkgap.

## Seismology

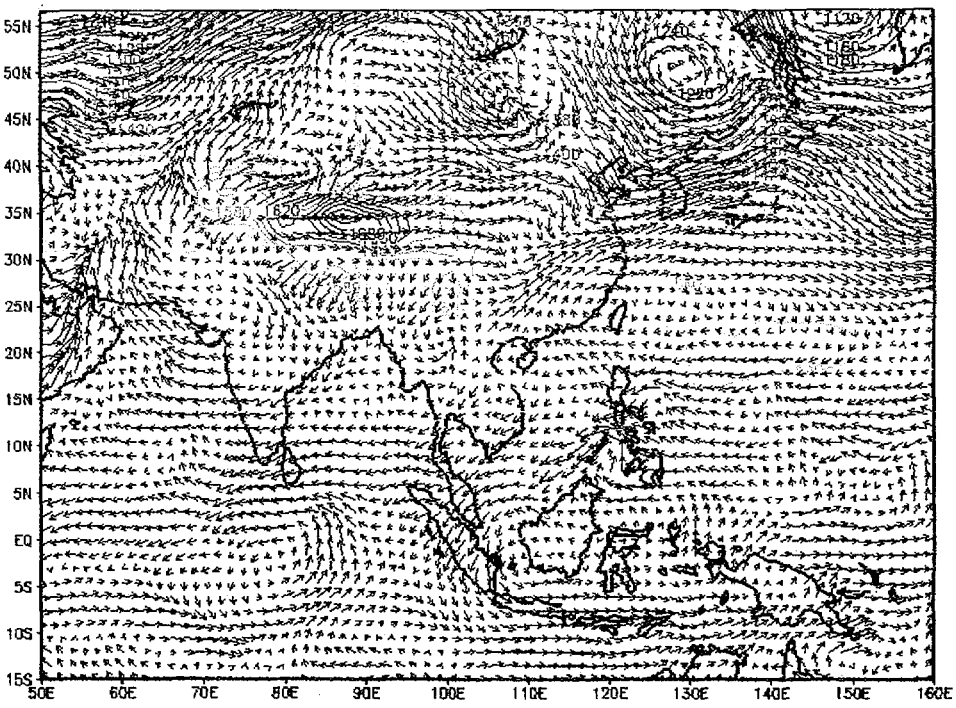
All the seismic monitoring and data processing facilities located at Mumbai, Gauribidanur and Delhi continued to function satisfactorily to detect the seismic signals due to earthquakes and underground nuclear explosions from the whole world. As part of our plans to upgrade the data acquisition and processing facilities the Seismic Array at Gauribidanur is being upgraded to a wide band digitally acquiring, communicating and recording array. Five digitally communicating stations with central receiving station was commissioned. Two numbers of three component wide band systems were commissioned one at Gauribidanur and one at Delhi Seismic Unit.

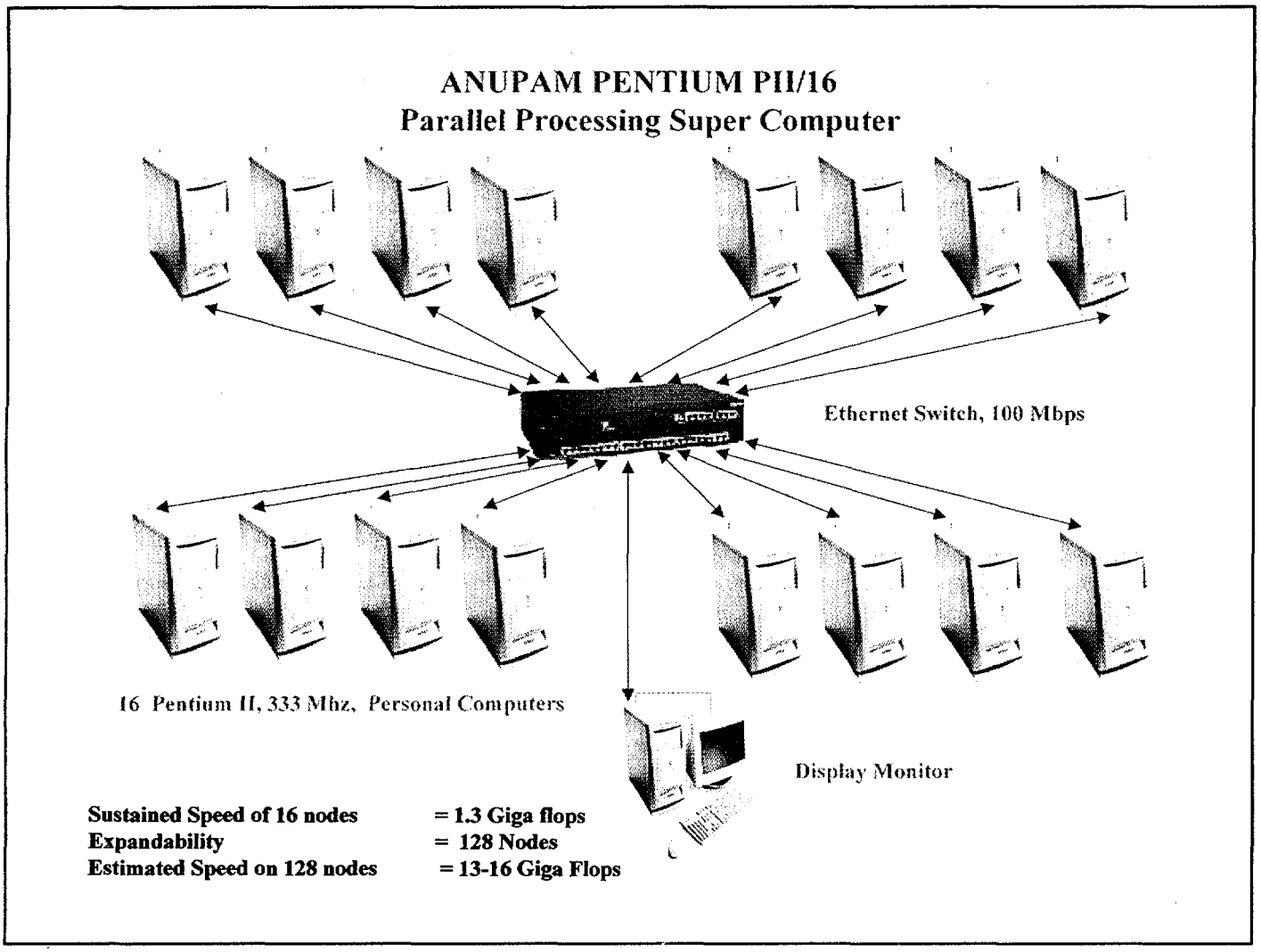
The seismograms generated at close in, regional and teleseismic distances by the May 11, 1998 Indian explosions (POK2) were analysed using (i) regional Lg and Rayleigh waves (ii) ratio of P & Lg amplitudes of both May 18, 1974 (POK1) and POK2 recorded at common stations, and (iii) corrected global P wave magnitudes. All these analysis gave the yield in the range 52-63 kt agreeing well with the announced yield and the post-shot radio chemical yield. The estimates of regional Lg magnitude of POK2 is 5.47 and the surface wave magnitude Ms is 3.56.

In house generated spectrograms of explosions and earthquakes giving details of seismic waves in frequency and time, were used as new technique to study the source features of these events. The analysis of POK2 and 28 May,1998 Pakistan explosion spectrograms showed that the ratio of source energies between these explosions were much larger than that predicted by global mb values.

A new regional magnitude scale for Lg waves was developed and the scale gave the magnitudes of Indian explosion and Chamoli earthquakes fairly accurately. A study of Rayleigh waves passing the Himalyan Crust showed

*Weather Model Data processed by using Aupam-Alpha Super Computer*






*Anupam Supercomputer*

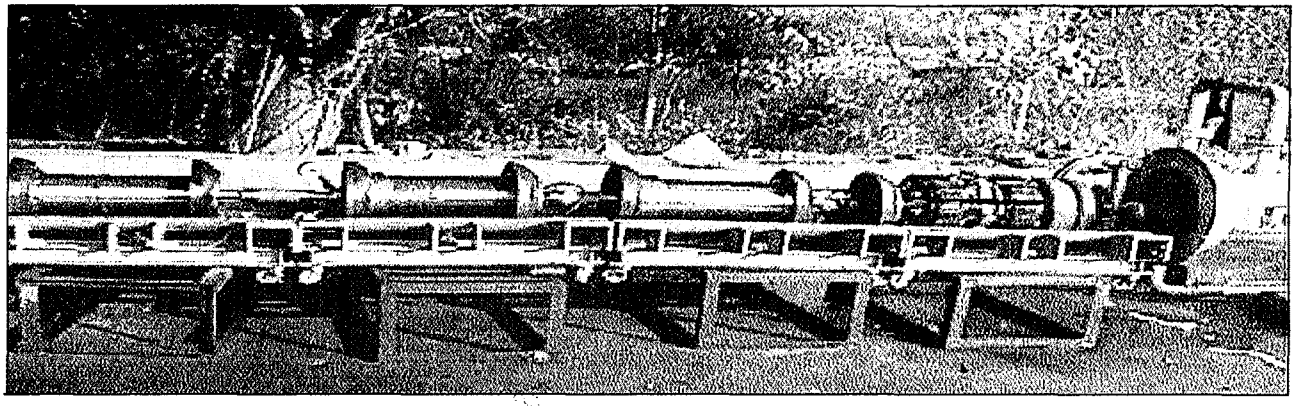
high Q along certain paths, indicating thickness of crust along these paths.

Research in the field of synthesis of seismograms, artificial neural network and spectral analysis for distinguishing seismic sources and estimating source parameters has brought out new results. The seismic evaluation of sites for installing vibration sensitive equipment was carried out for agencies within DAE and outside DAE.

**Electronics, Instrumentation and Computers**

Technology contributions from BARC to the reactor units at Kaiga and Rajasthan cover several computerised control and instrumentation systems

*Pipe Inspection Gauge (PIG)*



performing a wide variety of functions such as the plant protection, control of important processes and operator support. Programmable digital comparator system, dual processor hot standby process control system, dual processor hot standby reactor regulating system, PSS rod monitoring unit, channel temperature monitoring system, digital recording system, on-power refuelling machine control system, Supervisory Control and Data Acquisition System (SCADA), radiation data acquisition system and a large variety of radiation monitoring instruments are some of the areas of important inputs from BARC. The development of SCADA system is attracting a number of other agencies for its supply and technology transfer. Development of portable spectroscopy system, 16K/8K MCA PC add-on and Bed side Veno screen have made good progress. Vision systems facilty for material characterisation and automated inspection is being set up.

ANUPAM Super computer has been commissioned at the National Centre for Medium Range Weather Forecasting, Delhi, thus providing a successful alternative to currently used Cray X-MP dual processor resulting in considerable saving of expenditure on maintenance of the obsolete super computer. BARC Super computer is able to execute the full suit of the weather forecasting programmes in comparable time. A supercomputer consisting of eight Pentium-III nodes connected through high speed switch has now reached a sustained speed of 2 giga flops. A web based remote monitoring and control system has been developed and a technology synergiser is soon to be launched to bring in greater interaction between researchers and users of research.

Another development has been the completion of PC-based thermal Analysis system which can be used for providing high level of automation and processing capabilities to a number of thermal analysis systems at BARC and other units of DAE being used for thermo-gravinating, differential thermal analysis, thermo-mechanical analysis, etc.

A centralised computing facility to cater to the ever increasing computing needs of scientific community is being set up as a IX Plan project.

The Pipe Inspection Guage (PIG) system developed earlier in BARC has gone through successful trials at the test facility of Indian Oil Corporation at Faridabad, and is now ready for field trials in Barauni-Patna pipeline. Based on the success of this development, plans have been drawn up for building pipe inspection guages for larger diameter pipelines.

A portable, rechargable battery operated and simple system called "Bedside Vaso Screen" has been developed at Bhabha Atomic Research Centre which can be taken to the bed side of the patient for periodic screening of venous circulation in ICU and ICCU wards in hospitals. This system employs impedance plethysmographic principle for the assessment of peripheral arterial blood flow as well as the status of venous circulation. The system also employs a micro computer card Chameleon 220 and a LCD screen for data acquisition and display.

**Technical Physics & Prototype Engineering**

In the area of mass spectrometry, capability of the Inductively Coupled Plasma Source - Mass Spectrometer (ICP-MS) developed at the Centre, was enhanced and detection limits near ppb range were realized for the following elements: Zn, Ge, As, Rb, Sr, Y, Zr, Mo, Cd, Ag, Pd, In, Cs, Ba, La, Gd, Pb etc. An electric quadrupole assembly was also indigenously built and tested for eventual use on the ICP-MS system. One D/H mass spectrometer was delivered, installed and successfully commissioned at Heavy Water Plant (Manuguru) and another damaged spectrometer was dismantled and refurbished. Another mass spectrometer was completed in all respects for the isotopic analysis of lithium and boron samples.

A DC Arc Power supply was fabricated and delivered to AMD, Hyderabad after acceptance tests by the users. This unit, which is an import substitute, was commissioned at Hyderabad for emission spectroscopy work. Technology for the indigenous fabrication of sputter ion pumps was transferred to industry. A 100 Amp/40V 50 ppm stability magnet current regulator fabricated for Calicut University was tested and delivered to the users. Also a research scholar was trained at TPPED, BARC in the installation and operation of the power supply which is now operating at the Physics Department of the above University.

A combined ion gauge and convectron gauge control unit for the measurement of vacuum from atmosphere to $10^{-10}$ Torr has been fabricated and tested.

A data system was developed for the Li/B mass spectrometer that has been made for in-house use. This includes (1) scanning of isotopic peaks by the control of ion accelerating voltage and magnet current , and (2) data acquisition pertaining to ion currents of masses 6, 7 or 88, and 89 for isotopic ratio determination of mass 6/ mass7 or mass 88/ mass 89.

New data systems for D/H Mass Spectrometers were developed, including PC compatible cards. The systems, alongwith software, have been supplied for five mass spectrometers installed at HWP, Manuguru.

A data acquisition set up was also developed to in-situ acquire data from plant components for Real Time Monitoring of Aging of Power Plant Components for the fatigue study.

Design work towards development of double crystal monochromator for use on INDUS-2 beamline has made major advances.

Process was developed for preparing borosilicate glass having coefficient of expansion matching to Kovar metal. About 0.5 kg borosilicate glass was synthesised and a number of multipin wafer base GM (kovar) seals were fabricated using this glass. About 4.5 kg lead silicate glass powder was synthesised and used to fabricate single pin small and big level sensors for HWP.

Regular production of xenon flash lamps for laser programme, ionisation gauges for UHV systems, and glass to metal seals of different types was maintained. More than 100 flash lamps to CAT and 20 BA gauges to various users in BARC were supplied. Also Technology Transfer Documents were finalized to pass on the know how for commercial production of BA gauges and DRDs.

About 60 implantations have been carried out with the 30 KeV ion implanter. Boron, phosphorus, arsenic and litrogen ions of various energies and doses are implanted. Post implant oxide passivation study has been done. These detectors showed reduced leakage current and better stability compared to epoxy passivated devices.

A few $BaF_2$ scintillation crystals doped with various rare earth elements with different concentration have been grown and have been studied for their thermoluminiscence, photoluminescence and radiation damage tolerance.

Magnetisation experiments were performed using SQUID magnetometer in the peak effect region of superconductor $NbSe_2$ to investigate various metastable vortex states corresponding to different critical current densities.

First principles LMTO electronic structure calculations, along with lattice dynamical calculation of the phonon spectrum have been carried out on $Zr_2Fe$ intermetallic, in order to augment the inelastic neutron scattering and low temperature specific heat measurements performed on the polycrystalline samples of this material. Specific heat parameters, electron-phonon coupling constant and the superconducting transition temperature have been derived.

Manufacturing support was provided for building sub-systems for several ultra high vacuum based analytical instruments required for various DAE programs and the development, standardization and prototyping of UHV components was continued. Job shop help was also provided in manufacturing critical components.

**Chemical Sciences**

Chemistry is an essential and integral part of many aspects of nuclear energy and radioisotope application programme. IX Plan projects envisage setting up of advanced state of art Laser facilities for studying & controlling ultra fast chemical reactions, bond selective chemical reactions & isotope selective reactions and Facility for molecular design of advanced materials to synthesise molecules with designer properties (such as super conductivity & ferromagnetism), new generation of micro-porous materials, novel catalysts, nano-materials and diamond films.

New methods are being developed for decontamination, minimising biofouling, understanding thermodynamic & structural properties of proposed new fuels and spent fuels.

*Analytical Chemistry*

Apart from in-house requirements of various divisions of BARC and other units of DAE, analytical service support was provided to private and public sector organisations, hospitals and academic institutions, to solve their analytical problems. A total of 4040 samples involving 9380 determinations were analysed. The types of samples analysed included metals and alloys, inorganic compounds, organic and organo-metallic compounds, high purity materials, biological and environmental samples, reactor materials, oils and other miscellaneous samples. Several solution samples were also analysed for various metallic constituents. Various techniques like flame AAS, graphite furnace and hydride generation AAS and ion and gas chromatographic methods, neutron and charged particle activation analyses etc. were used. Other specialised services like thermal analysis, particle size and surface area analysis, determination of non-metals like C, O, N, S, H in metals, alloys and other materials were carried out, as and when needed.

To further enhance the analytical capabilities, state-of-the-art instruments like HPGe $\Upsilon$-ray analyser, electroanalytical system, atomic absorption spectrophotometer, inductively coupled plasma atomic emission spectrometer and other minor equipments were installed.

Several analytical procedures were developed. Important among them included a method for determination of sulphur in thoria, preconcentration and separation of $^{231}Pa$ from the monazite plant streams, estimation of trace impurities in high purity materials and reactor grade thoria and uranium, determination of boron by flow injection method, determination of arsenic in ground water and of trace metallic in treated sea water and in pharmaceutical preparations or their raw materials, analysis of silicon metal for trace impurities etc.

Analytical research was carried out on various aspects of separation techniques, supported membranes, electroanalytical and thermo analytical methods. A class-100 laboratory is being set up for the ultra trace analysis of high purity materials. BARC participated in the intercomparison exer-

cises on the preparation and standardisation of Bharatiya Nirdeshak Dravyas of National Physical Laboratory and collaborated with VECC on the helium recovery studies from Bakreshwar hotwater spring in West Bengal.

*Applied Chemistry*

In the field of catalysis and surface sciences, advances were made towards development of a H2 recombiner for removal of hydrogen from the containment areas of nuclear reactors under postulated accident conditions. Noble metal based catalysts with better adhesion properties were developed for this purpose and their poisoning behaviour was investigated in detail. Studies on fundamental aspects of catalysis included entrapment of molecular clusters in zeolite cages and catalytic behaviour of supported nanosize gold particles.

Thermal expansion studies on $ThO_2$-2Wt% $UO_2$ and $Th_{1-x}$ Cex $O_2$ (x=0.0, 0.04, 0.08 and 1.0) were carried out up to 1473 K. Several mixed oxides like $Ca_2Bi_2V_2O_{10}$, $Ca_2Bi_2V_3O_{12.5}$, $Ca_3BiV_2O_{9.5}$, $Na_2Bi_2V_2O_9$ and anion rich mixed fluorides $M_7M'_6F_{32}$ ($M=Ba^{2+}$, $Sr^{2+}$, $M'=Er^{3+}$, $Pr^{3+}$) were prepared and characterized. The phase relation studies on $YF_3$-$MgF_2$ were carried out. A few mixed oxides like Mn-doped $LaVO_4$ and $Bi_4V_2O_{11}$ were investigated for temperature programmed reduction and oxidation. The catalytic activity of some of them was also studied.

Iodine release experiments from $ThO_2$ – 2% $UO_2$ fuel pellets were carried out. Preparation, characterization and thermodynamic stabilities of $Cs_2ThO_3$, $CsZrO_3$, $Rb_2ThO_3$, $Rb_2ZrO_3$, SrThO$_3$ which are important for the prediction of AHWR fuel performance were studied. Preparation, characterization and thermodynamic stabilities of rare earth molybdates, strontium ruthenates etc. are in progress. Work has been initiated to study phase diagram and vaporization behaviour of the phases in the Ru-Te system. Attempts were made to prepare reduced ternary oxides such as $UTeO_4$, $ThMo_2O_6$, $ThMo_2O_7$ etc. and study their thermodynamic stabilities.

Photochemical degradation of ion-exchange resins was carried out in aqueous solutions, on a pilot plant scale from the point of view of waste management. Conversion of resins into $CO_2$ and water could be achieved in about 100 minutes with our photo reactor. Pulse radiolysis of heterocyclic thiols was studied for the first time to compare their radiation protection properties with other thiols. Ion-chromatography was used for determining the site of attack and mechanism of reaction of $e^-_{aq}$ and OH radicals with dihalobenzines containing different halogens.

Work connected with setting up of a Dynamic Autoclave system and chemical Decontamination of clean up system of TAPS Unit 2 is progressing satisfactorily. Studies relevant to this viz. material compatibility studies in decontaminant formulation, comparative dissolution characteristics of Cr substituted haematites and magnetittes in CEA and LOMI formulation, preparation of LOMI formulation using different cathode materials etc are being pursued. To develop a suitable chromous LOMI formulation as an alternative to vanadous complexes, Cr (II) complexes are being prepared by reacting Cr(III) hydroxide with different ligands. Studies are on to improve the current cooling water treatment practice in power stations.

**Novel Materials & Structural Chemistry**

Diamond coated WC tool inserts (GIPIX) have shown 25% increase in tool life in machining of cast iron piston ring stacks under actual industrial production runs (cutting speed = 80 m/min., Feed = 0.15 mm/rev.; depth of cut = 1 mm on O.D. and ID). Thermal conductivity of $ThO_2$ and $Th_{0.98}U_{0.02}O_2$ has been measured to look into the thermodynamic and transport properties of thoria based fuels. This information is likely to be used in advanced thoria based heavy water reactors. A number of uranium and rare earth based intermetallic compounds were investigated for their hydrogen absorption characteristics. Structural, magnetic, heat-capacity and transport properties were monitored as a function of hydrogen content and temperature. The indigenously designed and fabricated Time of Flight Mass Spectrometer has become fully operational during the current year. The equipment has been used for the photochemical investigations of a variety of atmospherically important molecules such as dimethyl sulphide, dimethyl disulphide and a number of halocarbons. The multiphoton ionisation and decomposition investigations have been carried out using nanosecond pulse lasers and the possible reaction mechanism for the photo decomposition of these molecules has been proposed. Chemistry of benzyl selenide complexes of Pt/Pd group elements has been investigated with a view to use them for the preparation of metal selenides.

**Radiation Chemistry & Chemical Dynamics**

The procedure for radiolytic preparation of polyvinyl alcohol-based hydrogels, free from any solutions, was modified and their physical properties like mechanical strength swelling characteristics and thermal properties were tested. These preparations in various sizes have undergone successful clinical tests in various city hospitals for healing of burn injuries. Results have been excellent. Application for patent and FDA clearance have been made.

Research work on ultrafast phe-

nomena using pico and femtosecond lasers was continued. Conformational changes in benzils, ultrafast relaxation processes in laser dyes and effect of H-bonding on rotational dynamics of pyrrolopyrrole derivatives was investigated. New work on ultra fast processes in metal nanoparticles in solution was carried out. Phonon-solvent relaxation processes in copper nanoparticles, manipulation of nanoparticles sizes on laser irradiation were investigated. Trapped state emission from $TiO_2$ nanoparticles in microemulsions was reported for the first time. Photo-oxidation of $CF_2Br_2$ to give BrO radicals, important from the point of view of atmospheric photochemistry was investigated. Free radical pathways in the 193 nm photodissociation of cyclohexadines have been studied. Radiation and photochemical studies on antioxidants, pineal drugs like melatonin and seratonin, substituted quinones and substitued fullerenes were continued. Reaction of nitroxide radicals with a large number of organic substrates was studied using stopped flow spectrophotometry. Excited state properties and electron transfer reaction of organic sulfides, thiophenols and many other compounds have been investigated. A new process for deposition of diamond films on suitable substrates has been developed and is being patented. The wavelength range for kinetic spectrophotometry, pulse radiolysis studies, based on a 7 MeV LINAC, has been extended upto ~1600 nm by incorporating an IR monochromator and a photodiode. Electron guns for our LINAC have been indigenously fabricated by CAT, Indore.

BARC has a strong group on theoretical chemistry. Work on theories of nanoparticle catalysed electron transfer reactions, solvent dynamical effects on charge transfer processes, dielectric friction and solvation time correlation function, nonpolar solvation dynamics in model micellar cavity, ionic solvation in charge transfer and solvent polarization in ionic solvation, dipolar liquids is being pursued with vigour. Theoretical studies on polymers at interfaces and adsorption of a Lennard-Jones fluid mixtures in slit pores are being carried out. Ab-initio quantum mechanical calculations were performed on several H-bonded complexes and intermolecular complexes of nitrogen oxides of interest to atmospheric chemistry. Theory of intensity fluctuations correlation arising in single molecule fluorescence spectroscopy has been developed.

### Water and Steam Chemistry

An activity transport code for predicting the radiation field build-up in the primary heat transport system of PHWRs is being developed. Thermodynamic calculations on the cation distribution in ferrites and chromites showed that a significant fraction of zinc and cobalt ferrites only transformed into inverse spinel at temperatures above 300°C. Computations on the thermodynamic feasibility of the various ion exchange reactions between ferrites and ions in the coolant water showed that zinc incorporation was relatively easy on magnetite than on nickel ferrite.

Interaction of copper ion with carbon steel surfaces in decontamination formulations and the adsorption of various chelating agents on magnetite and hematite surface were studied. Several substituted ferrites were synthesized by solid state methods and characterised. The dissolution behaviour of these ferrites, hematite and meghemite in EDTA, PDCA, HEEDTA, NTA and thioglycolic acid was studied.

A new method of instantaneous corrosion rate measurement of carbon steel in acidic medium based on amperometric estimation of hydrogen was developed. It was confirmed that only base metal assisted oxide dissolution reaction in carbon steel specimens with 40 mm magnetite film was occurring. Corrosion behaviour of carbon steel, monel-400 and Incoloy-800 in various decontamination formulations was studied using electrochemical techniques. An electrochemical cell with YSZ high temperature pH probe and in-house fabricated external pressure balanced reference electrode was set-up.

The chemical cleaning formulation evaluated earlier was successfully tested on a specimen trepanned from the tube sheet of a failed steam generator of MAPS. Enthalpy of the various reactions involved in the preparation and application of the chemical cleaning formulation was estimated and an engineering design for the mock up and actual steam generator cleaning at MAPS was prepared.

Based on the work done on bamacle (Balanus reticulatus) larval culture and experiments on the settlement behaviour of larvae, a larval bioassay protocol has been standardized. This method can be used for the evaluation of antifouling techniques using the Biofouling Test Loop Facility, which is in an advanced state of completion near MAPS premises. Bacterial biofilm formation on various heat exchanger material surfaces was studied under laboratory conditions.

Regular monitoring of the cooling water treatment programme of FBTR was carried out by assaying total heterotrophic bacteria, iron bacteria and sulfate reducing bacteria both in cooling water and on the carbon steel coupons exposed online in the cooling circuit. To develop a corrosion inhibitor for FBTR service water system components (carbon steel), various phosphonic based-polymer compounds formulations were made and tested. Based on field studies carried out at Rajasthan Atomic Power Station, chlorination regime of low dose

continuous chlorination for 24 hours every alternate day was recommended.

The primary system of high temperature high pressure (HTHP) system was commissioned and the secondary side hot commissioning is in progress.

### Bio-organic Chemistry

Antioxidants have assumed importance both from health perspective and as food preservatives. A related aspect is naturally occurring radio-protectants which can prevent radiation induced biomolecular damages by radical scavenging and upgrading in vivo defence mechanism. Earlier, a new polysaccharide, isolated from the Indian medicinal plant, Tinospora cordifolia was found to be a good immuno-modulator. A patent applied for the process of its preparation has been accepted. The protective activity of the formulation towards the g-ray induced damage of DNA, lipid and protein has been demonstrated.

Polypeptides have emerged as desirable high-value compounds due to their application as medicinal compounds including radio-pharmaceuticals. Efficient bio-evaluation of these requires high throughput screening and hence development of combinatorial libraries is being tried. To this end, two silicon-based linkers have been developed for the synthesis of several polypeptides including congeners of somatostatin, which are useful as radiopharmaceutical ligands. Developing asymmetric synthesis is both challenging and important from the point of view of material and biological sciences. Several such methodologies have been developed using terpene, amino acid and sugar based chiral auxiliaries. Another important variant is the biocatalytic approach, which has been pursued with whole cell system and invoking unconventional solvent engineering approach with pure enzymes. Based on these, several insect pheromones, pharmaceutical intermediates and ligands for actinide extraction have been synthesized.

*Encouraging results have been obtained with the pheromones synthesised at Trombay*

*GA-induced stage-specfic Alterations*

The synthesis of CMPO, an efficient actinide extractant has been scaled up to 0.6 mole with high reproducibility and its purification process standardized. Another class of actinide extractant, the malonamides, has been synthesized while synthesis of a new class of ligand, calixarenes is under progress. Biosorption is one of the viable methods for the management of low level radioactive waste. The process of biomass production has been standardized to get bio-material of similar characteristics.

Encouraging result has been obtained in the All India Coordinated trials for the control of sweet potato weevil pests using the BARC synthesized pheromone. A cheaper and highly efficient pheromone dispenser has been developed. Using mating disruption technique, the efficacy of synthetic pheromone of the cotton bollworm has been established in field application. In continuation of the ongoing project on use of insect growth regulator in sericulture in collaboration with Central Sericulture Training and Research Institute, Mysore, the BARC developed IGR formulation has been tested all over India and found highly satisfactory. A new and cheap formulation is now being tried for the same.

**Radiochemistry**

A method based on the absorption of gaseous fission products on active charcoal kept at liquid nitrogen temperature followed by direct gamma ray spectrometry has been developed for the estimation of the gaseous fission products (isotopes of xenon and krypton ) in the moderator cover gas of the PHWRS.

The cooling water at RAPS was assayed and investigated for bacteriological quality and biofilm formation on different substrata. Experiments to find out chlorine demand and optimum dose for controlling biofouling were also carried out.

With an aim to examine the effect of nuclear structure on charge distribution, Fractional cumulative yields (FCY) of several fission products in the mass region 128-148 have been determined radiochemically in the fast neutron induced fission of $^{244}Cm$ (99.43 atom%). From these data, charge distribution parameter, such as width parameter (sz) and most probable charge (Zp) were obtained uniquely for these mass chains.

During the dissolution of the spent fuel by chop leach process in the reprocessing plants a small but significant amount of residual fuel remains in the hull due to incomplete leaching of the crimped hull. A method based on the measurement of fission product gamma rays from the leached hull has been developed for the estimation of the fissile elements in the leached hull. The developed Hull monitor is being used to monitor the leached hull basket at KARP, Kalpakkam.

Labeled radiopharmaceutical preparations are routinely used in the diagnosis of cancer and functioning of organs like lever, kidney etc. by radioimaging techniques. It is of utmost importance to validate these preparations before they are injected into the patients. Radiochromatography is the present day accepted method to estimate the percentage of labeling and to study the stability of such labeled radiopharmaceutical preparations. Such a system was not available in India. Hence a Radiochromatography system has been assembled with the available units and additional necessary hardware was incorporated to develop the system. This system is installed and is in use at RMC, Parel, Mumbai and has been found to be a good import substitute. Similar systems are being developed for other users also.

With an aim to determine the macro and micro nutrients present in the soil sample and to identify the origin of different soils by trace element finger print pattern, a set of seven agriculture soil samples from different parts of India were subjected to neutron activation analysis. A total of 14 samples each duplicate were irradiated for 7 hours in APSARA reactor and the activation products were assayed by high resolution gamma ray spectrometry. The elements present in the soil are Na, K, Mg, Ca, Mn, Co, Sc and rare earths. A method has been developed for the estimation of trace level of arsenic in ground water by Proton Induced X-ray emission (PIXE).

**Fuel Chemistry**

The activities in this field include development of facilities for fuel fabrication, investigations on the behaviour of materials at high temperature, chemical quality control of nuclear fuel materials, process chemistry and studies related to the chemistry of actinides and fission products.

Sol-gel microsphere pelletization (SGMP) technique employs free-flowing sol-gel derived microspheres, in place of powders, as feed material for making pellets. After the successful demonstration of this technique for obtaining good quality high-density $UO_2$ pellets suitable for PHWR fuel, a large-scale preparation $UO_3$ microspheres was undertaken. $UO_3$ gel spheres were prepared in several batches, calcined and characterised to obtain around 260 kg of good quality product. Sol-gel microsphere pelletisation studies of thorium oxide were continued to obtain high density microspheres. These sintered spheres would be used for some diffusion-related studies.

Ion exchange studies of Pu(IV) by macroporous bifunctional phosphinic acid (MPBPA) resin have shown that Pu(IV) can be removed from $HNO_3$ solutions containing HF without the addition of any complexing agent to suppress the effect of HF.

Studies were carried out to recover Pu from oxalate waste (generated during Pu oxalate precipitation) by coprecipitation with calcium oxalate. Pu was reduced toPu(III) state. 36 g. of $CaCO_3$ per litre is needed to bring down Pu level from 81mg/l to 0.6 mg/l.

Work on the recovery and purification of plutonium from calcium fluoride matrix was continued. The feasibility of simple methods of plutonium hydroxide and plutonium oxalate precipitation, where calcium is left in

solution, has been assessed for their application to plutonium purification on bulk scale. Experiments were carried out taking thorium as a stand-in for plutonium. Thorium oxalate was found to contain 1300 ppm calcium, where as thorium hydroxide contained 3000 ppm. Thus quantitative separation of thorium in a solution containing large excess of calcium is feasible.

The suitability of stabilized zirconia as a host matrix for fixation of cerium, neodymium and uranium has been determined by studies on solid solubility and chemical durability. The work has also been initiated to establish the behaviour of plutonium in stabilized zirconia.

Several compounds were prepared in Ba-U-O, Ba-Th-O and Ba-Nb-O system by solid state reactions and characterised by XRD. A high temperature mixing calorimeter was designed for carrying out measurements on radioactive substances.

In connection with the participation in the Interlab comparison experiment among PREFRE, BARC and SAL (IAEA), the mass spectrometric analysis of the spiked samples as well as isotopic composition of Pu and U were carried out using rhenium double filament assembly. In case of U samples, the $^{235}U/^{238}U$ ratio and in the case of Pu samples, the $^{240}Pu/^{239}Pu$ ratio was determined by Thermal Ionisation Mass Spectrometer.

In the on going search for a suitable complexing agent for boron which could be used for separation and determination of boron by HPLC, chromotropic acid was identified as a probable complexing agent. A fast and efficient method for separating the individual lanthanide elements has been investigated using HPLC. The studies were carried out using a reversed phase column, a-hydroxy isobutyric acid (HIBA) as the eluent, camphor sulphonic acid / n-octane sulfonic acid as the ion pairing reagent and Arsenazo(III) as post column derivatisation reagent. A method has been standardized for the determination of nitrogen in the fuel samples. An Ion Chromatographic procedure with conductivity detection has been developed for sulphur speciation studies.

Determination of O/U ratio in uranium dioxide powders by determining U(IV) and U(VI) by biamperometry has been standardised. The O/U ratios and RSD was found to be ± 0.0016 which is comparable with literature data.

To ensure stringent specifications, chemical quality assurance of nuclear fuel requires accurate analysis of various major and minor constituents present in it. Analytical services were provided for the analysis of large number of samples received from RMD and other units of DAE by different techniques. A number of techniques such as Electrometry and complexometry for the analysis of U, Pu and Th, Mass spectrometry for isotopic abundance measurements, Alpha spectrometry for determination of 241Am content in Pu samples, Gas chromatography for gas analysis, X-ray diffraction for phase identification, X-ray fluorescence for elemental analysis, Ion-chromatography for non metallic constituents, Elemental analyser for C, H, N, O determinations were used for the analysing the samples. Hot vacuum technique with an on line QMS is used for determination of hydrogen and deuterium content in coolant channels of PHWR. Surface area and porosity measurement was done for a wide variety of samples received from various divisions in BARC. Post shot soil samples were analysed by mass spectrometry, alpha spectrometry and X-ray diffraction.

**Isotope Technology & Applications**

The radiation & isotope technology programme is oriented to meet the growing demand of radioisotopes & radiation technology in industries and health care services in India. This programme envisages upgrading Isotope Hydrology Laboratory, NDT capabilities, enhancement of electron beam irradiation services to Industries and development of new diagnostic & therapeutic radiopharmaceuticals for nuclear medicine.

In the area of Isotope and Radiation Technology applications, the work on construction of Food Irradiator for potatoes and onions as on Industrial scale is progressing well at Lasalgaon near Nashik.

Multi centric trials on phosphorous-32 coated stents for use in angioplasty procedures are yielding encouraging results.

Liquid filled balloon approach for endovascular beta irradiation to prevent restenosis after angioplasty is fast gaining popularity among cardiologists. The radioisotope chosen should be in a chemical form which could rapidly excrete out via the urinary bladder. In giving due consideration to this fact, a method for the preparation of 188Re-DTPA complex has been optimized.

Potential $^{125}I$ sources for treatment of ocular tumours and also prostate cancer is well-known. A method has hence been developed to prepare a large number of sources by physical absorption (coating).

Isotope hydrology laboratory is being upgraded with the state of the art instruments and isotope processing facilities are being refurbished. Development of selected radiopharmaceuticals is continuing.

An isotopic study has been carried out to find out the sources of water seepage in the basement in some parts of Jodhpur city.

A model watershed with Continuous Contour Trench (CCT) layout has been developed under the World Bank aided pilot Watershed Development

Projects (1983-93) at Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra. The system is found to be effective in soil and water conservation leading to augmentation of groundwater recharge. To quantify the efficacy of the approach, components of water balance need to be determined. With this aim, a collaborative research programme with Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola has been initiated.

During this year, gamma scanning of 12 different types of columns like crude distillation column, depropaniser columns, separator columns and quench towers raging 2 to 9.1 meters in diameter and having height in the range of 40 to 60 meters have been carried out in chemical and petrochemical industry. Four training programmes in radiography testing level-II as per ISO 9812 were conducted for about 140 participants from Indian industry.

A workshop was conducted on Dam Safety & Management jointly by Central Board of Irrigation & Power (CBIP) and International Commission On Large Dams (ICOLD) in which experts from BARC presented case studies of isotope applications on seepages in dams carried out in India in the last 3 decades. This has led to greater awareness on the benefits of isotope hydrology in dam safety and management.

A National Training Programme on isotope techniques for water resources management was held during November 1-20, 1999 at Centre for Water Resources Development & Management (CWRDM), Kozhikode, Kerala under the World Bank aided hydrology project. Experts from BARC participated in the programme and delivered lectures.

Under sediment transport studies in the Hooghly estuary, the suitability of dumping site for dredged material was investigated using radiotracer method. The study showed that the bedload movement was predominantly towards the south of injection point, i.e. towards the bay of Bengal. This has resulted in large financial savings to the Calcutta Port Trust.

Under the programme of Radiation Processing of Indigenous Natural Polymers, the RCA-CRP on biodegradable polyethylene/agrowaste combination was taken up. In this project, polyethylene films blended with rice husk and bagasse were successfully processed using electron beam irradiation and the film showed good mechanical strength and pronounced biodegradability.

**Bio-Sciences**

Research in bio-sciences is directed towards evolving high yielding food crops and delaying or preventing post-harvest losses by increasing shelf-life, developing newer modalities for low dose cancer radiotherapy and employing molecular and isotope techniques in basic biology for disease diagnosis and finger printing of individual & population.

The civil construction of POTON Irradiator at Lasalgaon near Nashik to demonstrate the feasibility of increasing the shelf life of Potatoes and Onions on commercial scale would make further progress.

A survey (MSP) is being conducted and will continue to assess the detrimental effects of low level radiation on man with special reference to population groups, occupationally exposed to permissible levels of low level radiation in nuclear industry.

In vitro methodolgy for clonal propagation of pineapple and grapes have been standardised. The in vitro raised plants after hardening would be transferred to the field for evaluation.

Nearly 300 random decamer oligonucleotide primers were used in screening six parental inbreds of three popular cotton hybrids. About 30 primers were identified as useful primers for determining the genetic constitution of the hybrid seed. Cotton hybrid seed lots are being analysed with these markers. The result so obtained would be compared with those generated in the grow out test carried out by the seed certification agency.

BARC participates in the Database, comprising laboratories from all over the world, in the international collaborative project on micronuclei in human populations. Compilation of the CBMN data, on baseline micronuclei frequencies, from normal healthy subjects, Beta Thalassaemia traits and constitutional chromosome anomalies cases, accumulated in the various projects undertaken by the laboratory from the years 1987 to 1997 was carried out.

A low level radiation research laboratory (LLRRL) building which is a part of Monazite Survey Project at Kollam, Kerala was inaugurated to study the effects of low level radiation on human population living for several generations and centuries in the high background radiation areas.

**Nuclear Agriculture & Biotechnology**

The R&D activities in this area are, application of nuclear techniques in agriculture with the objective of developing improved crop varieties, use of radiotracers in the study of fertilizers and behaviour of agrochemicals in the environment, and use of radiations in the control of insect pests; Biotechnological applications for micropropagation of economically important crops and production of bioactive compounds using plant cell culture and Enzyme and microbial technology. BARC has transferred several technologies which includes release of genetically improved crop varieties, transfer of protocols for large scale multiplication of tissue culture raised banana, transfer of bioreactor technol-

ogy for large scale production of plant biomass and transfer of biopesticide development technology. BARC has established linkages with Agricultural universities through MoUs for the effective extension of the research efforts.

Yield trial of Trombay mustard cultures at Nagpur Agricultural College showed TM-1 to be superior to the check variety in seed yield. Induced mutation studies in Brassica juncea resulted in the isolation of mutants for yellow seed coat, low glucosinolates and high oil content in the variety varuna. In B.napus seven lines stable for zero erucic acid and low/trace glucosinolate content were developed through single plant selection and evaluation.

Plants can be used to remediate soils contaminated with heavy metals. Species of Sesbania, a green manure plant, were used to study the uptake of lead, cadmium and uranium under hydroponic conditions.

The rDNA from groundnut has been cloned with a view to detect polymorphism and develop fingerprints for Trombay groundnut varieties. Using several varieties no rDNA length polymorphism has been detected. Efforts are underway to concentrate on a highly variable region of the rDNA gene namely the Inter Genic Spacer (IGS).

Blackgram varieties developed at Trombay namely TAU-1, TAU-2, TPU-4, TU94-2 and two national check varieties T-9 and LBG-17 were analysed by ISSR-PCR for polymorphism with an intention of developing DNA fingerprints.

Nineteen new groundnut cultures are in different stages of evaluation in the ICAR's Co-ordinated trials. Seventy five quintals of breeder seed of four Trombay groundnut varieties worth Rs.2.85 lakh was produced under contract farming at Kolhapur and dispatched to National, Maharashtra State, Orissa and Rajasthan State Seed Corporations

TAG-24 was included in 'Package of Practices' for summer cultivation for Rajasthan by Rajasthan Agricullture University, Udaipur.

Field trials were initiated for standardising a protocol for the trapping of red palm weevil by using its pheromone (4-methyl-5-nonanol and 4-methyl-5-nonanone in 9:1 ratio). The pheromone trap fabricated from locally available materials has shown success in catching the red palm weevils.

Initial experiments using sterile insect technique (SIT) on diamond backmoth (Plutella xylostella) showed that the optimum gamma ray dose to induce sterility without affecting longevity was 300 Gy.

In collaboration with HAL, Pune, the toxicological data needed for the registration of our biopesticide based on indigenously isolated Bt strain Bacillus thuringiensis var kenyae have been generated with the help of various institutes and formal application for its registration has been submitted to Central Insecticide Board (CIB) in May 1999.

Biocontrol mechanisms of Trichoderma pseudokoningii strain MTCC 3011 isolated at BARC revealed that hyphal parasitism, rather than the antibiotic production is responsible for the effective control of sclerotial rot of vegetables and rhizomes.

More than 1200 tissue cultured plants were provided to seven research stations/universities within and outside Maharashtra.

A simple method for the bulk purification of horse radish peroxidase with over 90% purity, 55% recovery and a K4 value of 30,000 was developed. This enzyme has a lot of applications in industry and diagnostics.

Biochemical and physiological evaluation of tissue cultured banana with respect to changes in the levels of sugars, organic acids and aminoacids, and the changes in the activity profiles of some enzymes during ripening has shown good results compared with the natural varieties.

Bioremediation is currently gaining importance as an economically alternative technology for the treatment of radionuclide,heavy metal and organic waste. A number of microbial and agrobased bisorbents were screened for their ability to biosorb uranium.

A new approach for affinity purification of Con A from Jack bean meal using yeast cells adhered on cotton cloth has been developed.

**Food Technology**

In the field of Food Technology, BARC has been engaged in research and development work related to preservation of food by gamma radiation as well as by the conventional and emerging methods. It has a pilot scale facility which has been licensed to carry out irradiation of food and has three gamma radiation sources for experimental irradiation. BARC was involved in the framing of rules and regulations related to radiation processing of food in the form of Maharashtra Control of Irradiation of Food Rules. It has filed applications for clearances of additional food items to the Ministry of Health & Family Welfare. BARC has also undertaken training courses for the operations of food irradiation facilities.

Various fruits and vegetables were studied for their amenability to preservation and hygienization by gamma radiation. These included mango, chickoos, papaya, tamarind, tomato and coriander leaves. It was found that in mango carotenoid development was not affected by the application of gamma radiation doses applied for delaying the ripening process Table hpe stage was achieved 14-16 days after irradiation compared to 7-8 days in control. Shelf-life of chickoos could

by extended by 2-3 days after application of gamma radiation and storage at ambient temperatures. A combination treatment of heat and gamma irradiation was found to extend the shelf-life of papaya without affecting its ripening parameters. Tamarind after irradiation was found to be free of bacteria, yeasts and mold as well as from any insect infestation. A non destructive method using X-ray machine has been developed for sorting of mangoes infested with stone weevil and spongy tissue.

Dried figs exposed to gamma radiation could be stored without infestation, whereas 60% of the non-irradiated samples showed insect infestation during a six month storage study. Salad and seasonings including tomato and coriander leaves contaminated with human pathogens could be effectively hygienized using gamma radiation.

Studies were also carried out on the radiation disinfestation of cereals, legumes and their products. Irradiation of maize at disinfestation doses was found to show least insect damage compared to that in control and fumigated samples. Macronutrient content of maize was unaffected by the irradiation process. Pre-packed besan irradiated at disinfestation doses of gamma rays showed no changes in its functional and sensory attributes up to a period of six months of storage. Similarly, disinfestation dose of 0.75 kGy applied to cowpeas did not affect the cooking quality and sensory attributes.

A combination of dipping treatment in common salt and gamma radiation could extend the shelf-life of a fish threadfin bream up to 5 weeks in ice. Storage studies of ready-to-eat meat kababs carried out up to 4 months suggested that a combination of grilling, vacuum packaging and gamma irradiation resulted in a microbiologically safe and sensorily acceptable product which could be stored at ambient temperature.

Detection of irradiated meat using ESR and GCMS analysis of radiolytic products of lipids were studied. ESR was also used for the detection of irradiated wheat flour. Root length and number were also tested for detection of irradiated shallots. Detection of irradiated spices by viscometry was also studied.

In waste utilization studies gamma radiation was found to increase the utilization efficiency of wheat straw for mushroom cultivation. The irradiated wheat straw was found to give higher mushroom yield in a lesser time compared to non-irradiated straw. Autolytic degradation of proteins in radiation sterilized chicken intestinal homogenates showed that the soluble products increased with a concomitant decrease in the total protein. At a higher temperature of 60°C rate of autolysis increased four fold resulting in a complete degradation of proteins. Jawala, a trash fish, was also found to be a source of protein hydrolysate. The homogenate prepared from fresh jawala could serve as a feed and food ingredient. A new antioxidant was isolated from Jawala fish. Hygienization of poultry feed for elimination of Salmonella was carried out using gamma radiation.

Increased production of invertase was obtained by fluidizing the biomass with invertase activity. Sodium erythorbate was found to be useful in controlling enzymatic browning in fruits during processing Xanthomonas campestris pv glycines, was found to undergo programmed cell death. The organism formed apoptotic bodies which contained DNA devoid of the indigenous plasmids of the organism.

Food Package Irradiator and other experimental facilities for irradiation were used for irradiation of food and experimental samples. Various food products irradiated included fish, tomato, green coffee beans, mutton, onion, potato, chicken, animal feed and frozen food samples for R&D work. Radiation processing of potato, onion and mango was carried out for M/s. Isotech Irradiators, Mumbai. Radiation processing of coffee-beans and maize was also carried out for insect disinfestation.

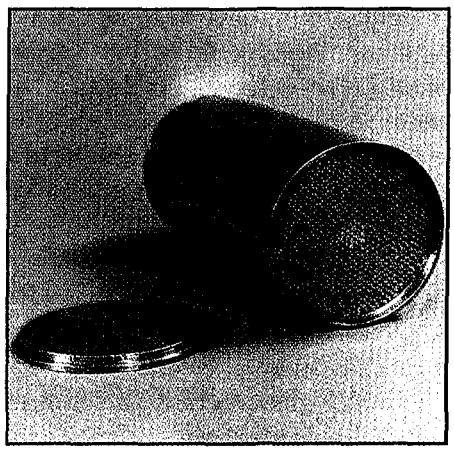
### Material Sciences

There is a wide range of materials, which find extensive applications in nuclear, space and defense applications. These strategic materials are being developed in-house for sustaining our nuclear programme.

Special effort is being made to upgrade the technology for the production and processing of Uranium compounds, develop processes for the separation of rare earths and Nuclear grade thorium, set up a lithium metal pilot plant and an advanced material processing centre.

Technology demonstration of fabrication of low temperature Nb-Ti multi filament super conducting cables is taken up and necessary machinery and materials are being procured. Using the existing facility, 50 mm long samples of 1.3 mm dia wire containing around 500 filaments each of 40 micron size have tested in the indigenously developed new cryo-

*Nb-Ti Composite Super Conductor Billet Assembly*



genic facility. 1100 Amps current could be passed through these samples at 5 Tesla and 4.20 K temperature without showing any resistive component. The new cryogenic facility has the capability to measure critical currents of samples up to 1200 Amps under magnetic fields going beyond 7 Tesla at 4.20 K. Computer programme to automate the acquisition of voltage-current characteristics of high current carrying super conductors is developed and preliminary testing is completed. Preparations are underway to carry out cable tests.

A data acquisition set up has been developed to in-situ acquire data from plant components for Real Time Monitoring of Aging of Power Plant Components for fatigue study.

Heat shrinkable shape memory alloy sleeves have been developed and are being supplied for the LCA Project. On the basis of BARC's support, ECIL has been awarded a contract for development of stabilised antenna platform for MMR of LCA.

Based on the technology developed on a laboratory scale, a two hundred litres per batch capacity plant for synthesis of D2EHPA has been successfully commissioned at Heavy Water Plant (HWP), Talcher. This plant was inaugurated on 3rd September 1999. After the successful trail runs, the plant is now operating on full scale and producing D2EHPA with quality better than imported one.

Experiments have been carried out on the synthesis of Tri (n) butyl phosphate (TBP) at the 12 litres batch capacity to standardise the operating parameters at this level of production and to generate necessary data required for plant design.

Mineral chemistry data on uranium bearing phases from Jaduguda, Bhatin and Narwapahar show that the uraninite has uniquely low Thorium, but relatively high heavy rare earth element (HREE) content, particularly yttrium. The various chemical ratios calculated from the data, clearly distinguish the different generations of uraninite that are petrographically identified.

A new process for purification of Ammonium diuranate cake (ADUC) produced as a by-product of IREL plant in Orissa was developed to attain the requisite purity of ADUC.

A project to set up Rare Earths development laboratory is completed to carry out R&D for pure rare earths, their alloys and finished forms for Industrial applications. Experimental R&D on phosphors, separations, hydro systems and pyro systems is in progress.

**Chemical Technology & Heavy Water**

A critical equipment is being procured which is a vital component in setting up an upgrading facility for heavy water used in Nuclear Power Plants. An alternative to this, an indigenous effort for design and development of critical equipment such as Turbo-expanders, He Compressor, Cryo- Heat Exchangers and Simulation Rigs are at various stages of progress which form central equipment for decontaminating and upgrading heavy water in PHWRs.

Construction of a Nuclear Desalination plant at Kalpakkam to demonstrate the feasibility, safety and economic viability of coupling nuclear reactor for sea water desalination is is progressing well.

**Technology Transfer & Collaborative Programmes**

Efforts to augment capability through strong linkages with academic institutions and other national laboratories are also bearing fruits. The programme of our joint activity on thermal hydraulics studies related to Advanced Heavy Water Reactor (AHWR) as also the Centre for Software Verification and Validation are taking shape at IIT Bombay. Our extensive linkages with various Agricultural Universities in Maharashtra, large scale component test work being done in the institutions like the Structural Engineering Research Centre, Chennai and Nuclear Engineering Programme with IIT Kanpur are some examples of new initiatives in this regard. These linkages will enable to add strength to the programme of BARC both in terms of extended resources as well as in terms of its quality.

BARC regularly makes available processes/technologies developed for in-house use to Indian industries for commercial exploitation. A number of technologies transfers and MoUs were carried out during the year. BARC assists the industries for quality assurance as well as for troubleshooting.

*The major achievement during the year 1999-2000 are as under:*

*Technology Transfer*: Number of technologies such as Foldable Solar Dryer, Lascan Dia Gauge, Triode Sputter Ion Pumps, TLD Reader, Mini-Micro Stepping Control Drive, ANUDAQ-20 and 100 MSPS Transient Digitizer have been transferred to interested parties.

*Technology Development*: A purchase order worth Rs. 1.95 crores has been placed by NPCIL for technology development and supply of 'Sludge Lancing Equipment' for mashroom type steam generators.

**Sale of products:**

Within the country

Various hi-tech Products such as X-Ray Proportional Counter, Anugami P PC interface Card, Virtual Reality Software, $BF_3$ detectors, $BF_3CaF_2$ complex containing $B^{10}$, Titanium anodes duly plated with enriched uranium, Boron Carbide, Gamma Scanning Equipment, Machined Uranium Pellets, Fuel Tube head, Lithium Carbonate and Hexamethyl Propylene

Oxime (HMPAO) have been supplied to interested parties/ companies.

**Exports**

Thoria ($THO_2$) buttons to M/s GE, USA, TLD cards & cassettes and TLD Personnel Monitoring Sysytem to M/s ISS, Saudi Arabia and TLDATE Software to City University, Hongkong have been exported.

Consultancy Services, Training Programmes and Accreditation of Laboratory:

Various Consultancy services in the field of Stress Analysis, Failure Analysis, Gamma Scanning, Welding, Powders Classification, Vibration Diagnostics, Irradiation of diamonds for colour enhancement, Radio Isotope Applications have been provided. Number of training programmes were conducted for Radiography testing and Nucleonic gauges, and Safety Aspects on Radiation Sources.

M/s Renentech Laboratories Pvt Ltd., Mumbai has been accredited to provide Personnel Monitoring Services to radiation workers in India.

**National and International Collaborations**

Number of MoUs have been signed during the year. Some of them are as under: Process Design Consultancy and technical back-up for setting-up of large sized thermal desalination plants (with M/s TAS Engg. Co.), Trouble-shooting and upgradation of Flourine Cell and Supply, Installation & commissioning of Flourine Purification system (with M/s Bloom Packaging)., Use of radiation and radioisotopes in agriculture (with Marathwada Agricultural University and Konkan Krishi Vidyapeeth, Dapoli), Technology for diamond polishing scaives (with M/s Diamond & Gem Dev. Corporation), Sponsoring M.Tech Students in Nuclear Engg. & Tech. (with IIT, Kanpur) for their absorption into DAE, Scaling up of Lepidolite ore processing technology (with M/s ACC Ltd.), Development of indigenous technology for manufacture of irradiation cross linked cables and heat shrinkable accessories (with M/s Nicco Corpn. ), Setting up of National Single Crystal X-Ray Diffraction facility (with DST), Strengthening of MSc (Radiation Phy) course (with Mangalore University), Development of Accoustic and RF Technology and setting up of Electron Beam Centre (with SAMEER), Development of double zero mustard (with NDDB), Development & modification of Solvent Extraction process for refining of Ammonium di uranate (with IRE).

The follow up actions for various projects under Indo-German and other schemes have been taken.

**Patents**

Patent granted - "process for synthesis of 5,10,15, 20-tetrakis {3,4 bis carboxy methyleneoxyl, phenyl} chlorin from 5,10,15,20-tetrakis {3,4 bis (carboxymethyl) eneoxy)Phenyl] prophyrin for detection of tunouirs has been granted.

Apart from this seven patent applications have been filed.

**Miscellaneous**

Various activities for BRNS projects were completed. Activities of INAE study group on Atomic Energy were co-ordinated and a report is being compiled. BARC home page was updated for all new technologies ready for transfer. The revenue earnings for the first 9 months year of 1999 -2000 is Rs. 5.27 crores.

**Medical Services**

*Radiation Medicine Centre (RMC)*

The three major areas of activities of RMC are, patient services, R&D and human resources development. More than 20,000 patients attended the outpatient clinics, a large number being thyroid patients. The radiopharmacy services and in-house manufacture of cold kits were continued.

$^{99m}$TC-radiopharmaceuticals are widely used as i.v. injectibles, in diagnostic nuclear medicine. These are generally formulated in hospitals just prior to i.v. administration, into patients by reacting $^{99m}TCO_4^-$ with the lyophilized contents of a Sn(II) ligand 'cold kit'. Following the imposition of sanctions, vital spares and accessories to the lyophilizer were not available. Thus, this impasse was overcome by adopting alternate process technologies for the small –scale manufacture of Sn(II) ligand 'cold kits'.

A new "Nude Mice" facility was established to support the R&D activities especially thyroid cancer. A beginning was made to start a veterinary diagnostic service facility for felines and other species.

A large number of sera samples from thyroid cancer patients are routinely assayed for serum Tg by conventional radioimmunoassay (RIA) at RMC. Altough, a relatively sensitive and easy to perform, the traditional RIA for Tg has limitations such as short shelf life of tracers Tg, time-consuming, narrow working range. To overcome these limitations of RIA, a two site immunoradio-metric assay (IRMA) has been optimized using in-house developed anti-Tg MabB10IV.

**International Relations - Regional Co-operative Agreement (RCA)**

India has been continuously enhancing its participation in the RCA activities. During the year 9 events were hosted in India in which 135 persons participated. A total of 61 persons from India participated in 38 other RCA events during the year. 9 members from RCA countries were provided training under IAEA fellowship scheme and 16 Indian experts extended their services to RCA MSs.

The Indian RCA National Home

Page was put on web and was demonstrated to the joint UNDP/RCA/IAEA Lead Country meeting at Vienna. In association with the Lead Country, India submitted a draft proposal regarding the format and probable contents of the RCA Regional as well as National Home Pages.

BARC experts participated in the various Advisory Group and Project Formulation Meetings in agriculture, isotope applications in industry, internal dosimetry, research reactor operation & utilization, distance learning for nuclear medicine technology & radiation oncology etc., and were actively involved in the review and formulations of project proposals for 2001-2002 cycle. India has submitted a total of 18 new project proposals apart from 3 ongoing projects for extension for the 2001-2002 cycle.

National Co-ordination Committees have been formed in the field of agriculture, isotope hydrology, energy and air pollution, involving the premier research institutes and various end-user organisations as one of the strategies adopted to bring the benefits of nuclear technologies to the end-users.

**Infrastructure Enhancement Programme**

Central workshop gives support to BARC programme in the field of design, development and installation of critical equipment & components required for the ongoing and future projects. CWS is continued to participate in the development of CMS detector & detector frames for PHENIX, end fitting bodies and fueling machines for 500 MWe PHWR, control rod guide tubes for TAPS, control rod drive mechanism components & seal cutting machines for PRP project, fuel spacer development for AHWR, special product handling system for EBC project Khargar among others.

To enhance its over three decades of experience and capabilities, Central Workshops was restructured to provide total integrated engineering solutions to the Scientific Community in BARC. Under the IX Plan, Precision Fabrication Facility has been set up, leading to the acquisition of several CNC Machines, Rapid Prototyping & Manufacturing System, Computer Aided Engineering Facility with high end engineering design solutions, including modeling assembly, analysis, CNC generation machining on the latest graphic workstations in the CWS Network. Excellence in Quality is the mission of Central Workshops provided through group effort of all involved.

Rapid Prototyping (RP) is the technology that produces models and prototypes from 3D CAD models, CT and MRI scan data and form3D object digitising / scanning systems. Today RP is fast becoming a logical extension of CAD/CAM. Stereolithography (SLA) based RP system SLA250/50 is being installed in CWS. Of the different RP techniques, SLA is accurate and faster. The prototypes can be used for design verification (which reduces design cycle time tremendously), Form Fit and Function tests. The RP models can be used as patterns for investment casting, vacuum casting and injection moulding etc. to produce number of metallic and nonmetallic components. The SLA based RP system in CWS is expected to be commissioned shortly.

Upgradation of Information Technology Services and Enhancement of Computing Facility are being carried out as part of infrastructure enhancement programme.

To meet the newly emerging demands of advanced Electronics & Instrumentation for various programmes of DAE, E&I facilities in the areas of High technology nuclear electronics, Vision system facility for material characterisation and automated inspection and Laboratory for electron/ion optics, complementary systems and related materials are being augmented.

# INDIRA GANDHI CENTRE FOR ATOMIC RESEARCH

The Indira Gandhi Centre for Atomic Research (IGCAR), primarily engaged in the development of sodium cooled fast breeder reactors to meet the long term power needs, has established over the years, comprehensive R & D facilities. Fast breeder reactors form the second stage of the Indian Nuclear Power Programme for effective utilisation of uranium, leading to the exploitation of the large energy potential in thorium in the third stage.

The Fast Breeder Test Reactor (FBTR), with its small core, was operated successfully with excellent performance of the indigenously developed plutonium-uranium carbide fuel, reaching a burn-up level of 50,500 MWd/t, by November 1999. A programme of irradiation of zirconium-niobium alloy cladding was taken up for pressurised heavy water reactors (PHWR) and post-irradiation examination was also carried out successfully.

With this expertise, the Centre has embarked on the design and development of 500 MWe Prototype Fast Breeder Reactor (PFBR). Significant progress was made in the design & development of components and systems of Nuclear Steam Supply Systems (NSSS) and the conventional systems of PFBR.

KAMINI reactor was operated upto its rated power level of 30kW and utilised for irradiation, activation analysis of samples and also neutron radiography of specimens.

The thrust of the R & D programme is presently aimed at supporting the design and the construction of the PFBR. In this connection, project work is progressing well on a 5.5 MWt (sodium heated) Steam Generator Test Facility.

All the computer systems at IGCAR and also various Software developed and implemented were made Y2K compliant.


*Hydraulic prototype of primary pump on test bed*

**Fast Breeder Test Reactor FBTR**

The reactor was operated at 8 MWt and samples of zirconium-niobium and zirconium-2 alloys, used as structural materials in pressurised heavy water reactors (PHWRs), were irradiated at a maximum targetted fluence to assess the in-reactor creep. One fuel subassembly of the Mark-I core, with a fuel burn-up of 50,500 MWd/t was discharged for post-irradiation examination (PIE) to assess its performance for increasing the burn-up further. Several important experiments related to reactor safety, major surveillance activities like the integrity test of the reactor containment building, visual examination of the reactor internals under sodium etc., were carried out. Further, the Y2K compliance test for the plant computers, that perform safety related functions were also carried out successfully.

It is planned to carry out physics experiments related to Failed Fuel Localisation, above core neutron flux measurements etc., before raising the reactor power for putting the Turbo-generator (TG) back into service.

**KAMINI Reactor**

The reactor was operated upto its nominal power of 30 kW and the Uranium-233 fuel attained a burn-up level of 245 MWd/t. The south beam tube was used for the first time for neutron radiography of various specimens and it is planned to operate the reactor for irradiation of samples for research, forensic purposes and also for neutron radiography of the irradiated fuel subassembly from FBTR.

A six day workshop was conducted for creating awareness among the research institutions / universities / industries, on the potential uses of the reactor for neutron radiography, activation analysis and radiation physics research.

**Prototype Fast Breeder Reactor (PFBR)**

Detailed discussions were held with Site Evaluation Committee and clearance from AERB for Kalpakkam site is expected shortly. Further progress was made in the conceptual design of components and systems of NSSS, Steam-water system, electrical and plant layout & auxiliary systems. Preliminary Safety Analysis Report (PSAR) for the above were under review by Internal Safety Committee and Project Design and Safety Committee (PDSC). Work related to the site infrastructure development was initiated.

The recommendations for the appointment of consulting engineers for the design consultancy services of PFBR were made.

*Technology Development for Fabrication of PFBR components*

The tube bundle assembly (85 tubes) for the reheater of the steam generator is expected to be ready soon. Trials on various welds for the evaporator of the steam generator were completed. The manufacturing drawings / documents for Control and Safety Rod Drive Mechanism (CSRDM), Roof Slab Sector and Transfer Arm were approved and manufacture was in progress.

*Structural Mechanics Analysis*

Various thermal hydraulics and structural mechanics analyses for ensuring the structural integrity of components of PFBR sodium circuits were completed.

## FAST BREEDER REACTOR R & D AND ENGINEERING

**Engineering Development**

The engineering development activities in support of PFBR include the experimental studies on Large Component Test Rig (LCTR), component hydraulics, sodium pump and also reactor instrumentation. The construction of the Boron Enrichment Facility and Steam Generator Test Facility (SGTF) were pursued.

The first phase of heat transfer experiments on the LCTR, a major sodium facility for heat transfer studies related to PFBR roof slab, was completed. Further experiments were being taken up. The distributed control system of LCTR was upgraded for acquisition of various data.

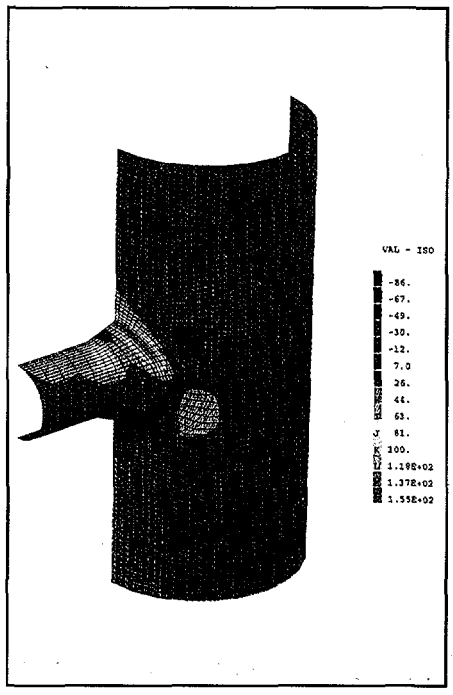
All the components for the facility, including the sodium piping, for sodium water reaction experimental studies, were erected. Ten tonnes of sodium was charged into the storage tank and the commissioning of the system was on hand.

Towards indigenisation of the heaters suitable for operation up to 600 deg. C, SS sheathed magnesium oxide insulated cable heaters were developed to meet the requirements.

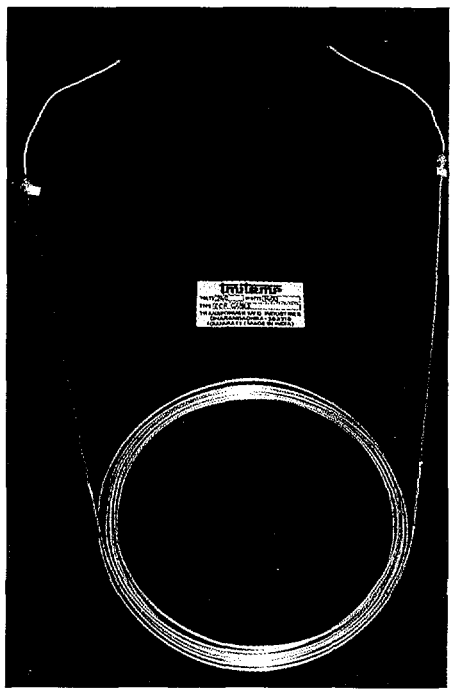
As a part of the development of hydraulics of the compact Primary sodium pump, the manufacture of the scale model (1:2.75) of hydraulic parts and erection of the test facility were completed.

The dynamic behaviour of the primary pump rotor assembly was inves-

*Bending stress distribution in the Steam Generator shell-nozzle junction*




*Indigenously developed M.I cable heater*



tigated in a full scale model and measurement of vibration at a speed of 400 rpm was completed successfully.

Development works on the slip joints for the primary and the secondary sodium pumps, made progress. Leakage flow and cavitation experiments were completed under aligned and inclined conditions, and manufacture of piston ring seals for the secondary sodium pump slip joint were completed.

Testing of the full scale dash pot assemblies of the Control and Safety Rod Drive Mechanism (CSRDM) and Diverse Safety Rod Drive Mechanism (DSRDM) were completed. Based on the results, labyrinth type V ring seal was selected as the primary barrier for both the mechanisms. In collaboration with IIT, Chennai, a temperature sensitive magnetic switch was developed and demonstrated.

Testing of the PFBR dummy fuel and blanket subassembly for pressure drop and cavitation behaviour were completed and the test section was installed for carrying out experiments on instrumented dummy fuel subassembly.

The work related to the evaluation of a flow distribution device and also a temperature mixing device for the intermediate heat exchanger was completed. The efficacy of different flow distribution devices for the steam generator was determined on a 3/5 scale model in a water rig.

Tendering action was initiated for 1/4 scale reactor assembly model, to study the thermal, hydraulic and vibration behaviour of reactor components. A 16-channel vibration analysis system was commissioned.

Development of a selector valve and a Positional Drive System was completed for the prototype Failed Fuel Identification Module (FFIM). The manufacture of a sodium immersible DC conduction pump for use in the Module was also completed.

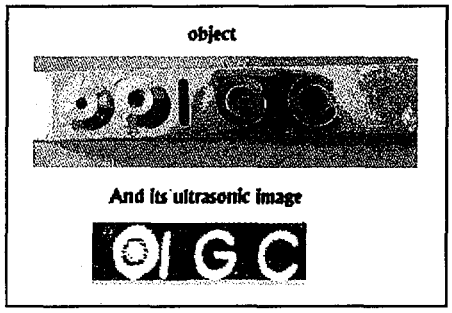
An experimental study was carried out to determine the effect of fill gases on the response times of the thermowell identical to core monitoring thermowells of FBTR.

A new dynamic sodium loop was under commissioning for conducting various experiments related to PFBR.

The capability of the ultrasonic under-sodium scanner of FBTR was improved.

An in-core flow measurement device using an earlier developed eddy current flow meter was tested for installation in FBTR.

The technology for the sodium level sensors developed indigenously, was transferred to industry. The sensors were under manufacture, while the electronics required were received.




*Object & the ultrasonic image*

The project for the SGTF made good progress. Civil works for the substation was completed, contract for the construction of the main building was awarded and the foundations were in progress. Work orders for the erection and commissioning of DG set and transformers were released. Detailed design of various components for the sodium loop were completed and orders for the fabrication released. All the sodium tanks were received at site. Design of fired heater for sodium was completed and action was initiated for fabrication and commissioning. Bids for the design, supply, erection and commissioning of the steam water system were evaluated and order placed Orders for the Boiler Feed Pump of specific ratings and fabrication of steam generator for the facility were also released.

The Isotope Separation Plant for production of enriched Boron-10 was in an advanced stage of construction. All the equipment were erected and the DM plant was commissioned. The piping spools fabricated were rubber lined and erected. The commissioning of the plant will be taken up shortly. The software for monitoring the plant parameters was getting ready. The engineering experiments set-up was under operation and 25% enhancement of the isotopic composition of Boron-10 was achieved presently.

Using IGCAR's expertise in the field of sodium technology, three training courses for a major petrochemical industry at Chennai, were conducted.

**Reactor Physics**

Periodic calibration of control rods, measurements of temperature and power coefficients of reactivity and monitoring of reactivity loss due to burn-up were carried out for FBTR operation.

The power calibration was verified to meet the surveillance requirements of technical specifications of KAMINI. The neutron flux at the thimble irradiation location in the reactor was also measured.

PFBR core physics design codes were approved by the Validation Committee. The safety analysis codes were also reviewed. The document on incident / Accident analysis of PFBR was under review. Probabilistic safety analysis of the shutdown and decay heat removal systems made progress. New multi-group data are being prepared for shield and core physics design.

**Material Chemistry**

Electrochemical hydrogen meter, based on molten salt electrolyte developed, was operated, calibrated and

used for steam injection experiments.

Carbon potential of stainless steel was measured using electrochemical carbon meters developed in-house.

Special sensor materials were developed. Efforts were continued to prepare nanocrystalline powders, for use as sensor materials.

The usefulness of the electrolyte based hydrogen sensors was tested for the decontamination of carbon steel components.

The experimental set-up for the production of sodium, based on molten salt electrolysis, was operated and one kilogramme. of sodium was produced.

Mass spectrometric experiments continued to deduce the thermodynamic data on compounds of tellurium, which play an important role in fuel-clad interactions.

Sodium zirconium phosphate, which is a candidate ceramic host material for nuclear waste immobilisation was synthesised by a novel process.

A novel method to correct for quenching of fluorescence intensities of metal ions was developed and demonstrated for estimation of uranium in ppm levels in solutions containing lanthanides and actinides.

For the standardisation of a common solvent extraction technique for determining various trace metallic impurities in uranium oxide, Standard Reference Materials with certified concentrations for many elements such as boron, cadmium etc., were established.

**Fuel Chemistry**

Solution Chemistry

A comprehensive programme was initiated to study the thermodynamics of actinide extraction by amides.

The kinetics of extraction of uranium from nitric acid medium by a macroporous bifunctional phosphinic acid resin was studied and diffusion coefficients and the activation energy for the extraction were determined.

A programme to measure the solubility of extractants in supercritical carbon-di-oxide was taken up for extraction of actinides.

**Thermo-Chemistry**

A novel method based on microwave combustion synthesis was developed to prepare Urania-Thoria powder that could be cold compacted and sintered to high densities at relatively low temperatures and the stability of the compounds was determined.

The fabrication of high-density uranium oxide pellets using microwave heating, which is found to be simple and rapid, was demonstrated.

**Pyro-Chemical Reprocessing**

The enthalpies of formation and the Gibbs free energies of intermetallic compounds in thorium-gallium (Th-Ga) & calcium-gallium (Ca-Ga) were determined.

An argon atmosphere glove box assembly was commissioned for carrying out various measurements on radioactive & air sensitive compounds.

**Nuclear Chemistry**

The dynamic adsorption coefficients of Krypton and Xenon on activated charcoal were measured and a preliminary design of the cover gas purification system for PFBR was completed.

Post-Irradiation Studies

A flow sheet was developed for the separation of uranium, plutonium, minor actinides and cesium-137 (Cs-137) from spent fuel solution and the separation of Cs-137 was demonstrated in the hot cells. This yielded a product solution, with significantly reduced gamma dose, which has enabled to carry out the subsequent separation in fumehood.

Four pellets of irradiated fuel of FBTR, with a burn-up of 25,000 MWd/t were dissolved in nitric acid in hot cells employing both direct and electro-oxidative dissolution techniques.

A large volume of degraded oil of radiation shielding windows was purified.

**Electronics and Instrumentation**

A Temperature Monitoring System for FBTR reactor vessel, was designed, developed and implemented successfully. A 16 Channel ASIC based alarm sequencer was developed for tracing the sequence of trip for boiler of FBTR. SCADA system for HWP (M) was made Y2K compliant and was handed over for regular operation.

A real time Data Acquisition System was developed for Isotope Separation Plant and commissioning was being taken up.

Fibre Optic based LAN for FBTR was commissioned and Client Server based maintenance management system was also implemented.

Testing of real time computer system for Lead Mini Plant, the demo facility for reprocessing of FBTR carbide fuel was in progress and will be commissioned during next year.

On-line frictional force measurement system for CRDM of FBTR was being developed and tested for implementation.

**Metallurgy and Materials for FBRs Metallurgy and materials Technology**

Low Cycle Fatigue (LCF) studies were conducted in air on indigenously developed modified 9Cr-1Mo steel, a candidate material for steam generators of FBRs, between 300-923 K.

Creep properties of modified 9Cr-1Mo base metal and weld joints prepared by shielded metal arc welding were assessed between 823 & 923 K.

The microstructures of Heat

Affected Zone (HAZ) in modified 9Cr-1Mo weld joints were reproduced by subjecting the base material to simulated isothermal heat treatments in the range of 1100-1623 K and tensile properties were determined at various temperatures on base metal as well as simulated HAZ.

Creep-fatigue interaction tests were carried out on indigenously developed D9 alloy with titanium to carbon ratio of 4, for various conditions.

A comprehensive FCG characterisation of 316 LN led to the development of a new FCG equation and better description of crack closure phenomenon.

Influence of nitrogen and titanium-carbon ratio on the hot cracking susceptibility of 316 LN and D9 alloy and also the secondary phases, deleterious to the weldability were studied. Indigenous technology for aluminsing inconel 718 for PFBR steam generator applications was developed. Welding electrodes for 316 LN stainless steel were developed indigenously, meeting PFBR specifications.

**Materials Characterisation**

An important process for producing electro-catalytic coatings on titanium meant for nitric acid application was developed and a process & product patent was filed.

Adhesion of bacterial cells to metal substratum is an important aspect in microbiologically influenced corrosion. In a continuing research, evidences were obtained for preferential growth of bacterial colony on samples of Stainless Steel, which were heat treated, to make them susceptible to inter granular corrosion.

The convergent beam electron diffraction technique was used to locate the lattice strain variations in welds and heat affected zones of ferritic steels, to estimate the residual stresses in welds.

The atomic force microscopy technique was employed to evaluate the mechanical properties of titanium-aluminum thin films grown on silicon substrates, at nano levels. The role of nitrogen in causing the variations in properties were also demonstrated.

A generalised thermodynamic equation of state was developed and used in assessing the thermophysical properties of intermetallics.

A new laser heating method was found to be useful in causing localised de-sensitisation of austenitic stainless steels.

Thermodynamic studies were carried out to demonstrate the efficacy of calcia in suppressing the vapour pressures of fission product compounds at 1000 deg. K. This data is extremely useful in modifying the structural concrete and also in developing coatings for containment of fission products in accidental conditions.

**Basic Research on Materials**

A low field SQUID magnetometer was assembled and tested successfully, which has paved the way for the development of systems for SQUID applications in materials technology including NDT. A small angle x-ray scattering facility for the study of deformation microstructure and dispersed nanoparticles in engineering alloys and other materials, was built, based on high intensity rotating anode generators.

Break-down maintenance of sophisticated imported equipment such as the cold box of helium liquifier and rotating anode x-ray generator, was carried out successfully.

Investigations on possible coexistence of superconductivity and ferromagnetism in some systems were carried out. High pressure X-ray diffraction studies on f-electron based di-aluminides were carried out. Ion implantation techniques were used to prepare novel embedded nanoclusters of silver, copper and aluminum in insulating matrices and these were investigated by various methods.

**Post-Irradiation Examination (PIE)**

An irradiation experiment in FBTR was undertaken to generate irradiation creep data of indigenously developed materials such as Zirconium-Niobium for PHWRs. Zircalloy Pressurised Capsules (ZPC) encased in stainless steel Irradiation Experiment Capsules (IEC) were irradiated and taken up for PIE.

The profilometry of four irradiated experimental fuel pins containing different compositions of fuel, discharged from FBTR was completed. The comparison of this data with the pre-irradiated data showed that the diameter of the pins have not changed due to irradiation.

Determination of the mechanical properties of the individual regions of Heat Affected Zone (HAZ) of 2.25Cr-1Mo weldments by conventional test methods poses practical difficulties in making test specimens from the small regions of HAZ. Hence, an attempt was made to determine the same by shear-punch test using miniature sized specimens.

**Non-destructive Testing and Evaluation**

The Synthetic Aperture Focussing Technique (SAFT) was successfully employed for the detection of inclined cracks on test specimens with artificial cracks introduced at different misorientations.

The magnetic Barkhausen emission technique was used to resolve the simultaneous variation in grain size and second phase precipitate size during thermal aging process in carbon steel.

Residual stress measurement of bi-metallic transition weld pad of SS 316LN and 9Cr-1Mo, candidate materials for PFBR applications, was carried out.

Methodologies for evaluation of

structural integrity of tail rotor blades of helicopters were developed and standardised as a part of life extension programme. Localised corrosion damage in IAF air crafts were also investigated.

The Department of Science and Technology project on Intelligent Processing of Materials (IPM) technology was under execution for the development of suitable methodologies for weld related applications and ceramic insulators.

### Remote Handling and Robotics

Design, construction and development of a Remotely Operated Power MANipulator (ROPMAN) with six degrees of freedom, along with a gripper, was completed for hot cell applications. The servomotor controlled motion of the ROPMAN facilitates its upgradation to a full-fledged robotic arm.

An external Pipe Inspection System (PISys), capable of performing circumferential and axial scans, was designed and tendered out for fabrication.

### Innovative Design and Engineering

Experimental work to study the compatibility of zirconium alloys with sodium was completed. The out-of-pile experiments to determine the thermal creep rate of zirconium alloys were carried out. Reference defects in the form of notches and holes were made on the full size coolant tubes of PHWR for use as a calibration standard for eddy current and ultrasonic testing of the coolant tubes at various nuclear power stations.

A study was carried out to understand the evolution of residual stresses with each weld pass in multi-pass welded plates of AISI 304 stainless steel and low carbon steels.

### Computer Science

Large computer system like ND-560, Super 32/70, SGI system servers and 16 workstations were operated with more than 98 % of time on round the clock basis. Six Nos. of xeon based servers and six P II based workstations were under procurement. To augment the Internet services a dedicated 64 kbps connectivity was established from VSNL, in addition to the existing V-SAT. The fibre optic campus backbone Network with firewall security system was commissioned. An additional 64 kbps internet connectivity was being obtained to take care of the increased load. The central e-mail server was upgraded with fault tolerant features.

The software in ORACLE for IGCAR administration functions with additional facilities for HRD related activities was installed and trial use was in progress. The first phase of the project on "Computer aided hospital management system" was commissioned. Development of other software modules for pharmacy, pathology lab etc. were completed and were under refinement.

### Health and Safety Engineering

### Radiological Safety Assessment Studies

A code to assess the deposition of activated corrosion products such as cobalt-60 and manganese-54 in the primary sodium loop of FBTR was developed.

The work on the environmental impact assessment study for PFBR was completed. Public hearing on the proposed plant, a pre-requisite for necessary clearance, was also in the process of taking up.

The aspects such as radioactive waste, estimated dose for hypothetical Core Disruptive Accident (CDA) and interfaces with other facilities at Kalpakkam were re-examined critically for revision of PSAR of PFBR. Also land use classification studies based on IRS Satellite data were completed.

A portable 30 metre meteorological tower was installed and the hourly data was archived for carrying out coastal atmospheric studies.

### Basic Studies in Radiation Physics and Biology

A rotating tritium target assembly for the intense pulsed neutron source was designed and fabrication progressed.

A new thermoluminescent phosphor based on calcium sulphate co-doped with silver and rare earth element was synthesised, which is capable of measuring radiation doses at high ambient temperatures.

Basic radiation biology experiments were continued with radiation exposure of blood samples, especially from smokers. A new "Sequential Estimation Technique", to estimate uranium, thorium, plutonium etc., in urine was undergoing trials.

### Radiation Protection

The Environmental Gamma Dose Logger, an atmospheric sampler and Gamma tracer were designed, fabricated and tested. Environmental gamma dose are being regularly archived and analysed.

Radiological surveys were conducted at coastal localities of Tamil Nadu, where extraction of minerals from beach sands are being carried out. A full-fledged Radon calibration facility was set up at IGCAR for carrying out country-wide radon mapping.

As a part of public awareness programme, lectures were given to the district officials and school students (about 1500 persons), on emergency preparedness. 20 Groups of visitors from academic institutions were briefed on fast reactor programme, nuclear safety, radiation protection, nuclear waste management and also emergency preparedness.

### Safety Engineering

Parametric computations were

made, using the two dimensional computer code developed for the assessment of the loading on the roof slab of the reactor vessel of PFBR under CDA, for varying pressures of Core bubbles (10 MPa to 400 MPa) and cover gas volume in the reactor in the range of 6 % to 25 % of the vessel volume, to tailor the experimental programme, for which the test vessel was fabricated.

All the eight sub banks of the 100 KJ condenser bank were tested for satisfactory performance. A scale model of PFBR vessel was fabricated to study the response of the top lid under different simulated energy release conditions.

Response of the fuel to slow power levels was being studied out-of-pile electrical heating, in stages.

As a part of the sodium concrete interaction studies, test runs with limestone concrete & liquid sodium at 500 deg. C were carried out in air and under inert atmosphere.

To arrive at a suitable design pressure for the reactor containment building of PFBR, the thermal consequences of Sodium fires due to the CDA were analysed using computer codes.

To study the heat removal capability of the core catcher proposed for PFBR, through natural convection under core melt down scenario, water simulated scaled down (1:4) model was designed and procurement action was initiated.

Safety surveillance inspections were carried out in all the facilities at IGCAR and BARC Facilities. Programmes on Safety education, first aid training, fire squad training etc., were organised.

**Fuel Reprocessing**

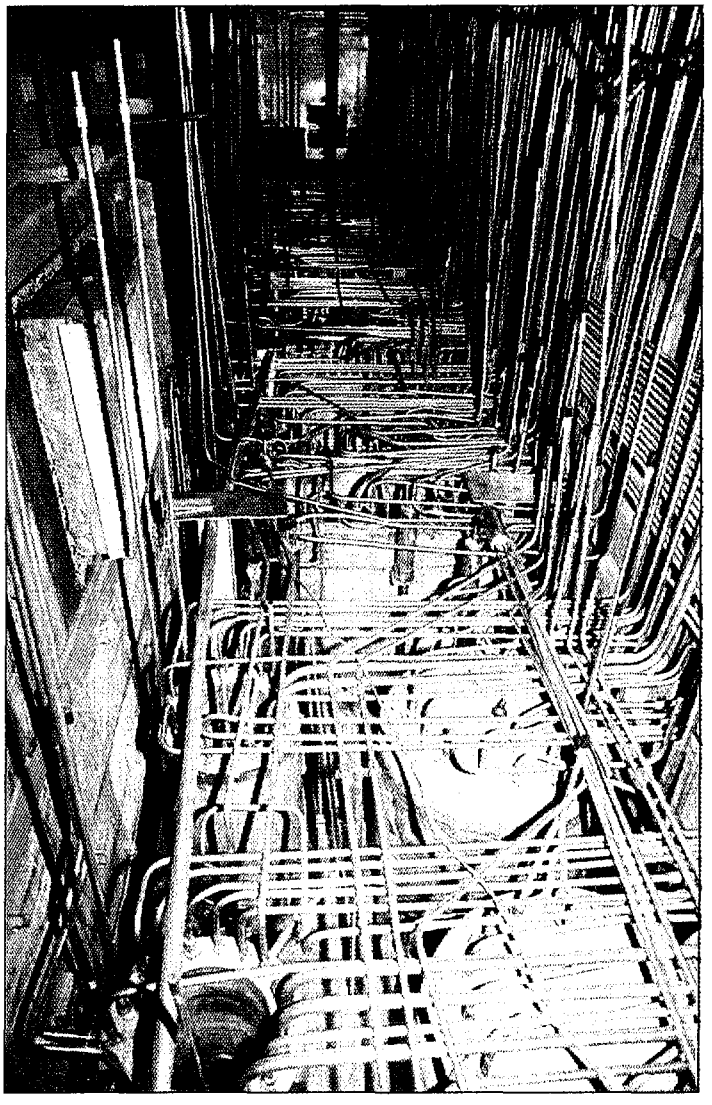
**Lead Mini Cell**

The Lead Mini Cell (LMC), a demonstration facility for reprocessing of FBTR fuel on laboratory scale was in an advanced stage of completion and the titanium electrolytic dissolver and titanium piping works were completed. With all the process vessels installed, the piping inside the containment box, is nearing completion. The in-cell crane reached an advanced stage of fabrication. The reconversion systems, instrumentation, control panels etc., were installed and pre-commissioning tests were in progress. The safety and commissioning reports were under review by SARCOP and the commissioning trials will begin soon.

**Fast Reactor Fuel Reporcessing Plant (FRFRP)**

Various equipment such as the chillers, condensers etc., were received at site, while the process vessels, which are under fabrication, are expected to be delivered soon. The off-gas ducting works were progressing well and are targeted to be completed during the financial year. Detailed piping drawings for the extraction cells were under preparation and the tender for the in-cell piping was under issuance. The building for the assembly of the Radiation Shielding Windows was under construction. Revamping of the emergency electrical power supply system progressed.

*A view of Lead Mini Cell*



### Uranium-233 Extraction Plant

Hot commissioning works related to the second campaign of Uranium-233 extraction from thorium rods were completed. A few rods were dissolved and U-233 was extracted and converted to oxide form.

### R & D Activities

A separate R & D facility for carrying out the various engineering and process related to developments was nearing completion. Many of the instruments for the measurement of physical property for reprocessing stream were procured and the installation was being taken up.

A newly developed 16-stage ejector mixer settler was used to conduct the Uranium-Thorium flow sheet runs and the results were found to be encouraging.

### Engineering and Technical Services Civil Engineering

The civil works related to the IX Plan, such as Structural Mechanics Laboratory, Centralised measurement standards and calibration facility, Substation for SGTF, Quality engineering Services and Test facility, Mechanical maintenance & vibration building, Main security building, compound wall and widening of roads, were completed. The buildings for micro-machining and assembly facility, remote handling & radiography and SGTF were in progress.

Construction of diesel generator building & trenches and the building for pickling & passivation of SS components for FRFRP were completed. The construction of radiation glass assembly shop and the false ceiling works were progressing well as per schedule.

Soil investigation and 90 metre bore hole depth studies were completed for PFBR site. Documents required for site evaluation of PFBR were submitted to AERB. Development of special concrete for thermal aging studies was nearing completion. Radiometric studies for development of high density and high temperature concrete were in progress.

Civil works related to BARC facilities such as CWMF, NDDP and WIP located at Kalpakkam and aided institutions such as Mehta Research Institute, Allahabad and Tata Institute of Fundamental Research, Bangalore were also progressing well.

The construction of 112 quarters at Anupuram will soon be completed. As a part of the "Housing and infrastructure development" project of the IX Plan, external electrification, sewer lines, road works etc., progressed well. Twelve nos. out of 102 quarters reached completion and the balance work continued.

A comprehensive software in Visual Basic, for monitoring of all the projects handled by CEG was developed and it was under implementation. Development of a "Contracts management system" was also taken up.

### Engineering Services

All the electrical, air-conditioning & ventilation and communication systems were being operated and maintained. Also, improvements were carried out in the end terminations of 11 kV cables.

Electrical and air-conditioning works made progress for the IX Plan projects activities related to QUEST, Main security building, Vibration & Mechanical Laboratory, Structural Mechanics laboratory etc., which are expected to be completed soon. Procurement of Substation equipment and internal electrification for SGTF were in progress. Specification for A/c works of other facilities were under preparation.

Sodium vapour lamps were introduced in place of Fluorescent lamps for better illuminations and saving in energy consumptions. Communications system was also improved.

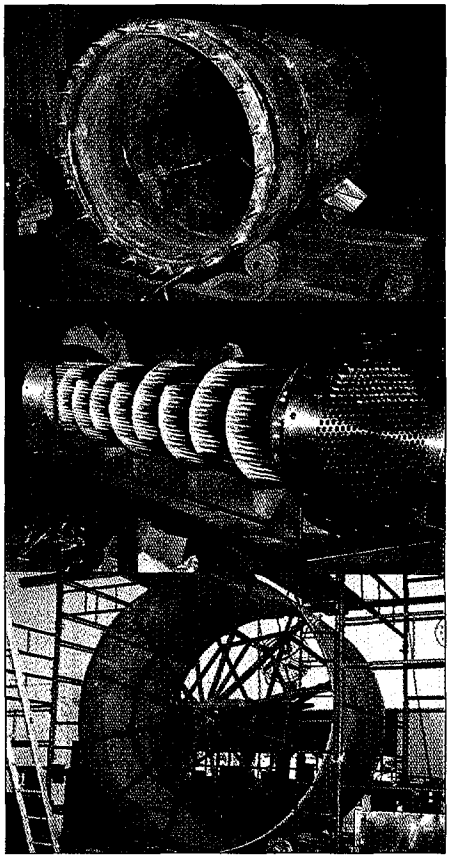
Internal electrification works were in progress in Anupuram. Arrangements were made to establish main and distribution substations for providing power supply.

### Quality Engineering

Quality Assurance, Non-Destructive Testing Services and Quality Audit were provided for various projects related activities such as FRFRP, Technology Development for PFBR, Sodium-Water reaction test rig, Boron Enrichment Plant, manufacture of CRDMs for FBTR etc., for IGCAR and also for other units of DAE such as HWP(M), TAPS, etc.,

Participation was made in the formulation of a draft quality assurance manual and the action plan for obtaining ISO 9000 for PFBR design.

*1. Annular Tank/Tube Rolling of Heat Exchanger Assembly*
*2. An over view of Heat Exchanger*
*3. Sodium Storage Tank : Main body shell welding under progress*



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# CENTRE FOR ADVANCED TECHNOLOGY

## ACCELERATOR PROGRAMME

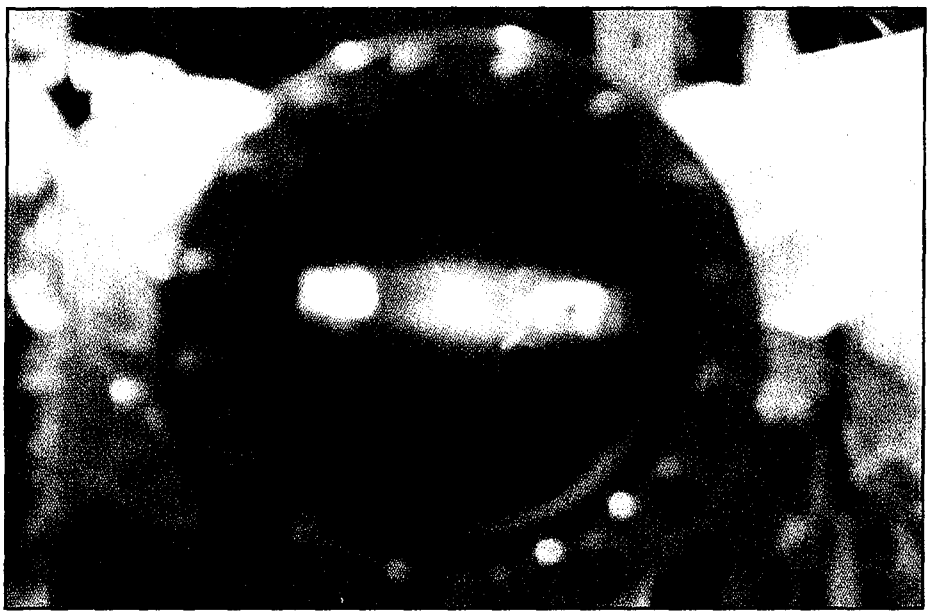
### INDUS-1

INDUS-I, the first Synchrotron Radiation Source (SRS) in India, reached a current of 160 mA on 28 July 1999. This current exceeded the design value of 100 mA by 60%. With the realization of INDUS-I, India has joined the select band of about a dozen countries who have the capability to design and construct such complex accelerators.

INDUS-I consists of three accelerators namely a 20 MeV microtron, a 450 MeV booster synchrotron and 450MeV storage ring. All the three accelerators including their subsystems, have been indigenously designed and developed. The subsystems include ultra high vacuum (UHV) system capable of achieving advanced pressures lower than $10^{-10}$ torr, high power vacuum pumps, microwave sources with components such as high power water load, high power couplers etc., and large electromagnets of various types.

With the 100 mA current stored in INDUS-I, the current reduces to half its value in about one hour. With time, the vacuum inside the chamber of INDUS-I ring will improve and the beam lifetime will increase.

The synchrotron radiation emitted by the electrons circulating in the storage ring is in the form of an intense narrow fan shaped beam. This radiation covers a large spectrum extending from far infrared to vacuum ultraviolet (upto 20 $A^0$). Further, the synchrotron radiation as seen in a fixed direction, is in pulses of 1-2 ns (nanosecond) duration. These properties make Synchrotron Radiation a powerful tool of research in wide-ranging areas of science and technology.

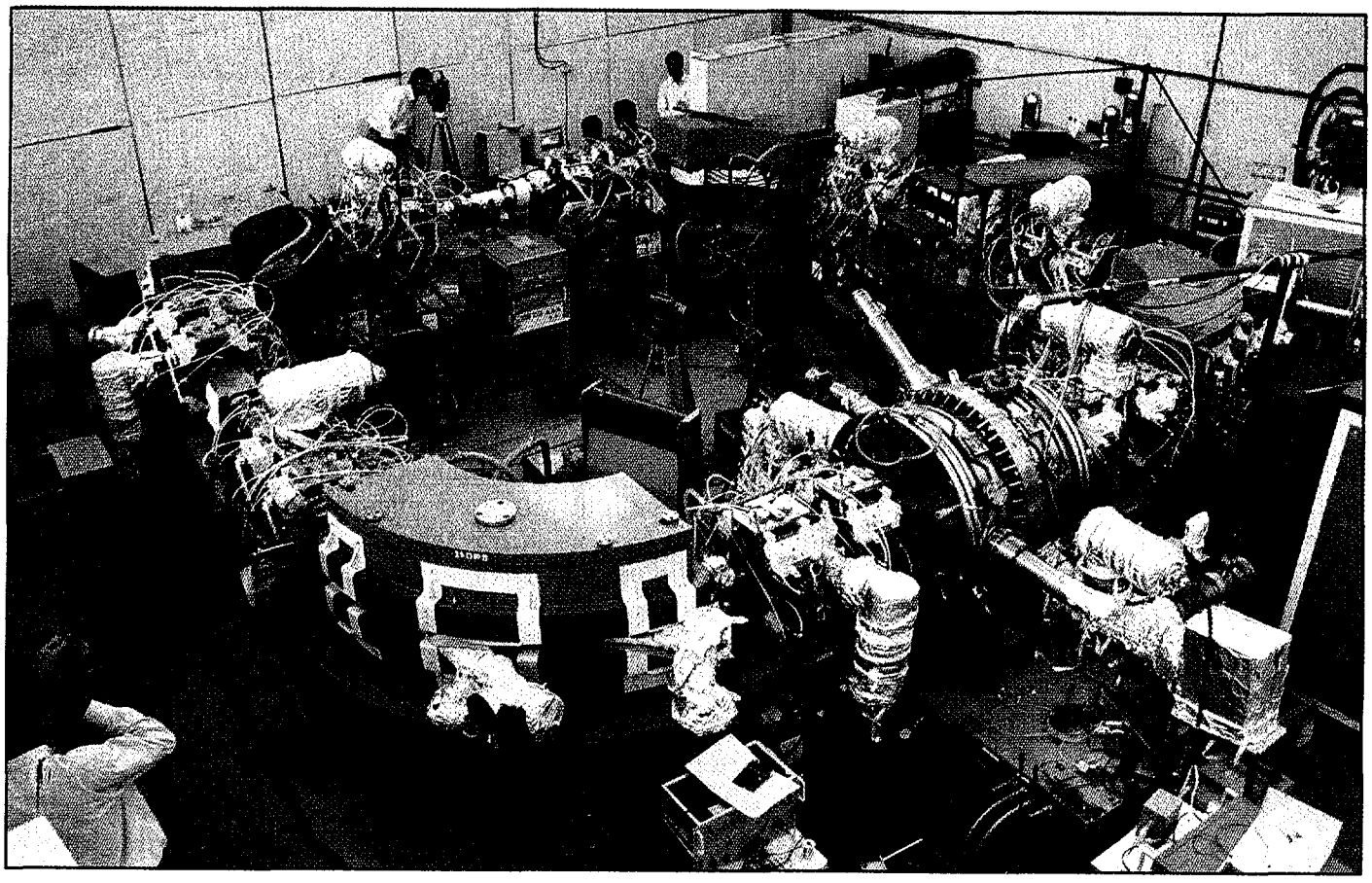


*Synchrotron light monitored at Indus-1 during its commissioning*

Five of the total nine beamlines for various applications of synchrotron radiation, have been designed and constructed by CAT, BARC and Inter-University Consortium for DAE facilities (IUC-DAEF). These beamlines have been designed for high resolution spectroscopy, photoelectron spectroscopy, soft x-ray spectroscopy and photophysics.

The photophysics beam line which covers wavelength range 900-2000 $A^0$, is a low resolution and high flux beam line, and is useful for time resolved spectroscopy, life time studies etc. The high resolution spectroscopy (HRS) requires wavelength range 400-2000 $A^0$ and is useful for HRS of atoms, molecules, auto-ionization etc.

A metrology beam line is designed to calibrate various sources, detectors, spectrometers in the entire VUV and X-ray range (20-2000 $A^0$) of wavelengths. The synchrotron radiation from Indus-1 beam line, in the range 20-50 $A^0$ wavelength can also be used for lithography in integrated circuit (IC) semiconductor industry.



*The 450 MeV INDUS-I - the first Synchrotron Radiation Source (SRS) in India, reached a current of 160 mA on 28 July 1999. This current exceeded the design value of 100 mA by 60%. India has now joined the select band of about a dozen countries who have the capability to design and construct such complex accelerators*

Some of the beamlines are expected to be available for experiments shortly, thus providing Indian scientists access to one of the modern tools of research.

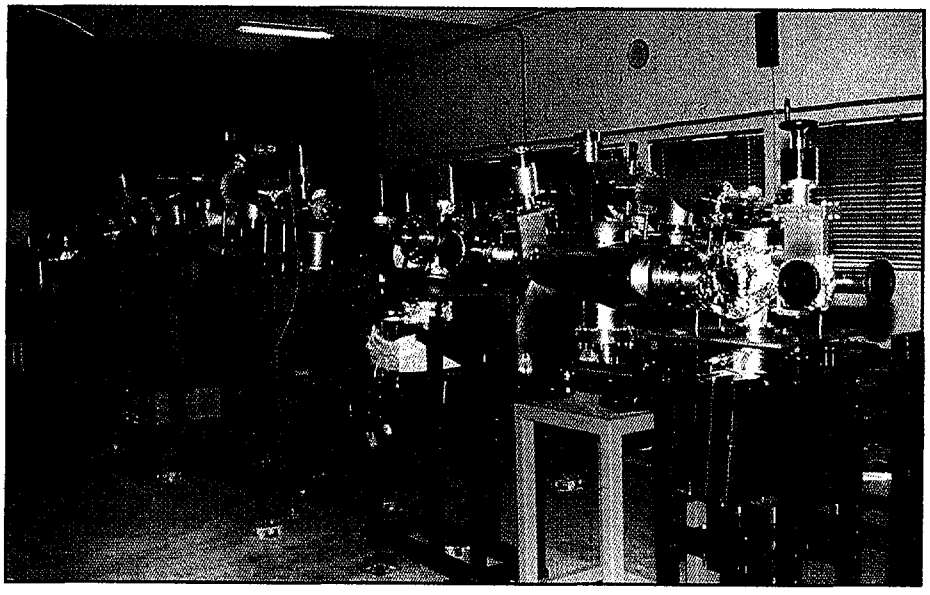
CAT has developed some of the precision components of the synchrotron radiation beamlines. These include mechanical systems capable of moving and rotating laser mirrors in UHV within 10 micron and 5 arc-sec accuracy, and electron beam deposition systems for multilayer mirrors.

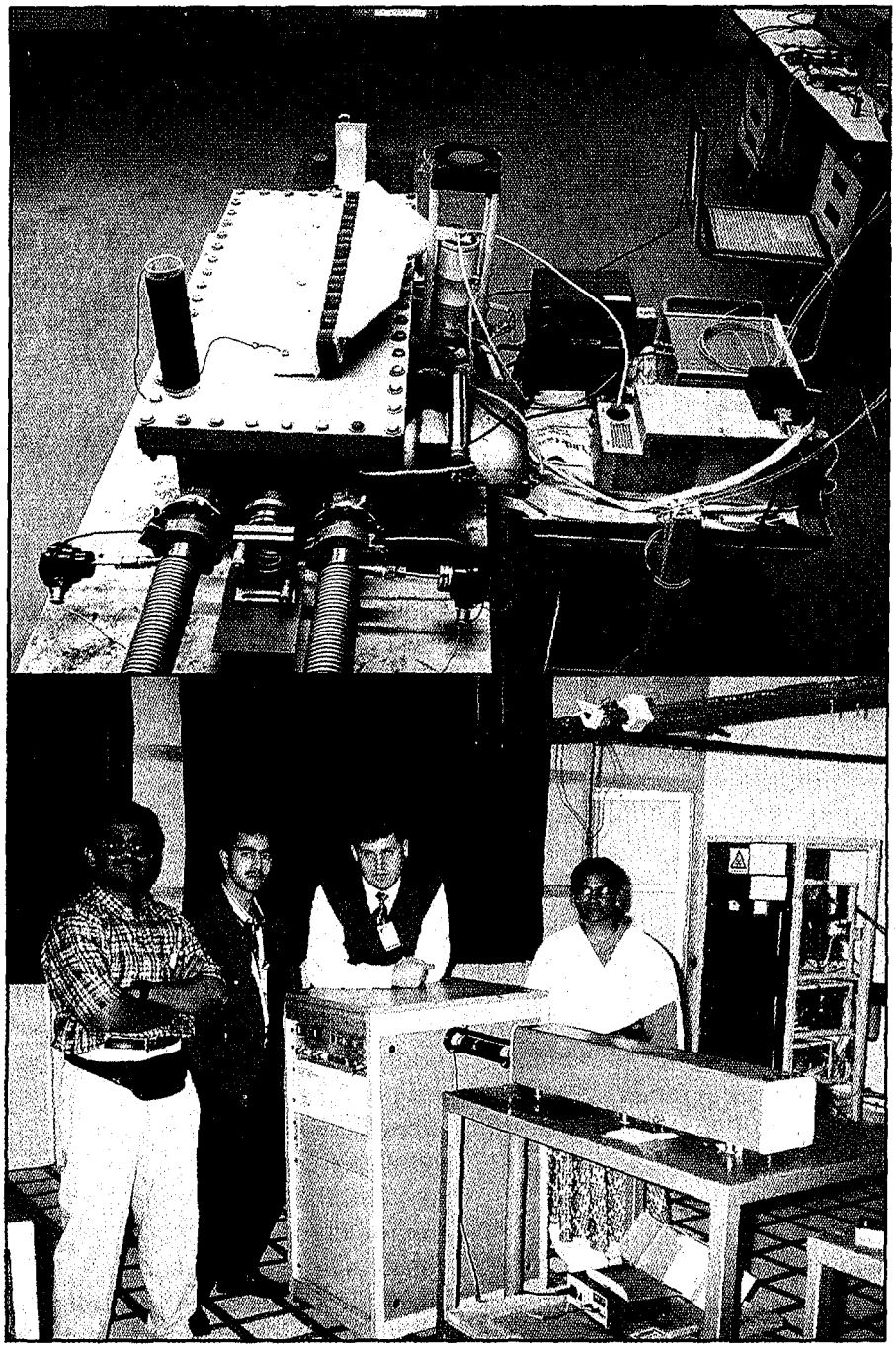
The civil construction with concrete shielding structures for industrial and medical accelerators has also been completed.

## INDUS-2

The electron storage ring of the synchrotron radiation source INDUS-2, with nominal operating electron energy of 2.5 GeV, has been designed to produce highly bright X- rays, with critical wavelength around 0.20 nm which can be reduced to 0.05nm with insertion devices like a 5 Tesla wiggler. Theoretical design for INDUS-2

*Metrology beam line of Indus-1*





*ZeCl excimer laser developed at CAT. The laser can be used for applications such as drilling an array of holes of size 20-100 micron in plastic, pulsed laser deposition of thin films, annealing of semiconductor thin films and generation of grating structures*

*Below : Pulsed Nd: YAG laser with second harmonic generation, installed at Syrian Atomic Energy Commission*

by beam dynamics has been completed.

The design of vacuum chamber of Indus-2 is very complex and critical job, because of the excessive heat produced due to electrical power dissipation in the equipment and devices in the INDUS-2 Tunnel, and also due to large electron/x-ray bombardment on the chamber by synchrotron and bremstrahlung radiation around the ring. Design of this vacuum chamber has been completed and fabrication is started in HAL, Nasik.

The LCW Plant building and the civil construction of shielded circular tunnel where INDUS-2 ring will be housed, has been completed.

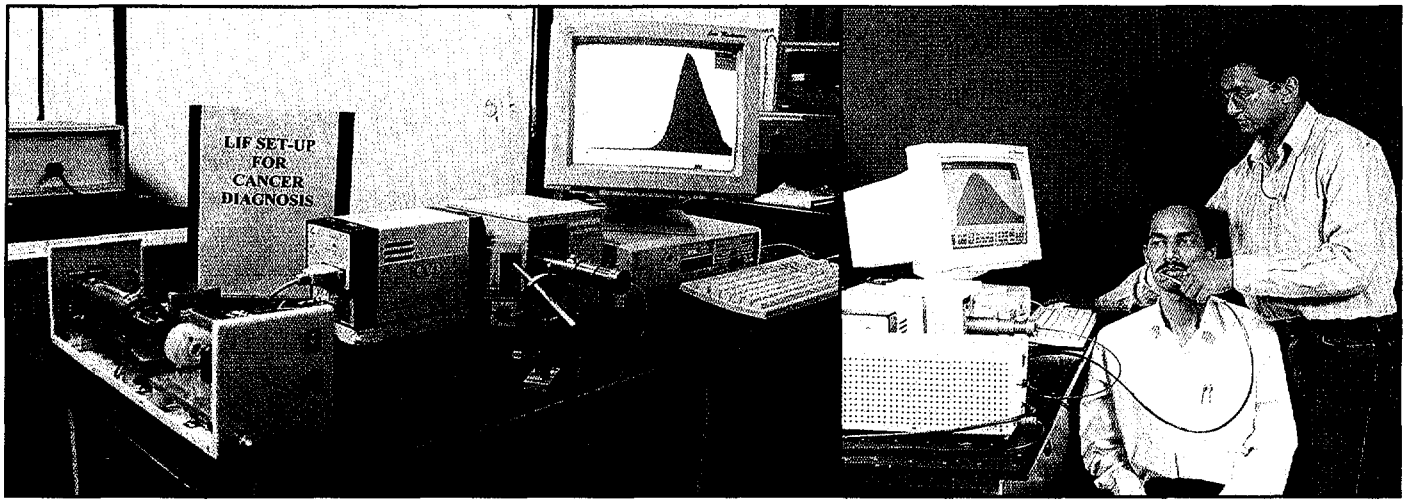
## LASER PROGRAMME

### Nd:phosphate Glass Laser Chain

High power pulsed Nd:glass lasers delivering a peak power of tens to hundreds of gigawatts are widely used for a variety of scientific investigations such as intense x-ray generation, laser-plasma interaction, nonlinear optical frequency conversion etc. A MOPA ( Master Oscillator Power Amplifier) based Nd:phosphate glass laser chain delivering 100 GW. 25 ps (FWHM) laser pulses (wavelength =1.054 micrometre) has been set up for laser-plasma interaction studies.

The laser chain consists of a mode-locked Nd:YLF oscillator, an electro-optic pulse selector, four Nd:phosphate glass amplifiers, three spatial filter-cum-image relay systems, a Faraday isolator, and a Faraday rotator.

A laser energy of 2.5 J is obtained after the last amplifier stage. The pulse duration measured by a non-collinear second harmonic generation based auto-correlator and an optical S-1 streak camera is ~25 ps, giving a peak power of 100 GW. The laser beam divergence is measured to be 175 microrad so that a peak laser intensity of $1.6 \times 10^{15}$ W/cm$^2$ is achieved on the target. The laser chain is being used for laser plasma




*Nitrogen laser being used in diagnosis of cancer of various organs by the study of laser induced fluorescence of tissues*

*A patient undergoing diagnosis of cancer of oral cavity*

interaction studies in high intensity short pulse regime.

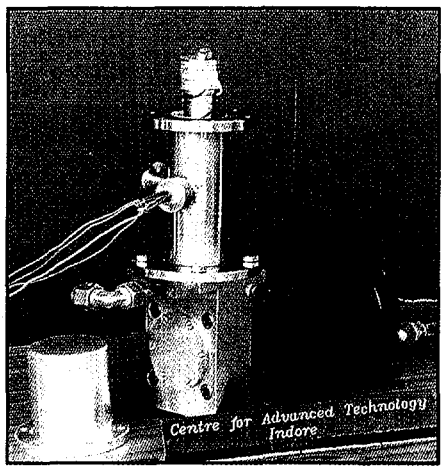
### XeCl Excimer Laser

A XeCl excimer laser has been developed having output energy of 50 mJ, prf 30 Hz, pulse duration 15 ns, beam size 15x8 $mm^2$ and gas life time of $5x10^5$ shots. The laser system consists of the laser head, centrifugal blower and a magnetic drive for the blower. The discharge assembly in the laser head consists of a Ernst profiled ground electrode and a cylindrical high voltage electrode. The high voltage electrode has provision for incorporating preionization pins. Two flow homogenisers at either side of the discharge ensure uniform flow of gas between the electrodes. The gas flow at the outlet of the blower is through a 2-inch diameter circular pipe. However, the flow between the electrodes is in the form of a sheet with a cross-section area of 500x15 $mm^2$. The flow homogenisers accomplishes this flow conversion in a compact fashion with reasonable pressure drop. In the final form, the laser can be used for applications such as drilling an array of holes of size 20-100 micron in plastic, pulsed laser deposition of thin films, annealing of semiconductor thin films and generation of grating structures.

### Biomedical laser applications

Applications of $N_2$ lasers in diagnosis of certain types of cancer, have yielded confirmatory results. Laser induced fluorescence studies of tissues, resected during surgery or biopsy from patients with cancer of oral cavity, breast or uterus, have provided very distinct signatures from those of normal tissues, after involved computer analysis. For clinical use two prototype equipment consisting of a CAT-built $N_2$ laser (7 ns, 100 micro Joule, 10 Hz), an optical fiber probe, and a gateable intensified CCD detector has been built. The diagnostic probe, developed in-house is a flexible fibre bundle, consisting of a single quartz fiber (NA 0.22, core diameter 400 micro metre) surrounded by six similar quartz fibres type. The central fibre carries the nitrogen laser beam and the six fibres surrounding it pick up the fluorescence for recording its spectrum. One of the systems is being used for diagnosis of cancer of oral cavity. Studies carried out on 25 patients have already provided very encouraging results. Other system has been installed at a local cancer scanning centre for diagnosis of cancer of uterus cervix. Studies on resected tissues were continued. A model was also developed to simulate the variation of fluorescence anisotropy as a function of tissue thickness. $N_2$ laser irradiation of red blood cells were observed to result in oxidation of haemoglobin.

*The expander part of a single stage cryocooler developed at CAT. The portion of vacuum jacket has been removed to show the cold tip*




### Pulsed Laser Deposition Facility

A Pulsed Laser Deposition (PLD) facility has been set up at the Cente incorporating Q-switched Nd:YAG laser. Using this setup, thin films of wide band gap semiconductors of ZnSe and ZnO have been grown. Currently there is considerable interest in the development of technology of semiconductor lasers and other photo-

nic devices in UV-Blue spectral range using these semiconductor materials. ZnSe, having a direct band gap of ~2.7 eV emits in blue-green region and ZnO, with direct band gap of ~3.3 eV, in UV region. Nanoparticle layers of semiconductors such as GaSb, InAs and metals like Cu, Fe in $Al_2O_3$ matrices have also been grown. Using CAT's PLD Facility collaborative work is being done with the Inter University Consortium (IUC), Indore; IIT. Madras and IIT, Mumbai on the frontline research in material science.

**Cryogenics**

A three stage closed cycle cryocooler has been developed at CAT. This is based on Gifford McMahon Cycle. This cryocooler is producing a lowest temperature of 6.5 Kelvin. A two stage cryocooler producing a lowest temperature of 10 K and a single stage cryocooler producing a lowest temperature of 30 K, developed earlier, are at present undergoing testing. These have completed more than 2000 hours and 500 hours respectively.

**Nonlinear Optics**

Optical limiting response of several organic materials was studied. These studies included carbon black suspension and single-walled carbon nanotubes. Experiments with 532 nm, 15 nsec duration laser pulses showed that optical limiting in the nanotubes suspension occurs mainly due to nonlinear scattering. The observed host liquid dependence of optical limiting in different host liquids suggested that the scattering originated from microbubbles formed due to absorption-induced heating. Optical limiting performance of carbon black suspension was found to be degraded at high laser repetition rates confirming that the limiting mechanism involves loss of the carbon particles due to vaporization. The degradation was more severe in suspensions with higher viscosity.

Properties of Bose-Einstein condensates were studied theoretically. A simple variational wave function was proposed to describe the ground state and vortex states of a system of weakly interacting Bose gas in an anisotropic trap. The proposed wave function is valid for a wide range of the particle numbers in the trap. It also works well in the case of attractive interaction between the atoms. Further, it provides an easy and fast method to calculate various physical quantities of interest. The results compare very well with those obtained by purely numerical techniques. For the first time, the predicated behaviour of aspect ratio has been verified.

**Development of Laser Materials**

Fabrication of a facility for making ferroelectric oxide films by the alkoxide based sol-gel spin-coating technique, has been completed. The facility consists of essentially two parts : (1) High purity mixed alkoxide precursor synthesis assembly. (2) Inert atmosphere thin film fabrication glove box. The unit can be used for coating ferroelectric film over (upto) 50mm diameter substrates in 0 - 6000 rpm range.

Large crystals of KDP & DKDP upto 40x40x200 $mm^3$ have been grown with indigeneons equipment. Such crystals are then oriented and cut for Electro-optical and harmonic-generation applications. These are supplied within CAT and elsewhere.

A home made facility was established for chemical vapour deposition for developing transparent ceramic plates of strategically important material Zinc sulphide, grown on graphite substrate.

**Lasers/instruments supplied**

A pulsed Nd:YAG laser with second harmonic generation was developed and installed at Syrian Atomic Energy Commission. The beam from this laser has energy 300 mJ, spot diameter 5 mm, divergence 0.85 mrad, pulse width 6 ns, peakpower 50 MW and pulse repetition frequency of 10 Hz. Similar lasers have been supplied to IIT, Madras, IGCAR, Nagpur University etc.

Surgical $CO_2$ laser systems were supplied to a hospital at Guwahati and to AIIMS, New Delhi. A high power 2.5 kW $CO_2$ laser system was delivered to Jadhavpur University for material processing. Laser processing being non-contact method, can cut the hardest material with ease.

One 500 Watt multi-beam $CO_2$ laser system has been supplied to M/s. Hindusthan Laser Ltd., Kodaikanal for sealing thermometer tubes.

A prototype $N_2$ laser induced fluorescence based system for cancer diagnosis is installed at Cancer Screening Centre at Indore.

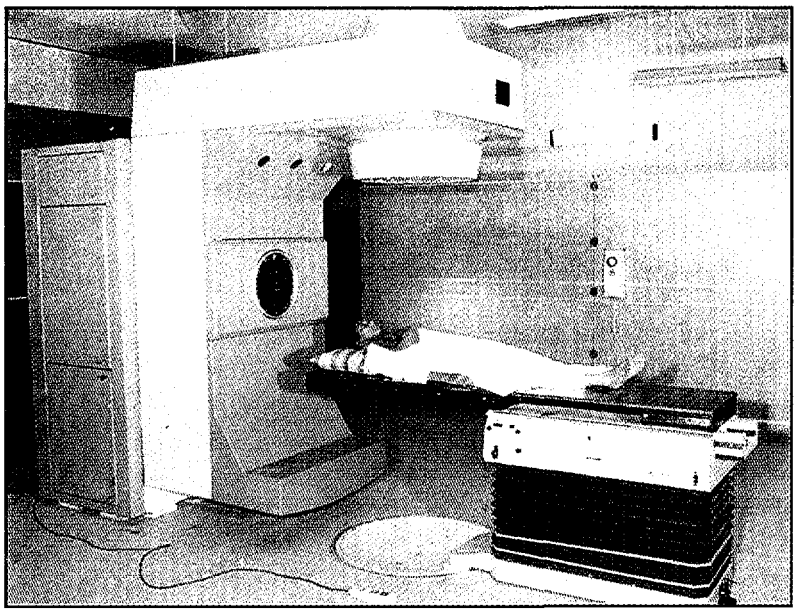
Two laser fluorimeters have been installed at AMD, Tata Nagar and Health Physics Unit, RAPP at Kota, respectively.

# VARIABLE ENERGY CYCLOTRON CENTRE

### Superconducting Cyclotron

The R&D project of constructing a Superconducting Cyclotron made a significant progress. Construction of the cyclotron building was going on as per schedule. Fabrication of the major components of the accelerator continued. The developmental activities for ECR source, beam line and computer based control were also initiated.

Ultrasonic testing of all the forgings for the main magnet frame being fabricated by M/s. HEC, Ranchi was completed, and machining of various parts continued. The superconducting coil winding setup was ready for test. Different components for the RF cavity were under fabrication. Contract for the cryostat was awarded to M/s. Air Liquide, France. Detailed fabrication plan was under process. Pile foundation work for the Superconducting Cyclotron building was completed; Escavation was in full swing, and Tenders for the super structure of Superconducting Cyclotron and for the 30 ton EOT crane were initiated. Development work on highly stabilised prototype power supplies for magnets and trim coils continued. The R&D work for computer control of the power supplies advanced significantly. Material for fabricating the superconducting cable was procured by BARC, and detailed planning for the fabrication continued. Prototype fabrication for RF electronic units also progressed.



*A patient undergoing treatment for cancer using 4MeV LINAC at RRMC, Calcutta*

The Liquid Helium Plant at M/s. Air Liquide, France was fabricated, inspected and delivered at VECC . Purchase order for fabricating the magnetic field mapping jig was placed.

The first design of the 14.5 GHz ECR source was finalised and procurement of crucial components advanced. Design and construction of the complex cryogenic distribution system was taken up. Complete technology for designing and constructing cryogenic transfer lines was developed indigenously. Detailed design of the entire system was completed. Sections of unshielded cryogenic transfer lines were fabricated and development of a prototype shielded cryogenic transfer line section reached an advanced stage of completion.

### Heavy Ion Acceleration

The work for the upgradation of the present cyclotron with ECR heavy ion source developed in-house, was almost complete. The Heavy Ion Acceleration programme at VECC resulted in the first heavy ion beams beyond 6 MeV/nucleon, in the country. First beams of 115 MeV Oxygen and 150 MeV Neon were extracted with currents over 50 nA. Even 200 MeV Oxygen was accelerated . In the next stage it is planned to increase the mass and energy range. The Vacuum level in the cyclotron was improved significantly for efficient acceleration of heavy ions from the ECR source. The cryopanel was designed , fabricated and installed in the 'dee' chamber. Using this device , the pressure was reduced to $1.1 \times 10^{-6}$ torr. A new versatile multiply-charged heavy ion source was being

procured and likely to be commissioned during 2000.

**Radioactive Ion Beam Project**

A Radioactive Ion Beam (RIB) facility is being built at the Centre in collaboration with Saha Institute of Nuclear Physics (SINP), Calcutta and with RIKEN, Japan. Considering the highly technological requirements of the project particularly in the areas of mechanical and radio-frequency engineering, VECC entered into collaborative ventures with SAMEER and CMERI.

Most of the systems / subsystems were either in the fabrication stage or ready for the start of assembly. The R&D activities on some of the systems were underway and the final design requirements would be frozen shortly. The procurement actions for most of the major equipment to be imported were initiated. The fabrication of the two-ion-source assembly, including the surface-ioniser, einzel lenses, decelerators etc., was completed and taken to RIKEN, Japan for testing. Improvements on the design were in progress. The coil-winding for the ECR-solenoids were over and coil-winding for quadrupoles for beam-lines were nearing completion. Final drawings for the ECR plasma chamber and the RFQ cold model were given to CMERI for fabrication. Order for the procurement of a high power RF transmitter for RFQ was placed and the development of low-power part of the RF transmitter was progressing in collaboration with SAMEER.

**Recovery and Analysis of Helium from Hot Springs**

At certain locations around Bakreswar, investigations conducted revealed an out-flux of large scale helium. A similar feature was observed in many areas adjacent to Dumka District in Bihar.

For experimental purpose, a portable helium extraction system was fabricated and installed at the site. Helium was extracted from air to a purity of >99%. A larger heat exchanger, built to enhance scale of separation, was undergoing laboratory tests.

**Computer and Information Technology**

Compus-wide networking was completed and Firewall software was installed to ensure network security. A personnel database was also implemented which was used to fabricate the medical cards ( CHSS ) for all the DAE employees in Calcutta. An exercise was carried out for Y2K readiness / compliance of computers and computer-based systems. Research continued in the fields of fuzzy database, neural network application and image processing. Work progressed for the development of fuzzy based control and the data acquisition system for heavy ion experiment.

**Heavy Ion Experimental Facilities**

For the use of heavy ion beams from the upgraded VEC machine, building of the two facilities for high energy gamma ray spectrometry, and the compact CsI(Tl)-PIN photodiode based charge particle multiplicity filter array were taken up during IXth plan. Tests of prototype detector elements were successfully completed and the basic design parameters of the array were frozen. The procurement of the CsI(Tl) crystals, compatible photodiodes, HAMAMATSU Model S1709 and hybrid preamplifier chips were completed and R&D activities commenced.

The other detector system, proposed to be set up, would be an array of $BaF_2$ detectors.

**Theoretical Physics Research**

The dynamics of fission was formulated and the precession neutron multiplicities and mean kinetic energies of the evaporated neutrons were calculated and compared with the respective experimental data over a wide range of excitation energy and compound nuclear mass.

The low-lying excitation spectra of $^{11}$Be and $^{19}$O were calculated on the basis of particle-vibration coupling model. Experimentally observed parity inversion of the ground state and first excited state of $^{11}$Be was reproduced.

Langevin equation was employed to describe nuclear fission dynamics at high excitation energies.

Stochastic resonance was explained as a maximum synchronization between deterministic periodic signal and noise. A formula for 'First Passage Time Density Function' at resonance for simple dissipative transport process was derived in terms of two universal functions.

In a second order chiral phase transition, the chiral condensate can become temporarily disoriented developing domain like structure. The effect of dissipation and noise on the domain formation was studied.

The collision of heavy ions at relativistic energies is expected to form of quark- gluon- plasma. Various signatures of this phase-transition were studied.

In a study related to the evolution of early universe it was shown that quark-nuggets rich in strange matter might have survived till now and contributed to dark matter. The formation and evolution of disoriented chiral condensates in such collisions was studied.

Propagation of heavy quarks in equilibrating quark gluon plasma was probed. The chemical equilibration of expanding quark - gluon - plasma was studied and reliable predictions made for electromagnetic radiations at RHIC and LHC energies.

A parton cascade / cluster hadronization model was developed

which attempts to describe nucleus-nucleus collision at relativistic energies.

A first ever estimate of the colour Debye screening was obtained using this model.

The radiation of single photons from relativistic heavy ion collisions was investigated.

### Experimental Nuclear Physics

Nuclear spectroscopy of near-spherical Pm-nuclei in the mass-140 region:

The high spin states of odd-odd $^{142}$Pm and odd-A $^{143}$Pm were investigated by in-beam gamma spectroscopy. An experiment was performed at the BARC-TIFR Pelletron and the proposed high spin level structure for 143Pm was tested by a modest shell model calculation using OXBASH code.

Decay mechanism of light hot composite nuclei produced by heavy ion collision:

Detailed measurements of light charged particle spectra ( for both proton and alpha particles) were undertaken and analysis progressed.

### Material Science Research

Research and Development activities on High Temperature Cuprate Superconductors based on YBaCuO and Bi-Sr-Ca-Cu-O systems were pursued. Using the Variable Energy Cyclotron, irradiation induced enhancement of critical temperature Tc and Critical Current density as a function of irradiation dose were thoroughly studied.

Studies were undertaken with the motivation of evaluation of radiation damage of nuclear structural materials like Zirconium and its alloys, and Stainless Steel (AISI 316 SS).

### Search for Quark - Gluon - Plasma

(a) SPS experiments

The data of the WA98 experiment, conducted earlier at the CERN SPS accelerator was analysed.

(b) ALICE experiment at the Large Hardon Colliders

The Indian team proposed to contribute a totally indigenous Photon Multiplying Detector ( PMD ) to the ALICE experiment at the LHC. The PMD will be a special type of gas detector based on honeycomb proportional chambers. The R & D for this design was almost completed and a Technical Design Report for the PMD was submitted to the LHC Experiments Committee at CERN.

### Regional Radiation Medicine Centre (RRMC)

The 4 MeV Medical LINAC performed satisfactorily and more than 7000 patient-exposures were taken during the year 1999. Apart from therapy work, scanning facility of various organs to more than 1000 patients, and radioimmuno assay (T3, T4, TSH) facility to more than 5000 patients were provided. A proposal was made to set up Radio iodine therapy for thyroid cancer at RRMC, Thakurpukur.

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*continued from page 2.36*

A Quality Engineering Services and Testing Facility was being augmented with equipment for inspection, destructive & Non-destructive testing services to cater to the requirements of R & D and other engineering projects related to PFBR.

### Management Services

The Purchase Management System was implemented under ORACLE environment at Madras Regional Purchase Unit (MRPU), upto release of Puchase Orders. A sophisticated Budget management system for all the Capital Projects of IGCAR was implemented for the preparation of Revised & Budget Estimates. A system for classification of expenditure for the Capital and Revenue budget of IGCAR was developed and implemented as feed back information and also as a MIS.

The complete indents database at MRPU was replicated at IGCAR and updated daily and feed back information was made available to the users at Kalpakkam.

LANs for the Purchase Unit and Management Services, IGCAR were being established.

All the systems developed and implemented at MPRU and IGCAR for Purchase and Project Monitoring were made Y2K compliant.

### Central Workshop

The major works carried out by the Central Workshop during the year were :

- Machining, fabrication and assembly of Lower part assembly of the Control Rod Drive Mechanism for FBTR; Failed Fuel Identification Module for PFBR; Annular tanks for fuel reprocessing; Heat exchanger for sodium loop ; a large size Sodium storage tank for Steam Generator Test Facility , and PFBR main vessel for core disruptive accident analysis and others.

-Development of dissimilar metal joining between copper and stainless steel plate for electromagnetic pump duct in collaboration with DRDL, Hyderabad.

- Repair welding of cracked turbine blade and shroud for MAPS and NAPS.

# ATOMIC MINERALS DIRECTORATE FOR EXPLORATION AND RESEARCH

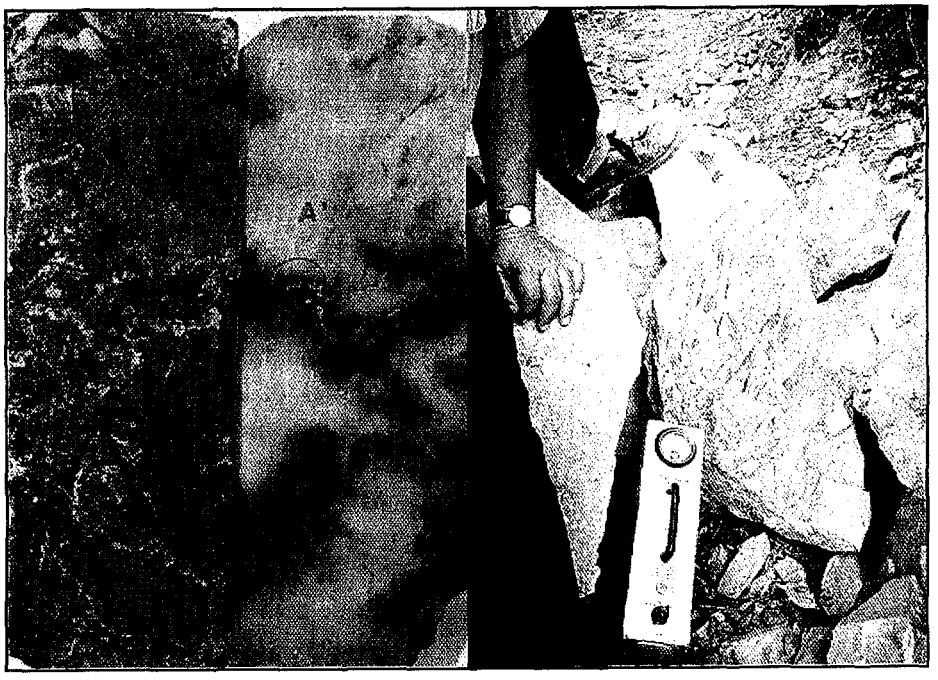
The Atomic Minerals Directorate for Exploration and Research (AMD) of the DAE carries out surveys, prospecting and exploration of atomic minerals required for the Nuclear Power Programme of the country. The R&D oriented activities of the Directorate include assessment, evaluation, characterisation, and categorisation of atomic minerals, design and fabrication of radiometric instruments and development of ore extraction flow sheets. Brief account of activities and achievements during 1999-2000 are given below:

## Uranium Investigations

### *Surveys*

The Airborne Gamma-Ray Spectrometric (AGRS) and aeromagnetic surveys were carried out over about 24,000 line kilometres, in parts of Bhima basin, Karnataka and Vindhyan basin, Uttar Pradesh and Bihar. These surveys corroborated the earlier located anomalies. However, magnetic surveys integrated with remote sensing data helped in delineating favourable areas and narrowing down target areas for further exploration.

Satellite data interpretation, digital image processing, photogeological studies, data integration and critical studies on various potential areas were also carried out.



*Split core from a bore hole of Gogi, Gulbarga District, Karnataka along with chromogram test. The brown patches on the chromogram paper are due to the presence of uranium minerals.*

*(Right): Uranium mineralisation associated with sandstone of Solan District of Himachal Pradesh*

Radiometric reconnaissance and detailed surveys were carried out in various geologically and structurally favourable areas over 12,800 sq km and 275 sq km respectively. These surveys resulted in locating / delineating new uranium anomalies and extensions of known anomalies in Andhra Pradesh, Meghalaya, Himachal Pradesh, Uttar Pradesh and Orissa.

Geophysical surveys comprising magnetic, electrical (IP and SP) and electro magnetic (TURAM) methods were carried out in selected areas of Madhya Pradesh, Rajasthan, Bihar, Andhra Pradesh and Karnataka. These surveys have helped in narrowing down target areas.

IP/Resistivity surveys deciphered concealed sediment basement contact at Gogi, Gulbarga district, Karnataka where exploratory drilling was in progress. A borehole drilled based on geophysical anomaly intercepted good grade mineralisation.

Gravity and magnetic surveys resulted in delineating gravity and magnetic anomalies and NNE-SSW and N-S lineaments around Julakallu - Venkatapuram in Palvadu sub-basin, Guntur district, Andhra Pradesh.

IP/Resistivity surveys resulted in delineating high chargeabiltiy zone coinciding with known sulphide and uranium mineralisation, and EM (TURAM) survey deciphered fracture zones at Chhota-Udaipur, Ajmer district, Rajasthan.

Geochemical surveys (water, soil and stream sediments) were carried out over 7000 sq km in different parts of the country. These have helped in narrowing down the target areas in parts of Cuddapah, Kurnool, Nellur and Chittoor districts of Andhra Pradesh. Anomalous haloes were delineated around Bodevandlapalle in Cuddapah district and Gajulapalle in Kurnool district.

*Exploratory Drilling*

Exploratory drilling aggregating to 28,000 metre has been carried out to probe / delineate the subsurface continuity of uranium mineralisation in different promising sectors. Continuity of ore grade uranium mineralisation (>0.10%) was established over considerable strike length (>500 m) at Gogi, Gulbarga district, Karnataka and Koppunuru, Guntur district, Andhra Pradesh. Uranium mineralisation with grade less than 0.10% $U_3O_8$, was also intercepted at Ghateshwar, Sikar district, Rajasthan; Peddagattu, Nalgonda district, Andhra Pradesh; Wahkyn, West Khasi Hills district, Meghalaya; Naktu and Kudri, Sonbhadra district, Uttar Pradesh and Surda, Singhbhum district, Bihar.

Additional uranium reserves of $U_3O_8$ were estimated at Wahkyn, Meghalaya under inferred category.

As a result of infilling core drilling in different blocks of Peddagattu area of Nalgonda district, Andhra Pradesh, part of the earlier estimated inferred category reserves was converted to indicated category.

**Rare Metal and Rare Earth Investigations**

Riverine placers, containing significant concentration of xenotime (ore mineral of Heavy Rare Earth Elements), were delineated in parts of Sonbhadra district, Uttar Pradesh and Gumla district, Bihar.

Detailed evaluation of known pegmatites was carried out and additional reserves of 7.60 tonnes of columbite were estimated. Additional reserves of 220 tonnes of xenotime bearing polymineralic concentrate were estimated from riverine placers of Gumla district, Bihar.

Upgradation of xenotime bearing pre-concentrate produced from Siri River, Raigarh district, Madhya Pradesh using improved flowsheet has resulted in recovery of xenotime concentrate analysing over 22 % yttrium oxide. Four recovery units located in Bihar, Madhya Pradesh and Orissa produced 41.80 tonnes of xenotime bearing concentrate, 3.37 tonnes of columbite- tantalite and 3.40 tonnes of Beryl.

**Beach Sand and Off-shore Investigations**

Assessment and evaluation of heavy mineral deposits along coastal tracts in Andhra Pradesh, Tamil Nadu and Kerala was continued.

A new heavy mineral potential zone with 25-30% Total Heavy Mineral (THM) content was located along coastal stretch of Nizamapatnam-Adavuladevi in Krishna and Guntur districts, Andhra Pradesh. Another zone was delineated in hinterland, of Thotapalli-Ambalapuzha area, Allapuzha district, Kerala.

Reports /executive summaries on different heavy mineral deposits were prepared and supplied to IREL and private agencies.

Export consignments of over 1,27,500 metric tonnes of garnet sands pertaining to private agencies, over 1,08,600 metric tonnes of ilmenite and 875 tonnes of sillimanite pertaining to IREL were sampled for issuance of monazite test certificate.

**Laboratory Investigations**

Laboratories under Physics, Chemistry, Mineralogy-Petrology-Geochemistry and Mineral Technology Groups, equipped with state of the art instruments, provided analytical support for the field investigations. Activities included :

- Analytical and instrumental support e.g. radiometric assay of surface and borehole core samples (28900 Nos.), gamma-ray logging of boreholes (36700 m), radiometric checking by shielded probe (1600 m), radon emanometry and repairs / calibration of field instruments. Mass spectrometric analysis of over 260 samples and sulphur isotope studies of about 40 samples were carried out.

- Low altitude data was acquired by indigenously fabricated notebook PC based AGRS system over Bhima and Vindhyan basins. Six portable gamma ray spectrometers were also fabricated.

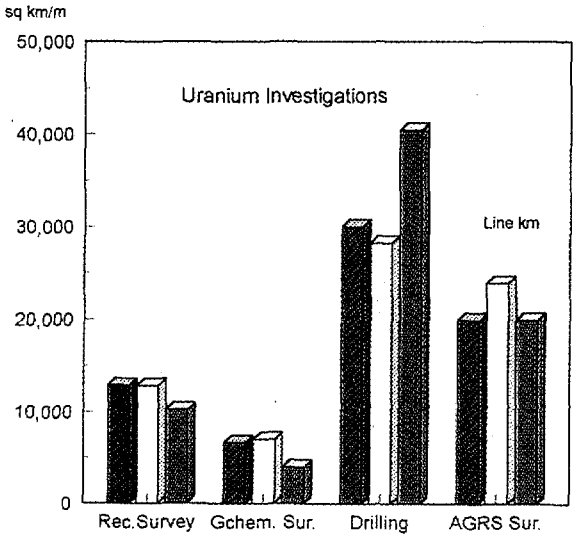
- Analysis of 11600 samples of water, soil, stream sediments, rock, mineral, ore and beneficiation products involving about 72,000 determinations. Analytical support was also extended to IREL, GSI and other organisations. Research and development were continued for refinement of analytical techniques.

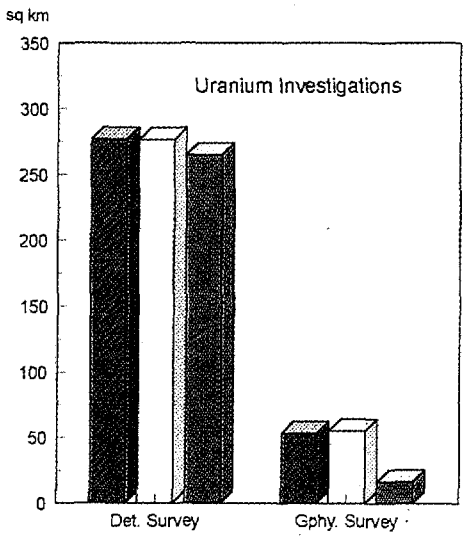
- A total of 2900 mineral analyses (45200 elemental determinations) were carried out by the Electron Microprobe laboratory. Samples studied include ore minerals of U, Th, rare metals and rare earths; and thorium oxide pellets of NFC.

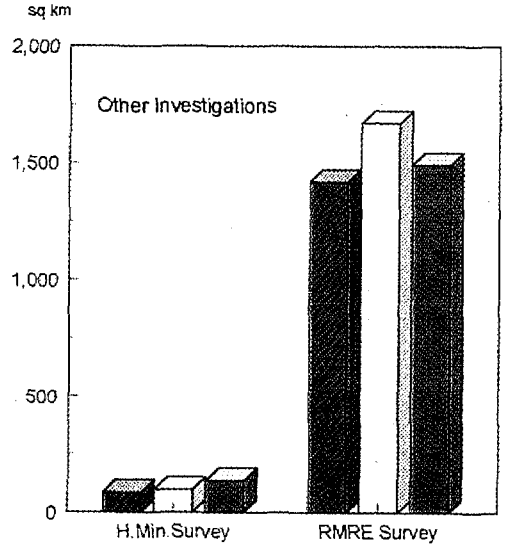
- A total of 332 samples were studied for identification of different uranium, rare metal and rare earth bearing minerals and measurement of unit cell parameters of a few of them. Samples from the CCCM, BARC, IREL, and ODS and that of BHEL were also investigated.

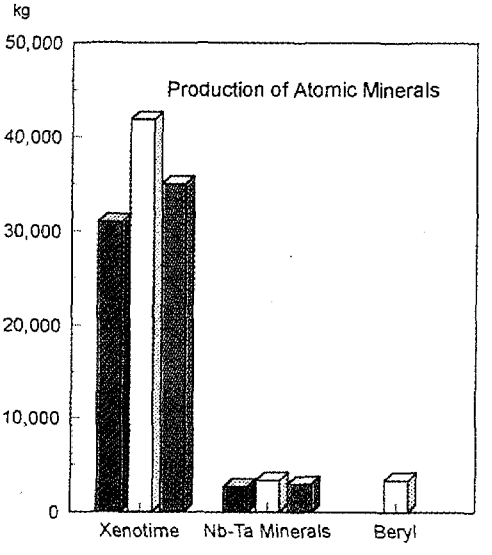
Petromineralogical studies on about

## PRINCIPAL ACTIVITIES OF AMD
## (TARGETS AND ACHIEVEMENTS)

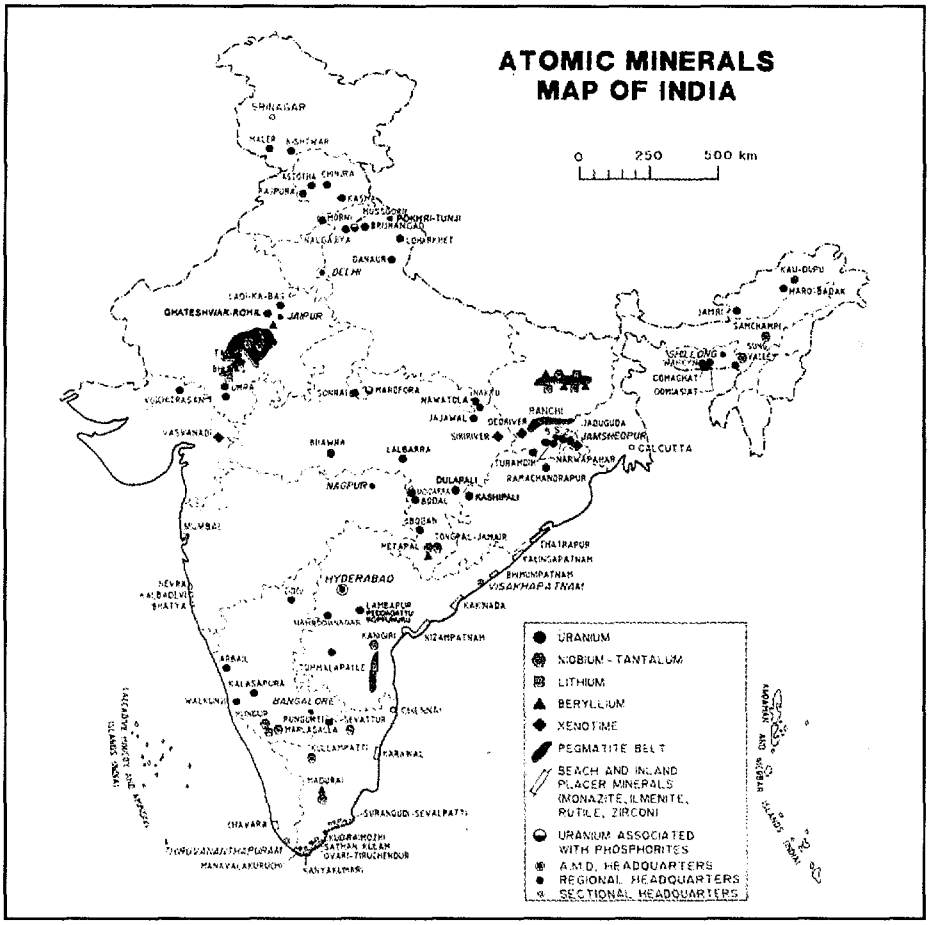



TARGETS 1999-2000 ACHIEVEMENTS 1999-2000 TARGETS2000-2001




2250 rock samples from various deposits / occurrences of atomic minerals, were carried out in the petrology laboratories. Petrological studies related to geotechnical studies were also carried out.

- A total of 3030 samples involving 51,270 determinations were analysed for quantitative measurements of different elements in the X-ray Fluorescence laboratories, whereas 2590 samples and standards involving 75,900 determinations were studied in the spectrograph laboratories.

-Hydrometallurgical characterisations of host rocks from different uranium deposits / occurrences and development of flow sheets for the recovery of rare metals were continued by Mineral Technology laboratory.

**Other Activities**

***Geotechnical Investigations***

Geological mapping of the pits of the reactor building (RB-3 & RB-4) of Tarapur Atomic Power Project (TAPP) was carried out and reports submitted to Nuclear Power Corporation of India Limited (NPCIL).

Reports on (a) Satellite Image interpretation and seismotectonic studies around Kalpakkam and (b) lithomorpho-tectonic evolution of Sankara-Sanawara Region of Jaisalmer district, Rajasthan were prepared and submitted.

***Mining Plan Approval***

Scrutiny of mining plans in respect of atomic minerals was continued as per the provisions of Mines and Minerals (Regulations and Development) Act, 1957. Two mining plans, one each in respect of Orissa Sand Complex (OSCOM) and Chavara extension block, IREL, were approved after scrutiny.

***Resource Generation***

Revenue amounting over Rs.73 lakh was earned by providing technical and professional services to various organisations and sale of columbite-tantalite to NFC. 22% of the earnings was from Non-DAE units like HZL, TATA, etc. and exporters of mineral sands.

**Research and Development**

Following R&D activities were carried out :

- Determination of Au, Pd, Pt and Rh in rocks, ores, concentrate and sulfide-float samples by ICP-AES/FAAS after reductive co-precipitation using Se - as collector.

- Estimation of trace impurities in reactor grade uranium using ICP-AES.

- Determination of W in Nb, Ta, V and Mo bearing geological samples using derivative spectrophotometry and ICCP-AES..

- Solvent extraction of Ga, In and Ti in geological materials.

- Sorption of PAR - metal complexes on activated carbon, as a rapid preconcentration method for the determination of Ce, Co, Cu, Ni, Pb and V in ground water.

- Determination of REE and Y in rocks by ICP-AES after solvent extraction separation.

- Rapid laser fluorimetric method for the determination of uranium in soil, ultrabasic rock, plant ash, fly-ash and red-mud samples.

- Spectrophotometric determination of submicrogram amount of in the anionic micellar medium of sodium dodecylsulphate.

# NUCLEAR POWER CORPORATION OF INDIA LTD.

## NUCLEAR POWER PLANTS IN OPERATION

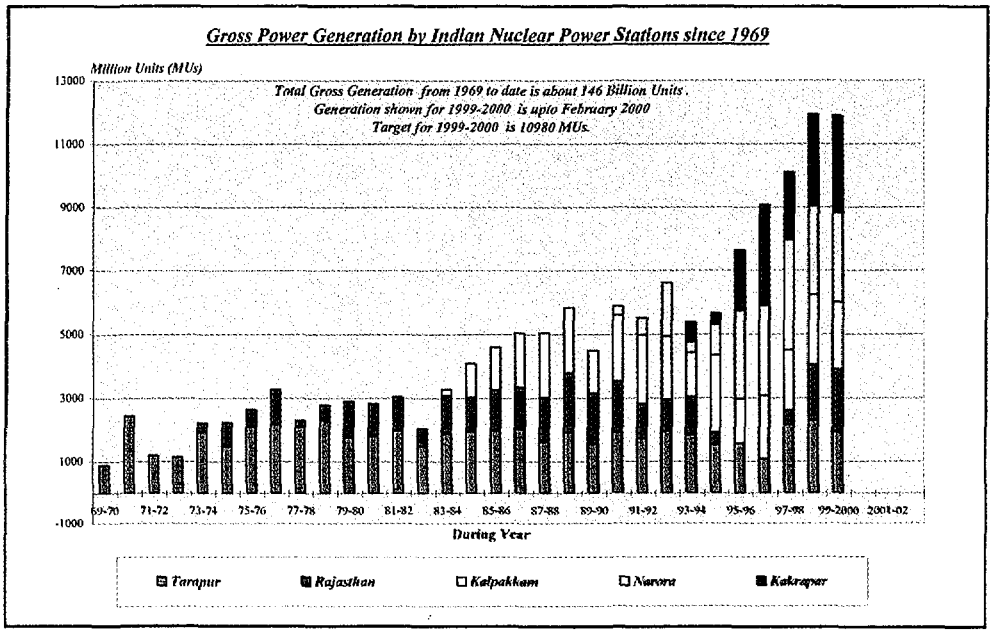
### Power Generation

There are a total of ten nuclear power reactor units under commercial operation with a total installed capacity of 1840 MWe. One 220 MWe reactor unit at Kaiga (Kaiga-2) has been synchronised to the grid on December 2, 1999. The unit would be declared commercial this year. Another unit of 220 MWe capacity at Rajasthan (RAPP-3) has also achieved criticality on December 24, 1999 and would be synchronised to the grid in the near future.

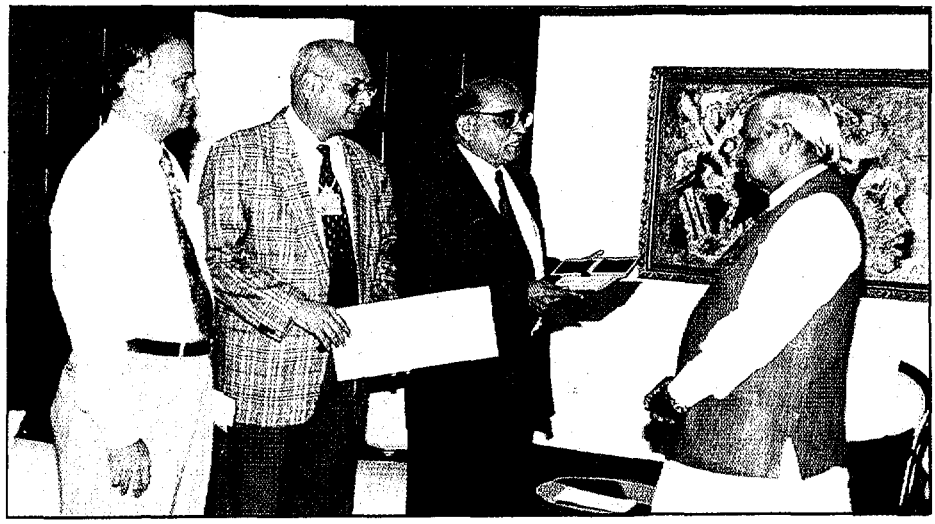
NPCIL has generated 1,32,264 MUs since commencement of commercial operation of its units till end of December 1999. RAPS-1, which is owned by the Department, has generated 10,275 MUs upto December 1999 since its commercial operation. The gross power generation by the Indian Nuclear Power Stations since 1969, is shown in the graph.

The company has improved its operating performance from an overall capacity factor of 47% in 1994-95 to 75% in 1998-99 (excluding RAPS-1).

The gross generation during the calendar year 1999 was 12,045 MUs. This excludes generation from RAPS-1, which was 964 MUs. The company achieved a capacity factor of 78%, registering a gross generation of 9,024 MUs for the period from 1.4.1999 to 31.12.1999 in the financial year 1999-2000. RAPS-1 generated 679 MUs during this period.




*Gross Power Generation by the Indian Nuclear Power Stations since 1969*



*Dr. Y.S.R Prasad, Chairman-cum-Managing Director, NPCIL, presented a maiden dividend cheque of Rs 50.44 crore to the Prime Minister at New Delhi, in a small function, in the presence of Dr R Chidambaram, Chairman, AEC, and Shri R M. Premkumar, Additional Secretary, DAE.*

Table: Unitwise Power Generation Performance is shown in the Table follows

| Reactor | Generation in (MUs) Calendar Year 1999 | Generation in (MUs) Financial Year 1999-2000 upto 31.12.99 | Capacity Factor (%) | Availability Factor (%) |
|---|---|---|---|---|
| | | | (1999-2000 upto 31.12.99) | |
| TAPS-1 | 944 | 600 | 57 | 64 |
| TAPS-2 | 1219 | 867 | 82 | 84 |
| **Total** | **2163** | **1467** | **69** | |
| RAPS-1 | 964 | 679 | 69 * | 70 |
| RAPS-2 | 1361 | 970 | 74 | 78 |
| **Total** | **2325** | **1649** | **71** | |
| MAPS-1 | 1356 | 1036 | 92 | 94 |
| MAPS-2 | 994 | 817 | 73 | 72 |
| **Total** | **2350** | **1853** | **83** | |
| NAPS-1 | 1271 | 1152 | 79 | 92 |
| NAPS-2 | 1580 | 1122 | 77 | 82 |
| **Total** | **2851** | **2273** | **78** | |
| KAPS-1 | 1592 | 1171 | 81 | 83 |
| KAPS-2 | 1703 | 1264 | 87 | 90 |
| **Total** | **3295** | **2435** | **84** | |
| Kaiga-2 $ | 25 | 25 | - | - |

* The capacity factor has been worked out based on the present power level of 150 MWe as authorised by AERB.
$ Infirm power (Kaiga-2 was synchronised to the grid first time on December 2, 1999).

**Tarapur Atomic Power Station**
(2x160 MWe BWRs)

The cumulative gross generation of the station, since it commenced commercial operation till the end of December 1999, was 54,748 MUs.

TAPS-1 achieved a continuous operation of 269 days from 20.7.1998 to 14.4.1999, which is the longest continuous operation period so far. Unit-1 achieved 100% Availability Factor and Capacity Factor exceeding 95% during six months of the calendar year 1999.

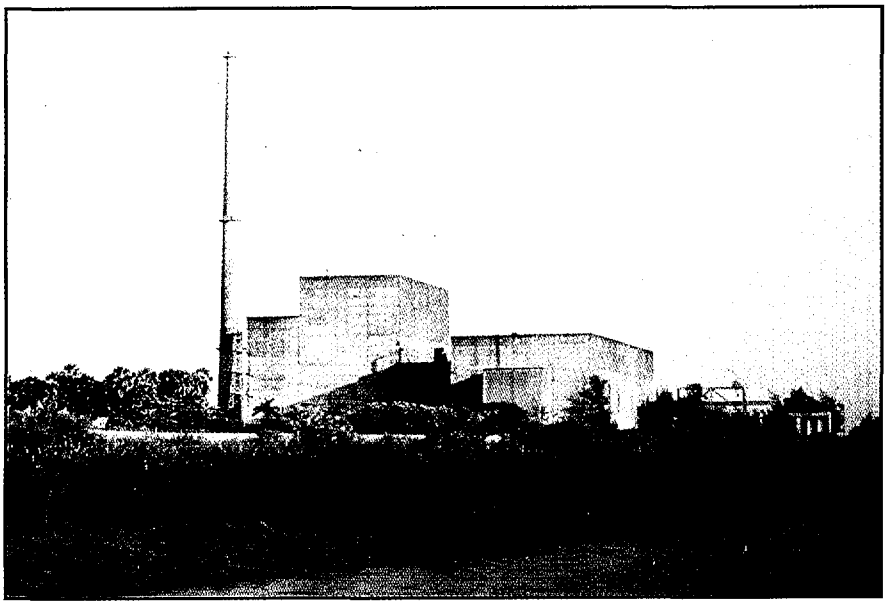
The unit accomplished its refuelling outage in a record time of 61 days, during which major jobs like regulatory inspection of reactor core shroud, enhanced in-service inspection of primary coolant system, Reactor Recirculation pump major overhaul and Drained reactor vessel works etc., along with other routine maintenance jobs, were undertaken.

TAPS-2 achieved 100% availability factor and capacity factor exceeding 95% during eight months of the calendar year 1999. The unit was under shutdown for about 30 days for repair on the Reactor Recirculation pump.

**Rajasthan Atomic Power Station**
(100MWe and 200 MWe PHWRs)

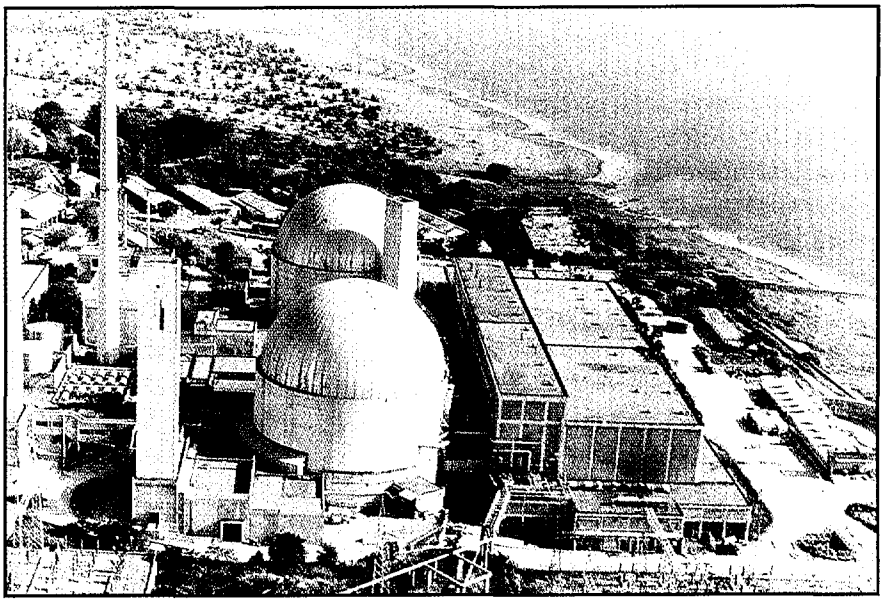
The cumulative gross generation of the station since it commenced commercial operations till the end of December 1999 was 27,235 MUs. The station generated 2325 MUs during the calendar year 1999 and 1649 MUs during the period 1.4.99 to 31.12.99 in the financial year 1999-2000.

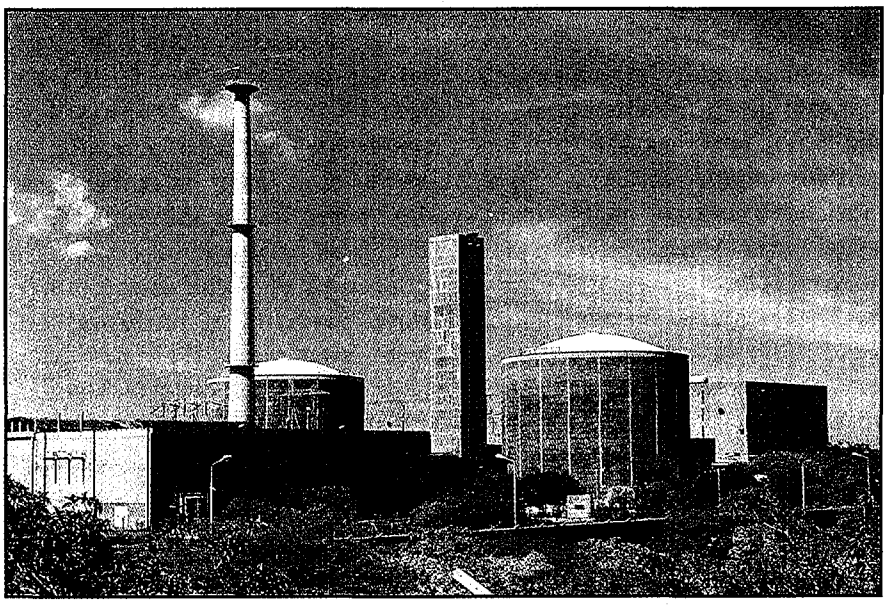
RAPS-1 availed a shut down for about one month for replacement of leaky gland cooler and another planned shut down for about 13 days for inspection of main generator and



*Tarapur Atomic Power Station-1&2*

*Rajasthan Atomic Power Station-1&2*





*Madras Atomic Power Station-1&2*

plugging of leaky tubes of condenser. The unit is operating at its maximum permitted power level of 150 MWe.

The Regulatory Board permitted RAPS-2 to operate the unit at 100% full power (FP) w.e.f. January 15, 1999 after its recommissioning and synchronisation on June 6, 1998, following the enmasse coolant channel jobs and systems upgradation. The unit was under planned short shutdown for replacement of mechanical seals of PHT pumps and to carry out relocation of control wiring of moderator system control valves. The unit also had a few process related outages during the period.

Madras Atomic Power Station
(2x170 MWe PHWRs)

The cumulative gross generation of the station since it commenced commercial operation till the end of December 1999 was 29,101 MUs.

The station generated 2350 MUs during the calendar year 1999 and 1853 MUs for the period 1.4.99 to 31.12.99 in the financial year 1999-2000.

MAPS-1 performed well recording continuous operation for about three months before it was taken out on January 2, 2000 for inservice inspection of coolant channels.

MAPS-2 which was shutdown in mid-February 1999 for in-service inspection of coolant channels (ISI) was synchronised back to grid on 24.05.1999 after completing ISI and ASD jobs. The unit had a record continuous run of 183 days from 19.06.1999 to 19.12.1999.

Narora Atomic Power Station
(2x220 MWe PHWRs)

The cumulative gross generation of the station since it commenced commercial operation till the end of December 1999 was 17,893 MUs. The station generated 2851 MUs during the calendar year 1999 and 2273 MUs during the period 1.4.99 to 31.12.99 of the financial year 1999-2000.

During the year, Narora Atomic Power Station achieved Environmental Management System (EMS) certification as per the ISO-14001 International Standard.

NAPS-1 achieved availability factor of 100% in the months of May 1999 and September 1999.

NAPS-2 achieved capacity factor of 100% and above in the months of February 1999 and November 1999, and 100% availability factor in these months and also in the month of July 1999. The Unit was shutdown for about a month to take up work of main air lock inner door.

Kakrapar Atomic Power Stations
(2x220MWe )

The cumulative gross generation of the station since it commenced commercial operation till the end of December 1999 was 13,537 MUs. The station generated 3295 MUs during the calendar year 1999 and 2435 MUs during the period 1.4.99 to 31.12.99 in the financial year 1999-2000. Both the units of KAPS performed well during the financial year 1999-2000 up to December 1999.

KAPS-I achieved a capacity factor above 100% in the month of March 1999 and availability factor of 100% in the months of March, April, May and September 1999. The Unit availed annual shut down for about a month during which technical specification related surveillance test, preventive maintenance checks of major equipment and cobalt elements removal jobs were carried out.

KAPS-2 achieved an availability factor of 100% during four months of 1999. The Unit had a planned shutdown for about 12 days to carry out reactor building leak test and technical specifications related tests.

## NUCLEAR POWER PROJECTS UNDER CONSTRUCTION

Kaiga Atomic Power Project -1&2. (2 x 220 MWe)

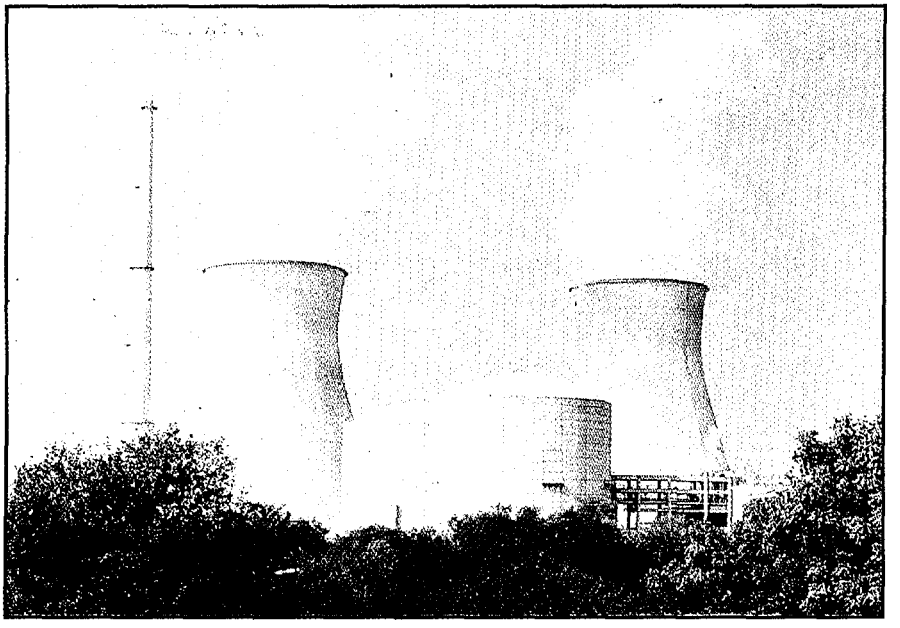
The project is for setting up a twin unit station of PHWR type, each of 220 MWe installed capacity. It is located at Kaiga in Uttar Kannada district of Karnataka and will supply electricity to southern grid. The project has achieved an overall physical progress of 97.53% and incurred an expenditure of Rs.2,586 crore upto December 1999.

Unit-2 of this project achieved criticality on September 24, 1999. Subsequent to certain tests, the unit was synchronised to the grid for the first time on December 2, 1999. The reactor set back test and Ramp power test were conducted after synchronisation as per the directives of AERB at 50% full power. The unit has been authorised by AERB to operate at full power. The unit is expected to commence commercial operation shortly.

The concreting of the Reactor Building (RB) inner containment dome of Kaiga-I, its prestressing and grouting works were completed. All the civil works in Turbine building (TB), Reactor Auxiliary building (RAB), DG building. Spent Fuel Storage Building, Service Building, D20 upgrading Plant Waste Management Plant were also completed.

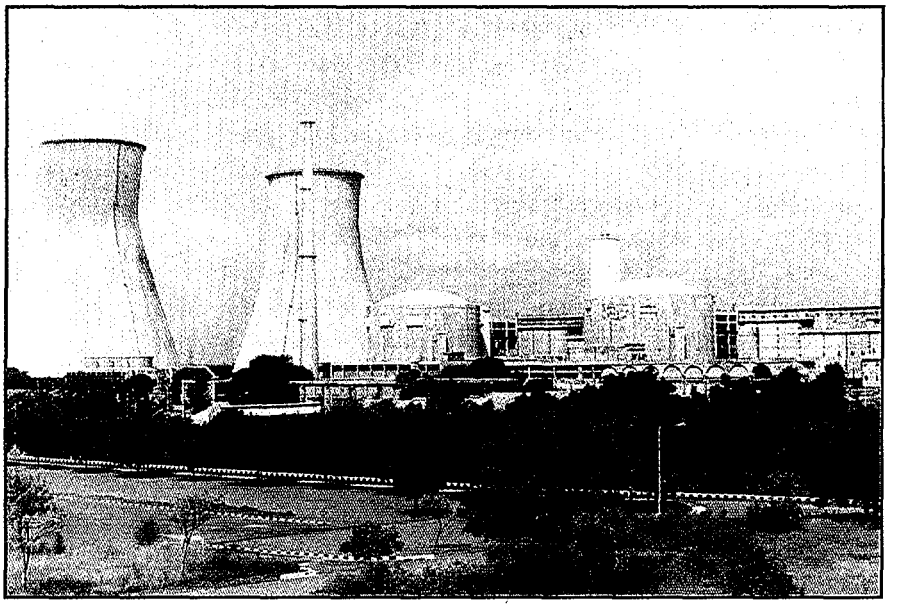
All the secondary cycle piping and conventional piping (outside RB) and most of the nuclear piping were completed. The turbo-generator has already been taken on barring gear. The compressed air and chilled water plant have been commissioned. The concreting of Outer Containment dome, painting of buildings and Hydro-test of Main PHT system, Moderator system and Reactor Auxiliary System are expected to be completed by March 2000. Kaiga-I is expected to achieve criticality in September 2000.

The Kaiga Project won AERB's



*Narora Atomic*
*Power Station-1&2*

*Kakrapar Atomic*
*Power Station-1&2*



*Tarapur Atomic*
*Power Project-3&4*

Industrial Safety Award and also the NPCIL Industrial Safety Award.

**Rajasthan Atomic Power Project-3&4** (2x220 MWe)

The Rajasthan Atomic Power Project is a twin unit station of PHWR type, each unit having an installed capacity of 220 MWe. It is located adjacent to existing two units of RAPS at Rawatbhata in district Chittorgarh of Rajasthan and will supply electricity to the Northern Grid. The project has achieved an overall physical progress of over 93% and incurred an expenditure of Rs. 2,078 crore up to December 1999.

RAPP-3 achieved criticality on December 24,1999 and is expected to be synchronised to the grid in the near future.

As regards RAPP-4, concreting of RB-4 inner containment dome and its prestressing have been completed. Concreting of its outer containment (OC) dome has also been completed. Epoxy painting of various floors and containment walls is expected to be completed by March 2000. All the civil works of TB, RAB NDCT ( Natural Drought Cooling Tower ) etc of RAPP-4 have been completed and the remaining civil works of IDCT-4 ( Induced Drought Cooling Tower ) are expected to be completed by end March 2000.

Tasks in progress include erection of nuclear piping and feeders, installation of feeder/header cabinet, erection of fuel transfer equipment and installation of Primary shut down & Secondary shut down system components.

The prefabrication and erection of common service piping outside RB-4 has almost been completed and 85% of the secondary cycle piping has also been completed. The erection of condenser alongwith 50% erection of Turbo-Generator and Auxiliaries, has already been completed.

Unit-4 is expected to attain criticality in November 2000.

RAPP-3&4 won the AERB's Fire Safety Award for the year 1998.

**Tarapur Atomic Power Project-3&4** (2x500 MWe)

The project is located adjacent to existing two unit of TAPS at Tarapur, District - Thane, Maharashtra State and will feed electrical power to western grid. The project comprises a twin unit station of Pressurised Heavy Water Reactor (PHWR) type, each unit of 500 MWe installed capacity.

The project has achieved an overall physical progress of 16.2% and incurred an expenditure of Rs. 1298 crore up to December, 1999. The scheduled criticality date for TAPP-4 and TAPP-3 are October 2005 and July 2006 respectively.

The Main plant excavation work for both units - 3&4 has been completed. The protective rock bund involving 1.4 lakh cubic metres of filling on Sea face has also been completed along with site grading. Heavy duty crane road with 8 nos. of hot-spot is in final stage of completion. All the tests required for geotechnical investigation have been completed and the test results have been accepted by AERB.

Work order for Pakage-2 civil works (i.e Safety related building consisting of Reactor building. Service building. Reactor Auxiliary Building, Control Building and Station Auxiliary Building etc.) has been awarded . Levelling course of RB-4 has been completed. Reinforcement laying work has commenced. First pour of concrete for RB-4 is expected to be taken up very soon. Levelling course for RB-3 and other buildings is also completed.

Work Order for Conventional Building (Package-3) such as Turbine Building, DM plant, Chlorination Plant, Fresh & Fire water reservoir, has been awarded. Work for Part Tunnel & Trenches has been substantially completed and tendering work for Marine structures is in progress.

Critical components such as calandria, moderator pumps, reactor headers, and pressurisers for both the units and PHT pump motors , TG components for the first unit had already been procured. The manufacture of Moderator heat exchangers, End-shields, Steam generators etc. are in progress. Orders for R.B. main structural steel, fueling machine bridge and column, shielding plugs, sealing plugs, condenser etc. have been placed and work of manufacture of these components has commenced. Pre-qualifications of bidders for electrical, common services, mechanical and primary piping packages have been started and are in various stages of progress.

**Kudankulam Atomic Power Project** (2x1000 MWe)

The Kudankulam Project is an Indo-Russian joint venture for construction of a nuclear power station consisting of two units of pressurised water reactors (PWR) VVER-1000 each having a capacity 1000 MWe, at Kudankulam in Tamil Nadu. The project is being implemented on a "Technical Cooperation" basis under the provisions of the Inter-Governmental Agreement (IGA) signed in 1988.

The work on preparation of DPR have been started with effect from April 1999. Under the DPR contract, around 25 premier design organisations/institutes of Russian federation are involved in the preparation of documents covering Preliminary Safety Analysis Report (PSAR), Plant Design, Project Management, Quality Assurance, and Project Cost & Finance. The design work to be submitted would comprise about 196 packages. The techno-commercial offer for implementation of the project would be submitted after approval of the DPR. The entire DPR contract is expected to be completed by October 2001.

The design works for infrastructures and township have been initiated. Construction of the property wall, approach road and preliminary works at Kudankulam site have been completed.

Efforts were made to assess the ground water potential in Kudankulam area. In this regard integrated geophysical deep resistivity survey was done by National Gelogical Research Institute, Hyderabad. While preliminary reports indicates the availability of water, the final report is under review. Test bore drilling is being initiated.

**Quality Assurance**

As a sequel for obtaining the ISO 9001 Quality Management System accreditation, implementation was carried out vigorously with positive benefits. As part of maintaining the path of excellence, Total Quality Management (TQM) initiatives were taken. As a follow up, senior management personnel of NPCIL were trained as Assessors for Business Excellence/ TQM. Self assessment of NPCIL towards Business Excellence /TQM under European Foundation for Quality Management Model, through the Confederation of Indian Industry (CII), was carried out and an Application Document was submitted to the CII. NPCIL received a certificate for strong commitment to TQM. A major thrust was made in the area of training to upgrade the skills and knowledge of engineers. A number of engineers were trained as certified Quality Engineers and in Non-Destructive Testing.

Core shroud inspection activities at TAPS were continued to achieve greater coverage of the welds. Design/ development for further improvements, was continued on manipulators for ultrasonic testing of Core Shroud. Manipulator system was developed and used for pre-service inspection of Coolant Channels of RAPP-3&4/Kaiga-1&2. During the year, Quality Assurance Systems were extended to operating stations and construction projects to assure compliance with quality requirements for safety and reliability.

**Health, Safety & Environment**

The safety performance of the stations continued to be excellent during the year. The radioactive releases to the environment and the occupational doses were kept "As Low As Reasonably Achievable (ALARA)" and were much below the prescribed limits. Off-site emergency exercises were carried out at various sites to test out the emergency preparedness plans.

The final report about the KAPS epidemiological survey entitled "Effects of Low Dose Ionization Radiation among the employees at KAPS: A cross sectional study " was released. The Epidemiological data work at RAPS, NAPS and Kaiga sites was completed. The data is under analysis at the Tata Memorial Hospital, Mumbai.

NPCIL-Safety Review Committee (NPC-SRC), the apex in-house safety body, continued to conduct appropriate interdisciplinary review of all safety related events and safety submissions. The review provides necessary guidelines to avoid events and ensures that all proposals are comprehensive, implementable, consistent and conforming to the relevant code requirements, enabling early resolution of the issues. So far, 102 such NPC-SRC review meetings have been conducted. The new technical specification for KAIGA-2 and RAPP-3 have been issued after approval from AERB. The revised technical specification for NAPS, KAPS & MAPS would be issued after approval of AERB. Various internal safety reviews and audits were conducted for assurance of Health & Safety aspects in the operating stations as well as in the projects under construction. Detailed safety review through ISROS (Internal Safety Review for Operating Stations) was conducted for RAPS.

Two internal peer reviews were conducted at Narora Atomic Power Station prior to an international WANO (World Association of Nuclear Operators) peer review which is expected to be carried out early this year. The Kakrapar Atomic Power Station was already reviewed by international WANO peer review team in early 1998 and improvements suggested have been implemented.

To upgrade Nuclear Safety aspects, a number of seminars were organised with the help of IAEA/WANO such as, "Conservative decision making" at MAPS, "Event Analysis methodologies" and "Good practices Workshop" at KAPS & "NPP's operational safety performance indicators"at TAPS.

Various activities related to Industrial safety, Fire Safety, Safety Culture, Environment, Occupational Health, Green belt development and ISO-14001 certification work of NPCIL sites, were continued.

Fire Hazard Analysis (FHA) for Kaiga was completed during the year and FHA for RAPP-3&4 made progress. The Central Building Research Institute (CBRI) Roorkee is developing a software for Fire Model. An in-house Fire Model named "NUKEFIRE"was developed during this year and is being upgraded through user-interactions.

The quarterly news bulletin "Industrial Safety News" continued to be published during the year. The Frequency Rate (FR) of Industrial accident (reportable injury accidents per million man-hours) has shown a steady drop over the last few years. The FR for 1998 was 0.85. This has shown further decline in 1999. In addition, 1999 has been a year without any serious/fatal accidents in the entire corporation in-spite of considerable peak level construction and commissioning activities.

# URANIUM CORPORATION OF INDIA LTD.

The Uranium Corporation of India Ltd. has shown a good performance during the year 1998-99. All the major producing units of the Company have recorded higher capacity utilisation compared to previous year. Improved efficiency in all fields of operation has resulted in higher production of uranium concentrate and rise in net income of the Company.

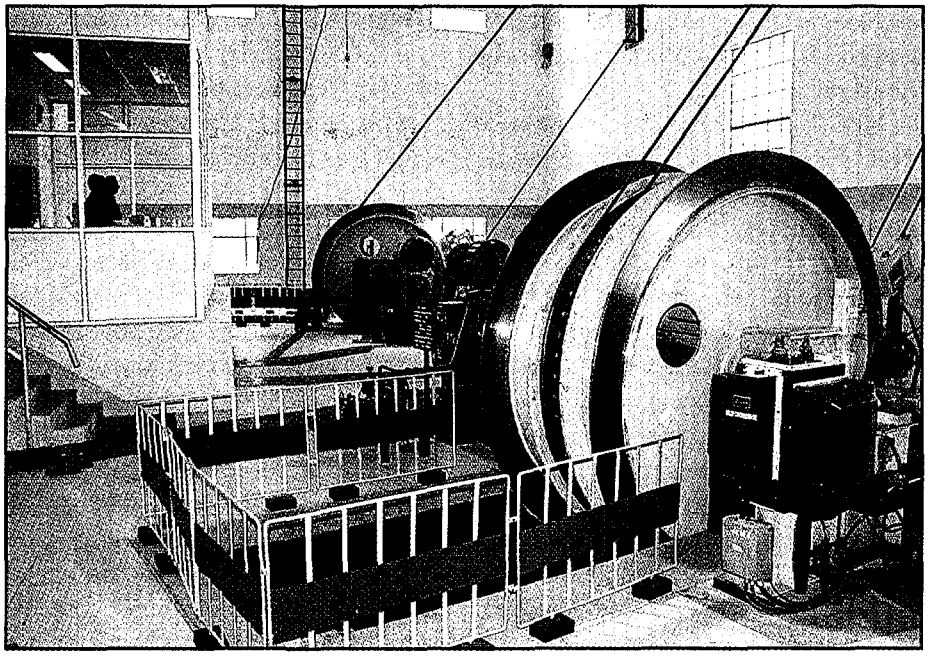
At Jaduguda, the first uranium mine of the country has been in continuous operation for the last 33 years. At present, trackless mining equipment are put to use in this mine by employing decline method of mining which has resulted in higher productivity. With the depletion of ore at the upper levels, the mine is now being deepened to 905m by sinking an underground shaft at a depth of 555m. Shaft sinking, lining and equipping are in the final stages of completion. After the installation of winder, the shaft will be made fully operational.

The Bhatin mine is also being deepened to 250m to create additional production levels.

The Narwapahar mine is now fully operational with modern mining equipment and technology. The 330m deep shaft has been commissioned. Deeper levels of the mine are also being developed.

The expanded Jaduguda Mill has also been commissioned. High Levels of instrumentation and automation are the hallmarks of the mill.

The production of uranium concentrate has also gone up appreciably.



*Cage and Skip winders of Narwapahar Vertical Shaft*

The production of uranium concentrates from the copper tailings at the two uranium plants of the Corporation has shown a decline during the year. This is due to the scaling down of operations of the Hindustan Copper Limited, as a result of which availability of tailings to the uranium recovery plants has been reduced.

With large tonnage of ore being mined and processed, additional facilities for storage of tailings have also been created. The new tailings disposal pond which is called the Third Stage Tailings Pond, has been indigenously designed, and incorporates an effluent treatment facility and a ground water monitoring system.

The Corporation has introduced computerisation at various levels of working. Necessary conversions / upgradation were carried out at all computer installation as a result of which a smooth transaction of all operations into the year 2000 was successfully achieved.

The Company is in the process of obtaining ISO-9001 and ISO-14001 certification for all its operations during this year. Accordingly, MECON Ltd, a Govt of India Undertaking has been engaged as consultant to assist and guide in the procedural details.

A very high standard of safety is maintained in all the units of the Corpora

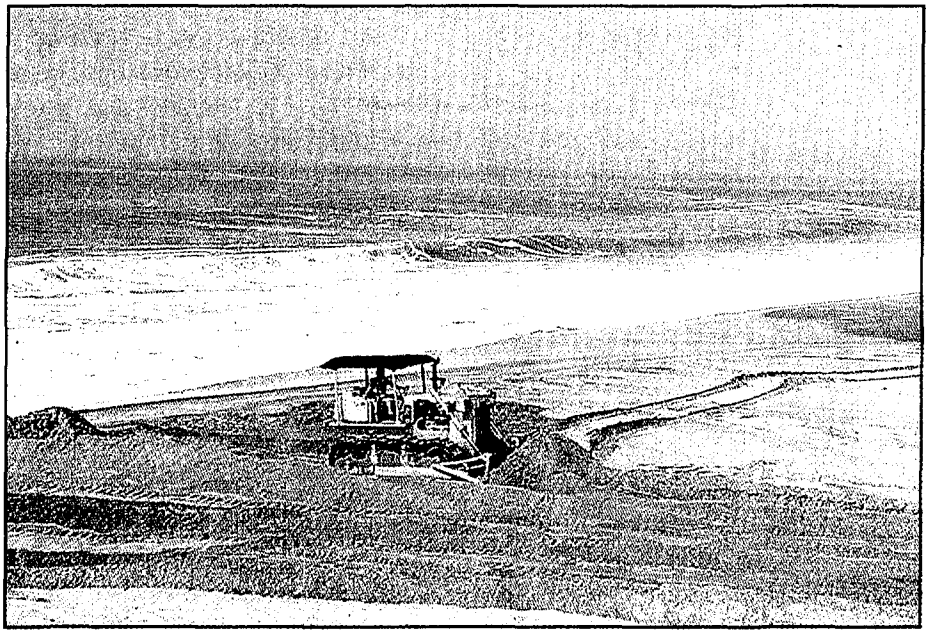


*continued on page 3.11*

# INDIAN RARE EARTHS LTD.

During the year 1998-99, the Company registered an all-time-high turnover of Rs.178.07 crore. The Company earned foreign exchange of Rs.61.84 crore from exports and was selected for the Capexil's Export award for 1998-99. As per the present trend, the Company is expected to improve the sales turnover to about Rs.200 crore during 1999-2000 with about three fold increase of the profit margin. The foreign exchange earning is likely to touch a figure of around Rs.70 crore. The Company has also been awarded a contract for supply of a mini-pilot plant for monazite processing at a value of US$ 2.33 million for the Nuclear Materials Authority, Egypt.

During 1999-2000, Chavara in all probability will exceed the revenue targets of production with respect to various minerals and value added products. The production at Chavara was affected by the non-availability of adequate quantity of raw sand. To improve the availability of raw sand, the Company is making all out efforts to acquire mining land at Karithura village by negotiated purchase from local villagers with the help of District administration. By implementing the Scheme, the Company has been able to acquire 9 acres of land so far and expects more in the near future. This will improve the production of Chavara in the coming years. The microzir project for production of fine zircon powder has also been completed.



*Manavalakurichi coast: Mining of Mineral Sand*

At Manavalakurichi, collection of raw sand from beach washing have restarted following an understanding reached with the local villagers. This will improve the availability of feed material and the performance of Manavalakurichi during 1999-2000. The project for additional recovery of zircon & rutile has been completed. The Manavalakurichi Unit obtained ISO 9002 certificate in the month of September 1999.

OSCOM achieved an all time high production of 177055 tons of ilmenite during 1998-99 which is nearly 80% of the installed capacity. OSCOM would have significantly improved mineral production during 1999-2000 had it not for the severe cyclone which resulted in a shutdown of the plant operations for 1-1/2 months. Notwithstanding, the adverse consequence of the cyclone, the unit is expected to improve its gross margin significantly during this year.

At Rare Earth Division the problem of accumulating inventory due to sluggish market and increasing losses were major concerns. The product mix of the plant has been appropriately modified with a view to containing the losses. The PRYNCE project which was originally envisaged to produce 95% neodymium oxide has been modified for upgrading the product quality to 99%.

The Company has signed a joint venture agreement with Austpac Resources



*continued on page 3.11*

# ELECTRONICS CORPORATION OF INDIA LTD.

### Operating Performance in 1998-99

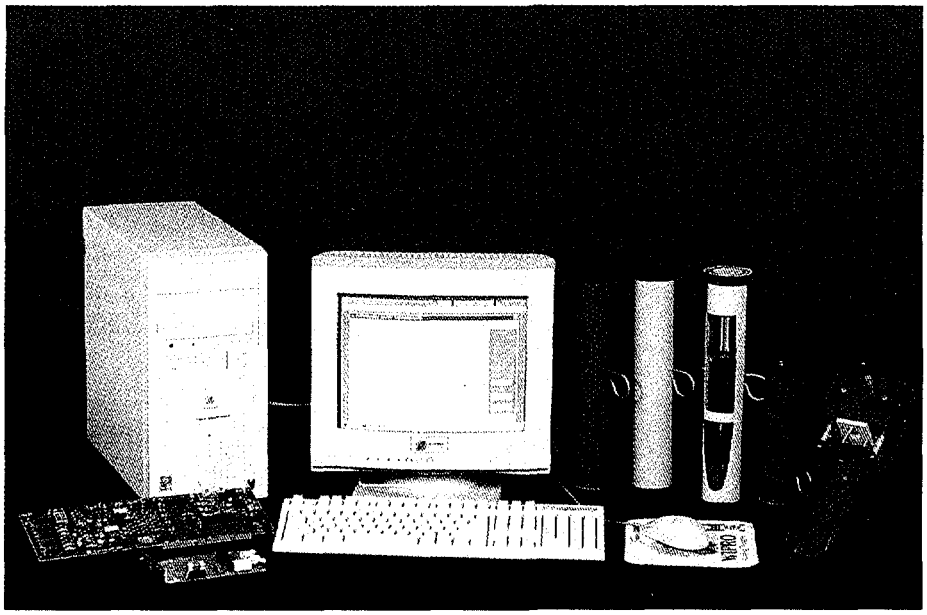
During the year 1998-99, the production of the Company was about Rs.238 crore and the gross income was about Rs.251 crore. The corresponding figures in the previous year were about Rs.311 crore and Rs.348 crore respectively. A total of Rs.198 crore worth of orders were booked during the year.

### MOU Performance

The Company signed a Memorandum of Understanding (MoU) with the Department of Atomic Energy for the year 1998-99 and the evaluation indicated the achievement rating as "Fair".

### New Products

The important new products introduced during the year 1998-99 were : Digital Distributed Control System (DDCS) for Thermal Power Plants; Programmable Tracking Antenna Control System for Space Applications; Data Link and Voice Information System (DAVIS) for Civil Aviation sector; PC Based Expendable Bathy Thermograph (XBT) Recorder for Naval Applications; Mobile Station Missile Checkout (MSMC) for Defence Applications.



*PC based XBT Recoding System*

### Sales Plan for 1999-2000

The Corporation has drawn up a Sales Plan of Rs.440 crore for the year 1999-2000. This includes supply of :

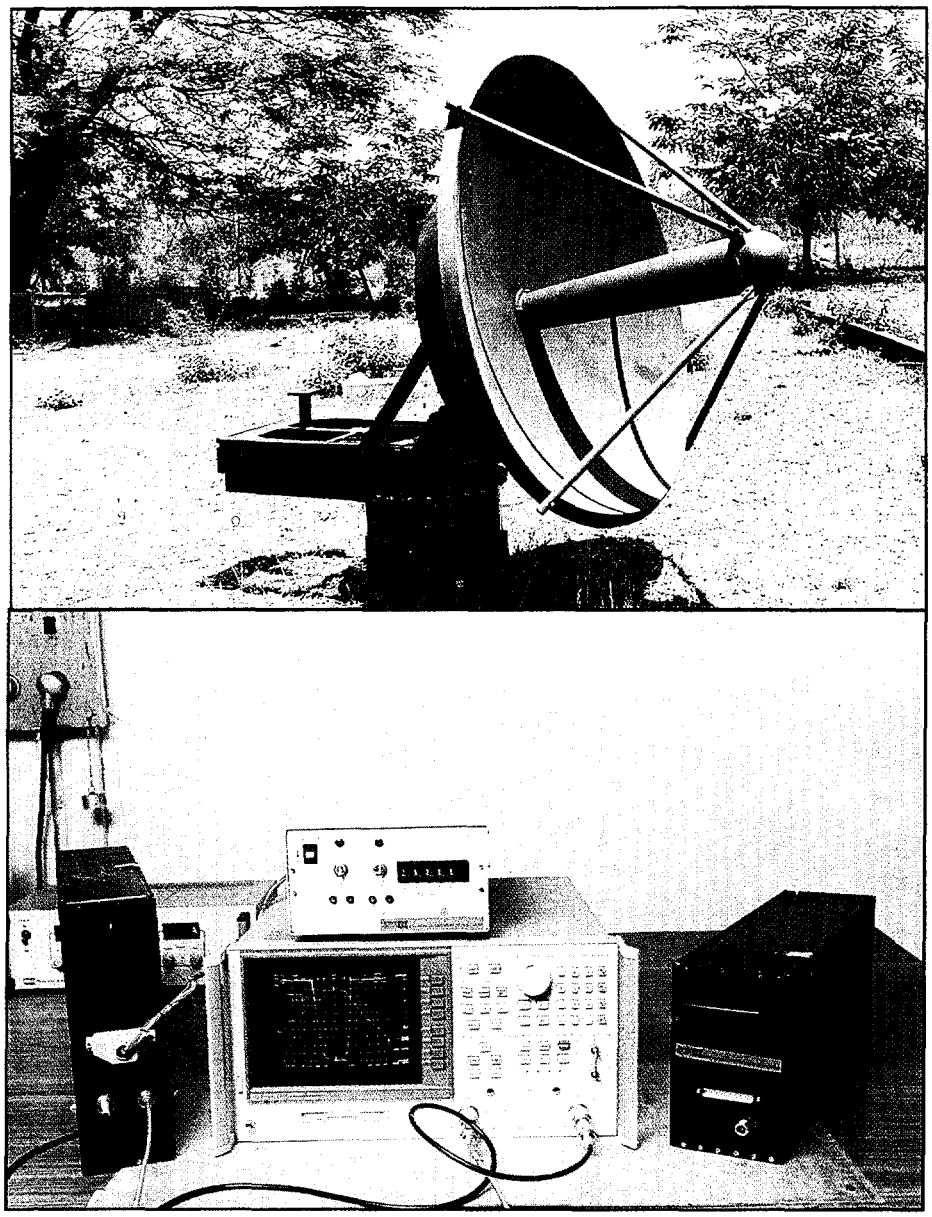
- Communication Equipment, worth Rs.60 crore.
- Antenna Sytems, worth Rs.55 crore.
- Instruments & Systems, worth Rs.30 crore.
- Strategic Electronic Equipment, worth Rs.20 crore.
- Telecom Products, worth Rs.39 crore.
- Computer Systems for Business Applications including service support to customers, worth Rs.76 crore.
- Control & Instrumentation Products, worth Rs.85 crore.
- Components, worth Rs.15 crore.
- Special Products such as Fuzes, worth Rs.60 crore.

### R&D Programme

The R&D programme of ECIL for the year 1999-2000 include :

- Doubly curved Antenna Mark-II.
- Ethernet Interface to ADIOS I/O Sub-system
- Solid State CVR to meet TSOC 123 (30-198)
- Compact X-Ray Generator.

*Doubly curved Antenna (Top) and Digitally Tunable Bandpass Filters*



- X-ray Mango Inspection System.
- Development of Deuterium Arc Discharge Lamp.
- Digitally tuned Multicouplers.
- Development of Module and Algorithm for Secure Data & Voice FH.

**Exports**

During 1999-2000 (till Dec. 1999), the Company exported the following products : Rs.25 lakhs worth of X-ray Generators, to Rs.25 lakhs worth of Notch Indicators to Hungary; Rs.12 lakhs worth of Gyros & Synchros to Malaysia, and Rs.5 lakhs worth of Software (DAISY) to France.

**Future Outlook**

ECIL plans to make investments on several New Products / Projects. The areas being focussed on include : Antenna Control Unit; Four Port Combiner; Barrage Jammer; Cipher Equipment; VHF Data Link; High Power RF and MW Components; Futuristic Automatic Data Handling System; Displays for Navy; Communication I/F for C3I.

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*continued from page 3.8*

tion. The implementation of the Ecology and Environmental Protection Programme is regularly monitored at all the units. The Environmental Survey Laboratory of the Health Physics Unit of BARC at Jaduguda and Narwapahar constantly monitor the background radiation in the environment surrounding the various facilities.

A thorough medical survey has been conducted in villages around Jaduguda to investigate if there is any disease pattern related to the operations of UCIL. A medical team comprising doctors from BARC, Tata Main Hospital, Govt. of Bihar, UCIL and radiation experts from Health Physics Unit, BARC had made a door to door survey in about 17 villages within a radius of 2 kilo metres around Jaduguda. The team has unanimously agreed that there is not a single case which can be ascribed to radiation exposure.

*continued from page 3.9*

NL, Australia for setting up a demonstration plant for producing 10,000 tons per year Synthetic Rutile Plant at OSCOM. The successful demonstration of this plant will pave the way of profitable harnessing of bountiful Orissa ilmenite for value addition.

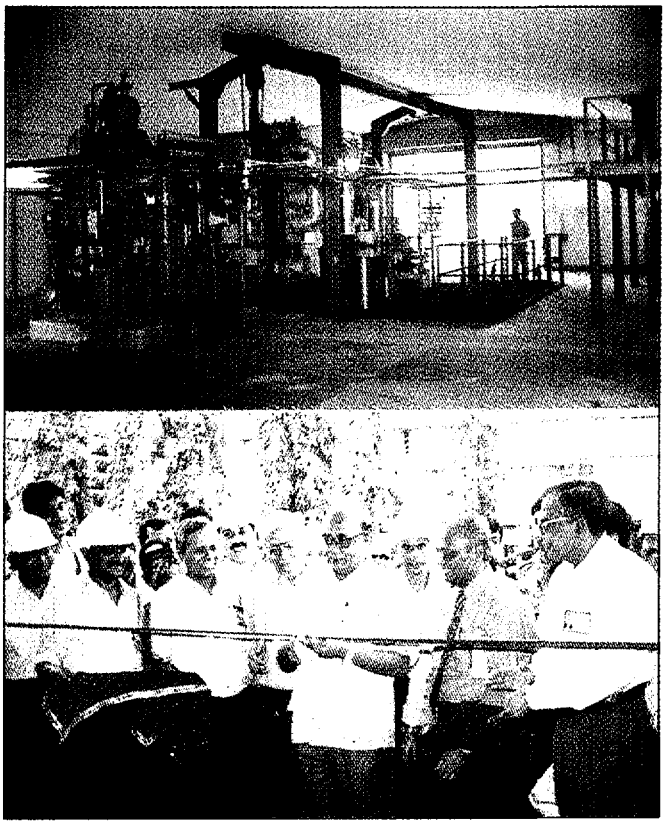
An agreement has been signed with Centre for Earth Science Studies, Trivandrum (CESS) for heavy mineral budgeting and integrated coastal zone management at Chavara. This study will throw up meaningful data which would guide the optimal mining of the coastal deposits with Kerala State.

# HEAVY WATER BOARD

Eight Heavy Water Plants are installed in the country to meet the heavy water requirements of Indian Nuclear Power and research Reactors. The Heavy Water Board manages the operation and maintenance of seven of these plants. The production capacity of Heavy Water in the country is more than sufficient to meet the domestic demand.

**Present Status**

For the period under report, the overall performance and the safety record of Heavy Water Plants were excellent, As a result of stable operation and continuous run of the plants the cumulative production achieved so far has exceeded the target scheduled for the period. It is expected that during the financialyear 1999-2000 production will exceed the scheduled target within the allotted budget due to major efforts in energy conservation. The continuous motivation and awareness of the plant personnel has also resulted in an overall reduction in specific energy consumption. The plants at Tuticorin, Baroda and Kota completed more than 8.6, 9.6 and 5.3 million manhours of continuous operation respectively without any reportable accident. Operation of the Heavy Water Plant at Talcher remains suspended due to unsatisfactory operation of the connected fertilizer plant of the Fetilizer Corporation of India on which the plant depends for feed stock and other inputs. Heavy Water Plant at Baroda has been stopped since end December, 1998 due to closure of old Ammonia plants of GSFC, Baroda to which it is linked.



*R&D Pilot Plant of D2EHPA at Heavy Water Plant, Talcher inaugurated by Dr. R. Chidambaram, Chairman, AEC*

A major modification for reviving operation of HWP, Baroda is initiated by the Board. The same includes development of "Ammonia Water Front End" Technology which will delink the ammonia based Heavy Water Plants from the associated Fertilizer Plant. Atomic Energy Commission (AEC) has approved the scheme in its recent meeting and financial sanction has been received.

**Plant Performance of plants**

During the period HWP (Manuguru) was running on a sustained basis except for few outages due to inhouse reasons. One unit of the plant has taken Annual Tum Around jobs for 18 days in May/June 99.

Major Turn Around of the Heavy Water Plant (Kota) was taken during mid August-October1999. During the rest of the period pint was running an a sustained basis except for few outages due to interruption in power and steam supply.

Performance of HWP (Hazira) during the period was very good except for few occasions when the feed gas supply wasrestricted/stopped due to non availability of natural gas from GAIL.

Performance of HWP (Thal) has been very good during the period and the plant has exceeded the scheduled target production for the period.

Performance of HWP (Tuticorin) during the period was very good.

Industrial relations in all the plants remained very cordial.

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Performance of HWP (Tuticorin) during the period was very good.

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**Major Modifications**

Effluent Heat Recovery system at HWP, Kota to recover heat from the liquid effluent is likely to be commissioned by end Jan 2000 this is expected to reduce the steam consumption by 3-5 MT/hr.

An additional transformer of 40 MVA has been installed at HWP(Kota) to improve the availability of power supply and trouble free run of the plant.

Implementation of ISO-9002 quality system has been completed at HWP, Tuticorin. It is perhaps the first plant within the department to get ISO Quality system certificate for the establishment as a whole covering entire activities including administration & accounts.

**Conservation**

Heavy Water Board has been putting in enhanced efforts in efficient use of energy, water and recycling of contaminated Oil generated in the rotary machines which use liquid film seals for shall staling. Schemes for Recirculation of heated effluent has been commissioned and is operating very satisfactorily resulting in significant reduction in energy consumption.

In order to strengthen the efforts towards energy conservation, it was decided to conduct Energy Audits at all Heavy Water Plants. M/s. National Productivity Council (NPC)) was entrusted to conduct the Energy Audit at HWP Hazira and Manuguru. Action plan On short-term and long-term recommendations have been worked out simultaneously for improving efficiency in Energy utilization.

**Diversification**

As part of future diversification a R&D Pilot Plant facility for production of Solvent Di-2-ethyl Hexyl Phosphoric Acid (D2EHPA) has been successfully commissioned at HWP, Talcher. The Board obtained the process chemistry from BARC. The facility is now fully operational and so far 2040 Kg. of D2EHPA has been produced and the quality of the same meets the international standards. Board has already supplied 1.5 MT to M/s. Hindustan Zinc Ltd. An external Agency has been requisitioned for detailed market survey for establishing demand which will be used for taking a decision regarding setting up industrial scale unit.

**New Initiatives**

Value Engineering Committees have been constituted at all HWPs to have strict control on inventory of spares and to ensure that the spared other materials being indented are essential and not ad going to add the dead inventory of the plant

Heavy Water Board in persuasion of the goal of achieving higher productivity/excellence in all aspects of Heavy Water Production has also undertaken subject of "Work Study" to assess on a scientific basis the manpower requirement and to have best deployment of manpower. Board has entrusted the work study at HWP (Kota) to "National Productivity Council" (NPC).

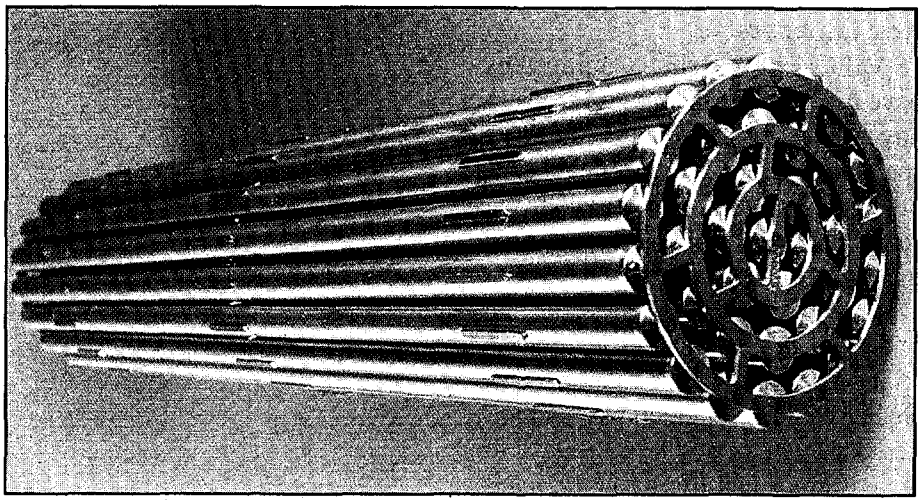
# NUCLEAR FUEL COMPLEX

Nuclear Fuel Complex (NFC) is responsible for manufacturing zirconium alloy clad, natural and enriched uranium oxide fuel assemblies for all the Pressurised Heavy Water Reactors (PHWRs) and Boiling Water Reactors (BWRs) respectively in the country and zirconium alloy structural components for these reactors including calandria and pressure tubes for PHWRs and square channels for BWRs. In addition, NFC produces seamless stainless steel and special alloy tubes of international standards for nuclear and nonnuclear applications.

During the year 1999-2000, the annual production target set for all the plants were met and in cases of Uranium Oxide Plant (UOP), Ceramic Fuel Fabrication Plant (CFFP), Enriched Fuel Fabrication Plant (EFFP), Zirconium Oxide Plant (ZOP) and Zirconium Sponge Plant (ZSP), the actual productions far exceeded the targets and all time high production figures were achieved. Apart from meeting the regular requirements of reload fuel for all the operating PHWRs at RAPS, MAPS, NAPS and KAPS and BWRs at TAPS, the initial fuel charges of KAIGA-I, RAPS-III and RAPS-IV were supplied well in advance.

### Technology Development & Upgradation

Several modifications were made in the manufacturing of high density natural uranium oxide fuel pellets for pressurised heavy water reactors. First, admixing of lubricants with uranium oxide granules prior to final compaction led to significant recovery of sintered pellets. The tool life of dies and plungers for pellet compacting was improved nearly three times utilising Cryogenic heat treatment. As a result, the down time of the powder compacting presses was significantly reduced. A novel method based on "roll compaction of uranium oxide powder followed by granulation" was introduced for producing free flowing uranium oxide granule. Thus, the classical "precompaction and granulation" is being phased out. The "roll compaction" technique not only increased the productivity but also resulted in consistency of granule quality.



*37- element PHWR fuel assembly for 500 MWe Tarapur Atomic Power Project -3&4*

A major campaign was carried out for recycling sintered $UO_2$ pellets scrap which had accumulated over the years for production of uranium oxide powder. This has led to substantial reduction in the generation of Uranyl Nitrate Raffinate Cake (UNRC).

Flow Induced Vibration (FIV) subassembly of PFBR was under fabricated for the first time.

PRP development work in Zr-1% Nb with respect to meeting mechanical and metallurgical property was completed and short term requirements of Fuel tubes, Poison Tubes and bars were met.

Development work with respect to fabrication of channel of size 46mm OD

tubes, Poison Tubes and bars were met.

Development work with respect to fabrication of channel of size 46mm OD x 0.7mm wall thickness was successfully completed. Manufacture of 23 metre long tubes in size 17.8mm x 2.56mm for steam generators of FBTR and manufacture of hexagonal channel in D9 material for FBTR and fuel clad tubes in sizes 5.1mm OD x 0.37mm wall thickness in SS 316 material for FBTR was completed.

For the first time inconel 600 was extruded with good quality and cold rolling parameters were also established for the manufacturing of tubes. This will meet the requirements of ongoing Pyrochemical Process Development Plant.

Austenitic stainless steel required for heat exchanger tubings in low wall thickness was successfully extruded at Horizontal Extrusion Press for the first time thereby reducing the process steps for manufacturing small diameter tubing.

An important milestone in the zirconium group was the installation and operation of slurry extractor unit for zirconium extraction. This coupled with process engineering improvements has resulted in considerable savings in the consumables. The process of making nuclear grade niobium metal was in progress was established at the Special Materials Plant.

### New Schemes

Three new schemes namely, 37 Element PHWR Fuel Project for TAPS-III & IV (PHWR 500 MWe), Replacement and Augmentation of Zirconium Sponge Plant and Advanced Materials Processing and Characterisation Facilities were sanctioned. These schemes were under implementation.

Pyrochemical Process for separation of zirconium and hafnium

The pyrochemical process involves the direct conversion of zircon sand mineral to crude zirconium tetrachloride, purification of tetrachloride and separation of zirconium and hafnium by distillation using a molten salt system. In continuation of the laboratory studies carried out at BARC, a 39-stage distillation column was experimented at NFC, with encouraging results of separation and leading to the clear understanding of molten salt technology. A vertical submersible pump for high temperature molten salt reached an advanced stage indigenous development. The design of the pilot plant equipment for chlorinator, purification and 60-stage extractive distillation column was completed and the same is expected to be made operational during next the 12-18 months.

### Spin-off Products

As a non-nuclear spin-off, NFC has undertaken supply of copper blanks for Prithvi and Nag Liners and supplied 52Nos. of blanks for trials to M/s.Metal & Steel Factory, Ishapore.

- NFC continued to cater to zirconium alloy needs of Fertilizer Industries and the requirements of M/s.GNFC Ltd. and M/s.RCFL.

- Tubes in special grades of alloy like 15CDV6 and aluminium alloy were successfully completed for space requirements.

- Silver alloy gaskets required for NPCIL, BHEL were successfully manufactured and supplied by Tool Room.

Indigenous Equipment Development

*A technique for welding of bearing pads and spacer pads on empty fuel tubes (19 element type) without causing weld depressions was developed and adopted on the existing production equipment.

*A laser power source based cutting equipment for decanning of rejected fuel elements for the reclamation of $UO_2$ pellets was developed in collaboration with CAT, Indore.

### Quality Assurance

Over the years, a comprehensive Quality Assurance Programme has been evolved for the manufacture and supply of fuel assemblies and zircaloy mill products for the nuclear power reactors and seamless stainless steel and special alloy tubes.

To enable NFC to enter global market for various products and services, the certification process for ISO 9002, will soon be completed. This exercise has helped NFC to revamp and update the calibration programme and completely review the total quality of documentation involving Quality Manual, Procedure Manual, various MEIs, QCIs and the Work Instructions.

With a view to attain 6-sigma levels of quality, a cell for Statistical Data Analysis has been set up. Further, as nondestructive testing techniques form a major part of the QA, emphasis has been focussed on indigenous development of automated Ultrasonic Testing Systems. An automated UT System for evaluation of zircaloy fuel tubes and another system for zircaloy billets are in advanced stage of fabrication and will be put into operation by April, 2000.

Another major effort was the development of suitable NDT methods for replacing the present destructive techniques such as metallography of end cap welds and shear strength testing for bearing pad welds of PHWR fuel assemblies. Ultrasonic testing was established as a reliable technique for 100% evaluation of PHWR end cap welds. Based on that, a fully automatic robotized Go-No Go system for UT of end cap welds was designed and fabrication initiated.

An innovative Quality Assurance for the initial fabrication and in-service inspection of SS 310 S pressure vessels used as reduction reactors at high temperature and corrosion was evolved for in-house zirconium sponge production. The plan implemented during the

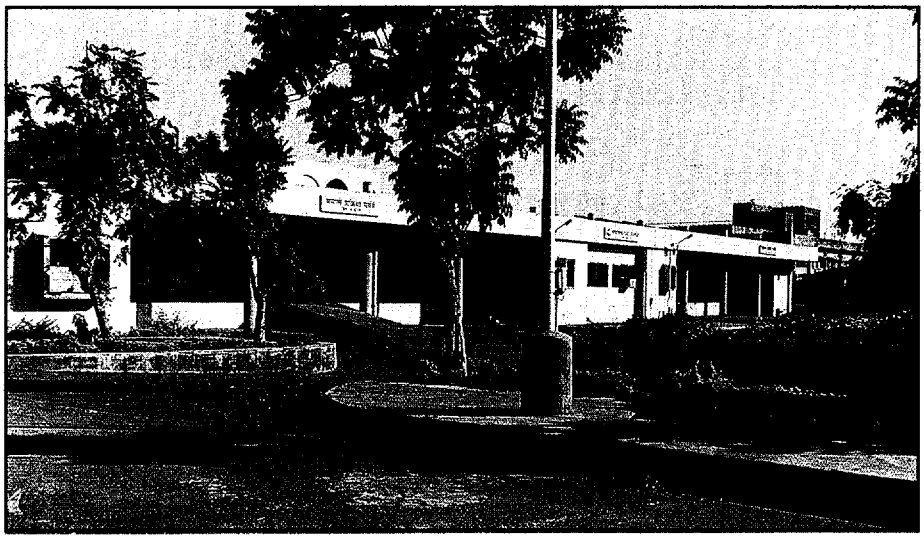
*Continued on page 4.10*

# BOARD OF RADIATION AND ISOTOPE TECHNOLOGY

The Board of Radiation & Isotope Technology (BRIT) produces and supplies a variety of radioisotope products including radiochemicals, labelled compounds of carbon-14 and tritium, nucleotides labelled with phosphorus-32, phosphorous-33 and sulphur-35, radiopharmaceuticals and RIA kits, radiation sources, gamma radiography equipment and gamma irradiator systems to users in the country and abroad. BRIT operates Regional Centres for Radiopharmaceuticals located at Bangalore, Delhi and Calcutta, RIA centre at Dibrugarh, Laboratory for preparation of labelled nucleotides, (JONAKI), at Hyderabad, and Cobalt-60 handling facility at RAPS site, Kota (RAPPCOF), besides the radiation sterilization plant, ISOMED, at Trombay. The work carried out under different programmes of BRIT during the year is summarized below:

**Radiochemicals**

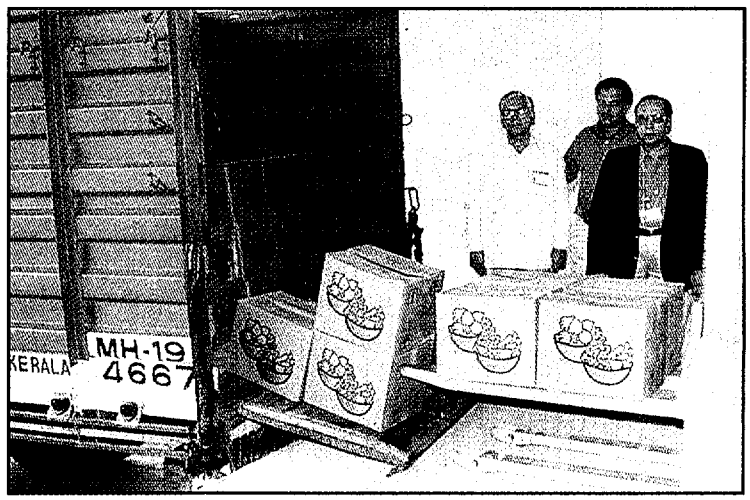
About 70.6 TBq ( 1910 curies ) of a number of reactor produced radioisotopes were processed in over 165 batches for supply to various users and for formulation of a variety of radiopharmaceuticals; these include radioisotopes such as molybdenum-99, phosphorus-32, sulphur-35, iodine-131, chromium-51, mercury-203 etc. About 10 kgs of phosphorus-32, calcium-45, and sulphur-35 labelled agrochemicals were supplied for use in agricultural research. Nearly one kg of promethium-147 self-luminous compound and 100 tritium gas filled light sources were supplied for illumination of instrument dials and other devices used by defence installations.



*Demonstration Plant for Radiation Processing of Spices at Vashi, Navi Mumbai*

**Radiation Sources**

A total of 12.95 PBq ( 350 kilocuries ) of radiation sources of low, medium and high intensity were




*First batch of samples being recieved for radiation processing on January 1, 2000*

fabricated and supplied for use in industry, medicine, agriculture and research. These include radiation sources of isotopes such as cobalt-60, iridium-192, and caesium-137. Over 800 consignments of iridium-192, totaling about 1.1 PBq ( 29.8 kilocuries ) were supplied in the form of sealed sources for radiography examination of industrial components used in various industrial projects in the country . Over 670 consignments of reference and custom made sources were supplied for use in industrial radioisotope gauges and educational institutions.

Over 130 consignments of iridium-192 in the form of 0.3 mm dia wire and six Cs-137 manual after loading kits were supplied to radiotherapy centres for use in brachytherapy, and sixteen large output sources of cobalt-60 of total activity 5.03 PBq (136 Kilo curies) were supplied to various teletherapy centres for cancer treatment.

Twelve adjuster rods containing over 100 PBq (2.7 megacuries) of cobalt-60 were unloaded from NAPS-I. These rods were transported to cobalt handling facility RAPPCOF at Kota for processing. Two adjusters were dismantled under water to estimate exact activity. About 5.88 PBq ( 160 kilocuries ) of Cobalt-60 was recovered and transported to BRIT laboratories at Trombay for fabrication of radiation sources for use in gamma irradiation plants.

**Export of Radioisotope Products and Equipment**

1.85 PBq (50,000curies) cobalt-60 source loaded in a newly developed Type B(U) transport cum-working container alongwith accessories, was exported to Atomic Energy Research Establishment at Dhaka, Bangladesh. One Gamma Chamber 5000 Unit loaded with 12,000 curies of cobalt-60 was exported to Atomic Energy Department of Myanmar in response to an order received from IAEA, Vienna. An export order from Japan Radioisotope Association for the supply of 32 nos. of cobalt-60 radiography sources is under execution. BRIT supplied a fume hood alongwith blower and other accessories to Sri Lanka in response to an order received from IAEA, and laboratory equipment and accessories of Tc-99m generator to Syria. BRIT also regularly exports Hg-203 to U.K and Germany and Ir-192 radiography source to Srilanka.

**Radiopharmaceuticals**

Over 45,000 consignments of different radiopharmaceuticals, cold kits and radioimmunoassay kits were supplied to various nuclear medicine centres and RIA laboratories for diagnostic and therapeutic use.

53 batches of Mo-99 Sodium Molybdate were processed,each batch of average 20 Curies, and around 3000 consignments were despatched . During this year, the processing and despatch of Mo-99 was shifted from Monday to Saturday so that all nuclear medicine centres can start using this product on the first day of the week.

56 batches of the other major radioactive product, I-131·Sodium Iodide solution were processed and more than 6500 consignments of solution (IOM-1) and 3752 consignments of capsules (IOM-2) were supplied. There were no interruptions in the supply schedule. The bimonthly production and supply of I-131 labelled product Hippuran I-131 injection (IOM-8) was continued.

A wide variety of raw materials, radioactive materials, additives, reagents etc. used in the production of radiopharmaceuticals were tested in addition to carrying out regular analysis of various batches of the radiopharmaceutical products.

RPL workshop provided full functional engineering support for the maintenance of the lab and equipment. Also design and fabrication of specially required tools was carried out in house.

The Regional Centres at Bangalore and Delhi regularly processed ready-to-use Tc-99m radiopharmaceuticals for use in the host nuclear medicine centres in addition to supplying the product to other needy hospitals in the region. The Centres at Dibrugarh and Bagalore continued to offer radioimmunoassay service to local hospitals.

**Introduction of New Product**

During this year the supply of a new product MIBG I-131 injection (IOM-50) was introduced with encouraging results from the users.

Production and supply of a new product-Kit for preparation of Tc-99m ECD injection ( TCK-42 ) was started on a regular basis.

A new package for the safe transport of radiopharmaceutical product in LP 20 lead containers was introduced making it uniform with the packing of LP-30 lead containers which was started last year. Introduction of these new packages resulted in greater ease and safety in handling both at packing and user's end, apart from obviating the need for wood for packing.

**Product Development**

During the year the work for development of the following products/processes were pursued:

- Kit for preparation of Tc-99m EC Injection
- $^{153}$ Sm EDTMP
- Kit for preparation of Tc-99m HIG/HIG fragments Injection
- Colloidal Chromic phosphate 32P suspension (CCPS )
- $^{153}$ Sm- Samarium phosphate colloid (SMPC)
- Hydroxy Apatite – 32P Suspension ( HAPS )
- Development of Tc-99m labelled agents for CNS Receptors

( IAEA-CRP)

- Jumbo Gel generator for Low Specific Activity Mo-99
- Automated Package Monitoring system for radioactive consignments

**Labelled Compounds**

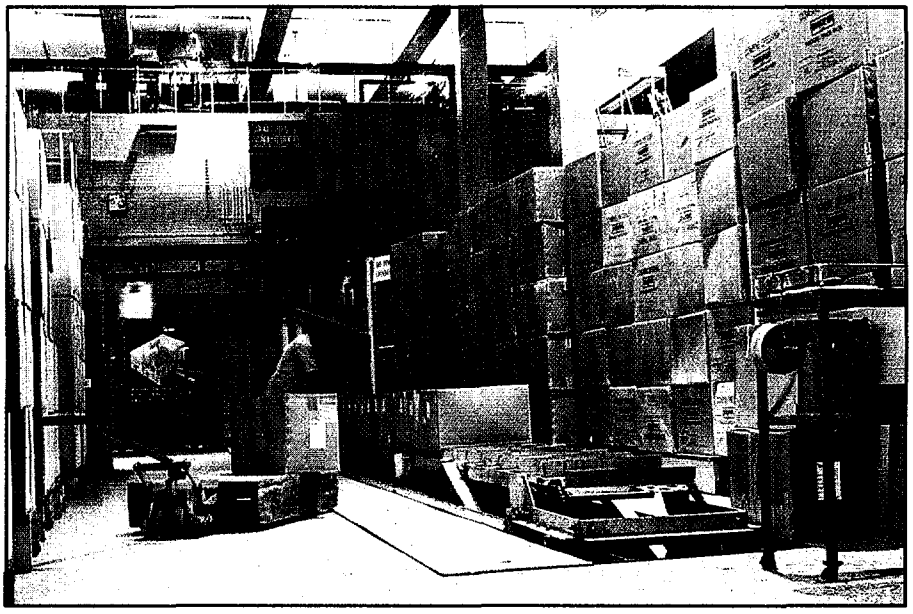
Over 900 consignments of carbon-14 and tritium labelled compounds and 1900 consignments of P-32, P-33 and S-35 labelled biomolecules were supplied to about 250 research institutions. The JONAKI laboratory at Hyderabad produced P-32 and P-33 labelled nucleotides on a regular basis, covering almost all the indigenous requirements of P-32 and P-33 labelled biomolecules for studies in molecular biology.

60 consignments of non-radio active ( cold ) kits for use in recombinant DNA technology were supplied. Custom synthesis of some important products for use in bio-medical research was also undertaken.

Oligonucleotides ( DNA primers ) of varying sequences and concentrations, as per researchers' requests, have been custom synthesized and supplied. Realising the importance of non-radioactive kits for molecular biology research, JONAKI laboratory is taking up R & D work in the areas related to non-radioactive kits.

**Radiation Sterilization**

After completing over 25 years of successful operation and enabling acceptance of "Radiation Processing" as a reliable technique for sterilization of medical disposable products, ISOMED, the first radiation sterilization plant in the country, continued to offer irradiation services to health care sector with an impressive growth. The plant availability factor was maintained at more than 90% and the capacity factor was also above 85%. Approx. 10,000 cu. meters ( 1,16,000 cartons ) of medical products such as dressings, disposable infusion and transfusion sets, surgical sutures, gloves and a number of other medical devices were sterilized at the plant during the year. A number of cartons containing surgical sutures, latex gloves, ayurvedic products, herbal extracts were radiation sterilized in ISOMED on behalf of user industries for export.



*ISOMED Plant, at Trombay*

During the year, ISOMED sterilized large consignments of Dai kits (midwifery kits ) and delivery packs for the benefit of women and child population in rural areas to help bring down infection of mothers and help minimize the infant mortality. A few milllion dai kits were sterilized at ISOMED Plant during the year by different manufacturers for supply to rural heath programme funded by WHO.

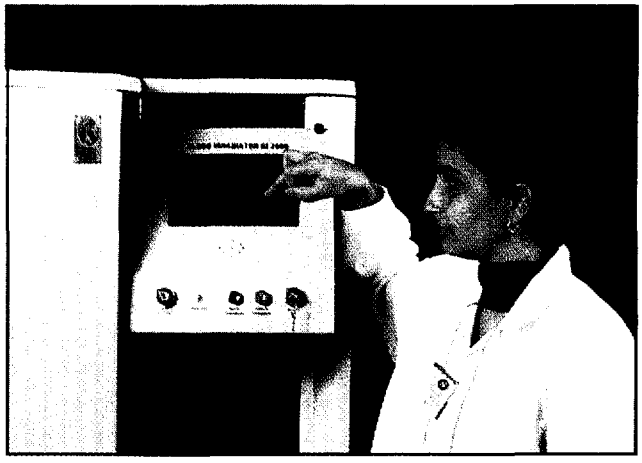
ISOMED also continued production and supply of items relevant to gamma radiation processing and health care programme such as ceric-cerous dosimeters, biological indicators, go-no-go irradiation indicator buttons, and disposable sterile drapes and trolley covers.

ISO 9002 certification process for ISOMED Services reached final stages of completion and the certification is expected to be achieved shortly. This will enable Isomed to provide standardized services to health care sector and better acceptance of ISOMED services in the international field.

**Radiation Equipment**

35 remotely operated radiography cameras Model ROLI-1 were supplied to industrial users for use in non-

*Blood Irradiator-2000*



destructive testing. Servicing of ROLI cameras prior to source replacement and mandatory checks, as recommended by Radiological Physics & Advisory Division, BARC, were carried out on all cameras .

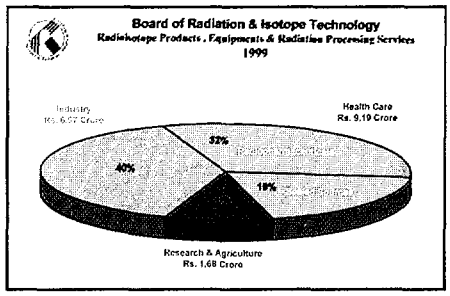
The design of the main components of a light weight, portable, depleted uranium shielded remotely operated camera was completed and the procurement for obtaining these items for 100 units as per BRIT design was in progress. The camera will have capacity to hold upto 2.8 TBq ( 75 curies ) of iridium-192. There is a long felt demand of the industry for an indigenous light weight gamma radiography camera.

Four Gamma Chamber Units were refurbished and replenished with fresh cobalt-60 source. The PANBIT facility at Shree Chitra Thirunal Institute of Medical Sciences, Thiruvananthapuram, was refurbished and loaded with about 3.33 PBq ( 90 kilocuries ) of cobalt-60 source.

Irradiation of blood and blood products by gamma rays is a good technique to reduce the risk of transfusion associated graft verses host disease ( TA-GVHD). The design of a blood irradiator ( BI 2000 ) using cobalt-60 source was completed. An advanced prototype unit is under fabrication. The unit will be ideally suited for use in the blood banks all over the country. Necessary type approval of the Blood Irradiator Unit for its use and transportation as a Type B (U) package was obtained from AERB. Action was initiated for the fabrication of the first lot of 10 nos. of blood irradiator unit.

**Sales Turnover**

During the calendar year 1999, more than 50,000 consignments of radioisotope products valued at Rs. 17.84 crore were supplied for use in industry, research, agriculture and health care.




Radioisotope products and equipment valued about Rs. 1.5 crore were exported to countries such as United Kingdom, Germany, Sri Lanka, Syria, Myanmar, Bangladesh and Tanzania.

**Capital Projects and Schemes**

*National Medical Cyclotron Facility, Hyderabad*

Under IX Plan, BRIT has initiated a project for setting up the National Medical Cyclotron Facility in the campus of Nizam's Inst. of Medical Sciences, Hyderabad, for production of entire range of cyclotron based isotopes. The DAE Review Committee on Radioisotopes and Radiation Applications recommended setting up a 19 MeV Cyclotron. Final decision and financial sanction are awaited.

*Demonstration Plant for Radiation Processing of Spices*

The Commercial Demonstration Plant for Radiation Processing of Spices, a project under VIII Plan, was complete in all respects . Requisite regulatory clearance from AERB and from Maharashtra State Drug & Food Administration and the Licence from the Competent Authority for regular processing of spices in the plant were obtained.

The plant is now ready for commercial demonstration and regular processing of spices in this plant has commenced. The plant, designed for a maximum capacity of 1000 kilocuries of cobalt-60 source, has been loaded with 100 kilocurie cobalt-60 source which will be gradually increased to its full capacity after obtaining requisite clearance from AERB.

*Augmentation of Cobalt-60 handling facility at RAPPCOF, Kota*

To process larger quantities of cobalt-60 which are now produced from various power reactors, and also to meet the increasing demand for Co-60 sources for use in industry and medicine,and to cater to export orders, the RAPPCOF facility at Kota was under augmentation.

Detailed drawings were prepared and various machinery items were procured. Project Implementation Committee was set up and action was initiated for timely procurement and installation of the necessary equipment.

*Augmentation of Radiochemical Laboratories at Radiological Labs., BARC*

The project intends to replace the existing radiochemical processing plant. The augmentation will facilitate processing of higher levels of activities of radioisotopes such as Mo-99, I-131, P-32 and miscellaneous isotopes with lower radiation exposure to the operators and will also enable BRIT to meet the increasing demand for these radioisotope products. Action has already been initiated for the procurement of hot cell equipment and other associated materials.

*Column Type Tc-99m Generator Production Assembly*

Under this Project, it is proposed to set up a facility for production of user friendly Tc-99m column generators which would facilitate handling of large levels of activity and aseptic handling facilities for ensuring pharmaceutical safety, apart from increasing the number of patients who could be benefited.

The Conveyor system was under installation. Setting up of the assembly

line for the production of generator is expected to be completed shortly.

*Design,Development of Radiation Equipment and Test Facility*

There is a great demand for improved versions of radiation equipment such as DU shielded lightweight radiography camera, blood irradiator etc. In addition, with the availability of large quantity of cobalt-60 from power reactors, there is a need to fabricate transport containers for the safe transport of large quantities of cobalt-60 sources used in radiation processing plants. All these equipment and containers need to be tested to demonstrate their compliance with relevant IAEA/AERB regulations. Currently, neither BRIT nor any DAE Unit possess testing facility for equipment/flasks. The total financial outlay for the project is Rs. 8.5 crore . This facility will be utilized for the development and supply of low cost blood irradiators containing cobalt-60 source to various hospitals throughout the country and also for the development of light weight, portable gamma radiography exposure device with depleted uranium shielding meeting with all the requirements of ISO 3999.

**International Relations**

Two scientists from BRIT visited Atomic Energy Research Establishment, Dhaka, Bangladesh, in connection with the execution of the order received for the supply, installation, and commissioning of 50 kilocurie cobalt-60 gamma irradiation plant at the Institute of Food and Radiation Biology, Dhaka.

One scientist from BRIT visited Saudi Arabia in connection with a quotation for supply of 300 kilocurie cobalt-60 source to the gamma irradiation plant at Saudi Arabia. IAEA- Regional Expert workshop on Quality Assurance in Cobalt-60 Brachytherapy source Production was organized by BRIT during November-December 1999 which was attended by participants from Japan, China and India.

## CENTRE FOR COMPOSITIONAL CHARACTERIZATION FOR MATERIALS

**Bulk Analysis**

The Centre continued to provide specialized analytical services to various organizations in addition to developing newer analytical methodologies through R&D work. Following were the activities of the Centre during the year of report:

A method for analysis was developed, using a combination of techniques, for determination of impurities in quartz at ppm and lower levels. Also, a chemical leaching procedure was standardized for purification of raw quartz, which resulted in a reduction in the levels of various impurities present in quartz.

Boron, a crucial trace element, is lost as boron trifluoride in dissolution using hydrofluoric acid. A method was developed which helped in the establishment of an indigenous facility in private sector, for the production of high purity quartz.

Methods were developed for the accurate determination of barium and titanium in the cereamic sample and the stoichiometry of germanium and selenium in germanium selanide.

Two colour photoionisation schemes for selective excitation of odd isotopes of gadolinium was studied. Five photoionisation schemes were identified in the Rhodamine-6G dye laser region, for carrying out selective excitation of odd isotopes of gadolinium. Experimental and theoretical (Spectral simulation) abundances of odd Gd isotopes in the two color resonant photoionisation schemes were compared which were in good agreement. Efficiency of the new photoionisation schemes were also studied.

To have a greater understanding of the resonant laser ablation technique and its applicability to elemental analysis at ultratrace levels, preliminary experiments were carried out. A study related to the tuning of dye laser to two-photon resonance transition of silicon. The laser repetition frequency was found to play a role on the ion yield.

**Ultra Trace Analysis**

A novel sample introduction method for the analysis of naphtha was developed, which considerably reduced the solvent loading in the plasma. Studies on the effect of refractory element coatings on the graphite platforms used in GFAAS revealed that the formation of the refractory carbides improved the sensitivity of some easily volatilized elements besides improving the life time of the tubes. Determination of In and Sn in Gallium metal samples were carried out using this approach.

Analytical methods for multi-element trace characterization of materials used in electronic industry, Cd, As, As2O3 and Sb were developed. Approaches using ICP-MS required development of matrix separation methods based on ion exchange, volatilization and solvent extraction. Direct analyses of these materials were also carried out to provide cross validation, and analysis of materials up to purity levels of 6N could be carried out routinely.

Trace impurity determinations of several 7N purity tellurium samples were carried out, using a combination of ICP-MS and GFAAS. An isotope dilution ICP-MS method was investigated for the ultra-trace level determination of boron in high purity quartz samples. Investigations on the application of Glow Discharge Mass Spectrometry for trace impurity character-

ization of ceramic samples are in progress.

Porous silicon layers prepared by electrochemical anodisation of Silicon wafers in HF based medium were investigated. P-type Si(111) wafers were anodised in solutions consisting of HF and methanol mixed in different proportions. The composition of the resultant layers on silicon was studied by ion beam analysis involving Nuclear Resonance Reaction Analysis and Backscattering Spectrometry.

In an investigation of analysis in oxide and carbonate matrices containing elements like Ca,Mg,Ce,Zr etc, a discrepancy in the values of fluorine was observed. Studies made attributed this discrepancy to gamma rays from the matrix elements in addition to flourine. Thick target yields of prompt gamma rays of 110 and 279 keV from arsenic, were determined. Depth distribution of fluorine was investigated in several HDPE bottles used in packaging industry. These bottles were fluorinated to modify their surfaces to enhance their solvent barrier properties. Graphite electrodes used in fluorine generation by electrolysis, were studied for their surface composition.

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*Continued from page 4.4*

last 4 years, with concomitant effective process control in the plant, enhanced the life of reactors by nearly 100%, with corresponding assurance of process safety and reduction of production cost. The expertise was also extended for qualification of fabrication of special high temperature reactors for titanium sponge production in 400 kg batch size at DMRL.

The NDT expertise involving eddy current and ultrasonic testing had been employed for the in-service inspection of heat exchangers at Kota and Manuguru Heavy Water Plants. Techniques were developed for indigenous manufacture of Eddy Current Probes for special applications and ISI carried out on the synthesis loop waste heat boiler of National Fertilisers at Guna. With an in-house design of Eddy Current coil, thermal sleeves of Indian Space Research Organisation were evaluated and qualified.

To cater to the highest fuel production, the Control Laboratory was carried out chemical analysis of 33,500 samples involving 2,21,000 estimations. Upgradation and development of new analytical techniques continued to cater to new types of matrices as well as to change over from manual to automated instrumental methods of analysis. The Laboratory has played a major role this year in carrying out Inter-laboratory comparison of ICP-AES estimation of impurities in uranium, with a view to harmonise the techniques of all the laboratories of Department of Atomic Energy. These experiments enabled certification of two standards of uranium oxide powder samples. A comprehensive Manual of Laboratory Methods for analysis of zirconium, uranium, stainless steel and other special materials were prepared, which would serve as Reference Document for ISO-9002 and NAB Certification.

**Health, Safety & Environment**

The industrial safety record of NFC remained very good. The Fuel and Tubes groups completed more than 4 million accident free man hours. Two major seminars organised included Risk Assessment and Health Hazards and Role of Trade Union in Safety and an Awareness programme on Criticality Safety for the NFC officers and supervisors.

# 5.0 SERVICE ORGANISATIONS

This Chapter describes the activities of the Service Organisations of DAE namely the Directorate of Purchase & Stores (DPS), Directorate of Construction, Services & Estate Management (DCS&EM) and General Services Organisation (GSO).

## 5.1 DIRECTORATE OF PURCHASE AND STORES

The Directorate of Purchase and Stores (DPS) and its Units provided material management support to the constituent organisations of DAE by way of purchases, receipt, issue, accounting, safe-custody and disposal of stores.

After computerisation of materials management activities of Central Stores Unit, BARC, work was taken up to provide on-line computer network for the Local Purchase Section of DPS. This work was successfully executed during the year. This resulted in speedier processing of small value indents.

The Technical Liaison Mission, Paris undertook the quality surveillance and inspection of the items against purchase contracts placed by DPS; sourcing/ expediting of supplies, quality assurance activities, locating and evaluating alternate source of supplies of critical and strategic materials etc, and assistance for collecting technical information and public relation support for delegates visiting on nuclear programmes.

Bilateral cooperation agreements in scientifically and technologically relevant areas for DAE programmes, were planned. Interactions were carried out with French Government and major industrial establishments involved in science and advanced technology fields.

High Level contacts were organised between India and France in the field of R&D, Technology, Regulatory aspects etc. Technical discussions during visits of senior officials were organised. Agreement for cooperation between India and France for Directorate level implementation was issued by the French Atomic Energy Commission on Waste Minimisation and Management. This document is under review by DAE.

A protocol agreement between AERB, and the Directorate of Nuclear Installation Safety, France was signed by the Chairmen of both French and Indian Regulatory Boards. As a follow up, an Indian delegation of AERB held technical discussions with French Professionals on Nuclear Security. They also participated in the emergency exercises organised at Paris.

*Work quantum handled by the Directorate of Purchase & Stores during the year of report*

| | | |
|---|---|---|
| Indents handled | : | 34600 Nos. |
| Purchase Orders placed | : | 32900 Nos. |
| Stores Transactions | : | 10.5 lakh |
| Value of purchase made | : | Rs. 499 crore. |
| Quantum of revenue realised by disposing scrap /unserviceable items( in 1999) | : | Rs. 1.89 crore |

*( Figures have been rounded off)*

DPS held price negotiations with the Trade and Industries which resulted in a saving of approx. Rs. 14.22 crore (1/4/99 to 31/12/99) and helped in concluding contracts with terms and conditions more advantageous to the Department.

## 5.2 DIRECTORATE OF CONSTRUCTION, SERVICES & ESTATE MANAGEMENT

Directorate of Construction, Services & Estate Management is responsible for the planning, design, engineering, execution, testing & commissioning of civil, public health, electrical, air-conditioning & ventilation works for housing, hostels, schools, hospitals, laboratories & various public buildings for various units of DAE including aided institutions and other departments of the Government. In addition, this Directorate is responsible for the operation and maintenance of all electrical, mechanical, civil, estate management and security services for the housing colonies of DAE at Mumbai. DCSEM also carries out upgradation of infrastructure facilities & energy conservation for their services.


*100 flats of Type III-C in the Western Sector of Anushaktinagar*

It is also responsible for various construction activities in Mumbai on behalf of BARC.

During the year of report, 104 flats of type II-B at Anushaktinagar were completed. Scheme worth Rs.70 crore to be completed at various sites of DAE establishments include projects at Trombay.

During 2000-2001, DCS&EM propose to execute construction schemes worth Rs.100 crore including projects at Trombay Township worth Rs.30 crore. In addition, a proposal to acquire 508 ready-built flats and other common facilities from Air India worth Rs.50 crore is under consideration by the Department due to limited area for additional Housing and related infrastructure facilities at Anushaktinagar.

Engineering Services Division - I & II of this Directorate maintained residential flats (8206) and public buildings which are of minor capital in nature. This Division is also responsible for the operation and maintenance of electrical power distribution, lifts, water supply distribution, sewer lines and sewage treatment plant and energy conservation of the services in the large township at Anushaktinagar.

The Estate management continued to manage the DAE estate and allotment of residential flats (8206), shops including public buildings and the security for the DAE Estate in Mumbai.

## 5.3 GENERAL SERVICES ORGANISATION

The General Services Organisation (GSO) looks after various common services such as estate management, transport, civil and electrical construction as well as maintenance, water supply, auto garage, hospital and other amenities in the DAE township at Kalpakkam. Services and facilities managed by GSO during the year in brief are as under :-

**Estate Management**

Allotment of residential quarters, shops and allied matters, Guest House, Hostels, Liaison with State Government and Local Authorities were looked after.

**Electrical Construction Works**

Laying of jelly filled communication cable was carried out to improve the inter communication system. Internal electrification of some residential quarters at DAE Township and Medical enclave, erection of a substation for emergency power supply continued.

The Civil and Electrical Maintenance works of all quarters /public buildings /sewage treatment plants etc. were carried out satisfactorily. Improvement of electrical distribution system in row type quarters and strengthening of street lighting system made progress.

DAE Hospital continued to provide medical facilities to about 25,000 CHSS beneficiaries. It was equipped with modern facilities, and expansion of its Out- Patient Department continued.

Transport facility operated smoothly and serviced commuting employees. For improving transport operations, preventive maintenance was implemented.

At Anupuram about 350 houses reached advanced stage of construction.

# 6.0 AIDED INSTITUTIONS

**For promotion of research in the frontier areas of nuclear science, mathematics and cancer, DAE provides grants-in-aid to seven Institutions. It also provides grant-in-aid to a society which is engaged in providing education to the employees of DAE.**

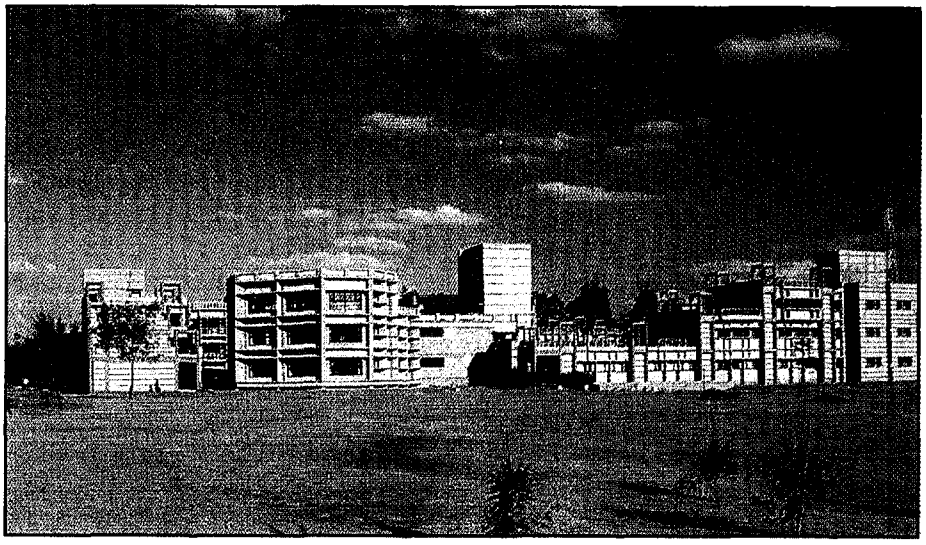
**This Section covers activities of these organisations.**

## 6.1 TATA INSTITUTE OF FUNDAMENTAL RESEARCH

The Institute's academic programmes are divided into three Schools: School of Mathematics, School of Natural Sciences and School of Technology & Computer Science. The academic programmes are backed by the state-of-the-art common research facilities.

The **School of Mathematics** continued to make impressive contributions to a variety of fields. An International Colloquium on "Algebra, Arithmetic and Geometry" was organised in January 2000.

The **School of Natural Sciences** is composed of several departments. In the *Department of Theoretical Physics* research continued in various areas of high energy physics, mathematical physics, condensed matter physics and foundations of quantum mechanics along with the upgradation, augmentation and diversification of the computational facilities. In the *Department of Astronomy & Astrophysics* studies in far infrared astronomy continued with the 1 metre balloon-borne TIFR telescope with high resolution spectroscopy. In the hard x-ray band of 20-200 KeV observations were made using Large Area Scintillation Telescope. Phase A studies were completed for the future multi wavelength X-ray Astronomy Satellite. In the *Department of High Energy Physics* studies based on electron-positron collisions and proton-antiproton collisions continued and progress was made in the cosmic ray experiments ant Ooty and Pachmarhi. The sensitivity of its torsion balances was improved by operating them at cryogenic temperatures (about 4° K). Development, fabrication and testing of new detectors for the CMS collaboration experiment for the Large Hadron Collider (LHC) continued. In the *Department of Nuclear & Atomic Physics* exclusive studies were made of high energy gamma rays as a function of angular momentum in rare earth region. The nonlinear optical properties of organic molecules on femtosecond time scale were examined and the relaxation process was studied. Experiments were conducted in molecular dynamics, ultrafast phenomena and light & x-ray production in intense laser fields. In the *Department of Condensed Matter Physics & Materials Science* identification was made of generic features of magnetic phase diagram of the vortex states in superconductors. Magnetic and magneto-transport studies in CMR oxide systems as well as on intermetallic compounds were carried out. A 12 tesla magnet system for high field magneto-transport measurements was set up. Nanocrystalline oxides were synthesised and their optical and transport properties were studied. Low dimension semiconductor structures were synthesised and their electrical and optical properties were studied. Microwave transmission in high $T_c$ Superconductors, especially Ag-doped and Au-doped YBCO



*Overall view of the Academic Block of the Institute of Molecular Biology at Bangalore*

films, at high magnetic fields at cryogenic temperatures was studied. In the *Department of Chemical Sciences* Structural, kinetic and mechanistic studies on the interaction of substrates with cytochrome P450 and oxidases were carried out. A multiphoton fluorescence correlation spectrometer for studying protein dynamics, experimental setup for quantitative measurement of TPF and SHG of organic dyes and dye aggregates, and rudimentary FT-EPR were set up. In the *Department of Biological Sciences* Genetic analysis of function and development of the nervous system in *Drosophila* was studied. Studies were made on the regionalisation of the vertebrate brain using genetic and molecular methods in mouse. Structure function analysis of receptors, G-proteins and enzymes and studies on role of signaling in plants was carried out. Molecular analysis of DNA dynamics in repair and recombination, regulation of sugar metabolism in yeast, characterisation of protective proteins during infection with the malarial parasite, structure and functions of Oncogenes and ion/water transport across cellular and artificial membranes were some of the areas of investigations. *Epidemiology and Dental Research Unit* continued the follow up study of 1,60,000 persons cohort in Mumbai and analyzed the data for the mortality rates according to tobacco use status.

At the *National Centre for Radio Astrophysics, Pune* real time diagnostics and continuum imaging with fully operational GMRT was achieved. GMRT electronics and computational facilities were improved. Observation was made of 21 cm hydrogen line at different redshifts over a wide range of frequencies. At the *Homi Bhabha Centre for Science Education, Mumbai* books (textbook, workbook, teacher book) for class V (Science) and class III (mathematics) were brought out. A comprehensive manual on Homi Bhabha Laboratory was prepared. Development of Audiovisual versions of materials was taken up. At the *National Centre for Biological Sciences, Bangalore* the Animal House was constructed and other buildings of the new campus were completed. Studies of topics in Structural and Cell Biology, Biology of Disease, Molecular and Systems Neuroscience, Developmental Biology and Genetics were made.

At the Pelletron the full resister grading system was installed. terminal charge state selector was developed and phase pickup system was completed. For the LINAC the closed cycle liquid He refrigerator was commissioned and three superconducting modules were installed.

In the **School of Technology and Computer Science** the theories/tools developed for reactive programming for hardware/software codesign were adapted and embedded systems were specified & designed. In the area of Computational Mathematics, efficient implementation of software packages for scientific computation was investigated. Studies were made in the design of web-scripting languages and authentication of protocols used for electronic commerce. A system for telepresence and Robot-motion planning algorithms were developed.

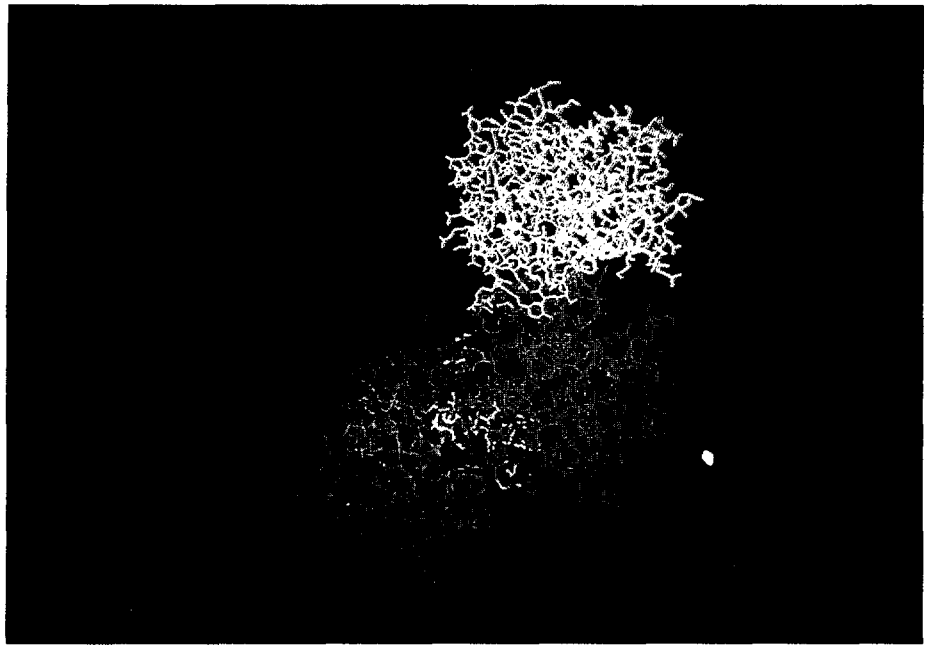
## 6.2 SAHA INSTITUTE OF NUCLEAR PHYSICS

Saha Institute of Nuclear Physics, entering its Golden Jubilee year on January 11, 2000, made impressive strides in research and developments in physical and biophysical sciences. It published about 200 original papers in national and international journals. The traditional Post-MSc Teaching Programme was continued as before. Weekly Colloquia and seminars on topical issues were held regularly. An Experimental High Energy laboratory, housing the Muon Arm Project (MAP), was created to further the CERN-India collaboration in ALICE (A Large Ion Collider Experiment). A new Canteen Complex, to operate from January 11, 2000, has been added to the Campus.

Following is the report as to the progress made in various disciplines vis-a-vis the targets set for the year in question.

In nuclear science, the prime question has been how to maximally utilise the available accelerator facilities. A two-prong handling was decided. On the one hand, the excited state properties of several nuclei in the mass region A ~ 70-80, 100 were ascertained and structure of near-spherical molybdenum isotopes were studied to detect the onset of nuclear structure deformation in the mass region A~100. The proton and neutron configurations of odd-mass and odd-odd bromine nuclei at different excitation energies etc. were also ascertained through heavy ion reactions at NSC. In a similar reaction of oxygen with molybdenum, the fusion excitation function was measured to assess nuclear structure dependence of the sub-barrier fusion reactions. Studies were also made to understand the mechanisms involved in the emission of light particles in heavy ion reactions. Interactions of exotic radioactive nuclei with the hydrogen nucleus have been studied. More experiments, particularly with a radio-active isotope of beryllium, at NSC are on the cards. Theoretical studies on nuclear reaction mechanisms will be continued.

On the other hand, various detection accessories had to be devised. To this end, a multi-detector stand was both designed and fabricated to incorporate gamma detectors for the Heavy Ion Beam experiments at the Variable Energy Cyclotron Centre, Calcutta (VECC), a detector set-up was created for measuring life-times of exotic nuclei which will be tested and installed



*The binding of two chymotrypsin molecules at the reactive site of the inhibitor (blue)*

at Radio-active Ion Beam (RIB) facilities in RIKEN, Japan, and RFQ and pre-buncher systems were evolved for the VECC-SINP RIB facilities. A gamma-detector array with provision for mounting upto six clover- and six high-purity germanium- detectors, as also a large sodium iodide (thallium activated) detector for isomer-tagged gamma ray spectroscopy at VECC are being assembled. Development studies relating the resistive read-out method in low-pressure gas detectors are being continued. A Bent Crystal Spectrometer for high-resolution atomic physics work is in the pipe-line.

In the field of applied nuclear physics, helium bubble formation around dislocations in implanted aluminium was studied and the growth characteristics were analysed from the measured positron lifetimes. The low-temperature properties of the bubbles are presently being investigated. Positron annihilation studies of niobium and silver nano-particles were carried out and the anomalous increase of free volume at the interfaces with decreasing particle size was verified. Work is continuing on positronium confinement in liquids in the "Bubble Model" framework with several interesting results.

In nuclear and radio-chemistry, the programme of production and separation of medically important carrier-free radionuclides of Lanthanide and Third Transition Series Elements was pursued exploiting the BARC-TIFR Pelletron and the indigenously developed ECR Ion Source at VECC.

As a party to the CERN-India collaboration in ALICE, the Electronic Science Group of SINP indigenously designed a VLSI chip, MANAS, to help measure the charge accumulated in the detectors in the MAP. Approved by the international Committee, this chip is to be delivered by a foundry-based Corporation at Chandigarh by March, 2000. A novel optoelectronic technique for ultra-accurate measurement of micron and sub-micron thickness of transparent sheets has been set up. A preliminary set-up for birefringence measurement, complete with a CCD Camera, is under way. In collaboration with Dr B C Roy Centre for Neuroscience, Calcutta, the group has also designed, fabricated and delivered a solid state 550 MHz microwave source complete with a radiator and a radiation chamber. This will help investigate effect of microwaves on release of neuro-transmitters in animals. A binary adder utilising novel properties of DNA is designed to effect miniaturization of information processing.

In Plasma Physics, significant progress was made as to the diagnostics development. Electron Cyclotron Emission Radiometer, now successfully installed, is being used to measure plasma temperature. Feedback Control System for the plasma position is nearing completion. A hard X-ray Analyser for the Tokamak is being developed. A launcher system for the lower hybrid current drive is being procured to initiate experiments by the mid-2000. Several useful experiments, like, Electrode Bias Experiment and those on the runaway electrons were carried out using the Tokamak with several interesting results. Side by side, theoretical work was also carried out with magnetohydrodynamics relaxation and wave propagation in plasma.

The Theory Group made several notable advances relating necleon-nucleon interaction, properties of nuclear matter at high excitation including onset of chaos, nuclear liquid-gas phase transition, transformation of baryonic matter into quark-gluon plasma, etc. In nuclear astrophysics, solar neutrino puzzle, supernova neutrino oscillations, oddities about neutron stars under ultra-high magnetic fields, effects of R-parity violation on direct CP violation in in B-decays, neutrino mass and magnetic moment in super-symmetric models without R-parity, cosmology of the early universe, cosmological evolution during the inflationary epoch, thermodynamics of anti-de Sitter Black Holes and charged multi-Black Holes etc. were investigated. Significant progress was made in Quantum Chromodynamics from

the light-front approach. Solutions for quasi-two and three-dimensional quantum spin models and phase diagram for t-J ladder model were exactly found with a view to understanding high-temperature superconductivity. Quantum integrable models including nonlinearity, relevant to optical communications and soliton formation, were also studied.

The target for the year 1999-2000 in condensed matter physics envisaged on the one hand to build up facilities for preparing and characterising novel materials, and on the other, to carry out work with the facilities already installed. Some equipment for surface and interface studies have been acquired and are in the process of installation. Development work relating spectroscopic studies, ion optics, upgradation of NMR Spectrometer etc. have been initiated with satisfactory progress. In basic research, a few single crystals of metallic oxides have been grown and their properties studied. Progress was made with synthesis of metal and alloy nano-particles of technological importance. Fabrication of multilayered with advanced techniques is progressing well. Substantial advances has been made in the area of growing organic films using the Langmuir-Blodgett technique. The SIMS Facility, installed recently, will help gain on the understanding of the growth of metallic multilayers. In polymer science, transport properties of polypyrrole-ferric oxide nano-composites were investigated, and non-linear conduction properties of polyaniline and EMI shielding efficiency of polyaniline-poly(vinyl alcohol) composite were explored. Side by side, theoretical studies were successfully carried out in magnetism, heavy-fermion systems, strongly correlated electron systems, transport phenomena etc. Next year, it is proposed to procure a Liquid Helium Plant, a Transmission Electron Microscope with Energy Dispersive X-ray (EDX) facility for characterising the nano-meter-sized materials. Main effort in the spectroscopic units will be to set up a mm wave spectrometer for studying properties of materials in their vapour phase. Nuclear Magnetic Resonance Group will devote concentrated efforts in upgrading the facilities including setting up of a spectrometer to reach out to the domain of magnetically ordered state. Transport properties will be investigated in Superconducting and Giant Magneto-resistance systems. In surface studies major thrust will be put on understanding the growth mechanism of both organic and metallic multilayer systems grown here.

In Biophysical Science, in respect of the project titled "Structure Function Correlation of Biomolecules at the Cellular and Molecular Levels", the sequencing of the structure of thiol proteases and WCTI was successfully carried out, and site-directed mutagenesis, expression and structural studies of WCI have been undertaken. Beside this, structural studies of other pharmacologically important molecules have been taken up. Recombinant vector for cancer therapy and genetic disorder, like hemophilia, now designed and constructed, are undergoing tests. Genome analysis of huntingtin gene and muotonin protein kinase gene responsible for neurological disorders is being carried out. Chinese hamster homolgue of two mitochondrial gene fragments were isolated from radiation-resistant cells. A classification scheme was worked out for cellular membrane clusters by microscopic image processing. Spectroscopic studies to understand the nature of interactions in the spectrin-based cytoskeletal network, those of other biologically important molecules, and studies on transcription initiation with the bacteriphase T7 RNA polymerase are in progress. Experiments on intra-cellular calcium changes in cell populations were done and environmental stress-induced signalling pathways explored. Plan for the next year envisages continuation of those works in progress. Also, attempts will be made to crystallize proteins from disease-causing viruses, to effect DNA anlysis of the huntingtin gene and myotonin protein kinase gene and other linked loci among normal individuals to trace the origin of mutation. Chromosomal analysis by banding and chromosome painting, and image processing studies on cyto-skeletal shells and protein aggregates etc. will be initiated.

In radiation- and photochemistry, electron transfer reactions between nucleic acids and nitroxides were investigated by steady-state and pulse radiolysis, and their redox potentials determined by cyclic voltametry. Chemical and magneto-kinetic studies on photo-induced electron transfer reactions were pursued with laser-flash photolysis. PH- and urea-induced denaturation of blood coagulation protein, prothrombin, were investigated. Effect of protein denaturants on the stability of microemulsions has been studied using light scattering. Molecular mechanism of nonsteroidal anti-imflammatory drug interactions was spectro-scopically explored.

The Institute is currently engaged in a few national and international collaborative programmes, the important ones being a) SINP-VECC Projects in (i) RIB and (ii) Superconducting Cyclotron; b) CERN-India Collaboration in ALICE; c) Crystallography, Molecular Biology and Structural Biology Programmes funded by the Dept of Bio-Technology.

## 6.3 TATA MEMORIAL CENTRE

The Tata Memorial Centre (TMC), which comprises Tata Memorial Hospital (TMH) and Cancer Research Institute (CRI), continued its activities in diagnosis, treatment and research in cancer as well as in training and education. Following were some of the major activities and achievements of the Centre during the period of this report:

### 6.3.1 TATA MEMORIAL HOSPITAL

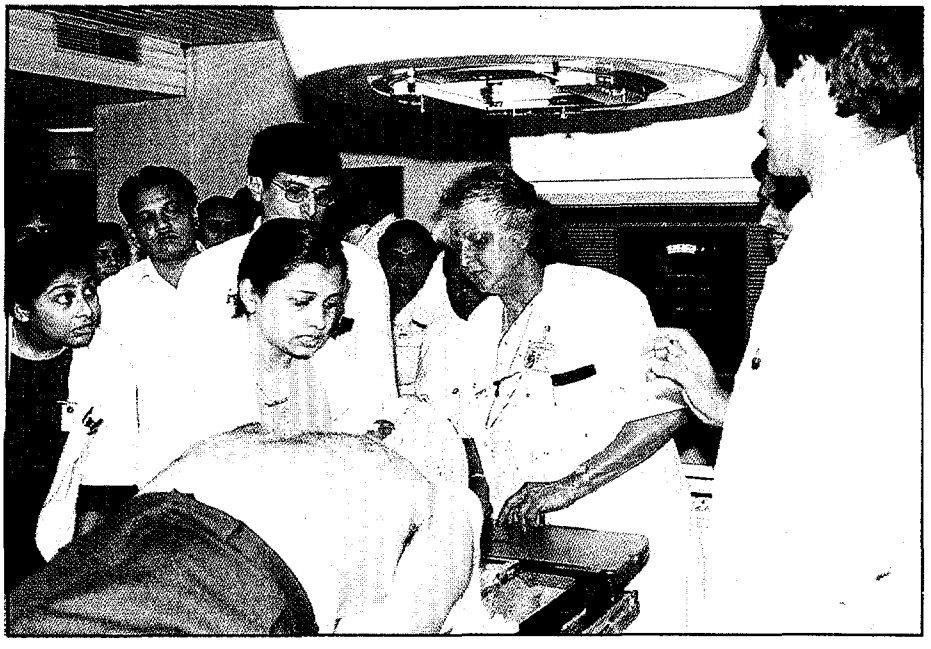
The Planning Commission in recognition of dedication and service of TMH, approved a special grant of Rs. 25.00 crore in 1998-99 and Rs. 5.00 crore in 1999-2000 for upgradation/ modernisation of the facilities at TMH. This was utilised for installation of major equipment such as the Magnetic Resonance Imaging, X-Ray machines, Mammography, Orthopantograph X-ray and Ultrasonography machines. A Linear Accelerator was also installed and commissioned for radiation therapy. A Hydroclave Waste Management Facility commenced functioning. The funds were also utilised to augment the Kitchen with modern equipment, renovate and augment Central Sterilisation and Supply Department with 4 state-of-the art Sterilizers etc., and to augment the airconditioning systems for the diagnostic and treatment areas as well as part of the Wards. Major renovation was undertaken in all the Wards, Rooms Patient Clinics for Physiotherapy and Occupational Therapy, Stoma Clinic, Purchase and Stores and Security Department, Dispensary and Laundry. Renovation of Operating Rooms to the state-of-art level made progress. A new Digital Library is being set up.

The Centre, had performed for the first time in India, placement of an expandable metallic colon stent for palliation of colon cancer, placement of double stent for tracheo-esophageal fistula in collaboration with thoracic service, and Endoscopic Ultrasound guided Fine Needle Aspiration of pancreatic and mediastinal tumours. The Centre, had developed biaxial hip joint which enables the patients to squat, sit cross legged, ride a bicycle and walk unaided on uneven terrain. The trials on the joint with amputee patients were successful.

A grant was given by the Bill and Melinda Gates Foundation through the International Agency for Research on Cancer of WHO for starting a collaborative project on "Cervical Cancer Prevention" with TMH Rural Cancer Project at Barshi. In view of the importance it gives to alleviation of cancer in rural population TMC continued its support to the project at Barshi. The First Rural Outreach programme for early diagnosis and treatment started by the Centre at Barshi continued by the Nargis Dutt Memorial Cancer Hospital (Aswini Cancer Research and Relief Society), Barshi with the support of the TMC.

The standard of patient care through higher standards in work ethics is being strengthened further. The Ethics Committee of the Tata Memorial Hospital, which also has outside expert members from medicine and law, critically evaluates the medical practices followed in the Hospital.

*Radiotherapy with Linear Accelerator: Therapy, Training & R&D are integrated at the Tata Memorial Hospital*



**Clinical Activities**

During the year, about 22,500 new cases were registered. In addition, over 7550 Referral Cards were issued for investigations such as Mammography, Pathology etc. as shown in the Table :

**Table**

| Lab. investigations/ Clinical activities | 1999-2000 |
|---|---|
| No. of patients registered | 22,446 |
| No. of Admissions | 11,463 |
| Pathological Investigations | 7,94,901 |
| Microbiological investigations | 19,844 |

*continued*

| Lab. investigations/ Clinical activities | 1999-2000 |
|---|---|
| Transfusion Medicine | 1,79,598 |
| Endoscopy &Therapeutic Endoscopy | 2,400 |
| Radiological Investigations | 51,166 |
| Surgery | 8,951 |
| Radiotherapy & Medical Physics | 14,186 |
| Bone Marrow Transplantation | 30 |
| Anaesthesia | 22,427 |
| Physiotherapy | 4,657 |
| Occupational therapy | 2,542 |
| Speech Therapy | 2,199 |
| Stoma Care | 1,978 |
| New cases ( Preventive Oncology) registered | 3,285 |

**Beyond Therapy**

TMC established several mechanisms to help patients in many ways.

Guidance to as many as about 13300 new patients was provided. Chemotherapy drugs at concessional rate were given to over 4100 cases and Rail/Air/ST concession forms were issued to about 66,500 patients. Accommodation was arranged for about 3500 persons and transportation was provided to over 1900 cases. Guidance and Counselling were extended to several patients and relatives.

Nursing care was extending to indoor patients including *Day Care* wards. *After Completion of Therapy (ACT) Clinic*, initiated in 1991, continued to give psychological and rehabilitation support to patients. The patient clinics for *Physiotherapy, Occupational Therapy, Speech Therapy, Psychology* etc. extended support to the patients for improvement in the quality of life. The *Stoma Clinic* provided comprehensive care to patients with Stomas, Fistulas, Pressure sores, incontinence and wound healing problems.

**Cancer Prevention**

Thirty percent of the cancers can be prevented if the life-style is changed. This can have a large economic impact especially as seventy percent of the patients are treated free of cost by the Centre. Photo and poster exhibitions, lectures and audio visual shows on the ill effects of tobacco and Cancer Awareness programmes were arranged at schools, colleges as also for the general public. A special programme including radio talks on women's cancers with focus on Cervix cancer, was arranged and free cancer detection services for women including pap smear test were offered throughout March 1999. On 31st May 1999, which is World No Tobacco Day, public awareness programmes on Tobacco through TV, Radio and Anti-tobacco messages in Bus Shelter Hoarding, Movie Theatres etc. were arranged. An awareness campaign on breast cancer was conducted in the month of October, which is internationally recognised as 'Breast Cancer Awareness Month'.

**Modernisation & Support**

The Hospital remained involved in implementing an *"integrated & online" Information System* for Patient Administration. Over 150 Pentium PCs were installed and connected onto the campus-wide network. The network facility was also extended to a variety of medical equipment. The medical equipment network was planned for necessary network traffic isolation, and the software was modified suitably. Y2K compliance for variety of medical/scientific instruments was ensured.

During the ensuing year, it was planned to set up a modern state-of-the-art *Medical Digital Library* with *"Video Conferencing & Tele Medicine"* facility in the Hospital. The facility is aimed at providing campus-wide speedy and easy access to important information via electronic media and also to reach other hospitals/health care units for distant diagnosis, consultation and bilateral medical information exchange.

Under the *Clinical Research Programme*, TMC continued to assist clinical researchers in data management, data analysis and other aspects of research projects. TMH continued epidemiological studies in respect of Radiation Occupational Workers and their families at nuclear power stations sites in India under a research agreement with NPCIL. The Centre undertook epidemiological studies on gastro-intestinal tract cancers.

**Academic Activities**

TMH published 159 scientific papers in international and national journals of repute. Twenty conferences/ workshops/seminars/symposia were conducted, several international/national conferences/workshops/seminars/ symposia etc. were participated and 130 lectures were delivered.

TMH is a post-graduate teaching centre affiliated to the University of Mumbai, National Board of Examinations, New Delhi and Maharashtra University of Health Sciences, Nashik. Recently, permission was also granted by Ministry of Health & Family Welfare to start M.Ch and DM courses in TMH. During the year, 42 post-graduate students were registered and 54 students were awarded degrees/ diplomas.

The Scientific Review Committee reviewed and approved 19 new research projects. The research activities in other research projects were continued.

The Hospital is a recognised training Centre for cancer education and research by national and international organisations such as WHO, UICC and IAEA. four WHO/IAEA fellows were trained and under an ongoing programme on Continuing Education in Oncology, 53 trainees were registered for various courses.

### 6.3.2 CANCER RESEARCH INSTITUTE

The research work at the Cancer Research Institute (CRI) continued to focus on basic studies on cancers important to India. These studies covered a wide area from mutations in oncogenes and tumour suppressor genes in relation to pre-cancer and cancer, gene therapy of oral cancers, immune cells involved in destruction of tumours, and the association of human papilloma (HPV) and herpes virus (HHV) in cervical, oral and oesophageal cancers. Tobacco is a major risk factor for cancers in India. The cancer risk due to occupational exposure of workers in tobacco industry is indicated by environmental and biomonitoring, Chemo-prevention is being proposed as an important strategy for cancer control. In experimental studies, curcumin, a common ingredient of turmeric appears to show promise as a chemo-preventive agent.

*Head and Neck Cancers* : One of the major focus of research renamed the head and neck cancer the number one cancer in India. The aim is to define changes in oral pre-cancer and cancer for early diagnosis and prognosis Oral pre-cancers and cancers showed over expression and inactivation of p53 and APC. Pre-clinical studies on gene therapy of oral cancers showed a significant decrease in viable tumour volume.

Pan Masala and Gutkha are extensively consumed. Potential carcinogenic action of pan masala was shown by CRI. Studies were conducted relating to chemo-preventive activity of turmeric in chemically induced stomach cancers in mice, and glutathione transferase (GST) and CYP-450 gene loci in tobacco associated cancer patients.

*Cancer of the Cervix*: HPV-16 and 18 were detected in 82% of cervical cancer, 80% low grades squamous intraepithelial lesions and 14% normal scrapings. Experiments were carried to augment tumour specific immune response in cervical cancer patients.

*Familial Cancers* : Breast cancer in a small percentage of patients, show a familial pattern. Studies undertaken on patients and unaffected family members showed lower immune activity in unaffected individuals. Molecular typing of the patients and their families for HLA Class-1 alleles was taken up to see if particular type is associated with familial breast cancer.

*Leukemia / Lymphoma :* Leukemic cells in Chronic Myeloid Leukemia (CML) patients show defective function. The mechanism of these defects were under investigation. Lymphomas also form major group of cancers. Induction of cell death and the role of the various signals were studied.

Umbilical cord blood is an important source of stem cells which in future may replace bone marrow. Methods for collection, isolation and preservation of stem cells were standardised. Work was carried out to enrich these stem cells and multiply them in vitro.

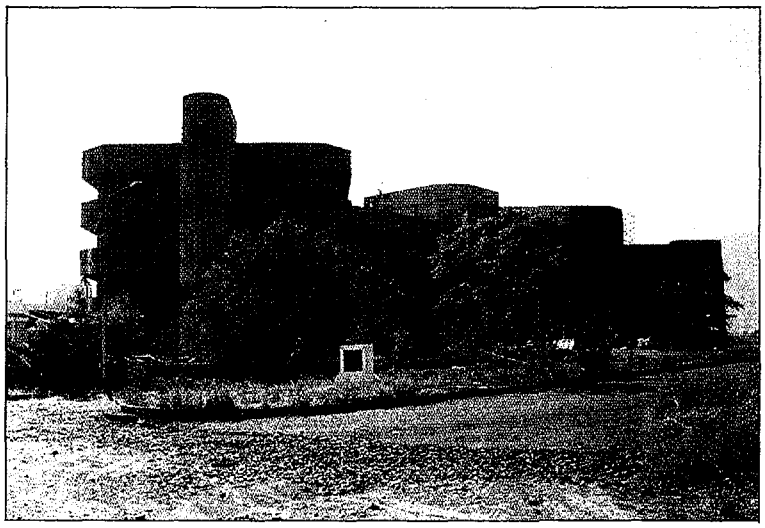
Effects of known drugs and green tea polyphenols were studied for their ability to inhibit secondary tumour growth." 4' dimethylepipodophyllotoxin" was synthesized by a new method and patent application was filed. Derivatives of this drug have been prepared for testing their anti-tumour activity.

*Studies of Viruses* : Human Herpes Virus (HHV-6) was detected in the plasma of 14 cases of bone marrow transplant. Chronic hepatitis B patients and patients with hepatocellular carcinomas (HCC) showed integration of hepatitis B virus (HBV) with truncated HB-X gene. Full length HBx DNA was seen in other patients. These observations may have a prognostic value.

### ACTREC Project

The Advanced Centre for Research, Treatment and Education in Cancer (ACTREC) being set up by the TMC

*CRI building for ACTREC at Taloja.*



at Owe Village, Navi Mumbai, will address to important issues relating to basic cancer research (as relevant to India), clinical cancer research and professional cancer education which can augment and improve standards of professional cancer care across the country.

Infrastructure for the Project was developed. Construction of the Research Centre Building, Animal House and Service Building was completed, construction of Ward Block reached completion and construction of Clinical Research Centre Building commenced. The 2nd phase of tree plantation has been completed.


## 6.4 MEHTA RESEARCH INSTITUTE OF MATHEMATICS & MATHEMATICAL SCIENCES

### Academic Activities

During the year under report, research work in Pure Mathematics covering number theory, algebraic, geometry, coding theory and analysis were continued. Similarly in theoretical physics, research work in Mathematical Physics, High Energy Physics, Condensed Matters and Astrophysics was continued. Lectures and Seminars were organised throughout the year to expose researchers in Mathematics /Theoretical Physics to the newer ideas and developments in various fields of these disciplines. A number of academicians from reputed institutes from within the country as well as abroad visited the Institute and collaborated their research work with the members of the Institute.

### Nurture & Contact Programme

The Institute conducted the third course under the Nurture & Contact Programme sponsored by NBHM, during the last summer, with guest speakers from Riwa University and Indian Statistical Institute, New Delhi, besides those of the faculty.

### Conferences/ Symposia

The Institute organised workshop on "String Theory" during October 18- November 18, 1999 in which 30 scientists from various parts of the country as well as abroad participated. Earlier, inaugural function of the Rajbhasha Golden Jubilee year was also celebrated on September 14, 1999.

### Awards

Prof. Ashoke Sen was awarded DAE's Homi Bhabha Chair. Two other scientists of MRI were awarded Swarnjayanti Fellowship by the Department of Science and Technology, Govt.of India, in Mathematics and Physics respectively.

### Construction

The Institute has already completed construction of various buildings including Library, Hostel, residences for its academic and non-academic staff under Phase I-A. The construction work under Phase 1-B for other buildings including Institute's main Administrative Block made good progress.

### Computing Facilities

The latest communication facilities of modern computing through Internet and VSNL, together with a very good library, were used by the Institute's staff and students and those from universities and colleges in the Northern belt.

## 6.5 THE INSTITUTE OF MATHEMATICAL SCIENCES

The Institute of Mathematical Sciences (IMSc) inaugurated in 1962 is a national institution of higher learning which fosters high quality fundamental research in frontier disciplines of mathematical sciences. It aims at disseminating knowledge and share information and thereby cultivate intellectual collaboration with peers inside and outside the country. It also attempts to stimulate a zest for creative work among students and young research workers in the country.

The three major areas of research of the Institute are: Theoretical Physics, Mathematics, and Theoretical Computer Science.

At present there are 44 members on the faculty with 14 Post Doctoral fellows and 35 Ph.D. Students.

The output of the Institute is basically publications in journals of international repute, presentations in international conferences by way of invited lectures and contributed papers and research monographs.

The Institute organised / co-sponsored the following national / international conferences / workshops :

- Orientation course in Theoretical Computer Science
- Cluster Supercomputer Meeting
- International Conference on Foundations of Software Technology and Theoretical Computer Science
- Sixth International Workshop on High Energy Physics Phenomenology (WHEPP-6)

The Institute faculty participated in several symposia / conferences inside and outside India. Many internationally reputed scientists visited IMSc for collaboration work with the scientists of the Institute and to give lectures, seminars and colloquia.

International Collaboration

The following international collaborative projects were underway:

- Indo-Russian Integrated Long Term Programme of Science and Technology
- Federation arrangement with Abdus Salam International Centre for Theoretical Physics at Trieste, Italy.
- DST-DAAD Projects in Theoretical Computer Science. This project involves both IMSc and University of Ulm, Germany.

Computerisation

During this year, there was further strengthening of the Institute's computer system in terms of hardware, software and internet services. A Cluster Super Computer System was made available to users. This was assembled with the hardware and software publicly available in the market through indigenous innovation.

The Institute's fully computerized library has been functioning as a Regional library catering to the needs of research scholars and scientists. The on-line version of the Mathematical Reviews data base (known as Math Sci Net) was installed. The OPAC (On line Public Access Catalogue) module installed in the library computer system enabled users to retrieve full information about books / journals they require. The Institute maintains a mirror e-print archive (xxx.imsc.ernet.in) of the original at the Los Alamos National Laboratory and provides a ready access to all preprinted publication in areas of research of IMSc.

The Institute conducts the following programmes to inculcate the spirit of fundamental research in young students and aspiring teachers:

- Summer Programme for college students
- NBHM Nurture Programme
- Apalat Fellowship to encourage bright B.Sc. students to take up physics or mathematics for higher studies.
- Institute Associateships for teachers from colleges and universities to visit and work at the Institute.

Awards

The Institute faculty won several honours and awards, A Professor of IMSc was awarded (posthumously) Shanti Swarup Bhatnagar Award for Mathematical Sciences.

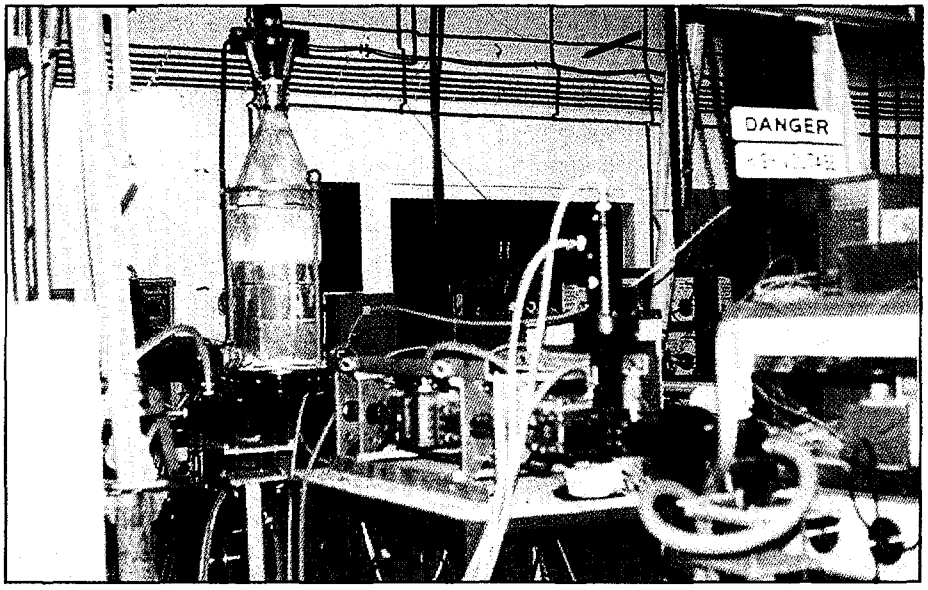
## 6.6 INSTITUTE FOR PLASMA RESEARCH

The Institute for Plasma Research (IPR) founded in 1986, is committed to the development of nuclear fusion as a futuristic energy source. The major activities of the Institute concentrate on experiments and future developments of Tokamak reactor concept, programmmes related to the theoretical and experimental work on fundamental plasma physics, application of the plasma science to industrial technologies, and development of technologies required for nuclear fusion.

The projects under implementation are : (i) Advanced plasma research – Steady-state Superconducting Tokamak-1 (SST1), (ii) Fundamental research/experiments, Plasma processing & Aditya Tokamak upgrade, and (iii) Technology development.

During the year 1999-2000, in the area of Steady-state Superconducting Tokamak-1 (SST1), a major order for

*Testing of Radiofrequency Klystron Tube at the Institute for Plasma Research*



manufacturing of machine shell was placed on M/s Bharat Heavy Electricals Ltd (Bhopal & Trichi). The fabrication activity progressed during 1999-2000. It is expected that the detailed engineering design of some of the auxiliary systems such as water cooling, power supplies, RF systems will be completed this year. Testing of RF-Klystron Tube, which will be used in a lower hybrid current drive (LHCD) system of SST1, was completed. Preparation for testing of RF-Gyrotron tube and implementation of ion cyclotron resonance heating (ICRH) system were progressing. Techno-commercial discussions continued for other auxiliary systems of SST1.

In the area of Fundamental research, Plasma processing and Aditya Tokamak upgrade, commissioning of large volume plasma device (LVPD) system was completed and experiments progressed. Part of upgradation of the Aditya Tokamak, data acquisition system and pulsed power supply systems (PPS) made progress. Design and implementation of Aditya Tokamak ohmic power supply system up gradation to suit SST1 needs were also initiated. Pulsed power experimental development setup for fast capacitor bank-6 kJ energy and long-term developments of 1.2 MJ capacitor bank were progressing. Setting up of Facilitation Centre for Industrial Plasma Technologies (FCIPT) at Gandhinagar, was undergoing, to promote a number of industrial ventures, which will convert the IPR knowledge base into products, processes and services predominantly based on plasma technologies such as surface characterization facilities, nitriding facilities, and large plasma ion implantation facilities. In addition, development of compact plasma torches and plasma based medical waste treatment technologies was also in progress. The FCIPT set up will be continued during 2000-01.

Under the Technology Development, the activities related to technology and prototype development of systems and devices.

## 6.7 INSTITUTE OF PHYSICS

The Institute of Physics IOP at Bhubaneswar is an autonomous research institution founded jointly by DAE and the Government of Orissa for promotion of fundamental research in frontier areas of Physics.

### Research Activities

The main areas of research consist of theoretical and experimental studies. So far as theoretical side is concerned, research is conducted in Nuclear Physics, Condensed Matter Physics and High Energy Physics. In experimental side, research is carried on in Condensed Matter Physics. There is an Ion Beam Laboratory with 3 MV Pelletron Accelerator for doing research. This has been augmented for carrying out Accelerator-based Mass Spectrometry (AMS) studies in Carbon-14 and Beryllium. This Project is funded by the DAE, DST, DOS, and CSIR.

About 100 papers were published in reputed international journals in addition to those presented in conferences & symposia.

### Collaborations

IOP had participated in Ultra-Relativistic Heavy ION Collision Experiment WA-98 at CERN. It has also joined the ALICE experiment at LHC. There are two experimental projects under Indo-U.S. collaborations and one is under Indo-French collaboration. The Indo-US collaborations are related to the development of a micro-beam facility and a joint collaboration regarding surface physics activity using both the accelerator & the X-ray standing wave facility.

*Awards*

A faculty member of IoP was elected as a Fellow of the Indian Academy of Sciences.

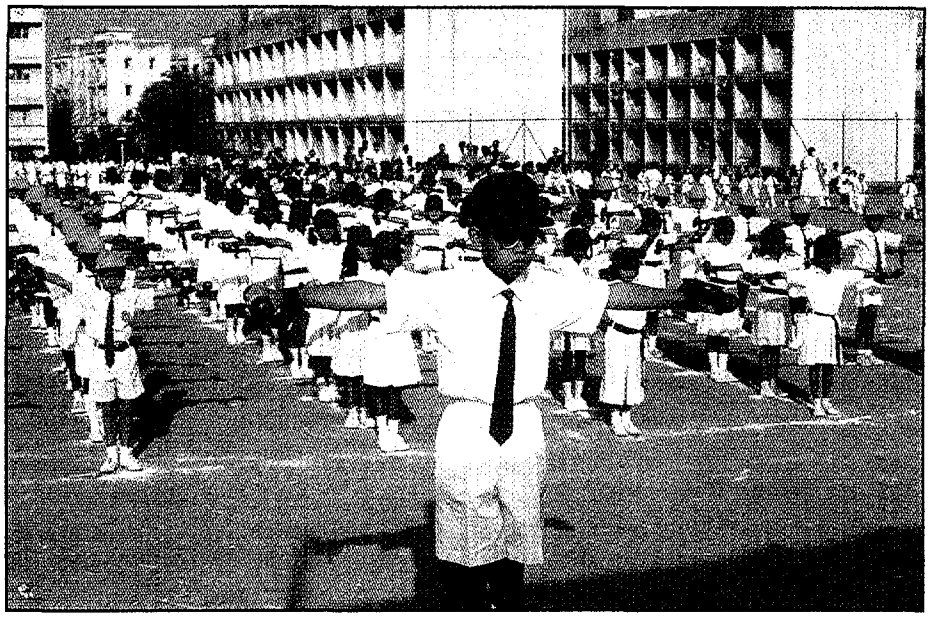
## 6.8 ATOMIC ENERGY EDUCATION SOCIETY

The Atomic Energy Education Society (AEES) established in 1969 manages 30 schools/Junior colleges at 14 different centres in the country. A number of steps were taken in enforcing discipline, introducing accountability, selecting promoting teachers and tightening of promotion norms for students to improve the academic standards of our schools.

After formation of the Academic Unit in the Central Office, notable progress was recorded in strengthening primary schools, improving interaction among the teachers, students and community, introducing computers and vocational education, assisting poor learners and gifted students, improving playground facilities by installing equipment, arranging workshops, seminars and orientation programmes for teachers, enriching the school libraries and improving library services in all its schools, streamlining vocational education especially for the drop out students by starting Refrigeration and Beauty Culture Courses, conducting an All India Art and Science exhibition, and many other programmes in sports, co-curricular activities, NCC etc, etc.

The AEC Schools and Junior Colleges at Narora, Hyderabad, Rawatbhata and Kakrapar were inspected with the help of reputed experts from outside the organisation. Follow-up action is in progress to overcome the shortcomings noted during the inspection of these schools.

As part of DAE's commitment, the AEES adopted 9 children (age group 7-10 year) from the rural areas and provided them with monthly scholarship, in addition to books and uniforms These children were identifed by conducting a talent search test in collabo-



*Students undergoing physical training at the Atomic Energy Central School-5, Mumbai*

*Dr. R. Chidambaram, Chairman, AEC inaugurating the Computer Lab in Atomic Energy Central School-4, Mumbai*

ration with Homi Bhabha Centre for Science Education.

The students from Class VI to IX and the NCC cadets participated in maintaining clean and green surroundings around their schools and planted 2000 saplings. Horticulture Day and Horticulture Week was celebrated at a few centres to bring an awareness of environmental protection among the students. The students of AEC Schools collected funds for the relief of families of the victims of the Kargil War and Orissa Cyclone.

The results in the Board examinations conducted in the year 1999 as follows :

82% of the 1735 students who appeared in the All India Secondary School Examination conducted by the CBSE passed the examination. Many of them passed with distinction. Similarly, 85 % of the 1643 students who appeared in Standard XII passed the examinations. The AEJC, Mumbai ranked fourth by securing six positions in the merit list in the Maharashtra State Board of Secondary and Higher Secondary examinations. Five students from AEJC, Mumbai were delcared successfUl in the IIT, and about 240 students secured admissions to other engineering and medical colleges.

A large number of students throughout the AEES system as well as several staff members of the teaching community distinguished themselves in the academic field as well as in sports, NCC and co-curricular activities, a girl student of Std.X1 from AEJC, Mumbai was awarded a cash prize of Rs. One Lakh in "SA RE GA MA" programme conducted by ZEE TV Pvt. Ltd. The AECS, Narora has been adjudged the 'Best School' in the U.S.O. and G.K. examination conducted by the Central Institute of General Knowledge, New Delhi.

# 7.0 OTHER ACTIVITIES

*Activities of DAE covered in this chapter are: International Relations; Support to Research in Nuclear Sciences and Mathematics, and Aided Institutes; Management Services; Emergency Planning; Use of Hindi; Public Awareness; Library & Information; Human Resources Development; Industrial Relations, and Employees' Welfare.*

## 7.1 INTERNATIONAL RELATIONS

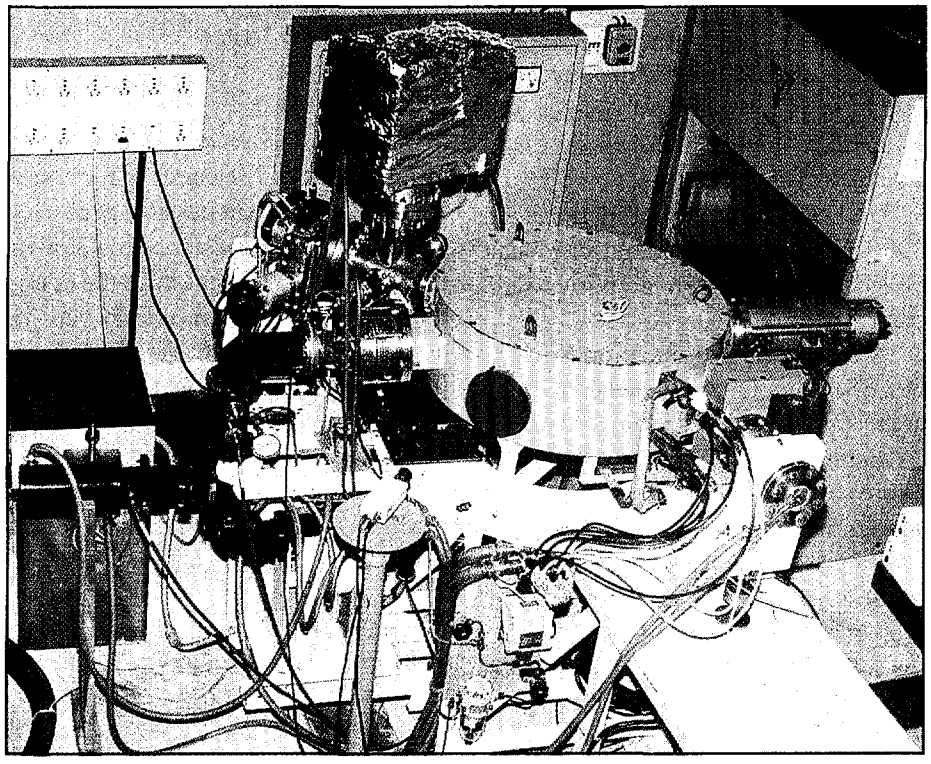
India has been a designated member of the Board of Governors of the IAEA since the inception of the International Atomic Energy Agency (IAEA). India continued to offer training facilities, fellowships, scientific visits etc. and to make available the services of its scientists for expert assignments both through the IAEA and to countries with which we have entered into bilateral agreements for cooperation in the field of peaceful uses of atomic energy.

About 474 scientists/engineers participated in international symposia, workshops and conferences held under the auspices of various UN and other international organisations as also the IAEA. 58 foreign scientists have been trained in India under IAEA fellowships programme and bilateral agreements signed between Government of India and other countries. India also hosted 16 IAEA meetings, symposia and 10 other international meetings during 1999-2000.

Chairman, Atomic Energy Commission (AEC) and Secretary, DAE led the Indian delegation to the 43rd Regular Session of the IAEA General Conference held in Vienna, Austria during September 1999. Bilateral discussions were held with a number of other delegations participating in the Conference.

Arrangement between the Atomic Energy Regulatory Board (AERB) and the Nuclear Installation Safety Directorate (DSIN) of French Republic for the exchange of information and cooperation in the regulation of Nuclear Safety was signed on July 29, 1999.

Having achieved a comprehensive development in nuclear technology for many years now, we are in a position to offer technology as well as equipment to other countries on a commercial basis. Concerted efforts are being made to publicise our expertise for the purpose of export of technology and equipment for peaceful applications of nuclear energy.



*Variable Energy Microtron Facility :The Centre for Advanced Technology (CAT) and BARC collaborated with Mangalore University to accomplish this project.*

## 7.2 SUPPORT TO RESEARCH IN NUCLEAR SCIENCES AND MATHEMATICS

DAE promotes research and development activities in the universities and other institutions of higher learning for the growth of nuclear and allied sciences through the Board of Research in Nuclear Sciences (BRNS). BRNS also sponsors conferences, symposia, workshops and seminars on topics of relevance to DAE programmes.

During this period under report 5 post-doctoral fellows were selected under Dr. K.S. Krishnan Research Associateship. Visiting Scientist Scheme was also initiated under which scientists from universities interact with DAE scientists.

As a part of DAE-University Collaboration BRNS approved setting up of a Centre for Formal Design and Verification of Software at IIT-Bombay, Mumbai, 8 projects for conducting coordinated study on thermal ecology and a project for setting up a LOCA Environment Simulation and Aging Test Facility for large components. A proposal for setting up a " National Centre for Fast Reaction Kinetics" at the University of Pune, Pune was also approved.

The Board also approved financial assistance for 83 new project proposals, renewed 128 ongoing projects and supported 70 symposia/ conferences.

The *National Board for Higher Mathematics (NBHM)* was constituted under the DAE in the year 1983 with the objective of promoting excellence in higher mathematics education and research in the country. With this mandate the Board has initiated several schemes such as helping the development of mathematical centres, giving scholarships to research workers at doctoral and post-doctoral levels. In 1999-2000 an annual budget of about Rs.4.8 crore was allotted to NBHM.

A major portion of the budget of NBHM is given to the mathematics departments of about eighty universities and colleges to enable them to purchase the latest books and mathematics journals. During the year under report about 3.50 crore was distributed under this scheme. In collaboration with the International Mathematical Union, NBHM has also initiated schemes for making mathematical literature accessible through electronic communication

During the year, NBHM provided about seven new fellowships at doctoral level and three at post-doctoral level. Like every year, this year also it conducted three Instructional Conferences to train young students at post-graduate level and research workers in the current areas of modern mathematics. Six national and eight International conferences were partially supported by NBHM.

During the year 14 young mathematicians were provided with travel support to participate in International Conferences. Thirteen Research Projects in mathematics were financially supported at a total cost of Rs.16 lakh.

With a view to spot talent at a very young age, NBHM conducts Olympiad contests at plus two (+2) level, NBHM is also responsible for selecting the Indian Team for participation in International Mathematical Olympiad (IMO). A team of six students participated in IMO-99 held in Romania during July 1999 and won three Silver and three Bronze medals. NBHM provides an annual grant of Rs.30 lakh for these activities. The successful students in the Olympiad Contests are nurtured for the succeeding four years and cash prizes are awarded to students whose progress is satisfactory.

UNESCO has declared the year 2000 as World Mathematical Year (WMY). Several new activities will commence.

Atomic Energy Education Society (AEES), Mumbai provides education to the children of the employees of the DAE and its affiliated institutions. To improve standard of teaching, achieve academic excellence and promote experimentation and innovation in the schools, the AEES has taken up a project "Infrastructure Development for achieving Excellence in AEES schools" at an estimated cost of Rs.2.43 crore during the IX Plan period.

## 7.3 GRANT-IN-AID TO INSTITUTIONS

The Department provides substantial amount by way of recurring and non-recurring grants to its aided institutions.

| Sl. No. | Name of the Institution | Budget Provision 1999-2000 (Rs. in crore) |
|---|---|---|
| 1. | Tata Institute of Fundamental Research, Mumbai | 86.39 |
| 2. | Tata Memorial Centre, Mumbai | 69.80 |
| 3. | Saha Institute of Nuclear Physics, Calcutta | 31.80 |
| 4. | Institute of Physics, Bhubaneshwar | 6.90 |
| 5. | Institute of Mathematical Sciences, Chennai | 5.93 |
| 6. | Mehta Research Institute, Allahabad | 6.98 |
| 7. | Institute for Plasma Research, Gandhinagar | 30.80 |
| 8. | Atomic Energy Education Society, Mumbai | 7.75 |

With the objective of improving the Cancer Control Measures in the country , the Department has also been providing financial assistance to some of the leading cancer centers in the country. The Department has approved six new research projects for the Cancer Institute, Adyar, Chennai by giving a grant-in-aid of Re.1 crore each year for three years. During the year financial assistance was granted to cancer research institutes/hospitals as given below:

| | |
|---|---|
| 1. Dr.B.Borooah Cancer Institute, Guwahati | Rs 71 lakh |
| 2. Cancer Institute,Adyar, Chennai | Rs 83 lakh |
| 3. Kamala Nehru Memorial Hospital, Allahabad | Rs 3.81 lakh |
| 4.Siddhivinayak Ganapati Cancer Hospital, Miraj | Rs 20 lakh |
| 5. R.C.C., Thiruvanthapuram. | Rs 40 lakh |

Miscellaneous: The Department has approved a collaborative project titled "Nuclear & Biotechonological Tools in Coastal System Research" undertaken by M.S.Swaminathan Research Foundation (MSSRF) at an estimated cost of Rs.3 crore for the period from 1999-2000. A Joint DAE-MSSRF project is designed to address the issues of ecological and livelihood security of the coastal region. Several activities have been initiated for enhancing the agricultural productivity and livelihood security of the coastal communities in a participatory eco-technology approach. The ongoing project also intends to develop models for sustainable natural resources management and development in Kudankulam, a semi-arid region with severe water scarcity. The Project also aims at exploring the benefits of "Application of Rare Earth in Agriculture". The amount is spread over a period of 4 years with an annual release of Rs.75 lakh.

During the current year, financial assistance granted to MSSRF is Rs.73.94 lakh

## 7.4 MANAGEMENT SERVICES

During the year, the Management Services Group (MSG) continued to provide Local Area Network (LAN) services to the DAE Secretariat. This network now functions on a round the clock basis. The MSG arranged for the provision of leased line connectivity to the Internet for the Secretariat. This facility enables the senior officials to acquire information from the Internet at any point of time. The Internet connectivity also enabled the Department to put up a website through which information on the DAE and its activities are disseminated to the public. The website functions as the web information portal for atomic energy activities in India and provides links to the websites of other organisations in the Department. The Management Services Group was actively involved in tackling the Y2K issue both as part of the Department's Y2K Task Force and in maintaining communication links between the Crises Management Group, DAE and the various operating plants during the rollover period. All the Y2K remediation activities across all the units of the Department, were monitored and coordinated in the Secretariat by the Management Services Group. In addition, the Group continued to maintain the information base on the performance of various operating units and prepared periodic information reports to the Prime Minister and the Atomic Energy Commission. It also prepared the Annual Action Plan and prepared the background papers for the reviews on the performance of various Public Sector Undertakings under the DAE. The MSG also continued to provide support to the CMG, DAE for carrying out its functions.

## 7.5 EMERGENCY PREPAREDNESS

The design of nuclear facilities require that fail-safe systems are adopted wherever critical safety aspects are involved and thereby ensure that accidents do not take place in the first instance. Further, even if an accident were to take place, features are incorporated to minimise its effects. Depending on the severity of an assumed accident, the resulting scenarios are defined as a Plant Emergency or a Site Emergency. Under both these conditions, the consequences of an accident would be limited either to the plant facility or to the site boundary, and therefore would not spill into the public domain. The various operating units of DAE have drawn up comprehensive Emergency Preparedness and Response Plans to handle postulated emergency scenarios like a Plant Emergency and a Site Emergency. Over and above these, as a measure of ensuring public confidence, the public authorities of the district where the nuclear power stations are located, have also put in place comprehensive Off Site Emergency Response Plans. An independent regulatory authority - the Atomic Energy Regulatory Board (AERB) is vested with formal powers to oversee implementation of the safety requirements at the nuclear power plants and other facilities. In addition, the Department has also established a Crisis Management Group (CMG) comprising senior officials of the Department to function as a nodal and coordinating agency vis-a-vis the Off Site Emergency Management officials during such situations. A reliable communication infrastructure is available to the CMG for this purpose. This includes multiple channels like wireless, telephone, facsimile and telex, with direct links to the nuclear facilities through two Emergency Control Rooms in Mumbai, which are manned on a 24 hours / 7 days / 52 weeks basis. As a means of ensuring that the Emergency Plans are in a high state of readiness, the nuclear facilities carry out a variety of Exercises for the postulated emergency scenarios. The exercises conducted during the year 1999 by the major facilities are given in the table below:

| S.No. | Type of Exercise | Nos. conducted in 1999 |
|---|---|---|
| 1. | Communication Exercises | 155 |
| 2. | Fire Emergency Exercises | 47 |
| 3. | Plant Emergency Exercises | 30 |
| 4. | Site Emergency Exercises | 8 |
| 5. | Off Site Emergency Exercises | 5 |

The five Off Site Emergency Exercises were carried out in the public domain surrounding the nuclear power stations at Tarapur, Kalpakkam and Kaiga and the heavy water plants at Rawatbhatta and Manuguru. In each of these, a large number of State government officials and various nuclear power station personnel were involved in conducting the exercise.

During the year, guidelines were also circulated to the State Governments and Union Territories for handling the presence or suspected presence of nuclear materials in the public domain.

## 7.6 SMOOTH TRANSITION TO YEAR 2000

During the year, the various units of DAE - comprising its constituent units, Public Sector Units and Aided Institutions, numbering 22, ensured Y2K readiness with respect to their respective functions. Due to the nature of their activities, there was a high degree of Y2K awareness in the organisations of DAE and some of them had started the work on ensuring Y2K readiness from mid-1998 itself. However, the setting up of the national high level Y2K Action Force by the Government was instrumental in structuring the response system throughout the Department. Of importance was the fact that national high level Y2K Action Force had identified "Atomic Energy" as one of the eleven mission critical sectors in the country for ensuring Y2K readiness. The DAE set up a Y2K Action Group chaired by its Additional Secretary. This Action Group monitored the implementation of Y2K resolution by all the 22 organisations of the DAE, each of which formed its own Task Force. The progress of Y2K resolution was monitored by the heads of the organisations, to whom additional financial powers were also delegated for this purpose.

In addition to the monitoring by the DAE Action Group, the independent regulatory authority - the Atomic Energy Regulatory Board (AERB) - also reviewed the implementation of Y2K readiness programmes with regard to ensuring safety in all the operations of the units of DAE.

The objectives of the Y2K resolution programme in DAE were to ensure: (i) continued safety in all its operations; (ii) continued operations / production / scientific work, and (iii) continuance of all administrative and other support functions.

The Y2K readiness programme at each of the units covered critical aspects such as detailed inventory preparation and assessment, remediation (including retirement, replacement, modification or work around), auditing and contingency planning. Particular attention was paid to both computer based systems and embedded components at the nuclear power stations, research reactors and other nuclear facilities. An estimated 15,000 man-days of effort by in-house personnel and an amount of Rs.7.8 crore was spent in the entire Department towards resolving Y2K related issues.

While continued safety in operations had been ensured, contingency plans, to handle any unanticipated Y2K related problem, had also been drawn up by the various units. These were in place well in time before the end of the year 1999. These plans included aspects like provision of additional manpower, material resources, standby systems, etc.

Within an hour following the midnight of December 31, 1999 all the major units such as Nuclear Power Stations, Heavy Water Plants and other nuclear facilities, confirmed their safe and continued normal operations to the DAE Emergency Control Room at Mumbai. Information about this was communicated to IAEA and also posted on the DAE home page and the NIC Website. By the first day of the new year all the units of the Department had confirmed their continued safe normal operations into the year 2000.

## 7.7 USE OF HINDI

The Department is a research oriented organization and the working of it is mainly scientific and technical in nature. The literature in such a high tech area of nuclear science is not available in Hindi. However, with the objective to promote the use of Rajbhasha Hindi in the various disciplines of nuclear science and technology, the DAE and its Units continued to hold seminars and talks on diverse subjects as in the past. Some of the highlights of the activities are detailed below.

Bhabha Atomic Research Centre organized seminars on Manav Swasthya Shrinkhla Ke Antergat " Gurde Avam Yakrit Rog Aur Unki Roktham" and "Parmannu Urja Karykram - Ek Samiksha". Besides the centre also organized a Rajbhasha Varta.

Nuclear Fuel Complex organized a scientific seminar on "Nabhikiye Endhan Abhilakshan Avam Gunvatta Niyantran". Centre for Advanced Technology organized one-day Hindi Seminars on "Soochna Praudyogiki" and "Syncrotron Vikiran Srot Indus-1 Ki Vaigyanik Tatha Audyogik Anusandhan Suvidhayein". Directorate of Purchase & Stores, Directorate of Construction, Services & Estate Management, Heavy Water Board, Nuclear Power Corporation, Atomic Energy Regulatory Board and Board of Radiation & Isotope Technology, jointly organized a Hindi Seminar on "Sahitya Vigyan Avam Darshan Ke Vividh Paksh". Uranium Corporation of India Limited organized a Hindi Seminar on "Shramik Shiksha Sambandhi".

One-day scientific seminars were

organized by Narora Power Station and Rajasthan Atomic Power Station also.

Progress was made in the implementation of the Official Language Policy of the Union in other areas also in the Department and its constituent Units as well as in the PSUs. In-service training in Hindi, Hindi typewriting and stenography was imparted to 486 officials, 71 typists and 16 stenographers. 347 officials, 65 typists and 39 stenographers are undergoing training in Hindi Language, Hindi typewriting and Hindi stenography. At present, the number of Devnagari typewriters and bilingual electronic typewriters being used in the Department and its Units/PSUs is 258 and 85 respectively. The use of these typewriters is being decreased gradually and the use of computer is being increased. Now the number of bilingual softwares to be used in personal computers has increased from 229 to 237. There are some bilingual electronic telex machines also in the Department, but due to increased use of fax machines their use is becoming less.

The Official Language Implementation Committee of the Department, Units and Public Sector Undertakings met to review the position regarding use of Hindi. Action continued to be taken to implement the provisions of the Official Languages Act. All Gazette Notifications. Cabinet Notes, Reports and other documents submitted to various Committees were prepared bilingually.

The quarterly Hindi Bulletin "Parmanu" which is brought out by the DAE to disseminate information about its research and development activities, plans and programmes entered its twenty fourth year of publications. Directorate of Construction, Services and Estate Management, BRIT, Rajasthan Atomic Power Station, Narora Atomic Power Station, Kakrapar Atomic Power Station, Tarapur Atomic Power Station, Madras Atomic Power Station, Bhabha Atomic Research Centre, Directorate of Atomic Minerals Exploration and Research, Atomic Energy Regulatory Board, Electronics Corporation of India Limited, Centre for Advanced Technology, Nuclear Fuel Complex, Heavy Water Board and Heavy Water Plant, Manuguru, Baroda, Tuticorin etc. published their House Magazines bilingually/Hindi. Directorate of Atomic Minerals Exploration and Research, Indira Gandhi Centre for Atomic Research and Nuclear Fuel Complex, also brought out souvenirs in Hindi on the proceedings of the seminars organised by them. The Hindi Vigyan Sahitya Parishad, a voluntary organisation of BARC, published a popular Hindi quarterly bulletin "Vaigyanik". Booklets/pamphlets on various subjects related to DAE's activities were also brought out by DAE and BARC in Hindi.

To encourage employees to use Hindi in official work, Hindi Day/ Hindi Week/Hindi Fortnight/Hindi Month were organised in the Department of Atomic Energy, Indira Gandhi Centre for Atomic Research, Heavy Water Board, Heavy Water Plant, Kota, Baroda, Tuticorin and Talcher, Atomic Minerals Directorate for Exploration and Research, Uranium Corporation of India Limited, Indian Rare Earths Limited, Electronics Corporation of India Limited, Centre for Advanced Technology, Nuclear Fuel Complex, Directorate of Construction, Services and Estate Management, Directorate of Purchase and Stores, Bhabha Atomic Research Centre and Nuclear Power Corporation of India Limited and its Power Stations, Mehta Institute of Mathematics, Atomic Energy Education Society and Atomic Energy Regulatory Board. Under the Incentive Scheme for writing original notes and drafts in Hindi, 138 officials were given incentives. Under the Incentive Scheme for Hindi typing and stenography, 13 typists and one stenographer were given incentives. Hindi workshops were organized at the DAE, Nuclear Fuel Complex, Electronics Corporation of India Limited, Heavy Water Board, Heavy Water Plant, Manuguru, Tuticorin, Directorate of Construction, Services and Estate Management, Board of Radiation Isotope Technology, Centre for Advance Technology, Atomic Energy Regulatory Board, Directorate of Purchase and Stores, Directorate of Atomic Minerals Exploration and Research, Hyderabad, Shillong, Nagpur, Nuclear Power Corporation of India Limited, Indira Gandhi Centre for Atomic Research and Indian Rare Earths Limited.

The Department and its Units and PSUs represent in their respective Town Official Language Implementation Committees and implement the decisions taken in these meetings in their offices. Centre for Advanced Technology, Indore of this Department is conducting the Indore Town Official Language Committee. The Director of the Centre is Chairman of this Town Official Language Committee. This year two meetings of the Committee were conducted and committee also brought out a sticker with the words "Rajbhasha Swaran Jayanti". The committee has honoured the scientists of Indore. Likewise, the General Manager of Heavy Water Plant, Tuticorin is Chairman of Tuticorin Town Official Language Committee. Four meetings of these Town Official Language Committee have been conducted successfully.

This year, the Department inspected five Units, one Aided Institution and nine sub-units/offices to evaluate the status of the progressive used of the official language. The Department has inspected all its sections twice at the interval 3-4 months.

In addition to getting prepared the sticker issued by the Department of Official Language on the occasion of

Rajbhasha Swaran Jayanti Year, the DAE has got prepared rubber stamps of "Rajbhasha Swaran Jayanti Varsh - 1999-2000" and posters depicting the sayings of learned persons related to official language.

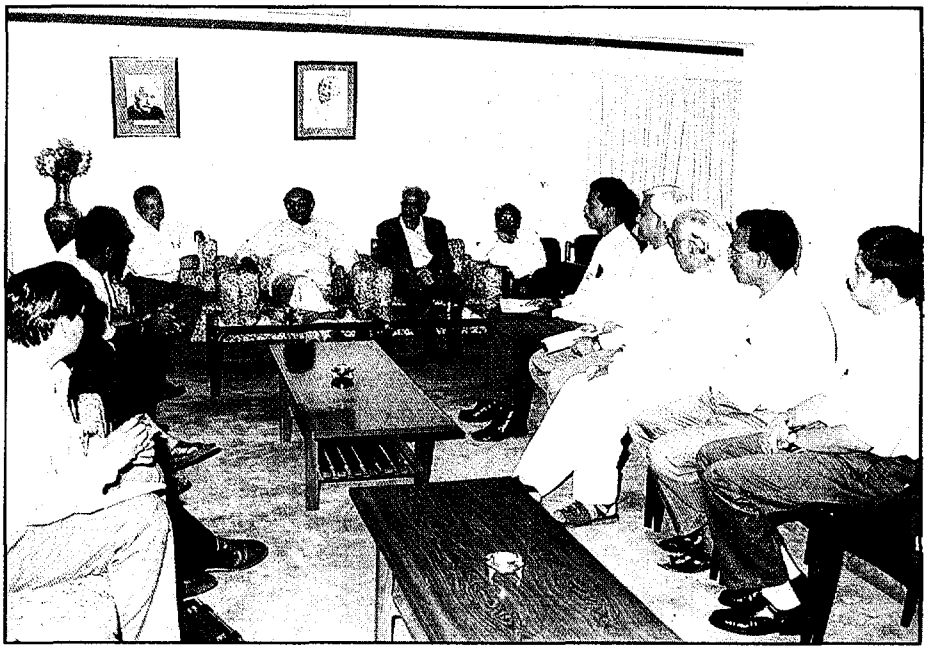
At present the DAE has one Joint Director (OL), one Deputy Director (OL) and two Assistant Director (OL), one Senior Hindi Translator and three Junior Hindi Translators. Units and PSUs of the DAE also have three posts of Deputy Director (OL), two posts of Manager (OL), one post of Senior Hindi Officer, 13 posts of Assistant Director (OL), two posts of Deputy Manager (OL), two posts of Asstt. Manager (OL), two posts of Hindi Officer, one post of Deputy Hindi Officer, nine posts of Senior Hindi Translators and 51 posts of Junior Hindi Translators. Besides, out of the Aided Institutions of the Department there is one post each in four Institutions.

Meetings of the Official Language Implementation Committee of IGC were held regularly and decisions taken were implemented. A "Hindi Fortnight" and Hindi Workshop were organised during September 1999. Translation of Gazette notifications regarding appointment, promotions, retirement and verification reports was done. As a part of the Hindi teaching scheme, Hindi typewriting course was conducted for two employees.

## 7.8 PUBLIC AWARENESS

DAE continued its efforts in spreading awareness on the peaceful applications of atomic energy among the public and kept them abreast with India's progress in this field. To achieve the objective, it organized and participated in several programmes which included quiz, essay contests, exhibitions, workshops and seminars.

The 87th session of the Indian Science Congress ISC-2000 organized by the Indian Science Congress Association and hosted by Pune University, Pune, was held in January 2000. Coinciding with ISC-2000, an exhibition - Heralding the New Millennium was organized. With theme as "The saga of Technology Development, Demonstration and Deployment", DAE presented a vivid picture of the whole gamut of its programmes and activities including Nuclear Power, Production of Radioisotopes and their applications in various sectors , Advanced Technologies, Spin-off Technologies and National Security. An added attraction was a section on Cancer Education. Over 2.5 lakh people visited the pavilion.



*Chairman AEC with the participants of the Journalists' Workshop*

Another major event where DAE took part was the Swadeshi Vigyan Mela– an exhibition with the theme as Science for Sustainable Development- organized by the Vigyan Bharathi, Students for Development and Centre Bharatiya Marketing Development at IIT Delhi in February 2000. The exhibition attracted more than one lakh visitors.

DAE was a participant in the KRISHI-EXPO 2000 exhibition organized by the India Trade Promotion Organization (ITPO) at New Delhi in January 2000. DAE exhibited it's achievements in the fields of Nuclear Agriculture, Tissue Culture, Biotechnology, Pheromones and their applications in weevil control and sericulture, radiation processing of food items. osmotic dehydration of fruits etc. Over 25000 people visited the exhibition.

Two workshops were organised by DAE in Mumbai for journalists of leading newspapers – one for the Indian Science Writers Association (ISWA) in April 1999 and the other for members from the National Union of Journalists (NUJ) in September 1999. The participants were shown various DAE facilities.

With a focus on enhancing awareness among the academic community, DAE participated in two seminars for postgraduate science teachers. The first one, which was the Fifth National Seminar on Peaceful uses of Atomic Energy, was organized in conjunction with the United Schools International (USI) at New Delhi in September 1999. The second seminar on Appli-

cations of Nuclear Energy was organized at Madurai, Tamil Nadu in December 1999 by the Tamil Nadu Science and Technology Centers (TNSTC) Chennai.

As a part of its continuing efforts to enrich awareness of the student community, DAE conducted the 11th All India Essay Contest in Nuclear Science and Technology in about 12 languages. The winners were taken around various facilities/units of the Department.

With Unit-2 of the Kaiga Atomic Power Station going critical in September 1999 and the Kudankulam project in the pipeline, a series of exhibitions, quiz contests and essay competitions were held in the South so as to improve public awareness and to give general public acceptance the necessary fillip.

An exhibition and quiz contest on Nuclear Science and Technology was organized by Bangalore University in October 1999. The focus was on operation and safety of PHWRs. About 6000 people visited the exhibition.

An essay competition on "Impact of Power and Non-Power uses of Atomic Energy "and a quiz contest for undergraduate students was conducted in August 1999 and October 1999 respectively at Tiruchchirapalli in coordination with TNSTC's new centre at Trichy.

DAE participated in a District Science Exhibition organized by the Tenkasi Arivial Mandram (TEAM) affiliated to the Federation of Science Clubs of Tamil Nadu (FSCT) at Tenkasi, Tirunelveli Dt. in November 1999. The visitors to the exhibition totaled over 7000.

The Rotary Clubs of Madurai in a concerted effort, held the Rotary Science Talent Exhibition (ROTASTEX) in Madurai in January 2000. DAE participated in this exhibition which was visited by over 5000 people.

For the first time DAE took part in the Delhi Book Fair at New Delhi organized by the India Trade Promotion Organization (ITPO) in August 1999. At the instance of the Ministry of Science, the scientific departments of the Government of India had a concerted participation in the fair, which is an annual event. DAE exhibited over 250 publications from various units. More than 10,000 people visited the exhibition.

DAE participated in an exhibition at the North Eastern Hill University (NEHU) Shillong, Meghalaya in November 1999. The exhibition was a part of a seminar organized by National Association for Applications of Radioisotopes in Industry (NAARRI). Over 2500 people visited this exhibition.

NPCIL's journal Nu-Power, continued to disseminate authentic information on various facets of generation of electricity through the atom.

In pursuance with its Public Awareness Programmes, it continued to take the help of universities/institutes as media of communication with the teachers and students in particular, and with the public in general.

Lecture-series were conducted on various aspects of nuclear energy and displayed exhibits and models at nine locations spread around the country.

NPCIL also participated in various commercial exhibitions for public awareness. These exhibitions were "Power Tech India '99" at Mumbai, "Energy and Environment Expo '99" at Bangalore and "Thermal Centenary Celebrations '99" at New Delhi. "Meet the Press " occasions were organised from time to time.

A CD-ROM consisting of multimedia programmes for education on nuclear energy remained in good demand from educational institutes. Similarly, a CD-ROM containing technical and safety aspects of the VVER-1000 was developed English, Hindi and Tamil for putting on the Internet for wider dissemination of information on the Kudankulam Project.

Yet another CD-ROM for delivering lectures with dynamic environment on special projection on NPCIL for senior engineers, was developed and screened to VIPs and MPs in particular and the public in general.

NPCIL also inserted articles and advertisements highlighting its activities and performance statistics in various newspapers and magazines. As a part of the corporate image building process, help of publishers of international repute, widely read magazines on power sector and published various issues on "Nuclear Power Corpo-

*DAE pavilion at the exhibition " Heralding the New Millennium" organised at Pune in January, 2000*

ration - creating enviable parameters". Rejoinders with authentic information were sent to the press and magazines as and when required.

Social welfare programmes such as eye camps, school activities, distribution of high yield seeds, street lighting, providing drinking water, education and plant-visits by teachers, students, VIPs and public were continued in and around the nuclear power plants.

*Conferences/Seminar/Symposia/Workshop/Training*

Nine numbers of Conferences / Seminars / Symposia / Workshop , were conducted by IGCAR during the year.

Forty scientific officers were deputed abroad for training/ international conferences/symposium/seminars during the year and 9 officers were sent for research work.

## 7.9 LIBRARY & INFORMATION

The DAE and its organisations such as NPCIL, BARC, IGCAR, CAT and others, have modern library and information structure. Their salient activities were as under :

To meet the information requirements the Central Library at Trombay has the necessary infrastructure and facilities including electronic information resources of BARC and other institutions of DAE. The library has a total collection of more than 10 lakh documents including more than one lakh books. It subscribes to more than 1,100 journals mainly in the advanced areas of science and technology.

At IGCAR, CD-NET server was installed to access various databases . A 480 CDs Juke Box facility will also be made available to LAN shortly. The IGC Newsletter, a quarterly publication of the Centre and also IGC Highlights-1997 were made available on the Internet. Elsevier's Science Server, a full text journals in electronic format is also being made available in the LAN. Towards the implementation of the state-of-the- art digital library, efforts are on hand to evolve a suitable design for the system for IGCAR, in collaboration with IISc, Bangalore.

To disseminate information on programmes, activities and events, reports, house journals and other information material in English and Hindi, have been regularly brought.

DAE publications brought out during the year, included documents such as Annual Report, Performance Budget and Official Reports for Parliament; journals and information material for media and public, and manuals, compilations and booklets for captive use. Various databases were also managed.

The Library of DAE provided information support to senior management of DAE.

## 7.10 HUMAN RESOURCE DEVELOPMENT

Training Division, BARC has the mandate of implementing two main stream training courses, namely, one year Orientation Course for Engineering Graduates and Science Post-Graduates (OCES) and five months Orientation Course for Engineering Post-Graduates (OCEP). 138 trainee scientific officers of 42nd OCES and 18 trainee scientific officers of 8th OCEP graduated this year and were absorbed in different units of DAE. BARC facilities have been utilised by educational institutions around the country for research & training. To extend this further, the Division coordinates the practical training/ project work in BARC for BTech/ MSc/ MTech students of Indian Universities. About 1400 students have done their training/ project work in the various divisions of BARC this year. Similarly, BARC also provides training facilities to a number of IAEA Fellows - coordinated by the Training Division. 24 IAEA Fellows availed this opportunity this year. A new scheme in collaboration with IIT Kanpur commenced in 1999 under which candidates selected pursue MTech in Nuclear Engineering & Technology at IIT Kanpur. These students, on completion of the course will be offered regular appointment in DAE. The Division is also engaged in assisting Vietnam AEC in setting up of a training centre on lines of BARC Training School.

Keeping in view of the requirement for developing managerial skill among senior officers sharing substantial administrative responsibility, Training Division is coordinating and organising Management Development Courses.

## 7.11 INDUSTRIAL RELATIONS AND EMPLOYEES' WELFARE

### Industrial Relations

The Industrial Relations in the Department continued to be smooth in-as-much-as JCM meetings were regularly held with the recognized Service Associations.

### Health Care

The Central Health Service Scheme (CHSS) covers over 72,300 beneficiaries. Due to the increased load in Anushaktinagar East and West Dispensaries, a new dispensary (Mandala Dispensary) and two new wards (having 20 beds each) were commissioned at BARC Hospital. The peripheral dispensaries continued to extend therapeutic and diagnostic facilities to the beneficiaries and 4.8 lakh patients were treated in these dispensaries during the period of report. The social service section rendered assistance to over 12,000 patients. In the Audiology and Speech Therapy Unit 3800 patients were treated.

The morbidity pattern of the prime

population were compiled under WHO codes and the prevalence rates of various ailments arrived at. These values were compared with the national values after standardizing the age structure.

The Contributory Health Services Scheme is presently in operation at as many as 11 places.

**Sports & Culture**

The Sports & Cultural Council of DAE organises sports and cultural activities of the employees of DAE organisations.

The XV All India DAE Sports & Cultural Meet was conducted in 11events by 9 different units at various locations. About 950 employees took part in these, after preliminary selections at their respective units. Two of the DAE employees got selected for International events - one participated in the World Power Lifting Championship held in Suncity, South Africa and the other in the Asian Veterans Tennis Championship held in Bangkok, Thailand.

Under Fine Arts activities, a painting competition was organised at All India level at Kota for all the DAE school children, in association with the Atomic Energy Education Society. In order to identity the sports talent among the children of DAE family - Annual Summer Camps in various sports were also held at most of the Centres. More than 1400 children took part in these camps and about 150 children selected out of these camps were imparted advanced coaching. Many of our children have excelled at various State and National level championships.

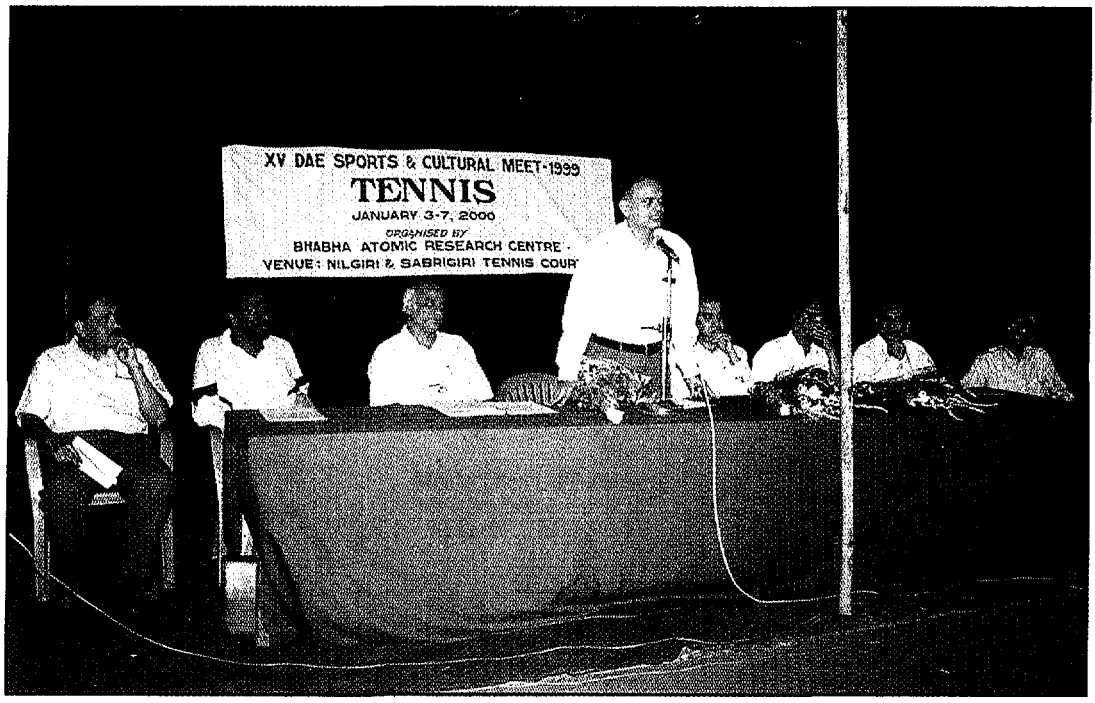
As in the past, this year also our annual trek - "GIRISANCHAR-11" was organised with the approval of the Indian Mountaineering Federation and around 225 persons from various units took part in the same.

Under its Health & Fitness Programmes 10 persons attended the International Yoga Conference at Bangalore. Many programmes on 'Healthy Living' awareness including Stress Management for senior officers were organised. Under such programmes, a very informative booklet on 'prevention of Kidney disorders' was also brought out. Two more Fitness Centres - one at Narora and the other at Kakrapar are being set up.

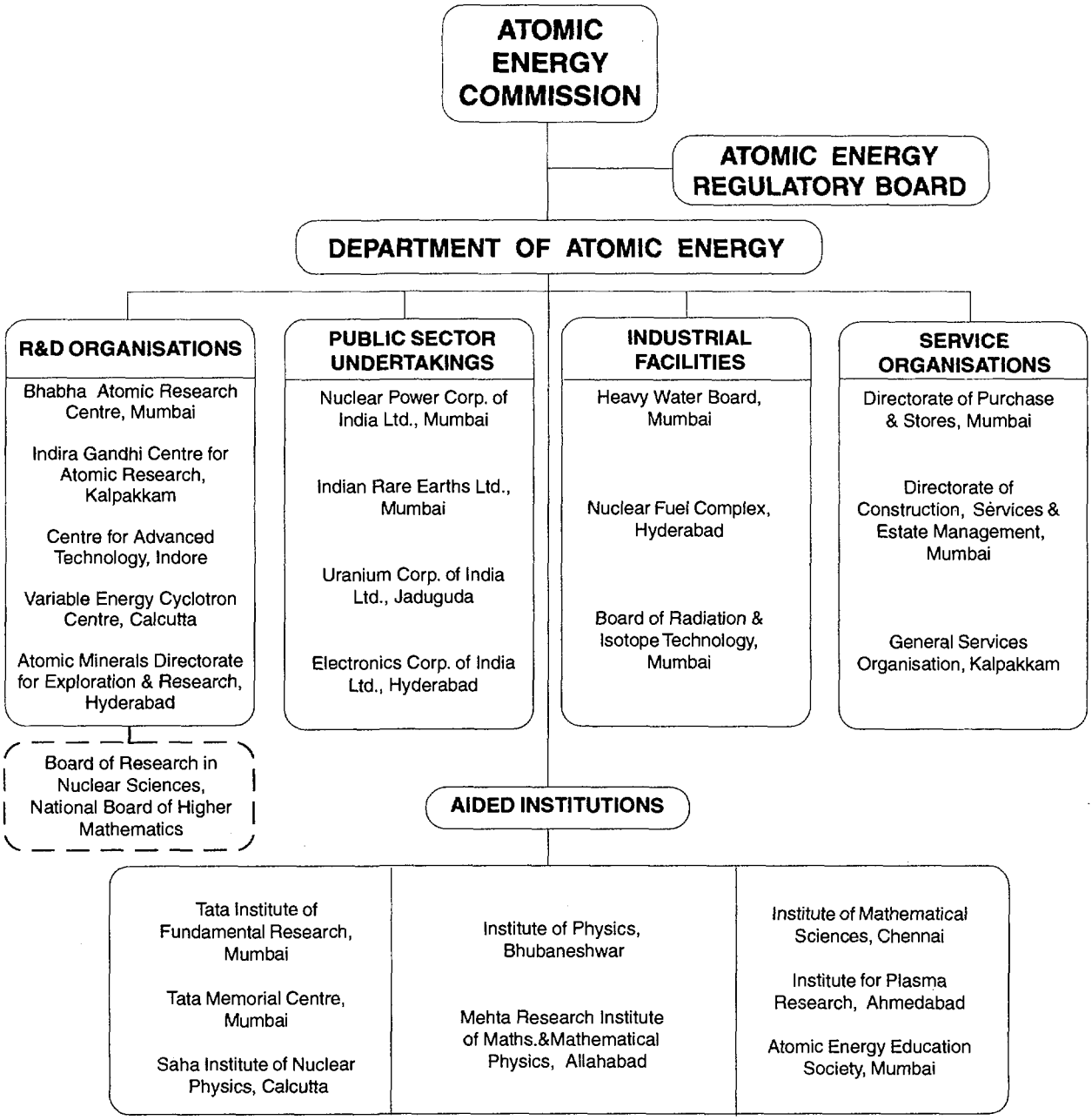
## 7.12 AWARDS

A team of two AMD scientists has been conferred prestigious National Mineral Award-1998 by the Ministry of Mines and Minerals, Government of India, in recognition of their significant contribution in the field of Geophysics for Airborne geophysical survey and instrumentation.

*The XV DAE Sports & Cultural Meet-1999, being inaugurated by Shri R. M. Premkumar, Additional Secretary, DAE.*



# THE ORGANISATION



# ORGANISATIONAL FUNCTIONS

The Department of Atomic Energy (DAE) aims at harnessing atomic energy for peaceful applications with emphasis on self-reliance.

DAE's main mandate is the production of safe and economical nuclear power, using indigenous uranium and thorium resources. Towards this end, it is involved in developing, in stages, pressurized heavy water reactors, fast breeder reactors, advanced thorium reactors with associated fuel cycle systems.

It builds research reactors for production of radioisotopes and carries out programmes on isotope and radiation technology applications in medicine, agriculture and industry. It develops high technologies such as accelerators, lasers, control and instrumentation, information technology, biotechnology and materials technology and also encourages technology transfers to other users and industry.

It supports basic research in nuclear energy and related frontier areas of science. It interacts with universities and academic institutions, and supports research and development projects having a bearing on DAE's programmes for mutual benefit.

It encourages international cooperation in related advanced areas of research and in mega science projects to enable Indian presence in the cutting edge of scientific developments, and

It contribute to national security.

## A) POWER SECTOR

The Power Sector comprises mainly the activities relating to power reactors, and allied R&D such as reactor engineering.

Contributing to this Sector are the Nuclear Power Corporation of India Ltd (NPCIL), a public sector undertaking of DAE, which is responsible for design, construction and operation of nuclear power reactors, and the Indira Gandhi Centre for Atomic Research (IGCAR) which is engaged in the development of fast reactors.

The R&D support to the Power Sector comes from Bhabha Atomic Research Centre (BARC), IGCAR and the Atomic Minerals Directorate for Exploration and Research (AMD).

NPCIL has 10 operating nuclear power reactors - two each at Tarapur (Maharashtra), Rawatbhatta (Rajasthan), Kalpakkam (Tamil Nadu), Narora (Uttar Pradesh), and Kakrapar (Gujarat) with a total installed capacity of 1840 MWe. The Tarapur reactors are boiling water reactors (BWRs) and the rest are pressurised heavy water reactors (PHWRs).

One pressurised heavy water reactor of 220 MWe at Kaiga (Karnataka) has synchronised with the grid and one similar reactor has attained criticality at Rawatbhatta (Rajasthan). These two reactors will soon attain commercial status.

Two PHWRs each of 220 MWe, are at advanced stages of construction at Kaiga and Rawatbhatta. Construction work on Tarapur Atomic Power Project-3&4, which will have two reactors of 500 megawatt capacity each, is progressing. 'Supplement' to the Inter-Government Agreement (IGA) for setting up of two VVER type reactors of 1000 megawatt each at Kudankulam (Tamil Nadu), has already been signed between the Russian Federation and India.

## B) INDUSTRY & MINERALS SECTOR

Industry & Minerals Sector comprises the industrial programmes of Nuclear Fuel Cycle supporting the nuclear power generation, and those relating to radiation & isotope technologies. The programmes under Nuclear Fuel Cycle cover Heavy Water Production, Nuclear Fuel Fabrication, Mining & Processing, Fuel Reprocessing, and Waste management. Contributing to the programmes are --

- ***Industrial Organisations***: Heavy Water Board (HWB) for production of heavy water, Nuclear Fuel Complex (NFC) for nuclear fuel fabrication and zircaloy products, and Board of Radiation & Isotope Technology (BRIT) for promotion of Radiation and Isotope Technologies.
- ***Public Sector Undertakings*** : Uranium Corporation of India Ltd (UCIL) for mining and processing of uranium, Indian Rare Earths Ltd (IRE) for mining and processing of mineral sand, and Electronics Corporation of India Ltd. (ECIL) for control & instrumentation equipment, and
- ***Research Organisations*** : BARC and IGCAR for Fuel Reprocessing and Waste Management, and R&D support.

The **Heavy Water Board** at Mumbai is responsible for production of heavy water for meeting the requirements of nuclear power as well as research reactors. Eight Heavy Water Plants have been installed at Nangal (Punjab) Tuticorin (Tamilnadu) Kota (Rajasthan), Baroda (Gujarat), Thal (Maharashtra) Talcher (Orissa), Manuguru (Andhra Pradesh) and Hazira (Gujarat). The plants at Kota and Manuguru use hydrogen sulphide and water exchange process developed at Trombay, the Nangal plant uses low temperature hydrogen distillation process and the other plants are based on ammonia-hydrogen process for heavy water production.

The **Nuclear Fuel Complex** (NFC) at Hyderabad fabricates and supplies fuel for the power reactors and zircaloy components for the PHWR reactors. It also fabricates enriched uranium fuel for the Tarapur BWRs and the thorium oxide blankets for the Fast Breeder Test Reactor (FBTR) at Kalpakkam. NFC operates plants for production of ceramic grade uranium oxide, zircaloy components, sintered pellets and fuel assemblies. Other facilities at the Complex are the

Stainless Steel Tubes and Ball Bearing Tubes Plants which cater to the needs of the Nuclear Energy Programme and the Industry.

The **Board of Radiation & Isotope Technology** (BRIT) promotes Radiation and Isotope technologies relating to radiopharmaceuticals, radiochemicals, radiosterilisation services for medical products, radiography equipment, radiosources and others.

BRIT operates a radiation sterilization plant, Isomed at Trombay, Radiopharmaceutical Laboratory at Navi Mumbai and Biomolecules Production Facility (Jonaki) and Centre for Compositional Characterisation of Materials (CCCM) at Hyderabad. In addition, the Board has regional centres for radiopharmaceuticals at Bangalore, Dibrugarh and Delhi. The Demonstration Plant for Radiation Processing of Spices at Vashi, Navi Mumbai has become operational.

The **Uranium Corporation of India Ltd.** (UCIL) at Jaduguda carries out mining and processing of uranium in the country. It has mines at Jaduguda, Bhatin and Narwapahar and operates a uranium ore processing mill at Jaduguda (Bihar). The Corporation also runs three uranium recovery plants at Surda, Rakha and Mosaboni.

The **Indian Rare Earths Ltd.** (IRE) mines and processes mineral sands containing thorium and rare earth minerals. The Company has three mineral sands separation plants at Manavalakurichi, Chavara and OSCOM at Chhatrapur, which produce minerals such as ilmenite, rutile, monazite, zircon and garnet. OSCOM also has a value addition plant which produces synthetic rutile. In addition to this, a Rare Earths Plant at Alwaye produces rare earth chlorides.

The **Electronics Corporation of India Ltd.** (ECIL) manufactures a variety of sophisticated electronic systems, instruments and equipment to meet the requirements of Atomic Power Stations, Defence, Railways, Telecommunications and other sectors. The Company is also a leading producer of computers and consumer electronics.

**BARC** operates Fuel Reprocessing Plants at Tarapur, Trombay and Kalpakkam and various waste management facilities and waste immobilisation plants (WIP) at Tarapur and Kalpakkam. **IGCAR** is also engaged in developing reprocessing technology in the field of fast reactors.

## C) RESEARCH & DEVELOPMENT

Contributing to the R&D Programme of DAE are its five research organisations. Also the Department fully supports seven national research institutes, provides financial assistance to prominent cancer centres in the country, and promotes research in nuclear and allied fields in universities and institutes of higher learning, and mathematics.

**DAE Research Centres** : The five research organisations of the DAE viz., Bhabha Atomic Research Centre (BARC), Indira Gandhi Centre for Atomic Research (IGCAR), Centre for Advanced Technology (CAT), Variable Energy Cyclotron Centre (VECC) and Atomic Minerals Directorate for Exploration and Research (AMD) are engaged in multidisciplinary research in the application of nuclear energy in power generation, production of radioisotopes and their applications in medicine, agriculture, industry, and hitech areas such as accelerators, computers, lasers, robotics, materials and advanced reactors, research in frontier areas of basic science, and others. As mentioned earlier, BARC and IGCAR also provide R&D support to the Nuclear Power and Nuclear Fuel Cycle Programmes, and AMD contributes to the development of mineral resources.

The **Bhabha Atomic Research Centre** (BARC) at Mumbai, is a premier nuclear research and development centre in the country. Its facilities include research reactors DHRUVA (100MWt), CIRUS (40MWt) and APSARA (1MWt) at Trombay for research and radioisotope production; Kamini (30 kWt) research reactor at Kalpakkam for neutron radiography, and plants for manufacture of uranium metal, nuclear fuels, fuel reprocessing and waste immobilisation, and seismic stations.

The Fuel Reprocessing Plants set up by BARC are operating at Tarapur, Trombay and Kalpakkam. BARC is also responsible for nuclear waste management and operates various waste management facilities and waste immobilisation plants at Tarapur and Kalpakkam. The Radiation Medicine Centre - a unit of BARC at Mumbai, is the regional referral centre of the World Health Organisation. A 14 million volt Pelletron Accelerator, set up at Mumbai by BARC in collaboration with TIFR, is a national research facility.

The **Indira Gandhi Centre for Atomic Research** (IGCAR) at Kalpakkam, Tamil Nadu, is engaged in the development of sodium cooled fast breeder reactor technology, related fuel cycle and safety. The Fast Breeder Test Reactor (FBTR) is its major research facility. IGCAR has also set up advanced laboratories for carrying out research and development work in the fast breeder reactor technologies such as metallurgy, reactor engineering, sodium technology, radiochemistry, reprocessing and safety. The Centre is developing a 500 MWe Prototype Fast Breeder Reactor (PFBR).

The **Centre for Advanced Technology** (CAT), Indore, Madhya Pradesh spearheads the national efforts in research and development of lasers, accelerators, high vacuum technology, cryogenics and technology for manufacture of large magnets. CAT is setting up a Synchrotron Radiation Sources (SRS) Facility which will be an unique research setup in the country. Indus-1 facility of SRS has successfully achieved beam current much higher than the target.

The **Variable Energy Cyclotron Centre** (VECC) at Calcutta is a national research centre in nuclear field. The variable energy cyclotron (VEC) delivers beams of nuclear particles for research in nuclear physics and nuclear chemistry, and produces radioisotopes for various applications. The

Centre is setting up a superconducting cyclotron.

The **Atomic Minerals Directorate for Exploration and Research** (AMD) at Hyderabad is entrusted with the research and development relating to radiometric and geological surveys, exploration, prospecting and development of various mineral resources needed for the nuclear power programme of the DAE.

**Aided Research Institutes**

The **Tata Institute of Fundamental Research** (TIFR) at Mumbai is the national centre for research in nuclear sciences and mathematics. It is engaged in frontline research in astrophysics, astronomy, computer science and molecular biology. The Institute's research facilities include a 14 MV Pelletron Accelerator and an NMR Facility at Mumbai; Balloon Research Facility at Hyderabad; Radiotelescope Array and National Image Processing Facility for Astronomy at Ooty, and National Centre for Biological Sciences at Bangalore. In addition, it manages the Homi Bhabha Centre for Science Education (HBCSE) at Mumbai. TIFR has set up at Narayangaon near Pune, a Giant Metrewave Radio Telescope (GMRT) for frontline research in radioastronomy.

The **Saha Institute of Nuclear Physics** (SINP) at Calcutta conducts research in nuclear physics, nuclear spectroscopy, nuclear and radiation chemistry, molecular physics, plasma physics, biophysics, molecular biology and instrumentation.

The **Tata Memorial Centre** (TMC) at Mumbai, comprises the Tata Memorial Hospital (TMH) and the Cancer Research Institute (CRI). It is a major centre for cancer therapy, research and education in the country. The Tata Memorial Hospital is equipped with sophisticated facilities for diagnosis and treatment of cancer. The Cancer Research Institute is engaged in cancer research and education. TMC is also setting up an Advanced Centre for Treatment, Research and Education in Cancer (ACTREC) in Navi Mumbai.

The (IOP) at Bhubaneswar (Orissa) is engaged in advanced research in theoretical and experimental nuclear, high energy and solid state physics. The research facilities at the Institute include a Pelletron Accelerator and a set up for Compton profile and positron annihilation experiment.

The **Mehta Research Institute of Mathematics and Mathematical Physics** (MRI) at Allahabad (Uttar Pradesh), carries out research in operation theory, consumability theory, particle physics and field theory.

The **Institute of Mathematical Sciences**, (IMSc) at Chennai (Tamil Nadu), is engaged in research in physics, mathematics and computer sciences.

The **Institute for Plasma Research** (IPR) at Gandhinagar (Gujarat) promotes and conducts studies in plasma physics, and aims at developing fusion as a source of energy. Having built India's first indigenous "Tokamak" Aditya, the Institute has commenced work on the development of a steady state superconducting Tokamak.

The **Board of Research and Nuclear Sciences** (BRNS) and the **National Board of Higher Mathematics** (NBHM) both at Mumbai, under the aegis of DAE promote activities including research in nuclear sciences and mathematics respectively at universities and other academic institutions. NBHM also participates in the International Mathematical Olympiad.

## D) SERVICE ORGANISATIONS

The **Directorates of Purchase & Stores** (DPS), and **Constructions, Services & Estate Management Group** (CS&EMG) both at Mumbai, and the **General Service Organisation** at Kalpakkam manage support functions such as purchases, stores, construction and maintenance of buildings, estate matters and general services.

The **Atomic Energy Education Society** (AEES) at Mumbai is an aided society of the DAE. It manages the atomic energy schools at various sites.

# PROGRAMME PROFILE

The DAE aims at harnessing nuclear energy for electricity generation; use of radioisotopes in agriculture, medicine and industry; developing high technologies such as accelerators, lasers, information technology and others; promoting R&D in nuclear science and allied areas; developing human resource, and contributing to national security.

*Nuclear Power*

DAE is pursuing a three-stage Nuclear Power Programme as follows, to maximise the use of uranium and thorium resources available in the country :

Use of natural uranium fuel in pressurised heavy water reactors (PHWRs) for electricity generation and production of plutonium in Stage I; use of plutonium produced in PHWRs, in fast breeder reactors (FBRs) and production of additional plutonium/uranium-233 fuel for electricity generation in Stage II, and use of thorium-uranium-233 in advanced reactor system in Stage III.

DAE has achieved comprehensive capability in the design, construction and operation of PHWRs. There are 2 boiling water reactors and 8 PHWRs operating nuclear power reactors in the country with a total installed capacity of 1840 MWe.

Two reactors each of 220 MWe capacity have attain cricality at Kaiga and Rawabhatta. Two more similar reactors at this locations are expected to become operational later this year. The design of 220 MWe PHWR has been standardised, and a high level of indigenisation in the nuclear fuel cycle has been achieved.

The design of the 500 MWe PHWR has been completed. NPCIL has started construction work on two such reactors at Tarapur.

The 'Supplement' to the Inter-Governmental Agreement (IGA) for setting up of two pressurised water reactors of 1000 MWe capacity each, has been signed between the Russian Federation and India.

With the successful commissioning and operation of the Fast Breeder Test Reactor (FBTR) at Kalpakkam, India is in the second stage of its Nuclear Power Programme. The Fast Breeder Test Reactor (FBTR) was operated at power levels upto 11.5 MWt and electricity was generated. Also, maximum burnup of 50,000 MWd/t for indigenously developed fuel has been achieved. Technology development of 500 MWe prototype fast breeder reactor (PFBR) is progressing at Kalpakkam.

Under the thorium utilisation programme, uranium-233, separated from irradiated thorium and fabricated into fuel elements, has been successfully used in a research reactor KAMINI at Kalpakkam. Thorium has also been used for flux flattening in the initial cores of the Kakrapar reactors. Work is progressing on the design of an Advanced Heavy Water Reactor (AHWR) which will make use of thorium as fuel.

*Nuclear Fuel Cycle*

The nuclear fuel cycle comprises activities supporting the nuclear power programme covering mineral exploration, mining, heavy water production and fuel fabrication to fuel reprocessing and waste management. The Department has attained self-reliance over the entire cycle.

*Minerals Exploration and Mining*

The exploratory efforts of the Atomic Minerals Directorate for Exploration and Research (AMD) have led to the opening of uranium mines at Jaduguda, Bhatin and Narwapahar in Bihar, which are now operated by the Uranium Corporation of India Ltd. (UCIL). Discovery of Domiasiat reserves in Meghalaya is an important success of AMD. The Directorate has located sizable uranium deposits at Lambapur-Yellapur and Tummalapalle in Andhra Pradesh.

Large reserves of thorium and zirconium have been identified by AMD in beach placers along the coastal tracts and other parts of the country.

Jaduguda, Bhatin and Narwapahar mines are meeting the uranium needs of the Nuclear Power Programme. The natural uranium from these mines is processed as yellow cake and sent to the Nuclear Fuel Complex (NFC) at Hyderabad for PHWR fuel fabrication.

Some of the placer deposits are being commercially exploited by the Indian Rare Earths Ltd. (IRE) which supplies thorium containing ores to the Thorium Plant at Trombay, and zircon to NFC for production of zircaloy components.

*Heavy Water Production*

Heavy water is used in the PHWRs as moderator and coolant. The indigenous heavy water production capability is fully proven. Eight Heavy Water Plants have been installed in the country. All the plants have shown good performance and safety record. While meeting domestic demand DAE is also in a position to export heavy water.

*Nuclear Fuel Fabrication*

Nuclear fuel assemblies for PHWRs and BWRs, along with zirconium components are manufactured indigenously at NFC. The Complex is also geared towards the development of components needed for advanced reactors such as PFBR. Fuel for research reactors is fabricated at BARC.

Development of new fuels is a thrust area of R&D at BARC. The Mixed Oxide (MOX) fuel bundles for Tarapur reactors have been fabricated successfully at the Advanced Fuel Fabrication Facility, Tarapur. MOX fuel has given good performance when loaded in Tarapur reactors. For PFBR annular uranium oxide fuel pellets were fabricated.

The fuel made of mixed uranium-plutonium carbide for fast breeder test reactor (FBTR) developed successfully at Trombay, has performed well. Carbide fuel core has been used in a fast reactor for the first time in the world.

***Fuel Reprocessing and Waste Management***

Fuel reprocessing and nuclear waste management constitute the back-end of the nuclear power programme. These technologies are now fully established in the country and industrial plants are in operation. Fuel reprocessing plants are operating at Tarapur, Trombay and Kalpakkam. A Lead Mini Plant for reprocessing of FBTR fuel will shortly go for cold commissioning. A plant for reprocessing of fast reactor fuel (FRFRP) is also under construction at Kalpakkam.

The waste treatment, conditioning and disposal systems have been operating at various nuclear installations. Vitrification of radioactive waste in a glass matrix, a complex technology, has been successfully developed by BARC. A Waste Immobilisation Plant (WIP) is operational at Tarapur and two such plants are coming up at Trombay and Kalpakkam. For final disposal of immobilised high level radioactive wastes, a programme of siting a repository in suitable deep geological formations is going on.

***Research and Development***

The Research and Development Programme of DAE is multidisciplinary and forms infrastructure for the power programme and nuclear fuel cycle and associated technologies. The programme also covers areas relating to medicine, agriculture and industry. The R&D programme is also geared towards the development of high-technologies in the areas of accelerators, computers, lasers, robotics, superconductivity and others.

***R&D Support to Nuclear Power Programme***

The R&D support to the Nuclear Power Programme comes from BARC and IGCAR.

BARC, in close coordination with NPCIL carries out research in areas of reactor engineering, reactor physics, nuclear chemistry, materials, advanced instrumentation, computer technology, electronics, safety and related basic sciences. The R&D programmes of BARC in reactor engineering have led to the development of number of technologies for power reactors.

The R&D at IGCAR relates to fast breeder reactor (FBR) programme in the areas of materials development, fuel reprocessing, safety of FBRs, fuel chemistry, sodium technology and others.

***Research Reactors***

The Department has acquired rich experience of over four decades in design, construction and operation of research reactors, and radioisotope production. Beginning with the commissioning of Apsara reactor in 1956, BARC set up four more research reactors. The latest, the 100 MWt high flux reactor Dhruva, is a fully indigenous effort. Dhruva and Cirus are the main reactors which produce radioisotopes and are used in research. The 30 MWt neutron source reactor Kamini built by BARC at Kalpakkam is used for neutron radiography. Towards thorium utilisation, work is progressing on the design & development of AHWR.

***Radioisotope Applications***

The radiation technology and radioisotope applications constitute an important technology mission of DAE. BARC is a major producer of radioisotopes for use in industry, medicine, agriculture and research and the Board of Radiation and Isotope Technology (BRIT) offers various products and services in the field of radiation and isotopes.

Radioisotopes in Industry : The radioisotopes produced at Trombay are widely used by industry for nondestructive testing, measurements, radiography and tracer applications. Medical industry is a major beneficiary of BRIT's radiation sterilization facilities. Isomed Plant at Trombay for sterilization of medical products, has serviced the industry for over two decades. Similar plants have been working at Bangalore, New Delhi and Jodhpur.

Radioisotopes in Medicine : In the field of medicine, the radioisotopes are used for diagnostic and therapeutic purposes. Radioisotopes from BARC are processed by BRIT for production of radiopharmaceuticals, radioisotope based products and equipment. The radiopharmaceuticals supplied by BRIT are used in about 7 lakh patient investigations per year. BRIT is also a major supplier of radioactive sources which are used in radiodiagnosis and radiotherapy in hospitals throughout the country.

Radioisotopes in Agriculture : Radioisotopes produced in BARC have been used in crop improvement, food preservation and other agricultural applications. BARC's mutation breeding programme has resulted in evolution of high yielding varieties of pulses, oilseeds, rice and jute. Many of these have reached the farmers and are cultivated in different parts of the country. BARC has also established irradiation technology for preservation of food. Irradiation of sea food, spices, potatoes and onions has been approved by the Government of India for export purposes. In April 1998, some more food items have been cleared for irradiation. In agriculture, radioisotopes have helped in monitoring the persistence of pesticides in soil and ground water. BRIT has recently made operational its Demonstration Plant for Radiation Processing of Spices at Vashi, Navi Mumbai.

***Safety and Environment Protection***

Safety has been an integral part of DAE activities. NPCIL has completed over 160 reactor years of operation with good record of safety which encompasses facets such as radiological safety, industrial safety, fire safety and environment protection. In all the nuclear installations, care is

taken to protect operating personnel, public and the environment, Safety is monitored by an independent body, the Atomic Energy Regulatory Board (AERB).

Setup at different sites, the Environment Survey Labs (ESLs) equipped with sophisticated equipment, constantly monitor environment, and advanced systems collect site related meteorological data.

A national network of environmental radiation monitoring stations is being established for detection of radiation releases as a part of a global environmental radiation monitoring (GERMON) network.

BARC's personnel radiation monitoring services benefit about 32,000 radiation workers every year.

***Basic Research***

Besides developing technologies for the nuclear power and associated programmes, including non-electricity areas, the DAE's research centres have been engaged in basic and applied research in frontier domains of sciences covering physical, chemical and materials sciences, molecular biology and astrophysics.

Basic research is also carried out in nuclear energy and frontline areas of science and technology at seven national institutes under the aegis of DAE, covering areas such as mathematics, physics, biosciences and astronomy at the Tata Institute of Fundamental Research, Mumbai; physics of condensed matter and plasmas at the Saha Institute of Nuclear Physics, Calcutta; cancer research at the Tata Memorial Centre, Mumbai; condensed matter physics, high energy particle physics and nuclear physics at the Institute of Physics, Bhubaneshwar; frontier disciplines of mathematical sciences at the Institute of Mathematical Sciences, Chennai; operations theory, consumability theory and other advanced areas of mathematics and mathematical physics at the Mehta Research Institute of Mathematics and Mathematical Physics, Allahabad and plasma physics at the Institute for Plasma Research, Ahmedabad.

***High Technology Development***

The research organisations of DAE have generated a number of high technologies. These include supercomputer system using parallel processing techniques; advanced remote handling and robotic devices and servo-manipulators for applications in industry; scintigraphic techniques used in organ imaging in medical diagnosis; surgical and industrial applications of lasers; accelerators for nuclear research and isotope production; Giant Metrewave Radio Telescope (GMRT) set up at Pune for research in astronomy; radiation and isotope technologies; and the specialised services for analysis and characterisation of ultra-pure materials at the National Centre for Compositional Characterisation of Materials, Hyderabad.

***Technology Transfer***

The multidisciplinary research carried out in frontier and hitech areas in its different research centres, has helped DAE in achieving self-reliance in Nuclear Fuel Cycle. Success has been achieved in transferring technology based on in-house R&D to the organisations within DAE engaged in mineral processing, heavy water production, fuel fabrication and reprocessing plants, and public sector undertakings.

Also, the spin-offs of the research and development work carried out under the aegis of DAE, has generated several technologies that have benefited a number of industries. These technologies include material and alloys, radioisotope based tools and techniques, agro-technology, lasers for surgery and industrial applications, electronic instruments and devices, and others.

***DAE-Industry Interaction***

A number of Indian industries have been the partners of DAE in its progress. This interaction has resulted in indigenisation of the Indian Nuclear Power Programme, and developing capabilities of the Indian industry in meeting the stringent demands of the present hitech age.

With the creation of the Indian Atomic Industrial Forum, the Department has strengthened its industrial interface.

***Promotion of Research & Mathematics***

Besides fully funding the seven national institutes, financial support is also extended by DAE to cancer research centres/hospitals for improving cancer control measures in the country. The Department, through its Board of Research in Nuclear Sciences (BRNS) — a major research funding agency in the country — promotes research and development in nuclear fields in universities and institutions by way of funding of research projects, offering fellowships, and supporting activities such as seminar and symposia. Also, through the National Board of Higher Mathematics (NBHM) financial assistance is provided to activities relating to mathematics.

***International Research Collaboration***

The R&D Centres of DAE have been participating in a number of International research collaborations. BARC fabricated and supplied shutter guide to the Rutherford Appleton Lab., UK; designed and developed Compact Muon Solenoid-Detector for CERN and a prototype detector frame for muon tracking for Brookhaven National Laboratory, USA. BARC also carried out collaborative experiments with Legnaro, Italy and collaborated with Berlin Neutron Scattering Centre.

VECC's simulation and design studies on ALICE-PMD (Photon Multiplicity Detector) reached completion.

***Human Resource Development***

The Training School at Trombay and National Training Centre at Rawatbhata are the premier training centres of the

Department. These provide specialised training to undertake multidisciplinary activities of DAE. A number of specialised courses in the fields of radiation and isotope technology, radiation medicine, health & safety and others are run by various DAE organisations.

DAE has also extended its training facilities to organisations at national and international levels in various areas which cover nuclear agriculture, nuclear medicine, radioisotope technology and many specialised services. DAE also offers training facilities, fellowships, visits and services of experts through the International Atomic Energy Agency (IAEA) or bilateral agreements for cooperation in peaceful uses of atomic energy.

***DAE-University Interaction***

Through the Inter-University Consortium for DAE Facilities (IUC-DAEF), research facilities at various centres of the Department are used by researchers of universities and academic institutions. Dhruva reactor at BARC has been in regular use by university scientists. Research projects are regularly pursued by the university scientists at Trombay. BARC has also entered into MoU with Mangalore University for training and technical guidance. At IGCAR, low energy accelerator facilities have been in use under this programme.

Research projects in universities and institutes, in the fields of nuclear sciences and allied areas, are funded by the DAE's Board of Research in Nuclear Sciences (BRNS) and the National Board for Higher Mathematics (NBHM).

***International Relations***

India has been a member of the Board of Governors of the International Atomic Energy Agency (IAEA) since its inception. In September, 1994 the country was elected as the Chairman of the Board of Governors of IAEA for one year.

Training facilities, fellowships, scientific visits and services of scientists for expert assignments are offered, by DAE both through the IAEA and to the countries with which India has entered into bilateral agreements for cooperation in the field of peaceful uses of atomic energy.

As an active member of WANO, Indian experts participated in Peer Reviews in many countries including the USA, Japan and South Korea. A Peer Review of the Kakrapar Atomic Power Station was conducted by the World Association of Nuclear Operators (WANO) in 1998. Similar review of Narora Atomic Power Station by WANO is expected shortly.

Concerted efforts are continued to publicise Indian expertise for the purpose of export of technology and equipment for peaceful applications of nuclear energy.

# ABBREVIATIONS

*ORGANISATIONS/FACILITIES*

| | |
|---|---|
| AFFF | Advanced Fuel Fabrication Facility |
| APSEB | Andhra Pradesh State Electricity Board |
| CWMF | Central Waste Management Facility |
| DOE | Department of Electronics |
| DRDO | Defence Research & Development Organisation |
| ESL | Environmental Survey Labs |
| FBTR | Fast Breeder Test Reactor |
| GOALS | Gurushikhar Observatory for Astrophysical Science |
| GSFC | Gujarat State Fertilizer Corporation |
| HMT | Hindustan Machine Tools |
| HOC | Hindustan Organic Chemicals Ltd. |
| HPU | Health Physics Unit |
| IAEA | International Atomic Energy Agency |
| ICRP | International Commission on Radiological Protection |
| IISc | Indian Institute of Science |
| IIT | Indian Institute of Technology |
| IMSc | Institute of Mathematical Sciences |
| KAPS | Kakrapar Atomic Power Station |
| KARP | Kalpakkam Fuel Reprocessing Project |
| MAPS | Madras Atomic Power Station |
| NAPS | Narora Atomic Power Station |
| NCCCM | National Centre for Compositional Characterisation of Materials |
| PREFRE | Power Reactor Fuel Reprocessing Plant |
| RAPS(P) | Rajashtan Atomic Power Station (Project) |
| REDL | Rare Earths Development Laboratory |
| RMC | Radiation Medicine Centre |
| RRMC | Regional Radiation Medicine Centre |
| TAPS(P) | Tarapur Atomic Power Station (Project) |

*MISCELLANEOUS*

| | |
|---|---|
| AFR | Away From Reactor |
| AGRS | Air-borne Gamma-Ray Spectrometry |
| AGSS | Aerial Gamma Spectrometric System |
| AHWR | Advanced Heavy Water Reactor |
| ALARA | As Low As Reasonably Achievable |
| BGL | Blackgram lectins |
| BWRs | Boiling Water Reactors |
| Bq | Bequerel |
| CCRM | Coolant Channel Replacement Machine |
| DNA | De-oxy Ribonucleic Acid |
| DPHS | Dual Processor Hot Standby |
| DSC | Differential Scanning Calorimetry |
| EB | Electron Beam |
| ECCS | Emergency Core Cooling System |
| ECR | Electron Cyclotron Resonance |
| EGA | Evolved Gas Analyser |
| EMF | Electro-motive force |
| EMI/EMC | Electro-magnetic Interference/Compability |
| EP | Embedded Part |
| ERDS | Emergency Response Data System |
| FIV | Flow Induced Vibration |
| GERMON | Global Environment Monitoring |
| GIS | Geographic Information System |
| HVE | Hot Vacuum Extraction Facility |
| AES | Atomic Emission Spectrometer |
| ICP-MS | Inductively Coupled Plasma Mass Spectrometer |
| IFG | Inert Gas Fusion Technique |
| ISROS | Internal Safety Review of Operating Stations |
| KDP | Potassium Di-hydrogen Phospate |
| KGF | Kolar Gold Field |
| KV | Kilo Volt |
| LCTR | Large Component Test Rig |
| LINAC | Linear Accelerator |
| LTVE | Low Temperature Vacuum Evaporation |
| MBN | Magnetic Barkhausen Noise |
| MGD | Million Gallons per Day |
| MIBG | Meta Iodo-Benzyl Guanidine |
| MOU | Memorandum of Understanding |
| MOX | Mixed Oxide Fuel |
| MSF-RO | Multi-Stage Flash Reverse Osmosis |
| MWe | Mega Watt (electrical) |
| MWt | Mega Watt (thermal) |
| NDT | Non-Destructive Technique |
| PCS | Process Control System |
| PERTS | Programming Environment for Real Time System |
| PFBR | Pototype Fast Breeder Reactor |
| PHWR | Pressurised Heavy Water Reactor |
| PIG | Pipe-line Inspection Gauge |
| PRL | Physical Research Laboratory |
| QC/QA | Quality Control / Quality Assurance |
| QGP | Quark Gluon Plasma |
| QMS | Quadrupole Mass Spectrometer |
| REE | Rare Earth Elements |
| RFQ | Radio Frequency Quadrupole |
| RIA | Radioimmuno-assay |
| RIMS | Resonance Ionisation Mass Spectroscopy |
| RIP | Repository for Immobilised Waste Product |
| ROLI | Radiography Camera |
| RRS | Reactor Regulating System |
| SCADA | Supervision Control & Data Acquisition System |
| SECC | Site Emergency Control Centre |
| SODAR | Sound Detection and Ranging |
| SQUID | Super-conduction Quantum Interference Device |
| SSMS | Spark Source Mass Spectrometry |
| SWRO | Sea Water Reverse Osmosis |
| TLD | Thermo Luminescence Detector |
| Th,Pu | Thorium, Plutonium |
| U-Zr-O | Uranium Zinconium Oxygen |
| U/Th-Mo-O | Uranium/Thorium-Molybdenum-Oxygen |
| UHF | Ultra High Frequency |
| VNTR | Variable Number Tandem Repeats |
| VSAT | Very Small Aperature Terminal |
| WDXRF | Wave Dispersion X-Ray Fluorescence |
| XRF | X-ray Radio Frequency |
| tpd | Tonnes Per Day |

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