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Nuclear India

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The 2.5 GeV Synchrotron Radiation Source INDUS – II is functioning at Raja Ramanna Centre for Advanced Technology, Indore, Madhya Pradesh. The picture above is of Front-End installed on BL-12, a “High resolution x-ray diffraction beam line”of Indus-2. The Front Ends for five other beam lines, have been taken up for installation.

Part of the XRD beam line in Indus-2 hall.

"Energy Independence has to be our nation's highest priority. Our target is to achieve Energy Security by 2020 leading to Energy Independence by 2030 and beyond. ..."

President A.P.J. Abdul Kalam interacting with engineers at Kudankulam Atomic Power Project

"Small aim is a crime"

I am indeed delighted to be in Kudankulam Nuclear Power Project, a project of Nuclear Power Corporation of India. Department of Atomic Energy has influenced Indian society in multiple fields. I understand that presently the total nuclear power generation capacity is 3900 MW using 16 nuclear reactor. I am happy to know that the nuclear power reactors are working with an average annual availability factor of 89%. This was made possible by adopting innovative fuel optimization and outage management techniques in operating stations. This is a notable contribution of the Nuclear Power Corporation towards high quality operation and maintenance of power systems in the country. I extend my greetings to all the scientists, technologists and staff. I am sure, you will excel in operational performance in Kudankulam Power Plants. When I was thinking what thoughts I can share with you since you are in the business of energy, I would like to give you a profile what should be the energy mix for India between now to 2020 and 2030. Hence, I have selected the topic "energy independence".

Energy Independence

In the field of energy, many innovations are taking shape. The world energy forum has predicted that fossil based oil, coal and gas reserves will last for less than ten decades. The energy is an important parameter for development. Continuously increasing cost of oil sourced from fossil material prompted many groups in the world to seriously consider the possible energy options. Based on our study, I have discussed about Energy Independence as part of my Independence Day Address to the nation, on 15 August 2005. There, I mentioned that Energy Independence has to be our nation's highest priority. Our target is to achieve Energy Security by 2020 leading to Energy Independence by 2030 and beyond. Of course there have been many discussions nationally as well as internationally on this subject. I would like to suggest certain actions to be taken on the energy missions for contributing towards energy independence in India particularly it is relevant to atomic energy scientists and the team of Nuclear Power Corporation.

Structure of Energy Sources

Based on the progress visualized for the nation during the next two decades, the power generating capacity has to increase to 400,000 MW by 2030 from the existing 130,000 MW. This has been arrived at taking into account the use of efficient transmission and distribution system and minimization of other losses. Energy independence has got to be achieved through three different sources namely hydel capacity, nuclear power and non-conventional energy sources primarily through solar energy, apart from thermal power. The hydel capacity generated through normal water sources and inter-linking of rivers is expected to contribute an additional 50,000 MW. Large scale solar energy farms of hundreds of megawatts capacity in

**Address of the President Dr. A.P.J. Abdul Kalam at Kudankulam Nuclear Power Project, Kudankulam, Tirunelveli, Tamil Nadu, 22 September 2006* certain number could contribute around 55,000 MW. The nuclear power plants should have a target of 50,000 MW of power. The balance 115,000 MW has to be generated through the conventional thermal plants through coal, gas and other renewable sources of energy such as wind power, biomass, power through municipal waste and solar thermal power. The most significant aspect, however would be that the power generated through renewable energy technologies has to be increased to 25% against the present 5%. Let me discuss about the profile of renewable energy systems.

The energy mix for energy independence envisages use of four routes: (a) Hydel + Thermal till coal availability (b) Solar power using high efficiency CNT based SPV cells (c) Thorium based nuclear reactors (d) Bio-fuel for transportation sector.

As all of you can see the Department of Atomic Energy is required to provide 50,000 MWs of electric power before 2030 contributing to make India energy independent. Indigenously, we have built certain capacity for generating electricity through pressurized heavy water route. Let us look at some details which gives us the confidence to take up more challenging tasks and meet the national nuclear energy targets.

India's first 540 MWe Pressurized Heavy Water Reactor

India's first 540 MWe Pressurized Heavy Water Reactor (PHWR), built based on indigenous technology at Tarapur, Maharashtra became critical on 6th March 2005. It is the largest indigenously designed and built power reactor in the country. The commissioning of this nuclear reactor, has indeed established our technological and managerial leadership.

The project at Tarapur comprises of a twin-unit station of PHWR type, each of 540 MWe installed capacity and are being built adjacent to the existing two units of smaller size. The first concrete (Grade M-60) was poured on 8th March, 2000 and criticality has thus been achieved in less than 5 years.

The design of the reactor incorporates all the basic features of the existing PHWRs. The safety features in the existing 220 MWe units, such as fast acting diverse independent shutdown systems, high pressure emergency core cooling systems, double containment, supplementary control room along with the safety objectives like redundancy diversity, avoidance of common cause failure have been incorporated in these 540 MWe units. However, extensive theoretical and experimental development followed by manufacturing was necessary for implementing these features. Apart from this, there have been additional design innovations, which were driven with the objective of maintaining and improving the indigenisation of nuclear power plant components. Certain equipments have been redesigned so that their manufacturing is within the capability of Indian industry.

Overall plant execution was done by contracting out packages of activities rather than single activities. This approach simplifies coordination, and therefore increases speed of execution of various works. This technological and project management experience will be useful for our future high-tech programme.

Completing of this project in a record time of less than 5 years is a testimony to the level of maturity that has been achieved by the Indian industry and the NPCIL. When I visited project site of Tarapur plant in 2001, I was very happy to see the engineers and staff of NPCIL working round the clock with the pride that they are going to build the first Indigenous 540 MWe power station. They have done it and India is proud of them. Similarly, now you are in the process of commissioning the first 2 X 1000 MW nuclear power plant using pressurized heavy water at Kudankulam. I am sure, through your technological capability, dedication and hard work, the plant will become critical in time during 2007 and very soon provide electricity to the grid. As known to the members of NPCIL, India has only limited uranium resources whereas we have plenty of thorium material available in the country. Hence, the focus of our nuclear scientist in the coming years has to be in the development of thorium based nuclear power plants.

Efficient thorium based nuclear fuel

Going critical of fast breeder reactor which is in an advanced stage of construction, development of Advanced Heavy Water Reactor (AHWR) and Accelerator Driven System (ADS) technologies have to be pursued in an integrated way. There are many scientific and technological challenges.

Fast Breeder Reactors: Fast breeder reactors can make a significant contribution to India's energy requirements, but the rate of increase in fast breeder reactor installed capacity has to follow a certain growth path as plutonium-239, the fuel for the fast reactors gets generated in nuclear reactors. Thus, the rate of new fast reactor capacity addition has to be determined by the rate at which plutonium can be bred. The breeding depends on the fast reactor design and the chemical form of plutonium fuel. Metallic fuel gives much higher breeding ratio whereas plutonium in oxide form gives a lower breeding ratio. So our basic research has to be on the development of metallic fuel on priority. It is only after we have established enough fast reactor capacity, we can shift to thorium based systems and continue to get power from thorium reactors for a long time.

Thorium Technologies: Country has already set up a facility for reprocessing thorium and has designed an Advanced Heavy Water Reactor (AHWR), which aims to derive two-third of its power from thorium and one third from plutonium generated from Fast Breeder Reactor (FBR). Implementation of the AHWR project and development of associated fuel cycle facilities will provide industrial scale experience in the handling of thorium. An important basic research area would be to develop reactor systems based on thorium wherein power derived from thorium can be increased and external input of fissile material can be minimized. It will definitely lead to early utilization of thorium in power production.

Accelerator Driven Systems: The other possibility for thorium utilization is through Accelerator Driven Systems (ADS). ADS have two main components: an accelerator and a reactor. A reactor system using only thorium as fuel cannot become critical as thorium is not a fissile material. To make it critical, an external supply of neutrons is needed. A 'spallation' source can provide an external source of neutrons to achieve criticality in an otherwise sub-critical system. The development of an appropriate proton accelerator is the first step towards the development of ADS. The research results will lead to building an accelerator and subsequently the use of accelerator for detachment of neutrons from heavy elements. Accelerator technology has many other applications. For example, accelerators are useful in health care for treatment of cancer and in basic research as tools to study structure of atom. Accelerators are also useful in the industry for chemical processing, where irradiation by accelerators can be used to improve the mechanical and electrical properties of cable insulation. How we can meet these research and development challenges?

I would like to recall two experiences. India's nuclear programme has always been under technological denials for decades from many countries. Every one of the nuclear scientists and science leaders realized that the self-reliance is the most promising route. Nuclear scientists have always shown the country how nuclear technology can be used for increasing the agricultural produce, medical application and nuclear power generation. Let me also share one of my experiences when I was chief of Aeronautical Development Agency (ADA). It was 1998; India achieved a very important national milestone. This resulted in many nations imposing technology denials and economic sanctions. Particularly, the Light Combat Aircraft programme came to a halt because of collaborating countries breaking the agreements on the development contracts undertaken. I took an emergency meeting of the ADA Board and we formed a National Team for LCA control system with 20 members drawn from 7 organizations in the country with a two years project schedule. In 18 months, we realized a world class digital fly by wire control system for the LCA. Now, four LCA aircraft are flying and 5th one is getting ready for flight test. Cumulative flying hours logged by the 4 aircraft is over 500 hours. The batch production of LCA TEJAS is to commence. The message I would like to give to our nuclear scientists is:

"Nationally we have the best minds, Enlist the national team, The government and the people are with you, Progress with your vast knowledge and experience, you will succeed."

Conclusion

Since I am in the midst of young scientists of Kudankulam , I would like to administer an oath on Courage, if you all agree.

COURAGE

Courage to think different,
Courage to invent,
Courage to discover the impossible,
Courage to combat the problems
And Succeed,
Are the unique qualities of the scientist.
As a scientist of Nuclear Power Plant, I will work and work with courage to achieve Success in scientific discoveries and Scientific achievements

My best wishes to all the scientists and technologists of Kudankulam Nuclear Power Project for success in their mission of providing all the technological and scientific support for making India energy independent by 2030.

May God bless you.

"Today, there is far greater realization, than any time before, of the importance of nuclear energy as perhaps the only viable solution to sustainable development without further aggravting the globlal environment that is already threatening serious climate change. ..."*

Dear Colleagues,

... To-day is an occasion when we take stock of our achievements over past one year and rededicate ourselves to the vision of our Founder Father.

... For a large country like ours, which is on a rapid economic growth path with per capita energy consumption still a very small fraction of level of energy use necessary for sustaining a reasonable quality of life, nuclear energy is of crucial importance to secure our energy independence.

... Seen in this context, the vision of our three stage programme laid out before us by our Founder, as a road map of nuclear energy development based on nuclear energy resources available in India and the all important mantra of self reliance has not only withstood the test of time but has also become even more important to-day. Let us all rededicate ourselves to this vision and this mantra.

... This year marks the successful completion of the Tarapur 3 & 4 projects 6 – 7 months ahead of schedule with substantial savings in terms of project capital cost. That this has been achieved for the first of its kind system developed indigenously is indeed remarkable and every individual involved with the activities related to this project deserves our compliments. These 540 MWe Units are among the largest units presently operating in India. We now have 16 operating units with a total capacity of 3900 MWe. As you are aware, presently we are constructing seven more nuclear power units. Unit 3 of Kaiga is expected to be operational this year. The Government has recently approved in principle construction of eight more units. When completed, this would take the total nuclear power generation capacity to around 14,000 MWe.

On the development front, the capacity of new Pressured Heavy Water Reactor (PHWR) Units has been enhanced to 700 MWe. This will help to reduce the unit capital cost further. Now we are also in a position to launch construction of 300 MWe Advanced Heavy Water Reactor, an innovative next generation technology demonstrator for energy from thorium, sometime next year. Our experience base on fast reactor fuel and its recycle has become considerably richer this year. We now have a focused programme for the development of short doubling time metallic fuel for fast breeder reactors in parallel with establishment of oxide fuel recycle capacity needed for the 500 MWe Prototype Fast Breeder reactor and additional breeder reactors to follow. Construction of PFBR is making rapid progress. Capacity expansion of back end of fuel cycle which forms the bridge between first and the second stage of our programme is also progressing rapidly.

On the power plant refurbishment front, MAPS Unit-I was put back on stream after replacement of its coolant channels and feeders. TAPS Units-1 & 2 were also put back on stream after major safety upgrades. For NAPS-I laser based channel cutting technology developed at RRCAT has been deployed. Laser technology for reactor coolant channel cutting and full scale replacement of reactor feeders are accomplishments realized for the first time in the history of PHWRs any where in the world.

The 2.5 GeV Synchrotron Radiation Source INDUS – II has started functioning at Raja Ramanna Centre for Advanced Technology (RRCAT). Soon it would reach its full design potential. INDUS – II, comparable to any other X-ray source of its class, would soon become a major facility to support a broad

Tarapur Atomic Power Plant - 3 & 4

**Excerpts from the Founder's Day Address-2006 (Octorber 30, 2006) by Dr. Anil Kakodkar, Chairman, Atomic Energy Commission.*

spectrum of researchers in their research over a wide range of disciplines.The Steady State Superconducting Tokamak (SST-I) at the Institute of Plasma Research is undergoing commissioning tests. We are now a full partner in the International Thermonuclear Experimental Reactor (ITER) Project.

Our vision of nuclear energy should now go well beyond nuclear power. We should now look at nuclear energy as a primary energy source to be deployed for a variety of end uses through appropriate energy conversion technologies. Demands of desalinated water and fluid fuel substitutes are likely to become very acute. This will happen earlier in India than most other parts of the world. I am glad that this aspect has been duly factored in our Research & Development strategies. Development of Accelerator Driven Systems, high temperature reactors, high temperature electrolysis systems, thermo-chemical splitting of water, solid oxide fuel cells, advanced membrane technologies and advanced materials technology are important thrust areas that we are working on in this regard.

With our programme expanding to wider horizons, we now need a broad range of materials. Sodium, enriched boron and a variety of solvents would be required in continuously increasing quantities. Our efforts to expand production capacities based on indigenous research are yielding rich dividends. These new activities along with efforts to bring in greater efficiency and cost reduction in production of heavy water and nuclear fuel have contributed towards freedom from external denial and more competitive nuclear power.

Banduhurang mine and Turamdih mill are expected to go in production by the end of the year. Our efforts to deploy electromagnetic aerial survey capability to explore deep seated uranium deposits should soon be in place. In particular, I am looking forward to the completion of indigenous development of such an instrument.

Besides nuclear power, there are several other domains where atomic energy applications contribute to national development and security. Our efforts to expand the reach of these applications to our society with the help of concerned departments of the Government of India and other partners are bearing fruits. More radiation processing plants are coming up in different parts of the country. We soon expect Indian mangoes reaching the US markets as a result of application of radiation processing. BRIT also supplied Cobalt-60 sources to Vietnam. Turn over of BRIT is rising rapidly. Outreach of TMC's cancer control programme is growing with telemedicine connectivity. International Union against Cancer (UICC) recently recognized TMC as the best institution in this area. Bhabhatron Teletherapy machine is expected to make a significant market entry this year. Efforts to deploy accelerator based radiation processing are progressing well at BARC and RRCAT. It is also a matter of considerable satisfaction that a large number of Nisargaruna bi0-digester plants have already come up and many more are in the pipe line. Number of radiation mutants that have been released for cultivation is steadily growing. BARC's contribution to agricultural output in terms of oil seeds and pulses has been truly outstanding.

Dear colleagues,

Sustained continuity of our activities related to research, development, demonstration and deployment has all along been a distinguishing feature of our programme Strong emphasis on research in all disciplines of science and engineering has enabled us the knowledge base needed for maintaining robustness in the implementation of our programmes. In order to encourage idea based research in support of our programmes with particular emphasis on strengthening the interface between research and technology development, we now have created a mechanism of Prospective Research Fund which can be sought by individuals or groups on a competitive basis. We are also moving towards enhancing student strength engaged in Ph.D level research in all our research institutions. Further, we are strengthening our bridges with the academic system in the country to reinforce higher education in disciplines of specific core interest to the atomic energy programmes.

In order to prepare students at plus two level to become proficient in experimental skills as they learn core science subjects and become capable of pursuing scientific research focused to meet national objectives, we are moving fast towards establishment of National Institute of Science Education and Research at Bhubaneswar and DAE – University of Mumbai Centre of Excellence in Mumbai. The Homi Bhabha National Institute is moving forward with its programme.

Dear Friends,

Dr. Bhabha had a dream and a road map to convert that dream into reality. We have made substantial progress on that path. We are now at a stage where we can confidently move forward more rapidly on our own, on the chosen path which is unique.

Excerpts from the Founder's Day Address – 2006 (October 30, 2006) by Dr. Srikumar Banerjee, Director, BARC

As a mark of our collective salutation and admiration to Dr. Bhabha on 30th October every year we gather in this venue to celebrate his birth anniversary by taking stock of our achievements during the previous year and rededicating ourselves towards the well defined mandate of our Centre.

As you are aware, the current year is being celebrated as the Golden Jubilee Year of BARC. Thus, it is all the more important for us to introspect. Our mandate is very clear. We work towards the growth of nuclear energy and towards applications of radiation technologies in areas such as health care, agriculture and food preservation. Besides, we have the responsibility of enhancing the national security and of keeping our country in the forefront of nuclear science and technology.

I am happy to announce that last year has been yet another successful year in our developmental efforts.

Research Reactors

All the three Research Reactors at BARC, viz., APSARA, CIRUS and DHRUVA have been operating satisfactorily throughout the year with high level of safety and availability. ... The modified fuel in DHRUVA has performed well achieving the desired burn up. The highest ever availability factor of 81.72% was achieved for DHRUVA during this year. Both the reactors have been utilized extensively for production of a large number of radioisotopes for medical, agricultural and industrial use.

DHRUVA continued to be the major national facility for neutron beam research programme. A large number of research scholars from various Universities and academic institutions in the country utilized the reactor under the aegis of the UGC-DAE Consortium for Scientific Research.

On August 4 this year, APSARA reactor completed 50 years of successful operation. During this year, APSARA was well utilised for some shielding experiments relevant to PFBR and AHWR.

Advanced Heavy Water Reactor (AHWR)

The optimised reactor physics design of AHWR core with 225 mm lattice pitch has been completed with burn up optimisation and for positioning of control and shut down devices.

An extensive experimental programme is underway to validate the design of AHWR. The Integral Test Loop (ITL) simulating the passive cooling system of AHWR has been operated to generate steady state and stability performance data.

The design of Advanced Heavy Water Reactor has undergone a pre-licensing design safety appraisal by the Atomic Energy Regulatory Board.

A Critical Facility is being built at Trombay for validation of AHWR physics design. The civil construction of this facility has been completed. ... Uranium Metallic Fuel Assemblies and Thoria fuel required for the entire reference core of AHWR critical facility have been fabricated and loading of fuel in critical facility is expected to start shortly. Erection of a new glove box line for manufacture of (Th-Pu) MOX fuel has started at the Advanced Fuel Fabrication Facility, Tarapur.

R&D support for the Indian PHWRs

On 21st May this year, TAPS-3 attained its first criticality. BARC has significant contributions in this major milestone of the Department's programme.Noteworthy developments include the liquid zone control system, the flux mapping system, the ion exchange process for selective removal of gadolinium nitrate in presence of boron from its moderator and an online system for vibration diagnostic for the steam turbine. BARC scientists were fully involved in the preparation of procedures and safety approvals related to the first approach to criticality.

The Flux Mapping System (FMS) has been designed in BARC to periodically monitor neutron flux. .... A solution for stable operation of large reactors like TAPS 3 & 4 is being worked out in collaboration with NPCIL engineers.

BARC developed software for training simulators for refueling

Reactor Block of Advanced Heavy Water Reactor (AHWR)

High voltage platform for the Accelerator Driven Sub-critical System (ADS) ion source at VECC

Solar powered Monitoring Station at Guwahati, Assam

operations for both 220 and 540 MWe PHWRs. The software has been delivered to NPCIL for Nuclear Training Centres (NTCs) at Tarapur and Rawatbhata.

Periodic removal of sludge from steam generators ensures better performance as well as longer service life of the steam generators. For the removal of sludge, a Sludge Lancing Equipment (SLE) developed by BARC for steam generators (SG) of Kakrapar Atomic Power Station (KAPS), was commissioned successfully in early July, 2006.

A new ultrasonic technique for measurement of axial creep of coolant channels has been developed and used both in 220 MWe & 540 MWe PHWRs.

Health Safety & Environment

A comprehensive accident safety analysis of the fuel handling operations in Spent Fuel Storage Bay of Dhruva reactor has been carried out.

To address the structural reliability issues encountered in the structural analysis of complex systems, a parallelized version of the in-house structural reliability analysis software "BARC-RAS" was tested on an 150-node configuration. A speed-up of the same order as the number of nodes was observed. This development will result in performing a large number of structural calculations required for reliability assessment, in a very short time.

Radiological Safety

BARC has designed and developed a Portable Personnel Decontamination Kit.

Altogether, 17 systems are deployed in the IERMON network so far.

Totally, 18 DAE-Emergency Response Centres (ERC) have been established to respond to any nuclear/ radiological emergencies anywhere in the country. One of the ERCs was inaugurated at AMD, Bangalore by Chairman, AEC on 13th September, 2006.

Pre-operational Environmental Survey has been initiated at proposed nuclear power project site at Jaitapur, Ratnagiri Dist., Maharashtra.

Front End Fuel Cycle Activities

50 MOX fuel bundles fabricated by BARC and loaded in KAPS-1 have performed exceedingly well without any failure upto design burn up of 12,000 MWd/T. It is planned to irradiate a few of the bundles upto 20,000 MWd/T burn up, which is three times that of standard natural UO_2 bundles.

Mixed carbide fuel fabricated by BARC has now exceeded peak burn up of 154 GWd/T in FBTR. BARC has recently supplied a consignment of Mixed carbide and Mixed oxide fuel for FBTR for the realization of a hybrid core. The PFBR experimental MOX fuel being irradiated in FBTR has now exceeded burn up of 59,200 MWd/te.

The production of the axial blanket pellets for PFBR is in full swing and about 20% of the PFBR core requirement has been manufactured.

A peroxide precipitation process has been developed for purification of impurities such as Boron, Gadolinium [Gd] and Samarium [Sm] in a bench scale set up.

Technology for decomposition of ammonium nitrate solution by fluidized bed thermal de-nitration has been established. The know how generated will be used in centralized uranium oxide conversion facility at Tarapur.

The Integrated Fuel Fabrication Facility has successfully made operational trials. This facility has been set up and made fully operational in a record time.

Spent Fuel Processing and Waste Management

There has been an all-round progress in the activities related to recovery of useful materials from spent fuel, management of associated high level radioactive waste, augmentation of facilities for enhancing the reprocessing capacities and the necessary R&D backup.

Plutonium Plant at Trombay has been brought back to normal operations after major revamping and modification jobs. The control and instrumentation system of the plant has been upgraded substantially. PREFRE, Tarapur has been operating with an excellent safety record with more than 4000 days of accident free operations.

Spent Fuel Storage Facility (SFSF) at Tarapur has been commissioned and the transfer of fuel from power reactors to the facility has commenced.

To meet the urgent demands at NFC, Hyderabad for wet processing of reject sintered pellets of depleted uranium, a process based on indigenously developed Ammonium Phospho-Molybdate (AMP) resin for removal of 137Cs has been developed.

At Tarapur, the Advanced Vitrification System has been commissioned and since August 11, the Joule Heated Ceramic Melter is

Mobile robot for remote survey and inspection developed at BARC

being operated uninterrupted for vitrification of High Level Waste. India has, thus, become one of the six countries who have developed and set up such facilities for vitrification of High Level Waste.

In parallel, to address the need of future vitrification plants, an engineering scale demonstration facility for cold crucible induction melting technology has been built and successfully commissioned.

Remote Handling and Robotics Applications

In our efforts towards exploiting automation and robotics applications, Extended Reach Master Slave Manipulator (ERM) of 9 kg capacity has been developed. Also, a sealed type Three Piece Master Slave Manipulator (TPM) with modular construction has been successfully developed. Its slave arm can be remotely replaced in hot cell using the in-cell crane. The sealed type construction of TPM prevents leakage of radioactive gases from hot cell to the operating area.

Equipment Manufacturing and Technology Development

The Extended X-Ray Absorption Fine Structure (EXAFS) Beam Line of INDUS II Synchrotron has been designed, manufactured and installed. A Linear Distancing System for calibration of Gamma Ray detectors has been designed and manufactured. The first unit, delivered to NPCIL, has been installed at TAPS.

A technological breakthrough was made by way of developing ceramic-to-metal (CM) feed through assembly for low speed canned motors. The assembly meets vacuum leak rate less than 1X10-9 Torr, withstand pressure of 200 bar and temperature of about 300-350^{o}C.

Physics

High damage threshold multilayer structures, that can serve as SP polarization beam combiners have been developed for isotopic enrichment studies.

An experimental facility to record laser induced fluorescence from single molecules was set up. The facility will enable investigations of protein dynamics using resonance energy transfer, protein-DNA interactions and radiation induced degradation in polymers and bio-molecules.

Materials

Experimental conditions were standardized to synthesise B_4C powder which is vacuum hot pressed to specific shapes needed as control rod and shielding material for PFBR. Using a multicavity die about 4000 pellets have been prepared as per required specifications.

Critical current density (Jc) of more than 800 amp.cm^{-2} has been achieved on bulk high Tc Yttria-123 superconductor of hollow cylindrical geometry prepared by top seeded melt growth technique using single crystal seed.

For meeting the requirements of Cobalt-60 isotope by BRIT, regular productions at the scale of about 12 kg cobalt oxalate has been started.

Crown ether (namely, Di-t-butyl benzo 21 crown 7) for extraction of Cs137 from high level waste has been successfully synthesized at a laboratory scale.

Chemistry

A convenient method for the preparation of high purity electronic grade trimethyl gallium, required for the preparation of gallium based semiconductor materials by the MOCVD technique has been developed. The TIFR group has grown thin films of GaAs using our material and has found them acceptable.

A spectrometer based on unique methodology of Fluorescence up-getting fluorescence information from second time scale.

A twin loop high temperature high pressure system made of stainless steel has been installed and commissioned at Kalpakkam.

Nuclear Instrumentation

The CAMAC (Computer Automated Measurement And Control), FERA (Fast Encoding Readout ADC) with PCI (Peripheral Component Interconnect) card has been specially developed and evaluated for India Gamma Array Experiment at TIFR. 28 such modules have been fabricated and will soon be supplied to TIFR.

All the 1000 Silicon Strip Detectors for CMS Experiment at Large Hadron Collider (LHC), CERN as micro-modules have been fabricated and characterized at BEL, Bangalore. As a part of BARC commitment, 5500 nos., of Quench Heater Power Supply and 70 nos., of Breaker Electronics have been delivered ahead of schedule to CERN through ECIL.

Developments in Supercomputing

BARC has developed 1.7 Teraflops Supercomputer based on 512 nodes parallel system, which is largest & fastest computer in the country. The honorable Prime

External View of New Super Computing Facility

Minister of India, Dr. Manmohan Singh inaugurated the new Supercomputing Facility at Bhabha Atomic Research Centre, Mumbai on 15th November last year.

A 20 Million Pixel (5120 x 4096) high-resolution wall-size Tiled Display system using commercially available multiple LCD's (4x4) has enabled advanced data visualization. The first of its kind system in the country is being used on regular basis to display voluminous analytical data. This system will have large scale defence and space applications.

DAE entered the era of Grid Computing by demonstrating a working Grid connecting three DAE sites namely VECC, Kolkata, RRCAT, Indore and BARC, Mumbai allowing users at VECC, RRCAT and BARC to submit Fortran jobs successfully to the DAE Grid.

Under DAE-CERN collaboration programme, BARC has developed many Grid middleware tools, namely, SHIVA - a problem tracking system, Grid-View - a grid operations and monitoring system, fabric monitoring etc., which are deployed in LCG grid at CERN, Geneva.

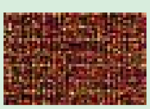
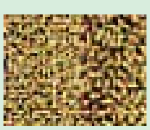
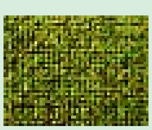
Radiation/Radioisotope Applications

BARC continued to make progress in the field of nuclear agriculture. A new groundnut variety, TG 38 has been released during 2006 for commercial cultivation in Orissa, West Bengal, Bihar and North-Eastern States for Rabi/summer season by the Ministry of Agriculture, Govt.of India. With this, so far 27 Trombay crop varieties have been released and gazette notified for commercial cultivation.

Besides, six more new Trombay crop varieties are in pipeline to be released. During 2006, one each in mustard, sunflower, soybean, groundnut and two in mungbean have been released by the State Varietal Release Committees in Maharashtra, Madhya Pradesh and Andhra Pradesh and awaiting for gazette notification.

Four Nisargruna biogas plants have become operational at

Trombay varieties Released (2006) (Awaiting Notification)

	Crop	Name	Identified by	Released for
	Soybean	TAMS-98-21	PDKV, Akola	Vidarbha
	Mustard	TPM-1	MPKV, Rahuri	West Maharashtra
	Sunflower	TAS-82	PDKV, Akola	Vidarbha
	Groundnut	TLG-45 TG-38B	MKV, Parbhani ICAR	Marathwada W. Bengal, Orissa, Assam/NE
	Greengram	TM-96-2	ANGRAU, AP	Andhra Pradesh

Nisarguna plant at Trombay

Hiranandani Estate (Thane), INS Chilka (Orissa), Ankleshwar (Gujarat) and Chandrapur (Maharashtra).

In the field of food irradiation, a Framework Equivalency Work Plan agreement has been signed between India and USA for export of mango from India to US after treatment with gamma radiation. Upgradation of KRUSHAK facility for this purpose has been initiated.

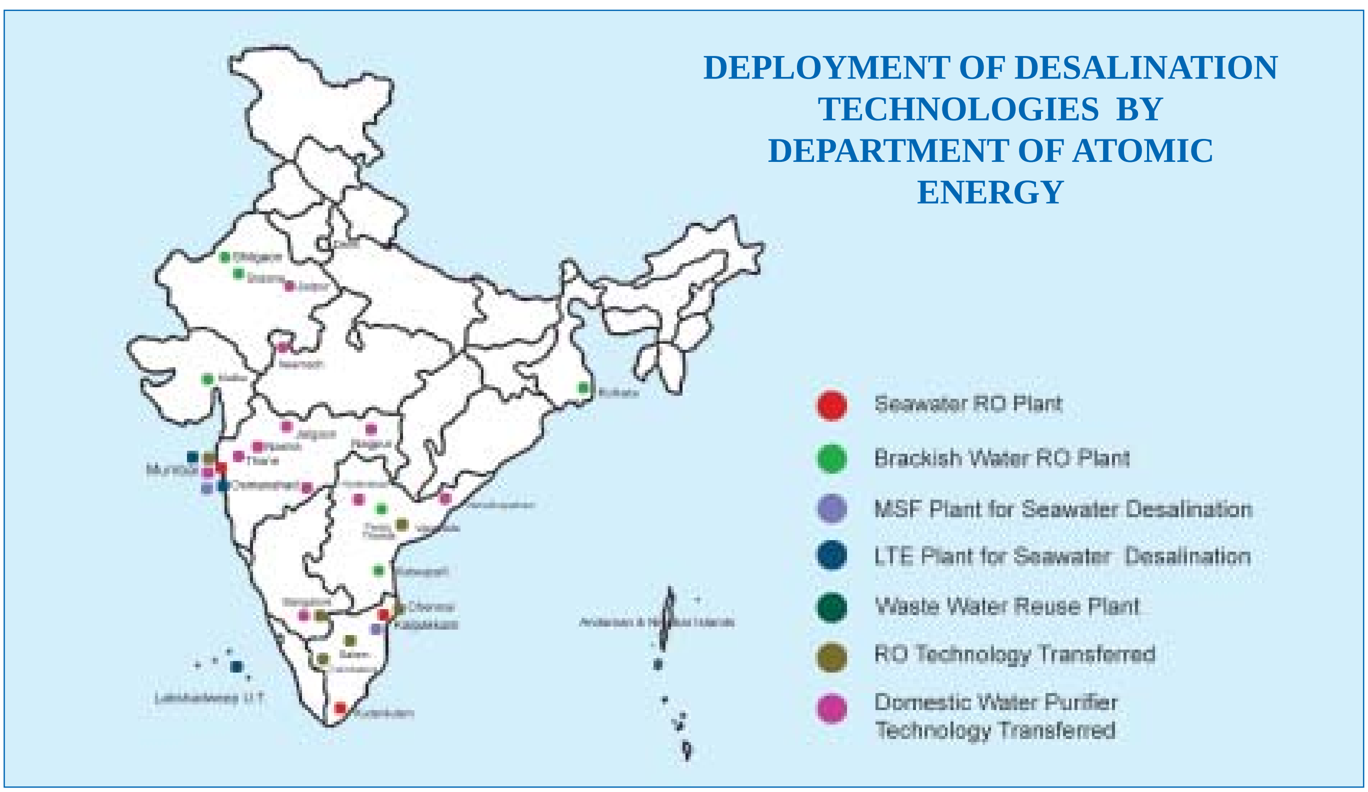
A Memorandum of Understanding has been signed between BARC and the National Centre for Electron Beam Food Research, the Texas A&M University, USA for co-operation for the advancement of electron and X-ray irradiation technologies for food preservation.

Desalination Technology

BARC will participate along with CSIR in the national effort in providing safe drinking water to all our countrymen. BARC developed technologies, such as, small Reverse Osmosis (RO) desalination units for producing drinking water from saline water, water filters for producing bacteria free safe drinking water, barge mounted desalination system for coastal areas and islands, and the development of indigenous polymeric membranes for brackish water desalination will play major roles in this massive programme.

XI Plan projects

Under the XI Plan, we have for the first time introduced in DAE, the scheme of prospective research funding to encourage the curiosity driven or new idea based R&D by an individual or a group of scientists. Such proposals can be submitted at any time during the Plan period.



Name	Year of Release	M: Maturity (days) Y: Yield (kg/ha) YI: Yield increase (%)	Released for	Remarks
Blackgram TAU-1	1985	M: 70 –75 Y: 800 –1000 YI: 24	Maharashtra	Large seed Most popular variety in Maharashtra
TAU-2	1992	M: 70-75 Y: 900-1000 YI: 18	Maharashtra	High yielding
TPU-4	1992	M: 70-75 Y: 900-1000 YI: 22	Maharashtra Madhya Pradesh	Large seed
TU94-2	1999	M: 70 Y: 900-1000 YI: 19-37	Andhra Pradesh, Karnataka, Kerala, Tamil Nadu	Resistant to Yellow Mosaic Virus
Greengram TAP-7	1983	M: 60 Y: 700-800 YI: 23	Maharashtra Karnataka	Tolerant to powdery mildew
TARM-2	1992	M: Rabi: 90 Y: 1000-1100 YI: 80	Maharashtra	Resistant to powdery mildew
TARM-1	1995	M: 80 Y: 765 YI: 45	Maharashtra, Gujarat, Karnataka, MP, AP, Kerala,Tamil Nadu, Orissa	Resistant to powdery mildew
TARM-18	1995	M: 65-70 Y: 1051	Maharashtra	Resistant to powdery mildew
TMB-37	2005	M: 64 Y: 1100 YI: 20	Eastern UP, Bihar, Jharkhand, Assam and West Bengal	Tolerant to yellow mosaic virus
Pigeonpea TT-6	1983	M: 135-140 Y: 1200-1300 YI: 15	MP, Maharashtra, Gujarat, AP, Karnataka, Kerala	Large seed
TAT-10	1985	M: 110-115 Y: 900-1000	Maharashtra	Early maturing
Soybean TAMS-38	2005	M: 90-95 Y: 1800-2000 YI: 20	Maharashtra	Early maturing, resistant to bacterial pustule, *Myrothecium* leaf spot
Groundnut TG-1	1973	M: 130-135 Y: 2400-2500 YI: 15-20	Maharashtra, Gujarat	Large seed
TG-17	1985	M: 115-120 Y: 1700-2000 YI: 15-20	Maharashtra	Less branches
TG-3	1987	M: 110 Y: 2000-2500	Kerala	More branches

Name	Year of Release	M: Maturity (days) Y: Yield (kg/ha) YI: Yield increase (%)	Released for	Remarks
Somnath (TGS-1)	1989	M: 110-125 Y: Kharif 2000 YI: 23	Gujarat	Large seed Spreading habit
TAG-24	1991	M: Kharif 100-105 Summer 112-117 Y: kharif 1300 Summer 2500 YI: Kharif 24 Summer 50	Maharashtra, West Bengal, Rajasthan, Karnataka	Most popular in all ground nut growing state, identified as national variety, High yield potential (9000-10000kg/ha) Semi dwarf habit, early maturity, high harvest index, high partitioning efficiency, wider adaptability
TG-22	1992	M: Kharif 115-120 Y: Kharif 1677 YI: 30	Bihar	Medium-large seed, fresh seed dormancy
TKG-19A	1994	M: 120-125 Y: summer 2000-2500 YI: 12-13	Maharashtra	Large seed, fresh seed dormancy
TG-26	1995	M: 110-120 Y: summer 2500 YI: 23-39	Gujarat, Maharashtra, MP	Semi-dwarf, early maturity, high harvest index, high partitioning efficiency, fresh seed dormancy Second popular TG variety, high yielding ability (9000-10000kg/ha), wider adaptability
TPG-41	**2004**	M: 120 Y: Summer 2407 YI: 26	All India	Large seed (65g 100 seeds) Fresh seed dormancy On farm trials 4551kg/ha 49% increase
TG-37A	**2004**	M: 110 Y: Kharif 1993 YI: 26-38	***Rainy season*** Rajasthan, UP, Punjab, Haryana, Gujarat ***Rabi/Summer*** W.Bengal., Orissa, Assam/N.E.	Fresh seed dormancy Oil 51% Wider adaptability
TG-38	**2006**	M: 115 Y: Rabi/summer 2500 YI: 20	Rabi/Summer W. Bengal, Orissa, Assam/N.E.	High yield potential in residual moisture situation
Mustard TM-2	1987	M: 90 Y: 1370 YI: 25	Assam	Appressed pod
TM-4	1987	M: 95 Y: 1470 YI: 35	Assam	Yellow seed
Rice Hari	1988	M: 135-140 Y: 6000 YI: 20	Andhra Pradesh	Slender grain type
Jute TKJ-40	1983	M: 125-130 Y: 2800-3100 YI: 10-13	Orissa	High yielding

LASER Equipment Developed at RRCAT

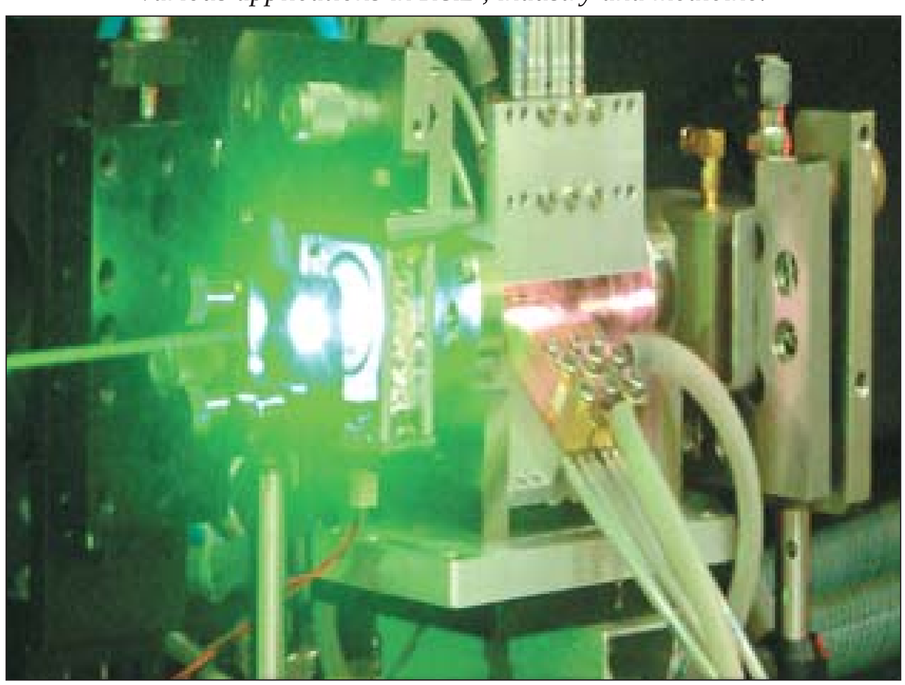
In the area of laser, their applications extend over a wide range. From fundamental studies in physics, chemistry, biology etc. to various applications covering medical, industrial, material processing, and defense etc to building extremely accurate atomic clocks for improved GPS technology to even producing nuclear transmutation with ultra powerful lasers. DAE labs have been pursuing programs in nearly all these areas. A set up which uses Nd:YAG laser (of up to 250W average power) was recently developed at Raja Ramanna Centre for Advanced Technology (RRCAT) deployed for in-situ cutting operation during the campaign for en-masse coolant channel replacement in Narora PHWR. Such a system can also help to further cut parts removed from the reactor for compact storage. A high power diode pumped Nd:YAG laser of 350 W and an intracavity frequency-doubled diode pumped green solid state laser was built by RRCAT as an alternative to copper vapour laser for pumping dye lasers. To promote industrial use of lasers, RRCAT has recently created a facility for autogenous laser welding of automobile transmission gear assemblies using indigenously developed high power CO_2 lasers. In the area of applications of copper vapour lasers (CVL), coherent UV radiation at 255 nm, 271 nm & 289 nm have been generated.

RRCAT has also built laser-based systems for quality assurance of uranium oxide fuel pellets being produced by Nuclear Fuels Complex. RRCAT has also set up a Metal Organic Vapor Phase Epitaxy (MOVPE) facility to grow multilayer structures for developing laser diodes. The first batch of prototype diode lasers have been already developed at RRCAT in the wavelength range of 740-1000nm. The maximum peak power delivered by the prototype aser diode is 4.2 W at 810 nm in pulse mode.

A Laser system

India's first green laser photo-coagulator for treatment of diabetic retinopathy of the eye and (Right) 25 Watts CuBr Laser

350 W diode-pumped high power CW IR laser. This laser will be used for various applications in R&D, industry and medicine.

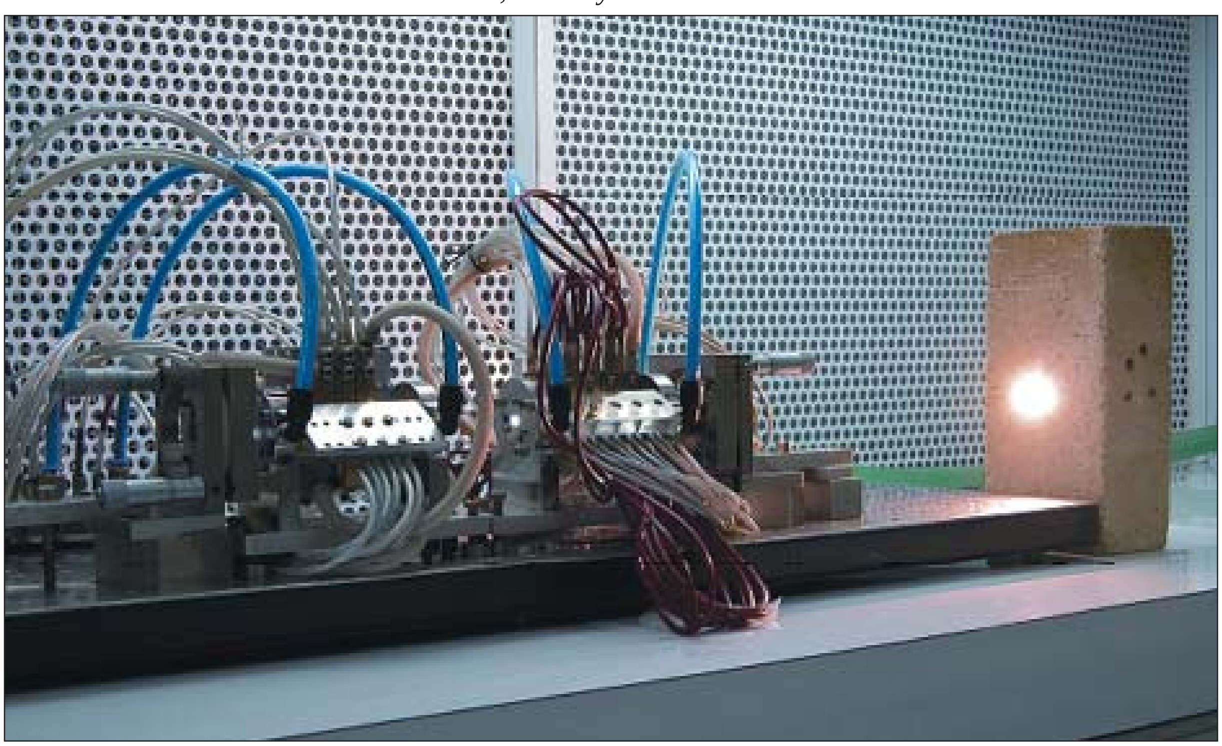


Applications in R&D, industry and medicine

Laser based Land Leveler. Technology transferred to M/s OSAW Udyog, Ambala

Laser Uranium Analyser. Twenty such units will be supplied to various units of DAE for uranium mining, radio chemistry, effluent monitoring and health physics applications. Two have been recently supplied to BARC, Mumbai and HWP, Talcher

350 W diode-pumped high power CW IR laser. This laser will be used for various applications in R&D, industry and medicine.



Bone Marrow Transplantation initiative at Tata Memorial Hospital

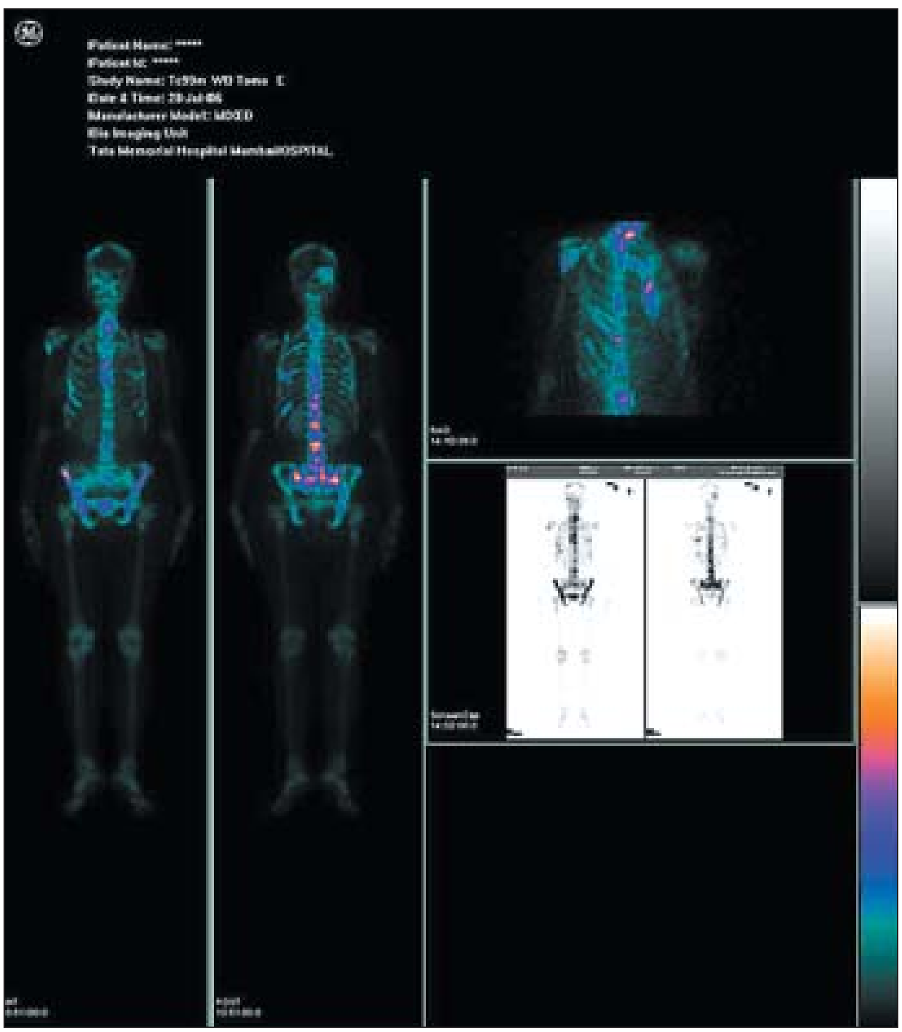
BMT or Haematopoietic Stem Cell Transplant (HSCT) is one of the most intensive and challenging treatment modalities. This highly specialized treatment demands expertise of specially trained physicians, nursing and paramedical staff, comprehensive supportive infrastructure, availability of special tests (e.g. HLA Typing) as well as special equipment (for stem cell separation, cryopreservation etc).

BMT is performed for a variety of cancerous and non-cancerous diseases. It is the only proven curative modality of treatment for certain blood disorders like chronic myeloid leukemia, aplastic anaemia and thalassemia major. It is often the only effective treatment in relapsed acute myeloid leukemia, lymphoma and some solid malignancies.

Tata Memorial Hospital was the first one to start BMT in India. Currently, there are more than 15 transplant centres in India and close to 1500 transplants have been done across the country.

BMT unit of TMH

The BMT Unit is an integral part of the Department of Medical Oncology of the Tata Memorial Hospital. It consists of a dedicated 6-bed ward. This unit has special isolation facilities to minimize chances of infection. A new BMT unit with another 6 beds is likely to be commissioned soon at the Advanced Centre for Treatment, Research and Education in Cancer (ACTREC) at Kharghar, Navi Mumbai.



TMH milestones in the Bone Marrow Transplant

First Indian allogenic BMT (1983)

First autologous BMT (1993)

Indigenous closed system for cord blood collection (1995)

First Indian Cord Blood Transplant (1996)

First Nonmyeloablative transplant (1999)

First Indian haplo-identical BMT (2003)

First Indian transplant for CGD (2003)

First Indian lymphocyte purging "in the bag" (2003)

First Indian Cord Blood Transplant using cryo-preserved SC from Cord Blood Bank (2006)

Stem cell transplant at TMH is done by a dedicated BMT unit.

The Tata Memorial Hospital did the first bone marrow transplant in India way back in 1983 for a 9 year old girl with AML. She is currently a software engineer and in remission. Since then TMH has been at the forefront of haematopoietic stem cell transplant scenario in India and has several "firsts" to its credit.

At TMH, a total of 317 BMT procedures have been done. During the year 2005, 42 patients underwent BMT and presently TMH is performing 4-6 transplants every month.

Types of SCT

HLA identical sibling donor allogenic transplants (N=206), the majority of allogenic transplants have been HLA identical sibling donor transplants. The most common disorder for which allogenic haematopoietic stem cell transplant has been performed at TMH, is Chronic myeloid leukaemia followed by acute myeloid leukemia and aplastic anemia.

Haploidentical transplants

It is a special type of transplant where stem cells are obtained from a family member with half of the HLA being matched. So far TMH has performed four haploidentical transplants; one for chronic granulomatous disease and three for aplastic anemia. These transplants have been performed in high-risk patients and as a desperate measure where HLA matched sibling is not available as stem cell donor.

Umbilical cord blood transplants

First UCBT was performed in TMH in 1996 and until now 4 such transplants have been done. In one of such patients, cord blood stem cells available from the cord blood bank were used. Unrelated donor transplants have not become a reality in India due to the lack of a proper marrow registry. Efforts are being made to start unrelated marrow registry in India.

Autologous transplants (N=112) have been predominantly performed for multiple myeloma, Hodgkin's disease and non-Hodgkin lymphomas. The most common indication for an autologous transplant was multiple myeloma. Both myeloablative and non myeloablative transplants have been done at TMH.

In keeping pace with the recent advances in the field of SCT, various BMT related procedures are being appropriately modified at our centre e.g. Peripheral Blood Stem Cell Harvest (PBSCH; as opposed to Bone Marrow Stem Cell harvest), use of TBI for conditioning regimen, judicious use of effective supportive care medicines like G-CSF, antibiotics, antifungals etc.

Paediatric transplants

Up till now about 60 paediatric transplants have been done at TMH. Majority of the paediatric transplants have been performed for haematolymphoid malignancies with about one fifth of transplants performed for paediatric solid tumours. Paediatric transplants have been performed predominantly for thalassemia and metastatic neuroblastomas. Bone marrow has been the major source of stem cells (80%) in paediatric age groups. Peripheral blood stem cell collection in a child as small as 3 years old has also been performed.

Cost effectiveness of transplants

Although allogenic and autologous transplants have become well-established therapies for several haematological & non-haematological disorders, cost is a major limiting factor, especially in the Indian conditions. Innovative methods have been used in TMH for significant cost reduction while maintaining efficacy. This has also been made possible by the wider use of peripheral blood stem cells and availability of cheaper alternative drugs.

The BMT Unit of the Tata Memorial Hospital continues to be at the forefront of haematopoietic stem cell transplantation.

Symposium on Nuclear and Radiochemistry (NUCAR 2007)

The eighth biennial symposium on "Nuclear and Radiochemistry" (NUCAR 2007) will be organized by the Board of Research in Nuclear Sciences (BRNS), DAE in association with the Department of Chemistry, Maharaja Sayajirao University of Baroda, Vadodara, during February 14-17, 2007. The symposium will provide a platform for effective interaction among the scientists in the areas of nuclear and radiochemistry and applications of radioisotopes. The scientists engaged in research in these areas from national laboratories, universities and research institutes from India and abroad, will attend that the symposium ,will cover :

-Nuclear chemistry and nuclear probes,
- Chemistry of actinides and reactor materials,
- Spectroscopy of actinides,
- Chemistry of fission and activation products,
- Radioanalytical chemistry,
- Radioisotope applications,
- Radioactivity in environment, and
- Nuclear instrumentation.

The scientific programme of the symposium will include invited talks as well as contributed papers. The contributed papers will be divided into oral and poster presentations.

For further details, please write to :
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E-mail:
p_padmaja2001@yahoo.com

Winners of the 18th All India Essay Contest in Nu -

Participants of the final round of the 18th All India Essay Contest in Nuclear Science & Technology organised by the Department of Atomic Energy, with Dr. Anil Kakodkar, Chairman, AEC, and officials of the Public Awareness Division, DAE.

The topics of the essay were : Energy scenario in India: Emerging technologies in nuclear power generation for safe and sustainable growth, Achievements and future prospect of radioisotopes and radiation technology in India, and Emerging applicationsof beam technologies: Present status and future prospects in India.

Swasraya Bharath 2006

Swadeshi Science Movement in Kerala is a popular science movement dedicated to national development in science and technology. On the occasion of the birthday of Hon'ble President of India Dr. A.P.J. Abdul Kalam, this movement celebrated national selfreliance week by way of seminar, students meet, science exhibition etc. as the Swasraya Bharath 2006, at Cochin, Kerala.

During October 11-17, 2006, DAE had set up an exhibition that showcased entire gamut of its activities and achievements, and was visited by over 12,000 people and more than 5,000 school/college students.

Shri L.N. Maharana, Chief General Manager, Indian Rare Earth Ltd., visited the DAE Exhibition "Swasraya Bharat 2006" at Cochin

TOPIC-1: Energy Scenario in India : Emerging technologies in nuclear power generation for safe and sustainable growth

Kum. Ajita Ashok Taware of Pune, Maharashtra (First Prize)

Kum.G. Rathna of Sivakasi, Tamil Nadu (Second Prize)

Kum. Dnyanada P. Relekar of Ratnagiri, Maharashtra (Third Prize)

TOPIC-2: Achievements and future prospect of radioisotopes and radiation technology in India

Kum. Akanksha Shrikant of Aurangabad, Maharashtra (First Prize)

Kum. Priti V. Parvekar, Dhamangaon, Maharashtra (Second Prize)

Shri Sudipta Ashe of Bhubneshwar, Orissa (Third Prize)

TOPIC-3: Emerging applications of beam technologies:Present status and future prospects in India

Shri Mahesh Umakant Patil of Nashik, Maharashtra (First Prize)

Shri Dinesh Singh of Jhunjhunu, Rajasthan (Second Prize)

Kum.Priyanka Thakur of Jaipur, Rajasthan (Third Prize)

Gamma Scanner

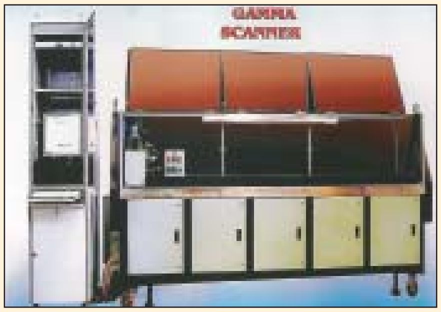
S. S. Taliyan
Reactor Control Division, BARC

Gamma ray spectrometry is a powerful tool for diagnosing the source of radiation. It has found wide acceptance in various fields including the measurement of power of the fuel rod of a nuclear reactor. The principle of gamma ray spectrometry involves detection of gamma rays of different range of energies that are characteristic of the constituent elements of the radioactive sources. The detector induces a voltage pulse corresponding to the energy of the incident gamma ray.

The gamma scanner developed in BARC is designed for low power irradiated fuel rods of a nuclear reactor for obtaining axial power distribution for the fuel rod. The detector is a NaI(Tl) crystal contained in a lead shielded enclosure. The data acquisition system collects the pulse data. The collected data is then processed by computer that calculates the power distribution along the fuel rod being scanned.

Major components of the scanner are, the linear and rotary motion drives, fuel rod grippers, detector assemblies, instrumentation, data acquisition system and a PC based control panel.

Two types of scanners are developed. The first scanner is meant for scanning fuel pins with a travel stroke of 1400 mm while the other is



Fuel Bundle Scanner

for scanning fuel bundles assemblies to accommodate a scan stroke up to 2000 mm. The design of the gripper allows loading and unloading operations of the fuel rod to be very quick and easy.

The software developed for operation and control is user friendly. The scanners can be operated in auto or manual mode. The parameters such as the linear and rotary speeds, scan time, travel stroke, pulse counts etc., are displayed on the computer screen. There is online display of power of the fuel rod during the scan operation.

The overall size of the scanners in mm is 2000x600x1500 H and 3200x600x1500 H for fuel pin and fuel bundle scanners respectively. The size of the control panel rack is nealy 780x580x2160 H for each scanner. The weight of fuel pin and fuel bundle scanner is nearly 500 and 600 kg. respectively.

The fuel safety is the prime requirement during scanning operation. Some of the fuel safety features provided in the scanners are as follows:

Duplicated sensors are provided to stop motion in case of overrun due to any reason. The fuel bundle is gripped by a nylon collet in order to avoid any scratch on the fuel bundle in the event of any slip. The ball screw assembly is completely covered with bellows/ metallic sheets to avoid any loose parts /foreign particles from falling on to the ball screw. The fuel pin /bundle is supported by nylon rollers to avoid any scratch on fuel surface during fuel rotation. The Fuel pin / bundle is held by friction grip in order to allow a slip in the event of high torque due to any reason. The detector is supported by rubber O'rings in the detector housing to avoid any jerk to the detector. Full short circuit protection is provided for electronic parts in the control panel.

Further details can be had from :

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