PM dedicates Centre for Advanced Technology in the memory of Dr. Raja Ramanna

On December 17, 2005, the Hon’ble Prime Minister Dr. Manmohan Singh dedicated the Centre for Advanced Technology, Indore, in the memory of Dr. Raja Ramanna. The centre was named as Raja Ramanna Centre for Advanced Technology.

Dr. Ramanna was instrumental in setting up this Centre for Advanced Technology in 1984. This Centre was established with a view to mastering advanced technologies, especially in the areas of lasers and accelerators. The progress achieved by the Centre vindicates Dr. Ramanna’s vision, by contributing to the nation’s needs. The Centre has played a pivotal role in delivering very high quality components and subsystems for the world’s biggest particle accelerator, the Large Hadron Collider, being set up by CERN in Geneva.

Dr. Raja Ramanna, then chairman, AEC, planting a sapling at CAT site, Indore (1983)
Prime Minister Dr. Manmohan Singh writing his message when he visited the Centre for Advanced Technology, Indore on December 17, 2005 to rename it as “Raja Ramanna Centre for Advanced Technology”

Modern science and technology are open up enormous possibilities for human development. The Dept. of Atomic Energy has been a pathfinder in this regard. This is a tribute to the leadership provided by people like Dr. Raja Ramanna.

Manmohan Singh
17/12/2005
On December 17, 2005, the Hon’ble Prime Minister Dr. Manmohan Singh dedicated the Centre for Advanced Technology, Indore, in the memory of Dr. Raja Ramanna. Following are the excerpts of his address.

“It gives me great pleasure to participate in this function to rename the Centre for Advanced Technology of the Department of Atomic Energy as the **Raja Ramanna Centre for Advanced Technology**. It is also an honour for me to dedicate the Synchrotron Radiation Source Indus-II to the nation today.

As Pandit Nehru said, scientific institutions are the temples of modern India and play a key role in the gigantic task of national development and nation building. India’s atomic energy programme has been recognized in the country and the world over, as a shining example of self-reliance and outstanding achievement.

This programme has benefited from the dedication of legendary scientists such as Dr. Homi Bhabha, Dr. Homi Sethna and stalwarts such as Dr. P.K. Iyengar, Dr. M.R. Srinivasan, Dr. R. Chidambaram, and Dr. Kakodkar, the present Chairman of the Commission.

Dr. Raja Ramanna was a shining star in this galaxy of outstanding scientists. An illustrious son of India, he served the country in various capacities including as Chairman of the Atomic Energy Commission and as Minister of State for Defence. Dr. Ramanna was a polymath. He mastered the frontiers of science; at the same time, he was an authority on India’s scriptures like the Gita and Upanishads; also an accomplished pianist and deeply knowledgeable about both Western and Indian classical music. He was also a leader with exceptional qualities who inspired generations of scientists. The BARC Training School, which he helped to found in 1957, was a turning point in the development of DAE. Dr. Raja Ramanna was a charming man blessed with great spontaneity. It was my privilege and pleasure to have known him personally.

Dr. Ramanna was associated with key milestones in India’s nuclear programme. He was involved with building the country’s first research reactor Apsara. At his initiative, the construction of the Variable Energy Cyclotron was taken up in Kolkata. He also gave impetus to the fast reactor programme in the country in the 70’s and 80’s. As the Director of BARC, he was the leader of the team which conducted India’s first nuclear test in 1974. Between 1978 and 1981 he was Scientific Adviser to Raksha Mantri.

Dr. Ramanna was instrumental in setting up this Centre for Advanced Technology in 1984. This Centre was established with a view to mastering advanced technology, especially in the areas of lasers and accelerators. The progress achieved by the Centre vindicates Dr. Ramanna’s vision, by contributing to the nation’s needs as well as placing India on the international nuclear map. The Centre has played a pivotal role in delivering very high quality components and subsystems for the world’s biggest particle accelerator, the Large Hadron Collider, being set up by CERN in Geneva.

The scientific and technological abilities of our scientists match the best the world over. This gives us the confidence to pursue increased exchanges with the outside world with India as an equal partner with the most advanced countries in the world. Just last week, India joined a select group of countries participating in ITER – the International Thermo Nuclear Experimental Reactor project and I congratulate DAE for this achievement.

I am optimistic that through constructive dialogue with the international community, we will soon be part of the mainstream with full civilian nuclear cooperation between India and international partners. Our non-proliferation track record and our scientific credentials will only add to India’s weight in international cooperative endeavours to harness all the applications of nuclear energy, for the country’s social and economic development, for meeting our growing energy needs, and for the greater glory of global scientific advancement as a whole. In this journey of excellence, this Centre, the Raja Ramanna Centre for Advanced Technology, will have a critical role to play.

Let me take this opportunity to convey to you – the members of the DAE family – the deep appreciation and gratitude of the nation for your commitment and your scientific accomplishments. You have our full and unstinted support for your endeavours.”
Within a few years of Enrico Fermi’s demonstration that nuclear energy could be controlled in a safe and reliable manner and even before India could achieve independence, Dr Homi Bhabha formulated his grand vision for the exploitation of atomic energy for peaceful purposes. Dr. Bhabha wanted India to be self-reliant, in this new emerging technology right from the beginning. In line with his vision the first research Reactor Apsara was built with indigenous efforts in the year 1956. This was followed up by the construction and successful commissioning of CIRUS research reactor in 1960. These early gains catapulted India into an ambitious nuclear programme, after which there was no looking back.

**Conception of Dhruva Reactor**

During early seventies, a strong need was felt for building a research reactor with higher neutron flux to meet the growing demand of radioisotope production and advanced research in basic sciences and engineering. This led to the setting up of the fifth research reactor R-5 at BARC, which was later named “Dhruva” by Giani Zail Singh, the then President of India. The construction of Dhruva was an important milestone towards development and implementation of indigenous nuclear reactor technology in India.

Dhruva is an example of a viable system, engineered within the limited means available in the country at that time, catering to production of radioisotopes of high specific activity as well as diverse requirements of a broad based multidisciplinary user community. This high neutron flux reactor was designed, constructed and commissioned entirely by Indian scientists and engineers and it reflects the country’s resolve to achieve self-reliance in the nuclear reactor technology.

Dhruva attained first criticality on August 8, 1985 and was dedicated to the nation on November 11, 1985 by Late Shri Rajiv Gandhi, then Prime Minister of India. Dhruva attained full power operation in January 1988.

**The Reactor:** Dhruva is a 100 MW (thermal) research reactor having a vertical core with metallic natural uranium as fuel, heavy water as moderator, primary coolant and reflector, producing a maximum thermal neutron flux of $1.8 \times 10^{14}$ neutrons per cm$^2$ per second. Heat from primary coolant is transferred to a secondary closed loop re-circulating system of dematerialized light water in a set of heat exchangers. The secondary coolant in turn is cooled by seawater. The sea-water coolant is drawn from the Mumbai harbour bay and flows through the heat exchangers.
in a once-through mode. The reactor provides facilities for basic and applied research, material testing, production of radioisotopes and training of manpower.

**Technological challenges and developments in making of Dhruva:**

Dhruva provided the right platform for various technological developments some of which were also adopted in the standardized Indian pressurized heavy water reactors (PHWR).

- Reactor shielding design was simplified by submerging the reactor vessel in a pool of light water thus reducing the Ar\(^{41}\) activity in the exhaust. This will also simplify the disposal of solid active waste at the time of decommissioning of the reactor.

- The thermal shield on top of the reactor was designed keeping in mind the ease of transportation from the fabricator’s premises to the reactor site. Instead of using heavy metal slabs with cooling coils, a box type design using a mixture of steel balls (filled at site) and water was adopted.

- Coolant channels were designed as semi permanent structures to allow easy replacement of coolant channels, if required.

- In order to provide flexibility for any future changes in the fuel and the core configuration, the positions of the fuel and shut off rods were made interchangeable. This requirement imposed a severe space constraint for accommodating shut off rod drive mechanism within the coolant channel dimensions. This challenge could be met by an innovative design of drum-cum-damper assembly.

- Stainless Steel reactor vessel weighing about 30 tons was fabricated in the central workshop of BARC. Many evolving technologies such as plasma arc cutting of thick (50 mm) SS plates, electron beam welding etc were developed and successfully employed for the fabrication of reactor vessel. Accurate dimensional and alignment checks for various components of the reactor vessel were done with the help of laser interferometre.

- Challenging task of fabricating 300 mm diameter zircaloy-2 re-entrant cans, for neutron beam holes, was met by rolling and seam welding zircaloy-2 plates. Since uniform thickness could not be achieved through hot rolling, a special cold rolling facility was set up at Mishra Dhatu Nigam Ltd (MIDHANI) Hyderabad. Electron beam welding of zircaloy-2 hemisphere to the zircaloy-2 tube was carried out at DRDL Hyderabad, after successful developmental trials keeping the weld distortions to a minimum. As zircaloy-2 is a highly reactive material and absorbs lot of oxygen and nitrogen at elevated temperatures, the welds were made in...
a glove box under an inert argon atmosphere.

- The 300 mm diameter zircaloy-2 reentrant cans were rolled into the stainless steel nozzles of the reactor vessel. Till then experience of rolling cylindrical sections of stainless steel and zircaloy up to a diameter of 125 mm only was available in the country. Extensive mock-up trials were carried out to get perfection in the quality of rolled joint. The mock joints were qualified by pullout test. The challenging task of accurate alignment of Zircaloy-2 reentrant cans with the beam hole tubes (located in biological shield concrete) was achieved after extensive mock up trials.

- Design of the fuelling machine for the safe and reliable operation, was another challenging work. The machine was to be designed to handle two nine metre long fuel assemblies with adequate neutron and gamma shielding, heavy water cooling and provision for making a leak tight joint with the coolant channel. For this the fuelling machine, (having lead filled compartments for radiation shielding) weighing over 300 Tons was designed to have alignment accuracy of ± 0.25 mm.

Utilization of Dhruva

Dhruva has been extensively used for basic and applied research in the frontier areas of science and technology, and radioisotope production. Besides utilization of regular irradiation facilities for these purposes, some of the fuel and other in-core positions have also been used for carrying out certain specific engineering experiments.

Radioisotope Production: The high thermal neutron flux, adequate excess reactivity and the large irradiation volumes enable large-scale production of radioisotopes with high specific activity. This results in handling and processing of comparatively reduced volume of radioactive material. The design provision has been made for loading and unloading of radioisotope samples on power. Nearly 70 different radionuclides produced in reactor are processed and supplied in various radiochemical forms. Bulk of the radionuclides prepared are used in nuclear medicine, agricultural research and industrial applications.

CIRUS and Dhruva, working in tandem, meet all the requirements of radioisotopes. During recent long outage of CIRUS for refurbishment, Dhruva alone met all the radioisotope requirements.

Radioisotopes Mo⁹⁹, I¹³¹, Sm¹⁵³, ...
List of Major Radionuclides Produced in the Reactor and their Applications

<table>
<thead>
<tr>
<th>Radio nuclide</th>
<th>Period of irradiation</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mo$^{99}$-Tc$^{99m}$</td>
<td>1 week</td>
<td>Preparation of Tc99 radiopharmaceuticals for diagnosis</td>
</tr>
<tr>
<td>I$^{131}$</td>
<td>3 weeks</td>
<td>Diagnosis and therapy of thyroid disorders and thyroid cancer</td>
</tr>
<tr>
<td>P$^{32}$</td>
<td>6-8 weeks</td>
<td>Radionuclide therapy &amp; P$^{32}$-labeled nucleotides</td>
</tr>
<tr>
<td>Cr$^{51}$</td>
<td>1 week</td>
<td>RBC labeling-for studies in biology etc.</td>
</tr>
<tr>
<td>Sm$^{153}$</td>
<td>1 week</td>
<td>Radionuclide therapy- treatment of bone pain in metastatic cancer</td>
</tr>
<tr>
<td>Ho$^{166}$</td>
<td>1 week</td>
<td>Radionuclidic therapy- treatment of rheumatoid arthritis</td>
</tr>
<tr>
<td>I$^{125}$</td>
<td>2 weeks</td>
<td>RIA, brachytherapy of cancers, X-ray source etc.</td>
</tr>
<tr>
<td>Sc$^{46}$</td>
<td>1 week</td>
<td>Sediment transport, underground water seepages studies</td>
</tr>
<tr>
<td>Hg$^{203}$</td>
<td>2-3 months</td>
<td>Mercury inventory studies</td>
</tr>
<tr>
<td>Br$^{82}$</td>
<td>4-7 days</td>
<td>Leak detection, residential time distribution measurements</td>
</tr>
<tr>
<td>Au$^{198}$</td>
<td>1 week</td>
<td>Seepage, sediment transport studies in hydrology</td>
</tr>
<tr>
<td>Ir$^{192}$</td>
<td>3 months</td>
<td>Industrial radiography &amp; brachytherapy</td>
</tr>
</tbody>
</table>

P$^{32}$, Cr$^{51}$ for medical use are produced and supplied weekly / fortnightly. About 100TBq (~2700Ci) of these radiochemicals are supplied to about 200 nuclear medicine centres in the country per annum. This caters to about 2.5 lakh patient investigations involving diagnostic and therapeutic applications in a year. I$^{125}$ which has a much better gamma merit ratio as compared to I$^{131}$ is the recent addition to the variety of radioisotopes for medical uses. I$^{125}$ is used world wide for radioimmunoassay (RIA) and as brachytherapy source for treatment of eye and prostate cancer. To meet the growing demand of radioisotopes and to facilitate production of I$^{125}$, second isotope production tray rod assembly was suitably modified. This assembly has facility for Irradiation of Xenon gas for production of Iodine-125 isotope and can be handled on power.

Radioisotopes produced are used in industries in eco-benign technologies (e.g., Radiation vulcanization of rubber latex, radiation sterilization of medical products, radiation cross linking, etc.) and also in the treatment of domestic and industrial waste (e.g., radiation hygienisation of sewage sludge, treatment of flue gases, etc.). Radio nuclides like Br$^{82}$, Hg$^{203}$, Au$^{198}$, Sc$^{46}$, La$^{140}$ Na$^{24}$ and others used for leakage and blockage detection in buried pipeline studies, Residence Time Distribution (RTD) studies in chemical reactors, sediment transport, effluent dispersion, seepage studies in canals and dams, etc., are produced against specific requirements of the users. Ir$^{192}$ is produced regularly for use in industrial radiography and brachytherapy.

Though there is no design provision for regular production of Co$^{60}$ radioisotope in Dhruva, two fuel positions were used for producing cobalt-60 of high specific activity in large quantities. Co$^{60}$ is used for radiation sterilization of medical products.

Reactor produced radionuclides for miscellaneous applications that support basic research in the country have been an important area of focus.

**Neutron Beam Research:** Neutron beam research at BARC received a great boost with the availability of Dhruva. In Dhruva two main new features are introduced, namely, through-tubes and neutron guides. Through tubes provide a clean thermal neutron beam picking almost from the centre of the core. A Neutron Guide-Tube Laboratory (GTL) with additional instruments having specific features has been built, adjacent to the reactor hall. Two nickel coated neutron guides, emanating from a beam port inside the reactor hall are taken into this laboratory.

A neutron beam shielded tunnel (100 Te in weight) has been installed at neutron beam hole TT-1015 which provides multi-ports for neutron scattering experiment, thus expanding
Experimental setup around Dhruva
the scope of research facilities. A National Facility for Neutron Beam Research (NFNBR) has been created as a part of the Solid State Physics Division (SSPD) at BARC to cater to the needs of the Indian scientific community in the field of neutron beam research. Scientists from BARC, other DAE units, universities and national laboratories use these facilities through collaborative research projects. SSPD scientists not only actively participate in the experiments and analysis, but also help the visiting scientists in understanding the intricacies of neutron beam research. Many of these collaborations are being supported by UGC-DAE Consortium for Scientific Research, BRNS, and other agencies.

There are 8 instruments in the Reactor Hall and 4 in the annexe Guide Tube Laboratory (GTL). In the reactor hall, two profile analysis powder diffractometers and the high-Q diffractometers have been provided specifically for structure studies of liquid and powder samples. These instruments utilize one or more linear He$^{3}$ position sensitive detectors. Usage of multi detector (5 PSDs laid side by side with some overlaps) system, covering an angular range of 3$^\circ$ ≤ 20 ≤ 140$^\circ$, has improved the throughput substantially. In fact now it is possible to record a diffraction pattern in a few minutes time, which was hitherto not possible.

In the guide tube laboratory, on G2 neutron guide, there are two Small Angle Neutron Scattering (SANS) instruments— a double crystal based and a conventional type, and a neutron reflectometer. A neutron spin echo spectrometre was test-operated at the end of neutron guide G1 and now it is used in the polarised small angle scattering mode.

In the immediate aftermath of the discovery of High-T$_{c}$ oxide superconductors in 1987, the single crystal diffractometre was extensively used in powder mode to record diffraction patterns for a very large number of such compounds and the structure parameters were refined by profile refinement. Subsequently, several single crystal investigations, notably on ferroelectric crystals have been carried out.

The profile analysis unpolarised neutron diffractometers have been the workhorses for studies of chemical and magnetic structures and for investigating phase transformations in different classes of magnetic and non-magnetic compounds.

The SANS (low-Q) diffractometers in the Guide Tube Laboratory have been extensively used for investigating spatial structures, inhomogeneities and agglomerates, with sizes of a few tens to thousands of nanometres. The double crystal based SANS diffractometre has been used to study pore size, pore morphology and pore surface roughness in different natural rocks, coal and porous silicon, fluid permeability and fractal dimensions in membranes, heat treatment effect on nanoparticle agglomerates, precipitates in nuclear materials and metallurgical alloy specimens.

Neutron Triple Axis Spectrometer (TAS), Filter Detector Spectrometer (FDS) or Quasi-ElasticNeutron Spectrometer (QENS) have been used to study dynamical processes like phonon dispersions, magnetic excitations, rotational and translational diffusion in molecular systems, etc.

The lattice dynamics of several geologically important minerals, available as natural single crystals, have been investigated by Triple Axis measurements.

The neutron reflectometer is suitable for vertical sample geometry and has polarised/unpolarised option. Chemical and magnetic profiles of thin film samples, multilayer, etc have been studied using polarised neutron reflectometry (PNR).

**Neutron Activation Analysis:** Neutron Activation Analysis (NAA) is essentially a non-destructive nuclear analytical method, capable of simultaneous multi element analysis. It is one of the major applications of a research reactor. Neutron being non-charged particle interacts with nuclei of isotopes of all elements resulting in nuclear reactions. The product formed in such a nuclear reaction might be a radioisotope. By measuring the radioactivity formed, concentration of the isotope that underwent nuclear reaction is measured. Using the isotopic abundance, elemental concentration is calculated. NAA has been used in a large number of areas of research like biology, geology, agriculture, anthropology, chemistry, engineering and industry, fisheries, forestry, medicine, oceanography, pharmacy and forensics.

Pneumatic Carrier Facility (PCF) at Dhruva is utilized for irradiation of short-lived isotope samples which require minimum transit time between the completion of irradiation and counting, for NAA. With higher neutron flux level in Dhruva PCF, elemental detection limits have improved and scope for studying short lived isotopes is also enhanced.

Prompt Gamma Ray Neutron Activation Analysis (PGNAA) using thermal neutron beam at Dhruva reactor has provided an avenue for the on-line analysis of various materials. A dedicated beam line for PGNAA is being developed. PGNAA and PCF would enlarge the scope for activation analysis as well as basic studies like nuclear spectroscopy.

**Material and fuel testing:** In order to develop various fuel and structural materials for Indian pressurized water reactors, a facility has been installed in one of the 300 mm diameter radial beam holes which would enable neutron irradiation of samples of fuel.
cladding, pressure tubes, end fittings, end shield etc. at controlled temperature to assess the effect on their fracture toughness, impact and other mechanical properties at various neutron fluences.

Dhruva core has provision for installing a facility for testing of advanced reactor fuels. An In Pile Loop (IPL) Facility with high heat removal capacity is being provided in Dhruva. This facility can accommodate fuel bundles of 500 MWe PHWR and AHWR for testing. The facility will be commissioned soon.

**Man Power Training:** During the last 20 years a large number of Engineers, Scientists, operators and technicians have been trained at Dhruva reactor. This trained manpower is contributing to our nuclear programmes in various capacities.

**Special Experiments Carried Out at Dhruva**

- **Validation of Thermal Hydraulic codes:** An instrumented Dhruva fuel assembly was irradiated in the reactor for validating the thermal hydraulic code used for estimating fuel clad temperatures.
- **Study of Irradiation growth in Zircaloy:** The manufacturing route of the Zircaloy calandria tubes for the Indian PHWR was to be changed from sheet rolling, bending and seam welding to hot extrusion and cold pilgering to obtain seamless calandria tubes, for reasons of economy and faster production rate. Samples of welded and seamless Zircaloy calandria tubes were test irradiated in Dhruva reactor to study their comparative in-pile growth behavior. These studies resulted in finalization of manufacturing route for the PHWR calandria tubes.
- **Study Of Applicability Of Neutron Noise Measurement Technique For Condition Monitoring Of In-Core Components For Heavy Water Reactors:** The neutron flux signal is composed of a steady or mean component of neutron flux produced by the power operation of the reactor and a very small fluctuating component called noise. Analysis of the neutron noise from suitably located sensors is a proven technique to monitor the condition of the in-core components of a light water reactor. However, it is generally felt that its applicability to a heavy water reactor will be limited due to the unfavorable transfer characteristics of these reactors. An attempt was made to check the applicability of this technique for PHWRs. An experiment was carried out at Dhruva using in core neutron detectors housed in a specially fabricated assembly. The result of this experiment showed the suitability of this technique to identify the change in condition of reactor internals which are otherwise inaccessible.
- **Accelerated Life Testing Of Ion-Chambers:** Neutron detectors of various types and sensitivities are developed by Electronics Division of BARC and Electronics Corporation of India Ltd. (ECIL) Hyderabad. Before these detectors can be used for various reactor regulation or protection systems they have to be tested for their performance under simulated conditions. One of the Dhruva beam holes is being utilized for accelerated life testing of newly developed ion chambers.

**Conclusion:** Dhruva has completed twenty years of operation with excellent safety record. It has contributed immensely to the nuclear science and technology in general and neutron beam research and radioisotope production in particular. Utilisation of Dhruva, both in terms of quantity and quality, has been of a very high standard. The safety and availability records for 20 years operation proves the soundness of the basic design and dedication of operations and maintenance personnel. The gains accrued with the construction, commissioning and operation of Dhruva certainly outweigh the efforts invested in its making and subsequent operation.
Jaduguda Uranium Mine, Singhbhum, Jharkhand:

Some facts on Radioactivity, Radiation and Environmental Impact

A.C. Kundu
Executive Director, UCIL

Jaduguda, with its uranium mine and mill, epitomizes the team effort of India's self-reliance in nuclear fuel with sustainable and environment-friendly development. Fears of adverse radiation effects have no scientific basis and are fictitious.

Jaduguda, the magic place, so named by the discoverers in 1951 because of the anomalous radioactivity encountered in some of the rocks flanking the hill slopes about 2 km from the historic copper workings near Rakha, is very special in many ways. India's first uranium mine and mill are located here epitomizing the successful indigenous efforts at locating and proving a deposit followed by mining and extracting uranium for use in our nuclear reactors. The pioneering scientific and technological efforts are of a very high order comparable to those achieved by advanced nations like USA, Russia and others. Each facet of this great endeavour being the first of its kind in India and represents the culmination of a team effort that began after India's independence under the great visionary and founder of India's atomic energy programme Dr. Homi Jehangir Bhabha and carried forward with zeal by illustrious scientists and engineers.

Prior to the discovery of radioactivity by Henri Becquerel in 1896 and nuclear fission in 1939, uranium was being used as colouring agent in porcelain ware to provide the beautiful canary yellows, a feature common to water-bearing secondary uranium minerals which in fact help in locating uranium deposits. Once the power of the uranium atom was realised, things about uranium became secret. Knowledge on processing materials with radioactivity, radiations and their effect on workers as well as environmental effects were also not shared. The first Geneva Conference on the Peaceful use of Atomic Energy in 1955 at Vienna, presided over by Dr. Bhabha and subsequent meetings under IAEA provided a forum for sharing information on a variety of topics related to atomic energy including the natural radiation environment and health related aspects. The International Commission on Radiological Protection (ICRP) founded in 1928, provides safety norms for radiation workers and most UN members including India adopt such norms for workers in uranium mines and other places where ionising radiations are part of the working environment.

Radioactivity and Radiation

When we talk of radioactivity of uranium, it pertains to ionizing radiations comprising alpha, beta and gamma during its decays through different elements such as radium, radon and polonium to form radiogenic lead. Unlike light or heat radiations, the radiations related with radioactive decay, as in the case of U, Th and K are 'ionising' i.e. they can remove electrons from an element and thus can effect changes in living cells. Such ionizing radiations are also produced by cosmic rays that come from space and vary from place to place depending on location and also altitude. The penetrating powers of radiations also vary depending upon the type of radiation (Figure 1).

Thus radiations are omnipresent and are part of our environment wherever such radioactive elements are present even in trace quantities. The intensity of which, however, varies depending upon the amount of uranium and other radioactive elements like thorium and potassium. Thus, the rock and soil that surrounds our home, office and other places contribute to the radioactivity. The food we consume also gives us some radiations. Thus the average dose that a person receives from background radiation in nature amounts to 1 to 2 mSv per year. In some areas of high natural background radiations such as...
the monazite-rich thorium bearing mineral sands of Kerala coastal tracts, radiation levels can reach up to 20 mSv per year. Radon gas emanated from building materials containing U and Th in trace quantities inside homes can add 1 to 3 mSv per year (Figure 2).

In poorly ventilated homes in a cold country radon contributions can be high up to 20 mSv. The food chain like milk and other items contain radio elements like potassium and polonium in trace levels and also contribute to the radioactivity. X-ray diagnosis gives a radiation dose ranging from 0.2 to 5 mSv per examination is not uncommon. Thus radiations are ubiquitous and are part of life. A healthy adult of 70 kg, in fact, gives out radiation of some 7000 Bq.

Radiation Levels at Jaduguda

Airborne and ground radiometric instruments in and around Jaduguda indicated that the rocks and soil covered areas give a range of radiation levels varying from 0.04 to 0.46 mGy/hr. The lower values represent natural background radiation whereas the higher readings represent feebly mineralized to ore zones with low grades (0.03 to 0.06% U₃O₈) which are mined at Jaduguda. Because of the excellent recovery of uranium from Jaduguda ores (>90%) the tailings produced contain very low levels of radioactivity. In comparison uranium ores processed by other countries like Australia (> 0.1% U₃O₈) and Canada (1-18% U₃O₈) are of higher grade and hence they need to take more care in their mining and processing. The most positive aspect of processing such low grade ores is that radiation hazards from gamma activity and radon levels are lower and the tailings produced contain wastes with very low radioactivity. International Commission for Radiological Protection (ICRP) recommends that occupational exposure to radiation workers should not exceed 50 mSv in any one year with a stipulation of 100 mSv over a period of five years which has been adopted by the Atomic Energy Regulatory Board (AERB) with a restriction to maximum dose limit of 30 mSv in any one year. The Jaduguda mine is well ventilated to avoid the accumulation of radon. At Jaduguda, monitoring is done on both external and internal radiation levels that the mine and other workers receive (Figures 3 & 4). It can be seen that the radiation doses received by individual workers had ranged from about 1 to 10 mSv/yr which is far below the limit prescribed by ICRP (50 mSv/yr) and significantly below the annual average dose of 20 mSv set by AERB.

The uranium ores that are processed in the mill to extract uranium introduces airborne radio-nuclide due to dust generation while crushing and grinding the ore. The radon progeny problem, as encountered in the mines does not exist here as most of the operations take place in well ventilated areas. The use of scrubber and

### Natural Background Radiation*
- Cosmic - from the sun and outer space - 0.4 mSv yr⁻¹
- Terrestrial - from the earth’s crust - 0.5 mSv yr⁻¹
- Radon - from decay of U/Ra - 1.2 mSv yr⁻¹
- Internal - sources in the body (e.g. ⁴⁰K) - 0.3 mSv yr⁻¹
- Total dose from natural sources - 2.4 mSv yr⁻¹

*UNSCEAR 2000

---

**Monitoring**

- **External Radiation Monitoring**
  - Survey meter
  - TLD
  - Surface & Personal Contamination

- **Internal Radiation Monitoring**
  - Radon Monitoring and Dosimetry using Solid State Nuclear Track Detector
  - Air Activity Measurement
  - Lung Burden
  - Radon/Thoron in Breath
  - Bioassay

---

*Figure 2*

*Figure 3*
waterspray avoids the dust and the use of HEPA filters prevents airborne pollution.

**Waste Management**

Mining operations at Jaduguda result in both ore and waste rock besides ground water that is contaminated by mine dust and seepage. Waste rock is used within the mining premises for filling low-lying areas, and excess quantities are stored in an area earmarked for storage. Mine water is reclaimed for use in the mill after clarification. After extraction of uranium, the mill produces two types of wastes namely slimes or slurry and liquids depleted in uranium from ion exchange columns. Both are neutralised with lime so as to remove the remaining radio nuclides such as Ra, Po, Pb along with heavy metals like manganese, iron, copper etc. that can pollute the environment. The slurry is then classified and the sand-sized fraction is pumped back to the mines for back filling the space left after the removal of ore. The remaining part of the slurry is pumped into the tailing pond where the slime settles and the clear water is decanted through wells and processed again at the effluent treatment plant (ETP) before discharging into the public domain. The ETP takes care to keep the levels of undesired elements like U (<300 mg/m³), Ra (< 900 Bq/m³), Cl (< 600 ppm) and SO₄ (<1000 ppm) and Mn (< 2 ppm) at levels prescribed by the pollution control board. The tailings pond is a well engineered containment structure having an earthen dam on one side while the other three sides are protected by hills. The seepage water from the pond is also monitored by observation wells for ascertaining statistical variations in the ground water as compared to the background concentrations.

Water from the Jaduguda mine and tailings pond is collected, clarified and reused in the ore processing plant (mill). Any remaining water is retreated with barium chloride and lime, clarified, and checked for their uranium, radium, chloride, sulphate and manganese levels and after ensuring that the norms of discharge prescribed by the various statutory bodies like the Pollution Control Board and AERB are complied, it is released to the public domain. The company’s ISO-9001:2000 and ISO-14001 certification ensures that these protocols are followed strictly.

The Health Physics Unit (HPU) and the Environmental Survey Laboratory of BARC, independently carry out environmental monitoring of the different units comprising the mine, mill, tailings pond, effluent treatment plant, and the areas around the Jaduguda for a radius of some 25 km, since inception. The HPU evaluates and ensures overall safety of the workers and public in accordance with the standards prescribed by AERB and ICRP. The HPU monitors the radioactivity and radiation levels in different samples such as water, soil, grass, vegetables, food stuff and aquatic organisms like fish, algae etc. Such a practice helps in maintaining a healthy environment and a better understanding of the impact of uranium mining and extraction on the environment.

The gamma radiation at 1 metre level above the tailings surface at different places vary from 0.8 to 3.3 µGy/hr averaging about 1.4 to 2.0 µGy/hr. Radiation levels decrease to background values of 0.10 to 0.15 µGy/hr at about 20 m from the embankment. The average annual exposure levels in and around 25 km radius of Jaduguda observed over the years range from 790 µGy/yr to 2490 µGy/yr, the maximum being near the pond (Figure 5a).

The radon concentrations at the tailings ponds are varying from 23.0 to 30.0 Bq/m³ and it reduces local background of 10 to 15 Bq/m³ close to the tailings pond boundary (Figure 5b).

Thus the annual radiation exposure levels in the public domain around the uranium mine, mill and the tailing pond compares well with the natural background radiations which clearly points out that UCIL’s operations have been very environment-friendly (Table-1).

**Radiation Safety and Health Aspects**

Effects of natural and man made ionising radiation on living things
including humans have been the subject of study ever since uranium became an energy element of immense potential. Lack of proper knowledge on radiation is the main cause of fear and unfounded apprehensions, aggravated further by misinformation. Radiations are thus as part of life as we breathe air, and is a permanent feature. It is natural that questions arise as how much radiation one can take safely, and what kind of dose levels become dangerous.

The ICRP norm is to keep the radiation dose levels in working environments as low as reasonably achievable (ALARA). It is here that elaborate studies on radiation effects have been completed and norms set for the dose levels for the persons working in radiation environment like an X-ray machine, a uranium mine, mill or a nuclear power plant.

The natural background radiation averages 1-2 mSv per year and may reach up to 20 mSv per year in some places. However, there are areas in the world where background radiations have been unusually high, as at Ramsar in Iran where background radiation levels reach up to 260 mSv. Thus lifetime doses from such high natural background radiations range up to several thousand mSv. However, in these parts there is no evidence of increased cancer or other health related problem. Even with higher doses of radiations as encountered by the workers at the time of nuclear accident, direct correlation between a high dose and cancer is yet to be proved. Nevertheless the practice in nuclear energy related activities, caution is taken to avoid higher doses and the ALARA principle of ICRP applies.

In fact radiation level with less than 100 mSv/yr do not produce any detectable difference in exposed vs. non-exposed patients as per Donald Hunters Occupational Diseases

<table>
<thead>
<tr>
<th>S.NO</th>
<th>LOCATIONS</th>
<th>GAMMA Radiation [Gy.h']</th>
<th>RADON CONCENTRATION Bq.m''</th>
<th>EFFECTIVE DOSE mSv.y'</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NEAR PWD ROAD DUNGIRIDI N</td>
<td>0.14</td>
<td>42±19</td>
<td>0.24</td>
</tr>
<tr>
<td>2</td>
<td>NEAR WATER TAP DUNGIRIDI N</td>
<td>0.15</td>
<td>42±19</td>
<td>0.26</td>
</tr>
<tr>
<td>3</td>
<td>BHATIN CROSSING TP 1</td>
<td>0.30</td>
<td>68±38</td>
<td>0.53</td>
</tr>
<tr>
<td>4</td>
<td>SEPARATION BUND BETWEEN TP 1 &amp; 2</td>
<td>0.17</td>
<td>27±13</td>
<td>0.30</td>
</tr>
<tr>
<td>5</td>
<td>NEAR WESTERN MOST FENCE TP 2</td>
<td>0.12</td>
<td>36±19</td>
<td>0.20</td>
</tr>
<tr>
<td>6</td>
<td>NEAR SW HILL SIDE FENCE TP 3</td>
<td>0.13</td>
<td>31±13</td>
<td>0.23</td>
</tr>
<tr>
<td>7</td>
<td>SOUTH SIDE NEAR CHAKRUKHA TP 3</td>
<td>0.11</td>
<td>19±0.08</td>
<td>0.19</td>
</tr>
<tr>
<td>8</td>
<td>NEAR DUNGIRIDI S</td>
<td>0.28</td>
<td>19±5</td>
<td>0.50</td>
</tr>
<tr>
<td>9</td>
<td>NEAR JAKHRA BETWEEN TP 1 &amp; 3</td>
<td>0.14</td>
<td>20±9</td>
<td>0.28</td>
</tr>
</tbody>
</table>

Table 1
Manual. At Jaduguda surface radiation levels average 2.66 mSv/yr which is far below the limit mentioned above. Even the mine workers and others working in the plant area receive less than 10 mSv/yr. Thus the allegations of deformed or mentally retarded children attributed to higher radiation levels due both natural or man made is not justified at Jaduguda. The cases have been thoroughly investigated by expert doctors as well as independent agencies. Such cases may be due to neonatal jaundice, difficult labour during child birth, repeated abortion, malnutrition, encephalitis and meningitis. Care, however, must be taken to protect from unwanted risks. Hence the precautions to avoid areas where wastes, such as the tailings ponds and waste rock dumps are located. These have been fenced and clearly marked as areas to be avoided. It is like avoiding garbage dumps and sewer water in day to day life. Health hazards related to radiation need to be understood properly. Such an understanding between the public and authorities engaged in development work can lead to the welfare of all. Public awareness in such matters is essential to avoid baseless fears and we need to persevere with educating people.

Workshop on Planning, Preparedness & Response to Radiation Emergencies

The 15th Training Workshop on ‘Planning, Preparedness & Response to Radiation Emergencies for Medical Officers’ was conducted by BARC’s Local Working Committee (LWC) for Radiation Emergency Medical Response (REMR) at AERB Auditorium, Mumbai during September 20-23, 2005. It was attended by 37 doctors from various units of DAE medical colleges, and the units of Armed Forces Medical Services.

Dr. P.R. Bongirwar, Medical Officer Incharge, Trombay & Vashi Industrial Dispensary, welcomed the chief guest, invitees and delegates.

Dr. Nair, Head, Medical Division & Chairman of LWC, REMR, in his introductory address said that the knowledge gained by medical officers through this workshop should percolate down to other medical and nursing staff at their work places.

Dr. D.N. Sharma, Head, RSSD, in his remarks enumerated various causes of radiation accidents and their consequences. He also spoke about 17 Emergency Response Centres (ERCs) being developed all over the country with the nodal centre at BARC.

In his inaugural address Shri S.K. Sharma, Chairman, AERB, congratulated the organizers on conducting such workshops. He described AERB’s mandate and its working through various committees to achieve its goal. He also exemplified concept of defence-in-depth which is used in construction of nuclear power plant, and emphasized on the need for training and emergency preparedness at all times.

Faculty for the training course was drawn from BARC, AERB and DAE. Apart from lectures and discussions on various aspects of management of radiation emergencies the training course also included visits of delegates to the Radiation Medicine Centre, Tata Memorial Hospital and BARC.

Dr. H.M. Haldavnekar welcomed the invitees for the Valedictory function held on September 25, 2005. Dr. P.R. Bongirwar, course coordinator, summarized the deliberations of the workshop.

Shri K. Muralidhar, Secretary, AEC & Head, MSG, DAE, presided over the valedictory function and distributed certificates of participation and CDs containing information about medical preparedness for management of radiation emergencies, to the delegates.

During the Inaugural and Valedictory functions, votes-of-thanks were proposed by Dr. S.S. Galinde and Dr. Ravi S. Jammibal respectively.
The mission of IGCAR is to render comprehensive Research, Development and Design support to the Indian Fast Reactor Programme. Over the years, comprehensive expertise has been developed in all the relevant fields, including reactor engineering, safety, materials, and reprocessing. In the process, IGCAR has established itself as a nationally and internationally reputed research centre not only in the primary areas of its activities but also in many associated areas. This has resulted in a gradual increase in the number of international interactions and collaborations. In deed, in several cases, the proposals for collaboration have originated from the foreign laboratories, a testimony to the overwhelming and clear strength of IGCAR in the relevant areas.

IGCAR has been an active participant in the International Working Group on Fast Reactors, and other International Atomic Energy Agency (IAEA) activities of interest to fast breeder reactor (FBR) programmes. IGCAR hosted during 13-17 January 2003, the IAEA Technical Meeting on “Primary Coolant Pipe Rupture Event in Liquid Metal Cooled Fast Reactors”, in which international experts from several interested member countries participated. IGCAR has also been actively participating in international cooperative research programmes of IAEA in the areas of reactor engineering, reprocessing, and safety. IGCAR has actively participated, along with France, Japan, Korea and Russia on the investigation of thermal striping damage of the expansion tank of Phoenix reactor. The thermal hydraulic as well as structural damage predictions made by IGCAR scientists matched very well with in-plant data. In another cooperative research programmes in which IGCAR contributed was greatly appreciated was on intercomparison of computer codes to predict seismic behaviour of liquid metal fast breeder reactor cores. In the cooperative research programmes on core mechanics of FBRS, the predictions by IGCAR scientists were found to be in good agreement with the experimental observations. IGCAR is actively participating in several current cooperative research programmes of IAEA. One example in the area of reactor physics is on updated codes and methods to reduce calculated uncertainties in reactivity coefficients in liquid metal fast breeder reactors; China, France, Japan, Korea, Russia and USA are collaborating in this project. Another example in the area of reprocessing is on the separation efficiencies for La, Ce and Nd in the oxide electro-winning process using MgCl$_2$ based electrolyte, in collaboration with China, Czech Republic, Japan, Korea and Russia. IAEA has initiated an International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) with a view to ensuring sustainable nuclear energy towards fulfilling energy needs for the twenty-first century. India is a member of this project. As part of this project, IGCAR is actively participating in a joint case study on assessment, using the INPRO Methodology, for an Innovative Nuclear Energy System based on a Closed Nuclear Fuel Cycle with Fast Reactors (CNFC- FR). The objectives are to assess the long term viability of technology options and innovations, and identify areas where research and development is required. The participating countries are China, France, India, Korea and Russia, and Japan as observer. IGCAR is an active member in the Technical Working Groups on nuclear fuel cycle options and nuclear data evaluation, and Standing Advisory Group on nuclear energy.

As a part of the protocol between DAE and the ‘Organisation Européenne pour la Recherche Nucléaire (CERN)’, Geneva, so far five scientists have been deputed from IGCAR to CERN, each for a period of one year, for carrying out testing, evaluating, and training the 1200 huge super-conducting di-pole magnets for the Large Hadron Collider (LHC); this is a giant underground accelerator designed for accelerating protons to 14 TeV and lead nuclei to 1150 TeV for basic studies in particle physics, the next major project of CERN.

IGCAR has also been actively participating in the collaborative research programmes with the premier R&D institutes in Germany under the aegis of Indo-German Bilateral Agreement. In the early years, the areas of collaboration included sodium chemistry, high temperature mass spectrometry, high temperature calorimetry, and solid state physics including radiation damage and low temperature physics. Subsequently, the range of collaboration has considerably expanded to include many other front line areas of common research interest in science and technology, including vibration noise monitoring and analysis for diagnostic purposes in nuclear power plants, and micro-meteorological studies using acoustic SOnic Detection And Ranging (SODAR) system for prediction of dispersal of radionuclides. These projects also fostered close collaboration between Indian and German scientists, including mutual visits. The experience and expertise thus generated have been valuable not only to IGCAR, but also to the host
institutions in Germany. An important area of direct interest is that of high temperature mechanical properties, namely, creep, fatigue and their interaction, and also fatigue and creep-fatigue crack growth behavior in liquid sodium. Over the years several projects have focussed on high temperature components: creep-fatigue interactions and fracture mechanics properties and their correlation for high temperature materials, including steels and their weldments, and also Ni-base superalloys; methodology for high temperature component life assessment; and monitoring & repair welding of high temperature components. The results from these studies have clarified many basic issues, and enhanced capability in life prediction of engineering components. An extensive project addressed the issue of environmental degradation of stainless steels and their welds and the effect of nitrogen content thereon, and corrosion properties of spun-melt ribbon and bulk metallic glasses of Zr-based systems with superior corrosion resistance. Another such extensive study has been on the science of oxidation of high temperature materials, a topic of perennial interest to power plants. Indo-German Collaborative Programme on Non Destructive Evaluation (NDE) is an extensive collaboration that charted several new paths - including development of ultrasonic and micromagnetic techniques with innovative approaches for characterization of microstructures and deformation process, and development of eddy current impedance imaging for quantitative characterization of defects and also knowledge based systems for NDE applications. Two IGCAR scientists obtained their doctoral degrees from a German University based on the investigations carried out under this programme. This interaction has considerably enhanced IGCAR impact and recognition as one of the premier NDE research centre in the international NDE community, and is a fine example of the importance and impact of such collaboration with premier international institutions. The early collaboration of IGCAR with the French Atomic Energy Commission (CEA) dates back to

Dr. Placid Rodriguez is Indian Nuclear Society president

Dr. Placid Rodriguez, former Director, Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam, has been elected president of the Indian Nuclear Society for a period from 2005 to 2007. He succeeds Dr. R. Chidambaram, former Chairman, Atomic Energy Commission. Dr. Rodriguez has had a career long association with the Department of Atomic Energy. After his retirement as Director, IGCAR, he became the Chairman of the Recruitment and Assessment Centre, Defence Research and Development Organisation.

He is currently a Raja Ramanna Fellow and a Visiting Professor at the Indian Institute of Technology (IIT), Chennai.

Previous chairmen of the Indian Nuclear Society include Dr. P.K. Iyengar, former Chairman, Atomic Energy Commission, and C.V. Sundaram, former Director, IGCAR.

Other Members of Governing Body

Vice President: Dr. V. Venugopal, Secretary: Shri G.D. Mittal, Joint Secretary: Shri R.K. Singh, Treasurer: Shri R.P. Singh, Joint Treasurer: Dr. Gursharan Singh, Members: Shri S.A. Bhardwaj, Shri R.K. Sinha, Shri H.S. Kushwaha, Shri M.L. Joshi, Shri S.K. Agarwal, Dr. S. Kailas, Shri A.K. Srivastava, Shri Jagdish Sharma and Shri S.K. Malhotra.
1969, when the fast breeder test reactor (FBTR) was conceived to be built by adaptation from the French fast reactor Rapsodie, with several design modifications. IGCAR reestablished collaboration with the French Atomic Energy Commission (CEA) in 1989 to exchange computer codes in the field of thermal hydraulics and structural mechanics. Under this collaboration, from CEA IGCAR received CASTEM 2000, PLEXUS and TEDEL codes for structural mechanics analysis. Recently, DAE has established collaboration with CEA in wider spectrum of areas related to safety of fast reactors.

IGCAR is a partner in some of the international collaborative projects under the aegis of Department of Science and Technology. An ambitious DST-DAAD collaborative project is aiming at comprehensive understanding and quantitative characterization of thermo-mechanical fatigue in power plant materials, and IGCAR and Universität Siegen, Germany, have been identified as the principal partners. Under the above project so far 4 Indian scientists visited Germany and 4 German scientists visited India. University of Science and Technology, Beijing and IGCAR are collaborating on a project on remnant creep life prediction model for power plant components. Another project is on yield criterion for superplastic metals and alloys with Moscow State University, University of Hyderabad, and IGCAR as the collaborators; recently a Russian scientist visited IGCAR for carrying out experimental work for this project.

Mention must be made here of collaboration between IGCAR and some internationally reputed laboratories, another reflection of the prestige of IGCAR as a research centre. In an Indo-French Collaborative Programme on Ferrofluids, a device has been developed that can measure forces of the order of $10^{-18}$ N between colloidal particles, and it has been effectively utilized for synthesizing ferrofluids and their emulsions with long term stability. The programme led to filing of four patents that include force apparatus, ferrofluid based magnetic flux leakage measurements for NDE and optical filters. The technology is now being adapted to develop dynamic seals for sodium pumps used in fast reactors. In collaboration with Centre for NDE, Iowa State University, a three dimensional boundary element model has been developed and validated for detection and quantitative evaluation of surface and subsurface cracks in structural components. In collaboration with Michigan State University, East Lansing, modelling of response of SQUID sensors developed in IGCAR for detection of defects through flux leakage measurements has been taken up for optimization of the sensor design.

The contribution to expertise pool of IGCAR from personal initiatives deserves a mention here. A few of our scientist have been awarded the prestigious Alexander von Humboldt Fellowship, which gave them the opportunity to work in premier laboratories in Germany. Many of our scientists have spent between one to two years as Post-Doctoral fellows, or shorter periods, in many leading laboratories in Japan, USA, Europe, and Australia. The areas of research for such visits have invariably been in the frontiers of current or near-future interest to IGCAR. Similarly, several scientists from foreign laboratories have visited IGCAR for periods ranging up to 1 year, to work on projects of common interest. These interactions promote inter-laboratory co-operation and cross-fertilization of ideas, and benefit the programmes of both the IGCAR and the concerned foreign institution.

---

**BRIT’s New Chief Executive**

Dr. A.K. Kohli did his graduation in Mechanical Engineering from Delhi University in 1974. He joined Reactor Engineering Division of Bhabha Atomic Research Centre (BARC) after completing one year course with 18th batch of BARC’s Training School. He did his M.Tech. in Design of Mechanical Equipment from IIT, Delhi in 1982 and Ph.D. on Radiation Resistant Solid Lubricants from IIT, Delhi in 1998. He has served as Head PFBR F/H & Shipping Cask Group in Refueling Technology Division and as Engineer-in-Charge Consultancy Services & Mechanical Technologies of Technology Transfer and Collaboration Division of BARC. He was involved in design and development of different components & sub-systems of PHWR fuel handling system and later PFBR fuel handling system.

He joined Board of Radiation and Isotope Technology in the year 2001 as Senior General Manager – Engg. Design, QA & Customer Support. He has served in various committees in different capacities. He has taken various new initiatives in furthering the activities of BRIT.

He has now taken over as Chief Executive, Board of Radiation and Isotope Technology with effect from January-2006. *****
Science & Technology Exhibition “Pride of India” of the 93rd Indian Science Congress at Hyderabad
Science & Technology Exhibition “Pride of India” of the 93rd Indian Science Congress held during January 3-7, 2006 at Acharya N G Ranga Agricultural University, Hyderabad, the Most Interactive Pavilion Award was bagged by the DAE pavilion.

Picture shows Head, Public Awareness Division, DAE receiving the Award.