IGC Newsletter

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Founder and Architect of the Indian Atomic Energy Programme

Inside

From the Director's Desk

Ethics, Energy and Equity

I had the honour of delivering the 1st "Dr. H. J. Bhabha Centenary Award Lecture" organized by Nayudamma Centre for Development Alternatives, Nellore, Andhra Pradesh and R.M.K. Engineering College, Kavaraipettai at R.M.K. Engineering College, Kavaraipettai on 10th April 2009. The lecture delivered draws inspiration from my mother and life and works of Dr. Homi Jehangir Bhabha. I am happy to share with you the text of the talk.

The earth planet with a population of more than six billion, over periods of civilization in different parts of the world, has brought better quality of life to many who celebrate science & technology, management, philosophy and broad variations of capitalism and socialism. The fact remains that more than two billions of the living population does not have access to energy, clean water, education and healthcare. The disappointing fact is that deprived citizens which include expecting mothers and children do not see hope and faith in the organizations in their own countries and the world systems. The population is likely to grow to about nine billion by the end of 2050 and the climate changes are threatening to deprive the under-privileged more than those who are doing well in the world.

We find that the world is divided between optimism and disillusionment. History is demonstrative of the fact that enlightened human beings can remove disillusionment with their capacity, capability, commitment, approaches and selfless service. The nations and the world bodies require leadership of intellectuals, social scientists, scholars and believers in voice of democracy to guide the systems and societies where politicians and bureaucrats combine their sensitivity to large masses with intellectuals and professionals to have high synergy for enhancing quality of life for deprived citizens of this planet in a systematic and demonstrative manner.

This brings to focus the importance of ethics of individuals and the organizations. The current scenario also demands coherent synergy between ethical organizations to deliver equity to all citizens on this planet. Equity to me means education with healthcare and equal opportunity. Realizing a developed civilization also means creating an echo system in various parts of the world for wealth generation and management. It is clear that cost effective energy, sustainable over centuries, for various parts of the world; with or without strong base in science & technology along with addressing the issues of global warming and sustaining and enhancing bio-diversity are the key issues. There is a need that energy, water, health, land and food are considered in a comprehensive and interlinked fashion for sustainable options to provide better quality of life to all the citizens of the planet.

Holistic approach to education which puts emphasis on learning, building skill sets, appreciation of ethics, sensitivity to all stakeholders in society and wealth generation, is key to India progressing in to a developed nation. Healthcare has to be holistic and cost effective to meet the needs of a country like India, which has large population of poor persons along with growing middle class and rich population striving for best healthcare to international standards.

I wish to address the issues related to energy and healthcare. The world requires increased emphasis on renewable distributed energy for all countries and enhanced contributions by nuclear energy for technologically capable countries. Each country shall have to make considered decisions for a bouquet of technologies to sustain energy and environment, on basis of broad principles as mentioned above. I would describe possible choice for India to meet the energy needs. India has good reservoirs of coal and hydro and these must be exploited with the best of technologies, on the immediate horizon of about fifty years. Emphasis on renewable energy, namely solar and wind must be done with best of the science & technology base in the country. Bio-waste is a good option for us while biomass should be carefully considered to ensure that this option does not conflict with the food cycle for human beings, cattle and other species. Strong R&D base in nuclear energy in the country and recent indicators that India would be integrated in the world nuclear energy system for civil nuclear energy allows us to forecast a large contribution from nuclear energy in the coming fifty years. I describe below energy scenario in India, three stage nuclear power programme, fast breeder reactor programme, future of fast reactors, nuclear fuel cycle, long term energy perspective, etc.

Energy Scenario in India

In the Indian context, the “Integrated Energy Policy” document of the Planning Commission, Government of India indicates that proven reserves of coal, the most abundant energy resource, at the current level of consumption can last for about eighty years. Of course, coal and lignite consumption will increase in the future and the reserves would last for a limited period. If domestic coal production continues to grow at 5 % per year, the total (including proven, indicated and inferred) extractable coal reserves will run out in around forty five years. The reserves of crude oil are merely 786 Mt. These can sustain the 2004-05 level of production for twenty three years and will last only for seven years at 2004-05 level of total consumption of the country including imports. Gas resources are also likely to last only for about thirty years at 2004-05 consumption level. Considering the increase in production in future, it may run out even earlier.

India needs, at the very least, to increase its primary energy supply by three to four times and its electricity generation capacity / supply by five to six times of the 2003-04 levels. By 2031-32 power generation capacity must increase to nearly 800 GWe from the current capacity of around 130 GWe. Coal accounts for over 50 % of India’s commercial energy consumption and about 78% of domestic coal production is dedicated to power generation. This dominance of coal in India’s energy mix is not likely to change in the next two decades. Similarly requirement of coal, the dominant fuel in India’s energy mix will need to expand to over two billion tonnes/annum based on domestic quality of coal. Meeting the energy challenge is of fundamental importance to India’s economic growth imperatives and its efforts to raise its level of human development. It is clear that nuclear energy has to be utilized much more intensely in the decades ahead. India has sixteen nuclear reactors (installed capacity: 3.9 GWe) operating and seven more (capacity: 3.38 GWe) under construction. Although nuclear power in India provides 3% of the electricity generated in the country now, it is estimated to go up to 25% by 2050. India has a special interest in developing fast breeder reactors and use of thorium as a source of energy as it has one of the largest reserves of thorium. Japan, China, Korea and Russia are also interested in development of fast breeder reactors in order to utilize the uranium resources efficiently. USA, France and many other countries are interested in using fast reactors as burners of minor actinides and long lived fission products and also to stay with and use this technology on a longer horizon for breeding and energy security.

Three Stage Nuclear Power Programme

The total energy demand of India in 2050 is envisaged to be about 1300 GWe in terms of installed capacity. The contribution of nuclear energy has to be increased at the fastest possible pace to be able to meet about a quarter of the national electricity demand in 2050. India has rather meager reserves of uranium (61,600 tonnes), the only naturally occurring fissile element that can be directly used in the nuclear reactor to produce energy through nuclear fission. However, nearly a third of the entire world's thorium is available in India. Thorium is a fertile element, and needs to be first converted to a fissile material, U^{233} in a reactor. The strategies for large scale deployment of nuclear energy must be, and are therefore, focused towards utilization of thorium. The large growth in nuclear power capacity can be realized only through efficient conversion of fertile materials into fissile materials and utilizing the later to produce energy. A closed nuclear fuel cycle, which involves reprocessing and recycle of fissile materials, is thus inevitable and that too, in a relatively shorter time frame than most of the other industrialized countries. Thorium reserves available in India amounts to 2,25,000 tonnes with an electricity potential of 1,55,000 GWe-y through multiple recycling. This means that thorium can provide fuel for 275 GWe capacity power plants for about 560 years.

The three stage nuclear power programme envisaged by Dr. Homi Bhabha consists of: Pressurised heavy water reactors (PHWR) with natural uranium as fuel (stage 1), Fast breeder reactors (FBRs) utilizing plutonium based fuel (stage 2) and Advanced nuclear power systems with utilization of thorium (stage 3).

The first stage has now matured into a robust technology with the availability factors of operating reactors touching 90 % consistently. However, the PHWR programme cannot be taken beyond a level of nearly 12 GWe, due to limited resources of indigenous uranium. The effective utilization of the uranium resources is possible only through the fast breeder reactor route by which India can achieve a power capacity of nearly 200 GWe for about 200 years. It was Dr. Vikram Sarabhai, who recognized inevitability and complexity of fast breeder reactors in India and put into action the second stage of country's nuclear power programme. For this purpose, he created a roadmap for truly interdisciplinary research, which finally led to the establishment of the Reactor Research Centre, later renamed as Indira Gandhi Centre for Atomic Research. India has entered into the second stage of the programme successfully, with the design and construction of 500 MWe prototype fast breeder reactor (PFBR) at Kalpakkam.

A question that is often asked is whether India needs the fast breeder reactors, particularly when other countries have abandoned this technology presently. The countries that have abandoned fast reactors are saturated with energy generation. But a country like India wherein the per capita electricity consumption is a meager 600 kWh, needs more energy. There is also undue concern of proliferation brought out in some international projections as FBR produces more plutonium than it consumes. Plutonium is a dual-use material, used in nuclear weapons as well as fuel for fast breeders. But in Indian programme, the plutonium generated in nuclear reactors is used for the newly coming up power stations, mostly fast breeder reactors. It is to be emphasized that the inevitability of fast breeders in India arises both from resources utilization capacity as well as growth capability. By the use of FBRs the utilization of uranium can reach 60 to 80 % as compared to less than 1 % with light water reactors (LWR) and PHWRs on once through cycle or a few percent with plutonium recycle. If plutonium obtained from PHWRs is straightaway used to sustain the thorium systems, then the total megawatt power capacity that can be installed would necessarily be limited and it will grow very slowly thereafter. To go to a much higher installed power capacity base at a faster pace, it is inevitable that we multiply the fissile inventory and at the present level of technologies, there is nothing better than fast breeder reactors.

Fast Breeder Reactor Programme

The Indian fast reactor programme started with the 40 MWt / 13.2 MWe Fast Breeder Test Reactor (FBTR), commissioned in 1985 at Kalpakkam. It is the only reactor in the world, which uses the uranium-plutonium mixed carbide as driver fuel. The choice of the mixed carbide fuel for FBTR was necessitated by the technological problems anticipated in the use of high plutonium content mixed oxide fuel, and the non-availability of enriched uranium. For the first core (Mark I), a Pu/(U+Pu) ratio of 0.7 was required in the fuel. For the Mark II expanded core, the Pu/(U+Pu) ratio is 0.55. The fuel cycle of FBTR is being successfully closed, thanks to the multidisciplinary, inter-institutional research programmes, which have been pursued in a focused manner. The Mark I mixed carbide fuel has performed extremely well, reaching a burn-up of 155 GWd/t, without any fuel pin failure (burn-up of a fuel material is defined as the energy extracted from a given mass of the fuel: it is measured in Megawatt/Gigawatt {thermal} days per tonne of the fuel). Over the years, the performance of the reactor systems, sodium systems, control rod drive mechanisms and other safety related and auxiliary systems of FBTR has been excellent. The purity of the coolant used in the reactor in the primary and secondary circuits was so high that there is no corrosion in the systems for years together. The four sodium pumps and their drive systems have been operating very well. Visual inspection of the reactor vessel internals has been carried out at two-year intervals and reactor internals have been found to be healthy. Presently FBTR is used as an irradiation facility for fuels and structural materials, in addition to carrying out some challenging experiments required to enhance safety of the future FBRs.

As a logical follow-up of FBTR, it was decided to build a prototype fast breeder reactor (PFBR). For PFBR, a uranium-plutonium mixed oxide (with PuO_2 content of 21% in the inner zone and 28% in the outer zone) has been chosen as the driver fuel. Unlike FBTR, which is of loop type wherein all the primary sodium components viz. core, sodium pump and intermediate heat exchangers are connected through pipelines, PFBR is a pool type reactor where all the primary sodium components are in a single large vessel called reactor assembly. The reactor has two primary and two secondary loops and four steam generators per loop. Austenitic stainless steel type 316LN is the major structural material for the sodium components and modified 9Cr-1Mo is the material for steam generator. The sodium temperatures are 820K/670K for hot and cold pools respectively. The design plant life is forty years with a potential to extend upto sixty years. The PFBR has many design features to achieve economy. A peak fuel burn-up of 100 GWd/t is targeted. The simple rectangular reactor containment building provides significant economy and construction advantages. The Government of India has accorded administrative approval and financial sanction for the construction of PFBR in September 2003. A Government company, Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI), was formed to implement this first commercial fast breeder reactor project. The first criticality of the reactor is scheduled in September 2010. BHAVINI would be a cradle to grow into a mega organisation for delivering 500 GWe of energy through FBRs in the 21st century.

Future of Fast Reactors

Immediately after the construction and commissioning of PFBR, a series of four 500 MWe fast breeder reactors will be constructed. It is important to reduce the cost of power to increase the competitiveness of the Indian economy, to increase the quality of life in India and to stay competitive in Indian energy market. The cost studies indicate that a series construction of four at a given one or two sites would reduce the cost by about 35 % (from Rs. 3.22 for PFBR to nearly Rs. 2.00 for future reactors). The construction time could be brought down to five years. With the experience available from nearly three hundred and eighty reactor-years of fast reactor operating experience available world wide, the present day capital costs are more close to that of water cooled reactors. Future plans are to go in for 1,000 MWe fast breeder reactors (beyond 2020) with improved design features and optimization at all stages. All efforts are focused on developing high burn-up and high breeding fuel, advanced structural materials and longer life of upto sixty years or more. It has also been decided that only PFBR and the next four FBRs will have the mixed oxide as the fuel and the future FBRs will use metallic U-Pu-Zr alloy as the fuel. This decision is based on the potential of metallic alloy fuel to safely go for high breeding and high burn-up. Beyond PFBR, fast breeder reactor cores would be so designed that the fuel can be switched to metallic fuels which have special significance to Indian energy scenario, for enhancing the pace of availability of nuclear energy.

To achieve the targeted growth in a sustainable manner, India has followed the philosophy of closing the fuel cycle at all stages. The power programme has thus been supported by the development of all the facets of the associated nuclear fuel cycle, with emphasis on economy, safety, minimum environmental impact, and potential for growth. The design and development activities for FBR as well as fuel cycle have the strong backup of extensive R&D inputs in the field of high temperature design, component development, thermal hydraulics, structural mechanics, materials and metallurgy, fuel chemistry, computers and instrumentation, safety and basic sciences.

Nuclear Fuel Cycle

Closing the fuel cycle is a key element of the FBR programme, without which it is not possible to realize growth in nuclear power. For a nuclear reactor, the front end of the fuel cycle consists of the fresh fuel fabrication plant and the back end consists of the spent fuel reprocessing plant integrated with re-fabrication and waste management. The fuel fabrication plant processes the fresh fuel to the required composition and size, fabricates the fuel pins and assembles them in the form of a fuel sub-assembly. To retain the fuel pins in the reactor for a longer time to extract more energy from the fuel, the primary limiting factor is the clad material that retains the fuel and the wrapper material, which holds the bundle of fuel pins. Hence development of advanced clad and wrapper materials for achieving high burn-up is being carried out by a combination of alloy design including innovative thermo-mechanical processing routes. Alloy D9 has been chosen as the clad for PFBR. A detailed characterization of D9 was carried out to establish the optimum amount of minor alloying elements needed for better creep, fatigue, creep fatigue interaction resistance and more important resistance to void swelling.

The PFBR fuel fabrication plant will be a part of the Integrated Fuel Cycle Facility to be set up at Kalpakkam comprising the reprocessing plant and waste management plant. The co-location concept obviates the need for transportation of plutonium rich fuel through public domain, thus avoiding the hazards during transportation. By the process of closing the fuel cycle, the high value fissile material remaining in the spent fuel is separated, processed and is recycled again to the reactor in the form of fabricated fuel pins. Minimizing the inventory of fissile material in the nuclear fuel cycle assumes importance due to cost considerations, growth of nuclear power and proliferation concerns. Considering these factors, co-locating the nuclear fuel cycle facility in the same location of the fast reactors is the preferred choice.

Reprocessing activities at IGCAR, Kalpakkam started with processing of irradiated thorium rods for separating U^{233}. This U^{233} has been used for fabrication of mixed oxide fuel test assembly for irradiation in FBTR, before use in fast reactors. A pilot plant scale reprocessing facility has been commissioned and reprocessing of FBTR fuel has commenced successfully. Based on the experience gained in this facility, a demonstration reprocessing plant is under construction and will be commissioned in 2009 to reprocess the FBTR fuel on a continuous basis.

The reliable and trouble-free operation of the pilot plant has also given the confidence to take up the challenge of design and construction of large reprocessing plant with matching throughputs of fuel from PFBR. This fuel cycle facility will be commissioned in the year 2012, to reprocess the irradiated fuel discharged from PFBR and close the fuel cycle. This presents a unique opportunity to introduce innovations in the flow sheet for the entire facility comprising of a fuel fabrication plant, a reprocessing plant and a waste management plant. The high level wastes usually generated in the reprocessing plants is a mine of wealth provided the useful elements such as cesium and strontium and other important elements are separated and deployed in medical and other societal applications such as irradiation of food, cancer treatment, sewage treatment etc. Also the radioactive wastes with long life can be recycled to reactors for burning. R&D in the area of development of process flow sheets to separate such elements is in progress.

Long Term Energy Perspective

With the increasing demand for energy, India has to look for technological solutions for generation of alternate fluid fuels to hydrocarbon fuels. Most of the technologies for this application need temperatures in the range of 973 to 1173 K. In particular, generation of hydrogen from water using chemico-thermal processes needs high temperatures exceeding 1073 K. Keeping this in mind, the Department of Atomic Energy has initiated programme to design and develop such a reactor system operating at high temperatures. In preparation for the Third Stage, development of technologies pertaining to utilisation of thorium have been a part of the ongoing activities of the Department. Considerable thorium irradiation experience has been acquired in research reactors and we have introduced thorium in PHWRs in a limited way. With sustained efforts over the years, a small scale experience over the entire thorium fuel cycle has been obtained. An example is the KAMINI reactor at our Centre, the only currently operating reactor in the world, which uses U^{233} as fuel. This fuel was bred, processed and fabricated indigenously. The advanced heavy water reactor (AHWR) programme provides a focal point for a time bound high intensity development in the efficient utilization of thorium and mastering Th^{232}-U^{233} bred reactors and fuel cycle technologies. In the accelerator driven system (ADS), high-energy proton beam generates neutrons directly through spallation reaction in a non-fertile / non-fissile element like lead. A sub-critical blanket with lesser fissile requirement will further amplify this external neutron source as well as energy. Development of such a system, which is already in progress in the Department, offers the promise of shorter doubling time with Th–U^{233} systems, incineration of long lived actinides and fission products and robustness to the approach towards realization of the objective of large scale thorium utilization.

Looking beyond fission, we have a mega energy potential in harnessing thermonuclear energy i.e. fusion energy. The international thermonuclear experimental reactor (ITER) project has recently been launched to explore the possibility of harnessing fusion power. Recently India joined as full partner of this mega initiative. On present indications, successful and practical fusion power systems may become available only around 2050. There is global interest in harnessing solar energy, wind energy, energy from biomass, bio-diesel, energy from waves and from ocean thermal gradients. All these will need to be explored and utilized wherever practical and economical. In some of these areas, more research and development is warranted. The petroleum costs being high and volatile, these options, once considered uneconomic, can become cost effective in not so distant future.

Department of Atomic Energy and Society

A unique feature of the Department of Atomic Energy is generating spin-offs to serve the strategic sectors, industries and society in a better way. To highlight a few, ionizing radiations are being used for sterilization of medical, food products and creating higher yield better varieties of pulses and cereals. Non-destructive examination techniques are applied for fingerprinting of ancient south Indian bronzes. A GIS based decision support system for real time application, commissioned in the Centre, is used for the real time atomospheric dispersion modeling and plume forecast. The resultant radiation dose due to the plume is dynamically synthesized with spatial data base of villages, road networks, schools, hospitals, population and animal husbandry. It provides complete online guidance during emergency situations and can be effectively used in other emergencies, such as chemical releases in plants, cyclones, storms, etc. There are many such applications, which need to be realized through collaborations. DAE is very keen in such collaborations.

IGCAR and Research in Healthcare

I wish to narrate three examples of applications of healthcare being pursued in close collaboration with medical institutes.

A Diagnostic Tool

Infrared thermal imaging has been employed for research studies in medical diagnostic related applications. The investigations include studies on breast cancer, wound healing, arthritis, deep vein thrombosis and varicosity. Thermal imaging is the surface mapping of the temperature using infrared sensors. The infrared sensor used is made of In-Sb or Pt-Si, having sensitivity for the spectral range of 3.6 to 5 μ. The temperature sensitivity is of the order 0.05 degrees.

It is well known that body temperature is a useful parameter for diagnosing diseases. There is a definite correlation between body temperature and most of the diseases. The use of infrared thermal imaging for medical diagnostics related applications is based on the fact that human metabolism involves energy conversion. The change in energy dissipation pattern is expected to be the reflection of altered conditions of metabolism and helps in identification of presence of diseases like cancer or for monitoring recovery processes such as wound healing.

Studies carried out using infrared thermography indicated that the technique is effective for non-invasive diagnosis of peripheral vascular diseases, with good correlation to clinical findings. Temperature gradients are observed in the affected regions of patients with vascular disorders, which is attributed to abnormal blood flow in the affected region. The temperature in the affected regions is about 0.7 to 1 degree above the normal regions, due to sluggish blood circulation. Studies carried out also indicated that infrared thermal imaging can be employed for detection of carcinoma breast. An important finding made during these studies is that surface texture of the human body plays an important role in optimisation of the procedures for diagnostic studies using infrared thermography. Image processing and analysis technique would enhance the sensitivity for infrared thermography for medical diagnostic applications. While the studies carried out give confidence in the use of infrared thermography for medical diagnostic applications, it is essential that standardised procedures, protocols and, image processing methodologies are developed for successful implementation.

SQUID Sensors and Magnetoencephalography

Superconducting Quantum Interference Devices (acronymed as "SQUID") are the most sensitive detectors of magnetic signals available today with a sensitivity higher than ten femto-Tesla. This sensitivity is so high that it is possible to detect even the tiny magnetic fields associated with the physiological activities of human heart (fifty pico-Tesla) or the human brain (less than two pico-Tesla). These sensors have a wide spectrum of applications ranging from SQUID magnetometers for laboratory research, SQUID based systems for non-destructive evaluation of materials and components, geophysical prospecting of minerals, multichannel SQUID systems for measurement of biomagnetic fields such as those associated with the activity of the neural networks in the human brain etc.

At our Centre, we have a comprehensive programme on the micro-fabrication of SQUID sensors that involves deposition of superconducting films under ultra-high vacuum conditions, photolithographic processing to realize the fine feature sizes in the micron range and plasma etching processes to realize device geometries. SQUID sensors developed at our Centre are being used in a variety of applications such as SQUID magnetometer for physics research. A SQUID system based on a precision X-Y-θ scanner for non-destructive evaluation of materials is already operational and is being used for advanced research.

A SQUID based system for magnetocardiography (MCG) / magnetoencephalography (MEG) is also under development at IGCAR. Since the biomagnetic signals are extremely weak (pico-Tesla) compared to the ubiquitous environmental magnetic noise (nano-Tesla), a magnetically shielded room has been established at IGCAR with a shielding factor exceeding 60dB at 1Hz. This extensive shielding makes it possible to measure and characterize even the tiny magnetic signals such as those associated with human heart and human brain. We are very excited that we have been able to observe the magnetic field signal from the human heart as also the MEG signals corresponding to the alpha rhythm of human brain.

Unlike electrocardiography and electroencephalography (ECG) (which requires attaching electrical leads), magnetocardiography and magnetoencephalography are non-contact measurements. Electrical signals observed are also distorted by conductivity distribution in the surrounding tissues while the magnetic signals are not so distorted since most tissues are very weakly diamagnetic. SQUID based measurement of biomagnetic fields is expected to complement the conventional diagnostic tools such as ECG and EEG. Source localization accuracies are expected to be much better in MEG compared to EEG. I request the doctors to visit our MEG facility at IGCAR to explore the possibility of collaborative work in this challenging area of research.

Biomaterials: Body Parts of the Future

Replacing a worn out part in a machine is no small an issue and the technology behind the replacement is nothing small either. When that's for a machine, imagine how much more it is for a living body. For example, a forty year old women has a worn out hip joint or a thirty year old has a fractured leg leaving them immobile for the rest of their life's. In such a situation introduction of biomaterials opened up the dead-end these people came to and promised them extended years of active mobility, that's the achievement the area of biomaterials truly brought about.

During the last ninety years, man made materials and devices have been developed to the point at which they can be used successfully to replace parts of living systems in the human body. These special materials able to function in intimate contact with living tissue, with minimal adverse reaction or rejection by the body are called biomaterials. The earliest successful implants were bone plates, introduced in the early 1900's to stabilize bone fractures and accelerate their healing. Advances in materials engineering and surgical techniques led to blood vessel replacement experiments in the 1950s, and artificial heart valves and hip joints were under development in the 1960s.

The number of implants in use indicates their importance to health care and the economic impact of the biomaterials industry. For example, it was estimated in 1988 that 6,74,000 adults in the US were using 8,11,000 artificial hips. It was also estimated that 1,70,000 people worldwide received artificial heart valves in 1994. Artificial joints consist of a plastic cup made of ultrahigh molecular weight of polyethylene (UHMWPE), placed in the joint socket, and a metal (titanium or cobalt chromium alloy) or ceramic (aluminum oxide or zirconium oxide) ball affixed to a metal stem. This type of artificial joint is used to replace hip, knee, shoulder, wrist, finger, or toe joints to restore function that has been impaired as a result of arthritis or other degenerative joint diseases or trauma from sport injuries or other accidents. Artificial knee joints are implanted in patients with a diseased joint to alleviate pain and restore function. After about ten years of use, these artificial joints often need to be replaced because of wear and fatigue-induced delamination of the polymeric component. Institute engineers are developing improved materials to extend the lifetime of orthopedic implants such as knees and hips.

Design engineers must consider the physiological loads to be placed on the implants, so that they can design for sufficient structural integrity. Material choices also must take into account biocompatibility with surrounding tissues, the environment and corrosion issues, friction and wear of the articulating surfaces, and implant fixation either through osteointegration (the degree to which bone will grow next to or integrate into the implant) or bone cement. Although the wear problem is one of materials, it plays out as a biological disaster in the body. Any use of the joint, such as walking in the case of knees or hips, results in cyclic articulation of the polymer cup against the metal or ceramic ball. The average life of a total joint replacement is eight to twelve years or even less in more active or younger patients.

When a man-made material is placed in the human body, tissue reacts to the implant in a variety of ways depending on the material type. Therefore, the mechanism of tissue attachment (if any) depends on the tissue response to the implant surface. Although bioactive materials would appear to be the answer to biomedical implant fixation problems, available bioactive glasses (i.e., bioglass) are not suitable for load-bearing applications, and so are not used in orthopedic implants. This is where R&D comes in, now studies are on to look into the loading of bioactive glass onto sturdy implant materials. We at IGCAR are presently working on the preparation of nanobioactive glass powders and loading them onto titanium surfaces by anodization, this modified titanium surfaces will possess more bioactivity because of the presence of bioglass and the mechanical strength lacking in bioglass is provided for by the titanium substrate.

The science of replacing organs or parts of organs that are crucial to our existence is both exciting and potentially dangerous. Although poor heart valve designs resulted in clinical failures in the past, the current limiting factor for long-term success is the materials themselves. Two types of materials are used for artificial heart valves. "Soft" bioprosthetic materials such as denatured porcine aortic valves or bovine pericardium and "hard" man made materials used in mechanical heart valves, the most successful being pyrolytic carbon. Regular bacterial growth can often be eradicated by cleaning a surface with a disinfectant or by treating our bodies with antibiotics. However, bacteria may irreversibly adhere to surface (both man-made and natural, such as human tissue) that are surrounded by fluids. Therefore efforts are being made to make the implant material surface antibacterial. In these lines, we at IGCAR have anodized the titanium surfaces to produce anatase type of TiO_2 which possesses antibacterial properties. Anodization will also increase the wear resistance of the material as well and make it less prone to bacterial inhabitation.

Biomaterials research is an exciting and rapidly growing field. The process of wear of implant materials is being studied extensively using sophisticated techniques such as bioferrography, using which the wear particles are mapped and quantified so that an effective mechanism for extending the life of these structures can be deviced. Future biomaterials will incorporate biological factors (such as bone growth) drug delivery devices and maybe some self healing factors onto implant materials. Although much has been achieved, there are still numerous gaps in the area and hence call for more attention. So, biomaterial is one area, which will flourish as long as the human body exists in this universe and as long as wear and tear will lead to the need for replacement.

To summarize, adequate energy, clean environment, nutritious food, clean water, comfortable home, security in terms of law and order, freedom of speech and actions, opportunities for realizing objectives of life commensurate with individual capability, robust gross domestic product of the country etc. are the indices of a good nation. The good quality of life has to be ensured by robust defence capacity and capability to ensure that the nation occupies a position of earned importance in the community of nations. The countrymen and the management system starting with Parliamentary law and order and administration system and other allied service functions in society have to be sensitive and philanthropist to work towards the good of the last citizen in the country and the world. A good nation works for enhancing capacity of the deprived nations rather than exploiting the poor nations. The world society has to be need based rather than greed based. Corruption is a disease, which is the result of poor ethics and greed. Parents, teachers, seniors and successful citizens have to take responsibility for rooting out this curse in the societies around them.

I urge the students to examine and analyze the robust heritage wheels of the east and chariots of the west without bias. The success lies in combining the best of the east with the west and discovering a paradigm shift and a balance which would enable successes for individuals and steadily increase elements of better quality of life to all the citizens of this planet.

(Baldev Raj)
Director, IGCAR

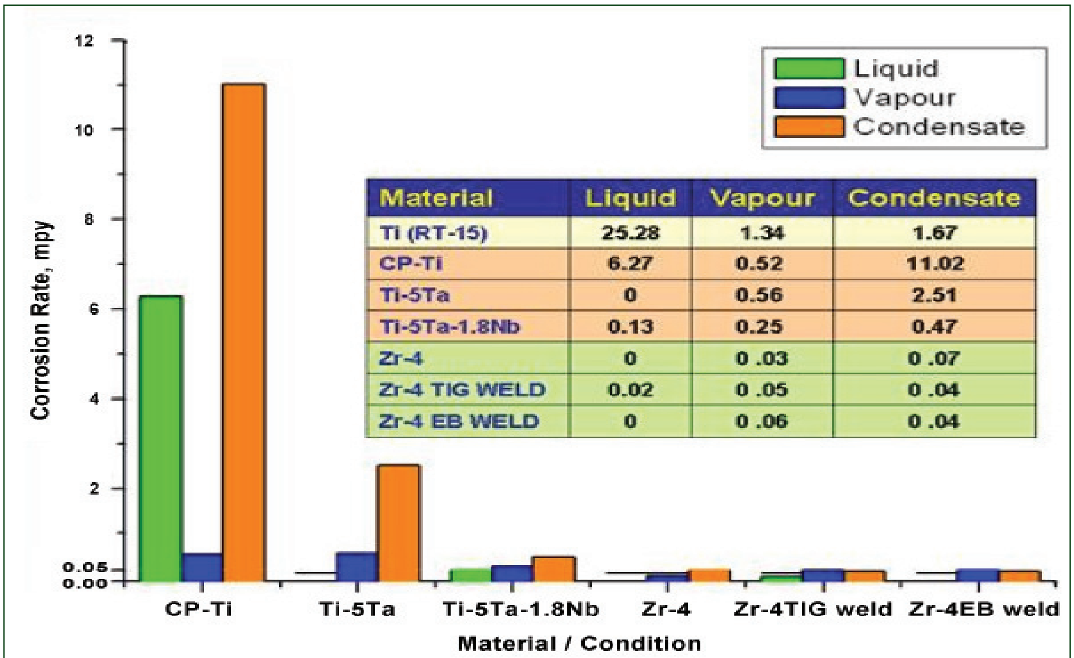
"Abundance of virtues is satisfying and evacuation of egos is bliss"

- Baldev Raj

Zircaloy-4 Dissolver for Application in Highly Corrosive Nitric Acid Media for FBR Reprocessing Plants

Indira Gandhi Centre for Atomic Research has embarked on materials development programme for critical applications in fast breeder reactor (FBR) spent nuclear fuel reprocessing involving nitric acid as process medium. Particularly, the focus was on the advanced materials for high concentrations greater than eight normal and at temperatures (boiling and vapour) of nitric acid employed in dissolver unit. Titanium, thus was chosen for the dissolver of CORAL reprocessing unit, has served efficiently approximately for three thousand hours of dissolution so far without any corrosion problem. New generation Ti-5%Ta-2%Nb alloy has been proposed for the future applications and the developmental efforts towards this is in progress in collaboration with Nuclear Fuel Complex (NFC), Hyderabad and Mishra Dhatu Nigam Ltd. (MIDHANI), Hyderabad. The excellent corrosion resistance of zirconium in nitric acid, and the plant experience at *La Hague* reprocessing plant, France over thirty years, led to the exploration of zirconium for dissolver and other critical applications. The expertise developed at NFC, Hyderabad in alloy development, fabrication and manufacturing of zircaloy based PHWR components, was thus utilized towards manufacturing of zircaloy based dissolver for FBR reprocessing applications.

The corrosion behaviour of NFC make zircaloy-4 (Zr-with Sn-1.4%, Fe-0.22%, Cr-0.1%) in wrought and welded forms in comparison with other candidate materials like commercially pure titanium, Ti-5%Ta and Ti-5%Ta-1.8%Nb was evaluated at IGCAR. Manual TIG welding and electron beam welding was carried out at NFC, and radiography of the welded zircaloy-4 was made for choosing defect free regions for corrosion investigations. Three phase corrosion testing conducted in liquid, vapour and condensate zones of boiling 11.5M nitric acid indicated superior corrosion resistance of zircaloy-4 in both wrought and welded conditions as 'near-zero corrosion material' in comparison to other materials (Figure 1). The electron beam welded samples did not show any deterioration and performed similar to wrought alloy. Scanning electron microscopic examination revealed



Material	Liquid	Vapour	Condensate
Ti (RT-15)	25.28	1.34	1.67
CP-Ti	6.27	0.52	11.02
Ti-5Ta	0	0.56	2.51
Ti-5Ta-1.8Nb	0.13	0.25	0.47
Zr-4	0	0 .03	0 .07
Zr-4 TIG WELD	0.02	0 .05	0 .04
Zr-4 EB WELD	0	0 .06	0 .04

Figure 1: Corrosion rate of wrought and welded zircaloy-4 after three phase corrosion test in 11.5M nitric acid medium

insignificant corrosion attack of zircaloy-4 and its welds in all three phases. The nature of surface films developed after corrosion testing characterised (by using XPS and SIMS) showed the formation of stable and adherent zirconium di-oxide film on the surface. Potentiodynamic polarization study in 11.5M nitric acid solution at room temperature also showed excellent corrosion resistance for both base and welded samples. The results of microstructure, microhardness, corrosion rate, morphology of attack and nature of surface film clearly established that zircaloy-4 is a candidate material for application in highly concentrated nitric acid at high temperatures in reprocessing plants.

Based on the results of the investigation, a zircaloy-4 testing system (Figure 2) of ten litres capacity with provisions for testing samples in liquid, vapour and condensate conditions was fabricated at NFC and commissioned at IGCAR to conduct long term corrosion evaluation. The studies conducted so far upto two thousand hours did not reveal any significant corrosion rate and attack on the samples. This gave the confidence to fabricate a full scale dissolver assembly similar to the dissolver in operation in CORAL plant at IGCAR. During June 2007 efforts were initiated at NFC for fabricating a dissolver assembly with minor modifications of the CORAL dissolver design for long term corrosion evaluation at IGCAR. The bill of materials for the full scale dissolver was made available at NFC through defect free ultrasonically evaluated casting, and well established manufacturing routes. Welding qualification and process optimization was made for defect free radiographic qualified weld joints for major portions. Stage wise fabrication and inspection was made in-house with the technical support from the Centre. A full scale dissolver assembly was thus fabricated during July 2008 and was subjected to double autoclaving of the dissolver assembly. The autoclaving provides artificially formed thick compact and adherent zirconium di-oxide layer on the surface which would further enhance the corrosion resistance, performance and service life. The inspection was carried out by NFC and the quality audit of the same was made by IGCAR.

Figure 2: Zircaloy-4 corrosion testing system (10 litres) for three phase corrosion evaluation in 11.5M nitric acid

The enthusiasm and synergy between the groups from IGCAR and NFC thus culminated into a product of high quality for periodic inspection and long term performance evaluation under simulated corrosive conditions of FBR spent fuel dissolution. As major effort in manufacturing, welding and qualification has been successfully met with the fabrication of full scale dissolver assembly, confidence is blooming to manufacture actual dissolver assembly for future FBR plant application. It also symbolizes the coherency and compactness between the management, R&D and shop floor personnel in achieving the target of producing in-house excellence for a critical application in the back end of the fuel cycle. The road map has been thus created for the manufacturing of many other zirconium based critical components for different parts of the Indian reprocessing plants and waste management applications.

(Reported by U. Kamachi Mudali,
Corrosion Science & Technology Division, MMG)
(on behalf of colleagues from IGCAR & NFC)

Zirconium is highly resistant to nitric acid environments and is considered as candidate material for various applications in spent nuclear fuel reprocessing plants involving highly concentrated nitric acid medium. In France, eighty tonnes of zirconium and five thousand five hundred meters of piping were employed in La Hague reprocessing plant for the manufacturing of various components like dissolvers, oxalic mother liquor evaporator and heat exchangers, vitrification dust scrubber, and liquid waste treatment reactors. Zirconium and its alloys are thus considered as candidate materials for various applications in spent nuclear fuel reprocessing plants involving nitric acid of high concentrations at high temperatures. They exhibit excellent corrosion resistance in nitric acid and are insensitive to intergranular corrosion unlike stainless steels of type AISI 304L, which are normally used in reprocessing plant in certain equipment like dissolver where highly concentrated nitric acid is used in the presence of oxidizing ions such as Fe^{3+}*,*Cr^{6+}*etc. Also, unlike titanium and its alloys, zirconium is unaffected by vapour and condensate phases of boiling nitric acid.*

Smart Card (RFID) based Photo Verification System for Screening of DAE Employees at CISF Security Main Gate

Presently entry of all the employees at the main gate is based on the photo identity verification of the card possessed by the employee. In spite of the security features (hologram etc.) built in the card, it shall be possible to duplicate the card. Thus it becomes difficult for security personnel to verify the authenticity of the card. To overcome this problem of possible duplication, all the employees of DAE were provided with a non contact smart card with 4kB of memory which is also known as radio frequency identification (RFID) card. A smart card is nothing but an electronically coded card with built in logic and memory or a microprocessor. Basically smart cards are of two types i.e contact type and non contact type. The non contact smart card works on radio frequency for communication and power supply requirement.

The advantage of the RFID card chosen, compared to each of the coded cards available in the market, like magnetic / barcode / barium ferrite cards, is that contents of RFID card can not be duplicated, shall not have wear and tear, long lasting and secure. Further, to read the memory of the RFID card, a set of keys (48 bits) are required, which are confidential and are unique to the employee. These keys cannot be read from the card, making it practically impossible to duplicate the card. A smart card based photo verification system has been designed and developed at our Centre by which the security personnel can easily identify whether a person carrying the RFID card is a genuine employee or not. The RFID card is from M/S Phillips with inbuilt controller, 4 kB memory and antenna for communicating to RFID reader and the card adheres to standard ISO14443A.

System Description

The system has been designed using microcontroller, RFID interface chip, RFID antenna for transmission, universal serial bus (USB) for communication to the personal computer and for powering the controller. The block diagram of photo identification system is shown in Figure 1. The RFID antenna transmits 13.56 MHz frequency, these radio frequency waves when interfere with the antenna of the RFID card generates EMF which will provide power to the card for reverse communication to the reader. The communication between reader and the card is very secure, as it uses encryption and decryption techniques. The antenna circuit is designed such that the card can be read from a distance of maximum

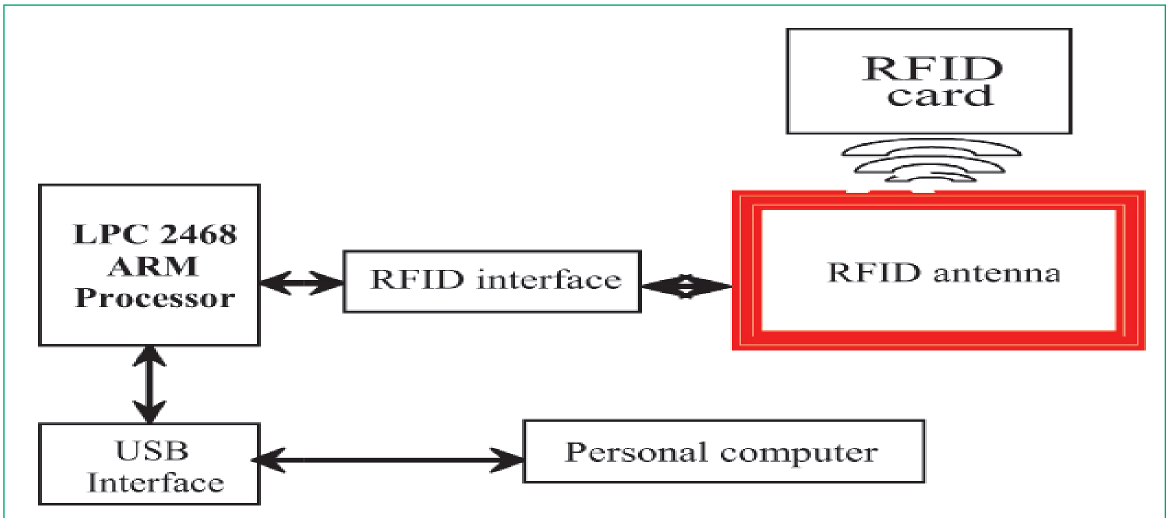


Figure 1: Block diagram of photo identification system

Figure 2 : GUI for photo verification system

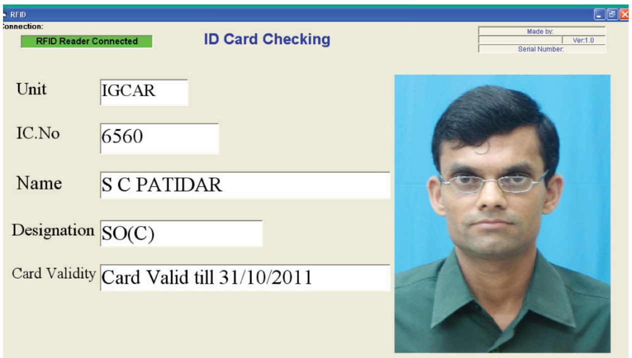


Figure 3 : ID card being read by RFID reader

five centimetres. Reader communicates by means of amplitude shift keying (ASK) of 100% reader to card modulation index, meaning that data is coded with short pauses in the transmission. During these pauses no power is transmitted to the card. This dictates special requirements to the chip in the card. Modified Miller bit coding being used for the communication between reader and card. Data communication between reader and the card takes place at a speed of 106 k bits/sec.

Hardware Description

The system was developed using a LPC2468 ARM (advanced RISC machine) based microcontroller and CLRC632 RFID controller. The developed board consists of USB (universal serial bus) port, and RS232 serial port. The board works on USB port for both power and communication to the personal computer, thus a separate power supply for the board is not required. The system developed is shown in Figure 2.

The PCB is designed with surface mounted devices (SMD) for both active and passive components, thus the board is more compact and highly reliable from functional point. The RFID antenna was designed for 13.56 MHz on a printed circuit board with SMD components, which shall interface to the microcontroller board via RMC (rail mount connector). The whole microcontroller board and the antenna board shall be mounted in a plastic enclosure of 10 cm x 10 cm with USB connection to the personal computer. The display shall be on a 32″ LCD display for better and clear view of the details of the person along with photograph. The firmware was developed using embedded C language using Keil compiler.

Software

The software consists of embedded software programmed in to the microcontroller written in C language (for acquiring data from RFID card such as person's identity card number, unit, name, department to which he belongs, card serial number, validity of the card etc.) and graphic user interactive software running on the PC is written in Visual Basic. This software acquires the data from the reader and fetches the corresponding photograph of the employee and displays on to the screen for verification by the CISF personnel. The photos of the corresponding employee shall be fetched from the data base stored on the hard disk. The security personnel view the employee details on the screen while seeking entry by showing the ID card to the RFID reader. An example of ID card display after it is read by RFID reader is shown in Figure 3. If the ID card presented is unauthorized, then the system shall raise a long beep with red LED indication on the smart card reader, which shall alert the security personnel of potential unauthorized entry. The system also has the facility to identify the personnel holding a valid or expired card by appropriate color display on the screen.

Future Plan

It is also planned to develop hand held RFID monitors which shall enable the security personnel to screen the employees on vehicles seeking entry. The same feature can be extended to verify the bus pass validity so that employees need not carry a separate card for verification. This system of ID card can also be extended for multiple uses like hospital and library purposes so that single card can be used for multiple applications.

The photo verification system with RFID technology shall certainly enhance the security at main gate to a great extent and can be extended to use at other radiological facilities.

(Reported by Suresh Chandra Patidar,
Electronics and Instrumentation Division, EIG)

Young Officer's FORUM

Shri Prashant Sharma did his B.Tech degree in Electrical Engineering from G.B Pant University of Agriculture and Technology, Pantnagar in 2003 and M. Tech degree in Electrical Engineering from IIT Roorkee in 2005 under the DAE Graduate Fellowship Scheme (DGFS). He is from DGFS- 2003 batch and joined IGCAR as Scientific Officer (SO/C) in September 2005.

Numerical Modeling of Eddy Current Flowmeter

Probe type of eddy current flowmeter (ECFM) has been considered for sodium flow measurement in primary pump outlet and at sub-assembly outlet in the prototype fast breeder reactor (PFBR). The eddy current flow meter is used for the flow measurement of non magnetic liquid metals. Figure 1 shows the schematic of probe-type eddy current flowmeter. It consists of a primary winding energized by an alternating constant current source. The primary winding (P1) is surrounded by two identical secondary windings (S1 & S2) on either side. When sodium is static the alternating flux produced by the primary winding induces equal voltages in both the secondary windings due to transformer action. When sodium is flowing, motion induced voltage is produced in both the secondary coils in addition to the transformer voltage. This voltage is subtractive to transformer voltage in upstream coil and additive to transformer voltage in downstream coil. As a result of this the voltages induced in the two secondaries differ from each other and this difference is proportional to the velocity of sodium. Thus the difference in the voltages of the two secondaries serves as a measure of the velocity of sodium.

The eddy current flow meter developed is compact with an overall size of 14 mm diameter and 150 mm length and consists of three coils (made from mineral insulated stainless steel sheathed copper and nichrome cables) wound on bobbin made of soft iron and enclosed in a stainless steel tube enclosure. In order to mitigate the effect of external magnetic field, a magnetic shield has been provided in the flow measuring device inside which the probe is inserted.

The main parameters in the design of eddy current flowmeter probe are : coil dimensions and operating frequency. The probe should cause as low hindrance as possible to the flow and therefore taking mechanical design and ease of manufacturing into consideration a diameter of 11.8 mm for the probe bobbin was arrived at. The primary and secondary coils both are made of mineral insulated cable to cater to the high temperature environment.

The operating frequency is arrived at keeping in view of the available skin depth and the achievable

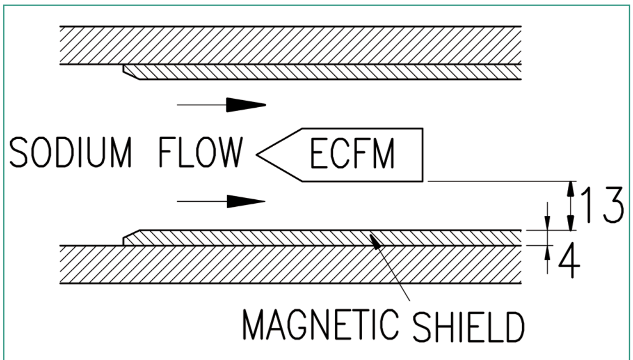


Figure 2: Arrangement of eddy current flowmeter in flow measuring device

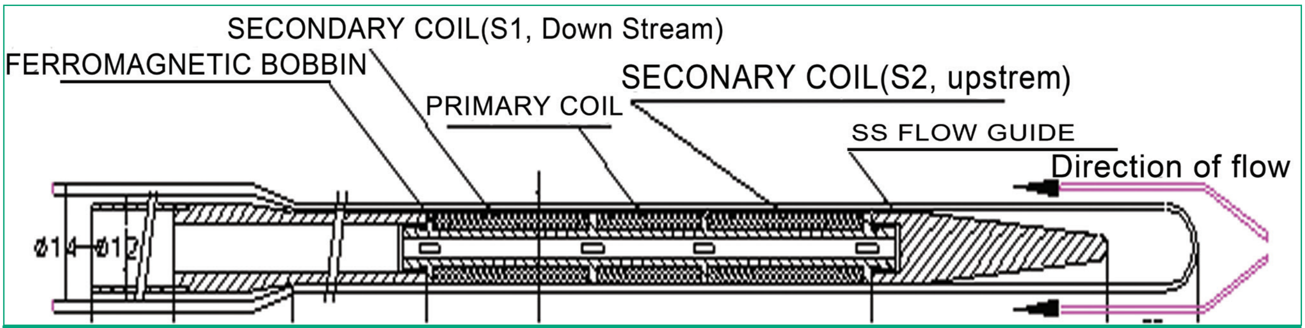


Figure 1: Schematic of probe-type eddy current flowmeter

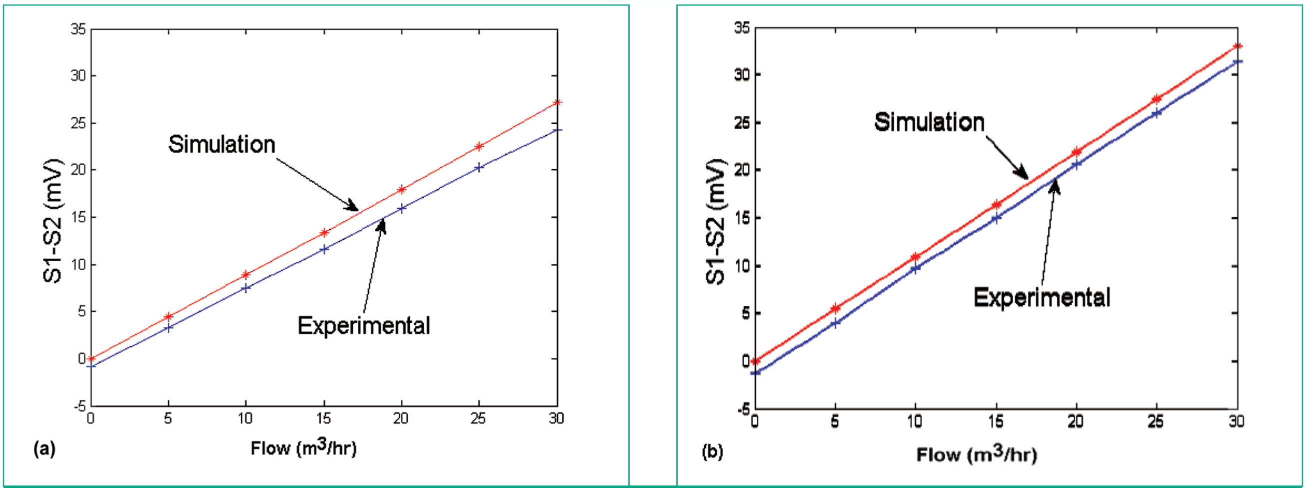


Figure 3: Comparison of results of experimental and COMSOL simulation (a) at 400 °C (b) at 500°C

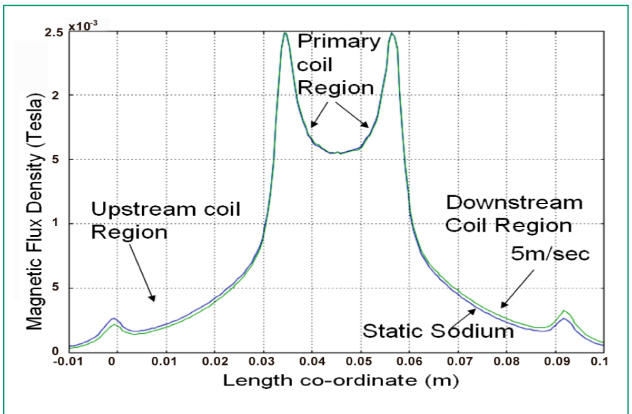


Figure 4: Flux density change with flow along the sensor length

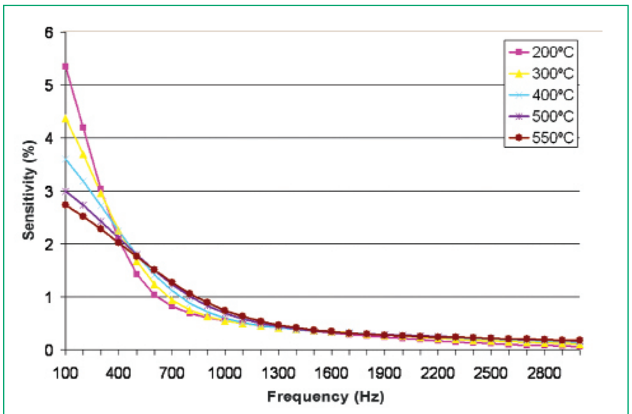


Figure 5: Variation of sensitivity as a function of frequency for the existing configuration of eddy current flowmeter

temperature compensation. As separate calibration of ducts and coils is not possible, the measuring device was treated as whole. Since it is difficult to calibrate each configuration in sodium, a finite element method (FEM) based model of the sensor was developed to determine the optimum frequency of operation and to predict the output of the sensor for various flow rates. Figure 2 shows the probe type eddy current flowmeter along with the flow measuring device.

The simulation results and the comparison with experimental results are shown in Figure 3. The slight mismatch between the experimental and the simulation results and some output even at zero flow is attributed to manufacturing limitations which prohibits exact similarity between the upstream and the downstream coils.

The flux density change with sodium velocity is depicted in Figure 4. A greater flux density in the downstream coil region compared to that in the upstream coil region shows the additive nature of motion induced eddy currents in the downstream side and the subtractive nature in the upstream side.

Simulation for optimum frequency was done and verified with the experimental data. Figure 5 shows the sensitivity at different temperatures for existing configuration. The intersection of the sensitivity curves corresponding to different temperatures gives the optimum frequency of operation of eddy current flowmeter where the variation with temperature is minimal. As seen from the figure the operating frequency for the existing configuration is 400 Hz and the sensitivity is 1.85 which matches well with the experimental value of 400 and 1.7 respectively.

The simulation model of eddy current flowmeter has led to easy prediction of the performance characteristics of probe. This effort resulted in arriving at the optimum design and eddy current flowmeter was fabricated and has been supplied for use in French reactor Phenix.

(Reported by Prashant Sharma, Components & Instrumentation Development Division, FRTG)

Young Researcher's FORUM

Effect of Power Plant Condenser Coolant Discharge on Marine Organism

Dr. K. Jahir Hussain did his M.Sc in Zoology from Madurai Kamaraj University and M.Phil from the American College, Madurai. He has obtained his Ph.D. from University of Madras in the year 2007. His thesis work has led to publication of ten papers in journals and two chapters in books. During his doctoral research he has discovered and described a new species (Glyptapanteles spodopterae sp. Nov.). He has authored a book entitled "Faunal diversity assessment at DAE campus, Kalpakkam". He is presently a visiting scientist and is working on biodiversity conservation and environmental impact assessment in Environmental and Industrial Safety Section, Safety Group

Power stations are being located near coastal sites in order to make use of the abundant availability of seawater for cooling purpose. There is a concern, that the hot effluent which also contains biofouling control agents when released to the sea, may affect marine life. If the affected organism is particularly important in the process of food chain, it gets reflected directly or indirectly in the distribution and abundance of other organisms too. Growing need for energy production by power plants makes it imperative to establish the real impact of discharge from power stations on the marine environment. Thermal pollution is a hot topic due to the negative effects of global warming. The GESAMP (The International Joint Group of Experts on the Scientific Aspects of Marine Pollution) recommends a temperature difference (ΔT) of seven degrees between the intake and outfall water from power plants in the subtropics and of five degrees in tropical waters. GESAMP concluded that, while any such effects tend to be localized, they may become significant where the capacity of the receiving waters is limited. In order to hypothesize thermal effluent effects over the potential influence of rising background temperature, it is necessary to define those effects. Generalization of effect is not possible because each site is unique in their microclimate and habitat pattern; hence, regional data are vital. Bivalves are widely used as bioindicators of all type of environmental pollutions in coastal areas, as they provide a time integrated indication of environmental contamination. Impact of heated effluents is more ostensible in these organisms, because most of them are sessile, sedentary and immobile. Bivalves of the genus *Donax* are important trophic link in surf zone food webs. *Donax cuneatus* is widely distributed

Figure 1: Satellite map of Kalpakkam coast showing the sampling stations

from coastline of Australia to India. In the east coast of southern India, *Donax cuneatus* is abundant and members of this genus are sensitive to thermal and chlorine stresses. Hence this species was chosen for the present study.

Sampling Design

The two reactors of Madras Atomic Power Station use seawater at the rate of 35 m^3sec^{-1} for the purpose of cooling the condenser. The cooling water, after extracting heat, is released into the sea. The sampling plan was devised so as to make a comparison of *Donax* populations at different spatial intervals along the coast from effluent outlet. Totally twenty stations were selected both on south and north side of mixing zone, twelve locations (S0, S10, S20, S40, S80, S100, S200, S400, S600, S800, S1000 and S2000) were selected on south side at a distance of 0 (near mixing point),10, 20, 40, 80, 100, 200, 400, 800, 1000 and 2000 metres respectively and similarly eight locations (N10, N20, N40, N80, N100, C3-N500, C2-N1000 and C1-N5500) were selected on north from the effluent outlet (Figure 1). The present study was conducted during January 2008. More locations were chosen on south side as during October-February the heated water plume moves southerly. Locations C3-N500 to C1-N5500 were considered as control stations because they are located opposite to plume flow. Preliminary investigation has indicated that the nature of impact was local; hence, more number of locations in smaller spatial scale was adopted in this study. *Donax cuneatus* was collected quantitatively from mid water mark of intertidal area at different stations. At each location, three replicates of one square metre sand samples were excavated up to 30 cm depth, and the sand was sieved on a 1-mm screen. All *Donax* were transferred to the laboratory for further investigation. Water temperature, total organic carbon of sediments and sediment characteristics were recorded.

Water Temperature

The mean water temperature ranged from 29.1±0.1 to 31.2 ±0.2 °C (Figure 2). On the south side it was almost same up to twenty metres (29.5 to 29.7 °C) from the mixing zone and gradually increased up to hundred metres to reach the maximum (31.2 °C). It started decreasing from hundred metres and stabilized at eight hundred metres (29.3±0.2 °C). On the other hand temperature regime on the north side was stable at all stations and ranged

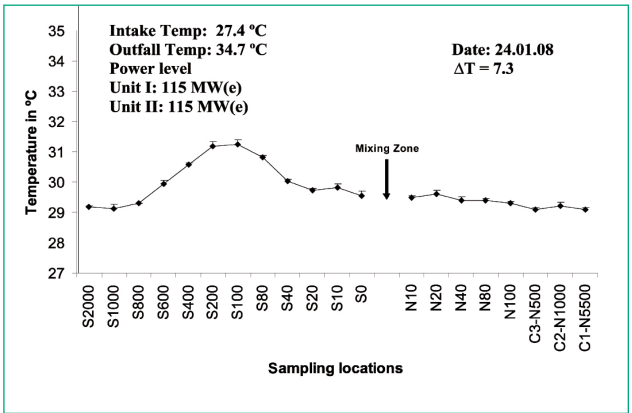


Figure 2: Surface temperature of shore water from mixing zone when the direction tends south

form 29.1±0.1 to 29.6±0.1°C on the same day. The temperature variation in the southern side, thus, is a clear indication of southerly movement of plume. The difference between intake and outfall temperature (ΔT) during the period of study was ~seven degrees. It was observed that the condenser discharge mixed with the coastal waters directly from the outfall and this direct flow gave higher momentum to effluent which pushed the plume further into coastal waters beyond two hundred metres. Hence, the temperature was comparatively low at areas flanking the mixing zone. The directly mixing discharge takes a reverse turn once the opposite force by wave action overtakes the discharge force and then travels along with the coastal water current. Due to this phenomenon, the spatial variability of temperature regime at shoreline is mainly governed by three factors viz., discharge velocity, resistance force by waves and strength of the coastal water current, in addition to the magnitude of the outfall temperature.

Total Organic Carbon in Sediment

Total organic carbon content in the sediment ranged from 0.27-0.70%, lowest being observed at the sampling station S200 and highest at S20 (Table-1). Relatively high values were observed at both sides near the discharge point, which could be due to the accumulation of dead and decaying biofouling organisms near the outfall area. On south side, total organic carbon values were relatively high at locations S600 (0.60%) and S1000 (0.61%) as these stations, were dominated by medium and fine sediment which retain more organic matter than the other types of sediment. Control sites C1-N5500, C2-N1000 and C3-N500 showed almost similar total organic carbon content, which ranged from 0.42 to 0.48%.

Table 1: Physico-chemical parameters of different stations during the study period

Location	Total organic carbon %	Sand characteristics	
		Dominant sand grade	mm
S0	0.54	Fine and Medium	0.12-0.25
S10	0.65	Coarse and Medium	0.5-0.25
S20	0.70	Coarse and Medium	0.5-0.25
S40	0.38	Coarse and Medium	0.5-0.25
S80	0.35	Coarse and Medium	0.5-0.25
S100	0.51	Coarse and Medium	0.5-0.25
S200	0.27	Coarse and Medium	0.5-0.25
S400	0.31	Coarse and Medium	0.5-0.25
S600	0.60	Fine and Medium	0.12-0.25
S800	0.41	Fine and Medium	0.12-0.25
S1000	0.61	Fine and Medium	0.12-0.25
S2000	0.45	Coarse and Medium	0.5-0.25
N10	0.48	Coarse and Medium	0.5-0.25
N20	0.64	Coarse and Medium	0.5-0.25
N40	0.49	Coarse and Medium	0.5-0.25
N80	0.54	Coarse and Medium	0.5-0.25
N100	0.51	Coarse and Medium	0.12-0.25
C3-N500	0.42	Fine and Medium	0.12-0.25
C2-N1000	0.45	Coarse and Medium	0.5-0.25
C1-N5500	0.48	Fine and Medium	0.12-0.25

Sediment Characteristics

From locations S10 to S400 and at S2000, sediment was dominated by coarse and medium sand (0.5-0.25 mm) in equal proportions, whereas, from S600 to S1000 and at S0 the sediment was dominated by fine and medium sand (0.12-0.25 mm) (Table-1). Similarly on the northern side, all stations near mixing zone were dominated by coarse and medium sand. In the present study, strong currents due to the discharge, produced channels around the bank and resulted in the plunging action of the waves. Most of the large shores have a narrow range of grain sizes in the swash zone and they are usually composed of fine to medium sand as has been observed at control stations C1-N5500 and C3-N500. Multivariate clustering was carried out for all sites with respect to the environmental variables viz., water temperature, total organic carbon, substrate characteristics and beach slope. Four distinct clusters were observed and S0 stood apart from the rest of the stations due to the absence of swash zone. Stations nearer to mixing zone (S10, S20, N20, N10 and S40) formed one group and stations away from zero point (C1-N5500, S1000, C3-N500, S800 and S600) formed separate group. Intermediate locations (S80, S100, S200 and S400) formed another cluster. Moreover, it is interesting to note that the far away stations (S200 and C2-N1000) were clustered with some stations near zero point (N40, N100, and N80) as a result of similarity in microclimate and substrate characteristics.

Population Size

Donax cuneatus population on the swash zone ranged between 1.3±1.5 to 88.3±9.6 m^{-2}. On the south side of the mixing zone, abundance of *Donax cuneatus* increased with increasing distance. Their population was meager up to hundred metres (S100) south from mixing point and abundance gradually increased from hundred metres and stabilized at S400. It reached a maximum at S1000 (64.0±3.6 m^{-2}). The abundance pattern was same on north side too but, less abundance was observed up to eighty metres (N80). Maximum abundance was observed at control location C3-N500 (88.3±9.6 m^{-2}). Two other control locations C1-N5500 (51±3.6 m^{-2}) and C2-N1000 (52±6.5 m^{-2}) showed relatively less numbers. ANOVA revealed that a significant difference ($p < 0.01$) existed among stations located near mixing zone (S10 to S200 south and N10 to N80 north) and stations away from mixing zone (S400 to S2000 south and N100 to C1-N5500 north) with reference to abundance of *Donax cuneatus* (Figure 3). Interestingly, stations located after S400 and N100 were not statistically significant with two control stations (C1-N5500 and C2-N1000). Moreover control station C1-N5500 was distinct from all other stations with reference to the abundance. The above statistics showed that the primary impact was not more than four hundred metres south and hundred metres north from mixing zone. Statistical comparison (Tukey's pairwise test) not only revealed

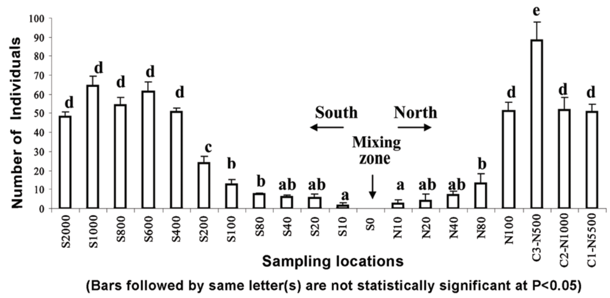


Figure 3: Abundance of *Donax cuneatus* at different spatial scale away from mixing zone

the difference among control and impacted site, but also indicated the impact boundary. From the mixing zone of forty metres on either side was highly impacted, eighty to hundred metrres towards plume flow (south) was moderately impacted and eighty metres north of mixing point also witnessed moderate impact. After hundred metres, north was not affected by the effluents, whereas, the area between hundred to four hundred metres south was influenced marginally. The impact boundary observed presently was very much less compared to the previous findings. This could be due to characteristics of costal current prevailed during North East monsoon (southerly current) period which is not as strong as that of the South West monsoon (northerly current) period. Strong currents may carry heated plume to longer distance and extend the impact boundary. Station C3-N500 was most abundant station, which is statistically different from all others. It could be due to the favorable environmental conditions like easily penetrable sand and favorable swash climate. Moreover, station C3-N500 was totally free from human disturbance because it is a prohibited area falling under the DAE campus. On the other hand, abundance at station (S2000) far away from impact zone was marginally less in number because of *Donax cuneatus* harvest by coastal fisher folk living near this area. Comparatively high population of *Donax cuneatus* was encountered at station C3-N500, S600 S800 and S1000 where 0.12–0.25 mm sand size was dominant, which might facilitate better burrowing and thereby reducing the predation pressure. Moreover, medium and fine sands usually have an abundant meiofauna and macrofauna because of more organic matter per unit area. In agreement with above statement, *Donax cuneatus* population was relatively high at stations S600 to S1000 where medium and fine sand was dominant and total organic carbon content was comparatively high. In contrast, abundance was relatively less at sites S10, S20 and S100 in spite of high total organic carbon content. This disparity could be due to the influence of other parameters such as sediment characteristics, slope and temperature. The abundance was relatively low at stations S40 to S200 where mean water temperature was comparatively high. However, when all the observations were taken into consideration, no clear correlation could be observed between population density and temperature. In general multivariate clustering analysis based on the environmental characteristics and population trend of *Donax cuneatus* showed similarity. This indicated that the microclimate prevailing at those particular locations are structuring the *Donax cuneatus* population.

Conclusion

The present study showed that the effluent from the MAPS has a local effect on *Donax cuneatus* population, which covers up to four hundred metres towards south and hundred metre towards north of the discharge point. Apart from temperature other environmental parameters viz., sediment characteristics and beach slope have also influenced the abundance. Hence it can be concluded that, the abundance pattern of *Donax cuneatus* on sandy beaches of Kalpakkam is not governed by single factor like temperature but by multiple interacting factors. Present knowledge on impact of effluents on marine life is sketchy, hence further in-depth investigation is required to estimate the impact zone at either side during different seasons. Such contributions are vital to understand the tropical marine ecosystems where animals are more prone to thermal effects because they normally live in a temperature regime which is close to the upper tolerance limit.

(Reported by K.Jahir Hussain and colleagues, Environmental and Industrial Safety Section, Safety Group)

News and Events

DAE Sports Meet - Badminton
February 2-5, 2009

As part of XXIV DAE Sports Meet, badminton meet was organized at badminton auditorium, Kalpakkam during February 2-5, 2009. The DAE teams from various parts of India took part in the meet with zeal and spirit. Dr. B. Venkatraman, Chairman, Steering Committee welcomed the gathering. Shri A.S.L.K. Rao, Chairman, Kalpakkam games promotion council briefed about the inception of DAE sports meet and its role in promoting harmony among the staff of various units of DAE. Shri S.C. Chetal, Director, Reactor Engineering Group inaugurated the event and delivered the inaugural address. Shri B.K. Nashine, Convener proposed the vote of thanks.

The Rameswaram Team representing the Kalpakkam Units won the teams event (men) and Golconda team was the runner-up. The Veteran team championship trophy was won by Golconda team and Rameswaram team was the runner-up. Ajanta team bagged the women's team championship and Ellora team won the runner's trophy. Ellora team also received the fair play award. Shri K. Ramamurthy, Station Director of Madras Atomic Power Station presided over the closing ceremony and gave away the prizes.

(Reported by S. Thirunavukkarasu, Kalpakkam Games Promotion Council)

Shri S.C. Chetal, Director, Reactor Engineering Group, IGCAR with the members of the victorious Rameswaram Team and the members of organising committee

Conference/Meeting Highlights

5th CEA-IGCAR Annual Seminar on Liquid Metal Cooled Fast Reactor Safety
March 10-13, 2009

Under the continuing Indo-French Collaborative activities, 5th CEA-IGCAR Annual Seminar meeting on Fast Reactor Safety was organized by IGCAR during March 10-13, 2009. Nine French and twenty eight Indian delegates (from IGCAR, BHAVINI & AERB) participated in the seminar. Dr. Baldev Raj, Director, IGCAR inaugurated the seminar and stressed on the need for maintaining high levels of standards towards ensuring reactor safety and commended the collaborative agreement that has laid foundation for sharing of rich technical information on reactor safety on a continuing basis. A total of about twenty presentations were made under topics on reactor operation, in-service inspection, Phenix end of life tests, PFBR commissioning program, loose parts monitoring, active vs passive decay heat removal systems, fuel safety etc. A detailed review of the status of collaborative works in the domains of sodium chemistry, hydrogen sensors, experimental and numerical simulation of sodium aerosol distribution, sodium leak detection, tritium behaviour in sodium, sodium water reaction, corium coolant interaction etc. was carried out. Further, the areas for future collaborative works such as IGCAR participation in the Phenix end of life tests, development of high temperature sensors for in-service inspection, evolving robust fuel safety criteria for mixed oxide and carbide fuels, structural integrity assessment etc. were identified.

Dr. Baldev Raj, Director, IGCAR and CEA delegates during the Annual CEA-IGCAR Seminar

(Reported by Shri V. Balasubramaniyan, Heat Transport Systems Division, REG)

Visit of Dignitaries

Dr. M.R. Srinivasan, former Chairman and Member, AEC visited the Centre during January 23-24, 2009. He was presented with the status report on PFBR, roadmap and directions for future FBRs, metal fuel development and fast reactor fuel cycle facility by senior colleagues of the Centre. He visited laboratories in Fast Reactor Technology Group, Corrosion loops and Hot cells in Metallurgy and Materials Group and Structural Mechanics Laboratory, Reactor Engineering Group, Facilities in Safety Group and the construction site of PFBR at BHAVINI. Dr. M.R. Srinivasan highlighted the advantages of going nuclear in tiding over the energy crisis without disturbing the environment to the Trainee Scientific Officers and Research Scholars of the Centre. The talk was followed by interactive session, where he clarified the doubts raised by the student community. He has also addressed a joint convention of students from all the schools at Kalpakkam Township.

Dr. M.R. Srinivasan, former Chairman and Member, AEC with Dr. Baldev Raj, Director, IGCAR along with the Trainee Scientfic Officers and Research Scholars of the Centre

Dr. Rajan Gupta, Nuclear Physicist, Los Alamos National Laboratory, USA visited the Centre during January 24-26, 2009 and held discussions with senior colleagues of the Centre on the development of website on energy, which provides information about global energy systems and projects. Dr. Rajan Gupta interacted with the Trainee Scientific Officers and Research Scholars of the Centre at the Training School Hostel premises. He also visited the laboratories in Materials Science Division, Metallurgy and Materials Group and construction site of PFBR at BHAVINI.

Dr. Rajan Gupta,Nuclear Physicist, Los Alamos National Laboratory, USA during his discussion with Shri S.C. Chetal, Director, REG and other colleagues of the Centre

The IAEA team during the visit to the Centre along with Dr. Baldev Raj, Director, IGCAR and other senior colleagues

A team from IAEA led by **Dr. C. Ganguly,** Head, Nuclear Fuel Cycle and Materials Section, IAEA along with Ms.Kristie Hasnen, Multimedia Producer and Mr. Petr Pavlicek, Cameraman accompanied by colleagues from DAE visited the Fast Breeder Test Reactor, Madras Atomic Power Station and the construction site of PFBR at BHAVINI during February 13-14, 2009.

Dr. Casimir Pierre Zaleski, Scientist, CGEMP, University of Paris Dauphine, France and Mrs. Ann Downing Maclachlan Zaleski visited the Centre during February 27-28, 2009. They visited the Fast Breeder Test Reactor, laboratories in Fast Reactor Technology Group, Structural Mechanics Laboratory and the construction site of PFBR at BHAVINI.

Dr. Casimir Pierre Zaleski and Mrs.Ann Downing Maclachlan Zaleski in conversation with Dr. Baldev Raj, Director, IGCAR

Prof.K.L.Chopra, former Director, IIT-Kharagpur and Honorary Professor,IIT-Delhi visited the Centre during March 2-4, 2009. He delivered the "5th Vikram Sarabhai Memorial Lecture" on "Tailored thin films and nanomaterials". Prof.Chopra held discussions with Director and Senior colleagues of the Centre and visited various laboratories in the Centre and the construction site of PFBR at BHAVINI. The Trainee Scientific Officers and Research Scholars had an interaction session with Prof.Chopra at research scholar enclave in the township. Prof.Chopra also presented a popular lecture on "Ethics in Science" to audience at IGCAR.

Prof. K.L. Chopra, Former Director, IIT-Kharagpur and Honorary Professor, IIT-Delhi with Scientific Officers, Research Scholars and colleagues of the Centre

Shri Pallava Bagla, Science Correspondent, NDTV while delivering his talk to Trainee Scientific Officers and Research Scholars at research scholar enclave

Shri Pallava Bagla, Science Correspondent, NDTV visited the Centre during March 2-6, 2009. He spoke to Trainee Scientific Officers and Research Scholars of the Centre on "Taking CHANDRAYAAN to masses" at the Research scholars enclave at Township.

Forthcoming Meetings / Conferences

International Conference on Sol-Gel Processes for Advanced Ceramics (SGPAC-2009)

October 11-14, 2009

As a part of the birth centenary year of Dr. Homi J. Bhabha, an International Conference on **"Sol-Gel Processes for Advanced Ceramics (SGPAC-2009)"** is being organized by IGCAR, Kalpakkam during October 11 – 14, 2009. It is sponsored by Board of Research in Nuclear Sciences (BRNS), Department of Atomic Energy. The conference will be held at the Convention Centre, Anupuram (Kalpakkam). The objective of the conference is to bring together the specialists from various research groups of different countries to discuss the latest developments in the area of sol-gel processes for fabrication of different types of ceramics including nuclear ceramics and facilitate the exchange of ideas across the interdisciplinary R&D groups. The following is the list of topics to be discussed during the conference:

- Sensor materials
- Glasses and glass fibres
- Coatings and thin films
- Bio ceramics
- Nuclear ceramics
- Aerogels and porous ceramics
- Engineering ceramics
- Nanoceramics
- Ceramic fibres
- Process design and modeling

Important Dates

Receipt of preliminary registration forms	....	April 1, 2009
Second circular	....	May 1, 2009
Submission of extended abstracts	....	May 31, 2009
Acceptance	....	August 1, 2009

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Awards & Honours

- **Dr. Baldev Raj** has been conferred *"FICCI Award", the highest recognition for an individual by the Federation of Indian Chamber of Commerce and Industry (FICCI)* for the outstanding contributions to Science and Technology in the context of Industries and Society.

  He has been invited to be a *Member, Board of Advisors, "The Al Gore Sustainable Technology Venture Competition, India"* for the year 2009.

  He has been made *Member, Advisory Board of Summer School on Modeling, Experimentation & Validation (MeV), Idaho National Laboratory, Argonne National Laboratory & Idaho State University,* 21-30 July 2009.

  He has delivered *2nd Y.M. Mehta Memorial Award Lecture, Indian Institute of Metals* (Vadodara & Mumbai Chapters), 2009

  He has also been conferred the *1st Dr. Homi J. Bhabha Centenary Year Award* by Nayudamma Centre for Development Alternatives, Nellore for the year 2009

- **Dr. B.V.R. Tata,** Materials Science Division, MSG has been awarded the *MRSI Medal for the year 2009 by Materials Research Society of India (MRSI)* in recognition of his significant contributions to the field of Materials Science and Engineering.

- **Smt. K. Vijaya,** Physical Education Teacher of Atomic Energy Central School-2 Kalpakkam has been awarded *"Best Teacher-2007",* for her meritorious service in the field of teaching. She received the award from her Excellency Smt. Pratibha Devisingh Patil, President of India.

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