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Golden Mahogany
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**BARC Scientists Honoured**
From the Editor’s Desk

The Founder’s Day is celebrated every year at BARC on the occasion of the birth anniversary of Dr. Homi Jehangir Bhabha. This year it was celebrated on the 28th of October 2011. This issue covers all the major events that were a part of the Founder’s Day celebrations.

Beginning with the Founder’s Day address by the Chairman, Dr. Srikumar Banerjee, the present issue also carries the verbatim address by Dr. R.K. Sinha, Director, BARC, reports of prize distribution to the winners of the DAE All India Essay Writing Contest, presentation of Industrial Safety Shields, release of the Founder’s Day Special issue of the BARC Newsletter and the Founder’s Day guest lecture by Dr. D.V. Gopinath. The DAE (Excellence in Science, Engineering and Technology) Awards 2010, were given to the award winners by Dr. R. Chidambaram, Principal Scientific Advisor to the Government of India. A brief report of this event is also covered in this issue.

Apart from the coverage of events on Founder’s Day, this issue also carries five contributory articles: a Research article, two Technology Development articles and two Feature articles. The Research article describes the process of fabricating AC-based metallic foam by powder metallurgy for possible use as shock absorbing mediums. Two Technology Development articles are covered in the issue. The first one reports the use of a non-intrusive technique, Particle Image Velocimetry (PIV) for simultaneous measurement of velocities at many points in a fluid flow. The second one describes the development of a compact and portable system, for the detection of radioactive nuclides. Each of the Feature articles focuses on potentially important areas of R&D: Radiation processing of minimally processed Ready To Cook (RTC) convenience foods and opportunities and challenges in the field of nanophotonics.

Starting from January 2012, we would like to encourage BARC Scientists and Engineers to send us short articles of about half a page each, containing important R&D accomplishments. This would reach a wider audience.

Hope you all enjoy going through the issue.

Dr. K. Bhanumurthy
On behalf of the Editorial Committee
संस्थापक दिवस - 2011

शुक्रवार, 28 अक्टूबर, 2011

डो. श्रीकुमार बैंजो
अध्यक्ष, परमाणु ऊर्जा आयोग एवं सचिव, भारत सरकार, परमाणु ऊर्जा विभाग का संस्थापन

जैसा कि आप सभी जानते हैं, हमारी गतिविधियाँ अपने क्षेत्र में, विभिन्न स्तर के मानदंडों के अनुसार श्रेष्ठता के साथ अपनी राज्यीय जड़ताओं और प्राथमिकताओं को पुरा करने की ओर उन्मुख होते हैं। पिछले वर्ष अनेक उपलब्धियों के साथ पट्टनों से भरा हुआ वर्ष रहा है। इस दौरान विभिन्न के उत्पादन, नाभिकीय ईंधन के उत्पादन एवं पूर्वसुरु के उत्पादन (पेट्रोजुल) के पुनर्संचालन में अब तक का श्रेष्ठ रिकार्ड बनाया गया है, जबकि कुछ नई चुनौतियाँ भी सामने आयी हैं। आप कुछ मिनटों में इनमें से कुछ को चुना में आपके सामने करूँगा।

पिछले वर्ष जब हम मिले थे, उसके बाद से नैसर्गिक मौसम बुरा हो मिला है और इस वर्ष वनस्पति और जीवन जीवन जीवन से मुक्त बना हो चुका है। इस वर्ष जलवायु वनस्पति जीवन जीवन से मुक्त बना हो चुका है। इसके बावजूद हमारे देश में कुल 20 नाभिकीय रिकार्ड हो गये जिनमें रोगियों का श्रेष्ठ 4780 MWe है। केंद्रीय सेवा के इकाइयों के उत्पादन, जिसमें सामान्य शोधक, चैनल प्रतिस्थापन तथा सामान्य जीवित जीवित जीवन से मुक्त बना हो चुका है, के बावजूद इसे फिर से ग्रेड के साथ सिंक्रेनाइज कर दिया गया है।

स्वदेशी और आयात, बीमारों जीवन से उत्पादन के उत्पादन के वर्तमान में वृद्धि होने के लिए क्रांतिकारी विभिन्न उद्योग में पिछले वर्ष के तुलना में लगभग 40% की वृद्धि होने की उम्मीद की गई है। विशेष रूप से, गोतम क्षेत्र में गुणक 80% से अधिक है जबकि रिकार्डों का प्रतिशत 90% से अधिक हो गया है। क्रांति और राज्यमंडल में 700 MWe के चार श्रेणी भारतीय रेडियो रिकार्डों (पीएमडब्ल्यूआर) का निर्माण कार्य प्रारंभ कर दिया गया है। क्लासिकल में 500 MWe के पीएमडब्ल्यूआर के निर्माण कार्य का 80% कार्य पूरा हो गया है।

"प्रयास साझियों,

अपने प्रयास संस्थापक डो. होमी जहांगीर भाभी की 102वीं जयंती के अवसर पर में आप सबका हार्दिक अभिविन्द करता हूँ और कपड़ा देता हूँ। जैसे कि हमारी परीक्षा रही है आज के दिन हम पिछले वर्ष की उपलब्धियों का मूल्यांकन करते हैं और अपनी विभिन्न गतिविधियों के माध्यम से अपने राज्य को और साक्ष्य करने के लिए अपने आपको एक बार फिर सम्मिलित करते हैं।"
BARC CELEBRATES FOUNDER’S DAY

बायर की कार्यक्रम को लागू करते समय नामांकन विभाग संयंत्रों को सुरक्षा सरकार के लिए, उच्चतम प्राधिकरण का विषय है।

इस संयंत्र में कई कदम उठाए गए हैं और एनईसीएसएन के कार्यालय तथा एआईआरसी द्वारा संचालित सुरक्षा पुनर्खेत्रण को सिस्मानियों में से कई सिस्मानि के नए हो लागू के नए रूप हो की कार्य का जा चुकी है।

राष्ट्रीय सुरक्षा विनियमक प्राथमिक को सार्वजनिक दर्शन उत्पन्न करने के लिए संसर्ग में एक विशेष पुर-व्याप्ति किया गया है।

हम याहूड़ी पंजाबी योजना को समाप्त करने के लिए आगरा और गुरुवारी योजना के कुल में लगभग 3.66 करोड़ था।

याहूड़ी योजना को क्रम किया जाएगा जिस के लिए चुकू घर बनाए जाएगा। अभी भारतीय योजना को जारी रखने के लिए चुकू घर बनाए जाएगा।

इस संयंत्र के दौरान भारत ने का संयंत्र ने 300 मै.एमा मात्र रूपान्तरित किया।

इस वर्ष का भारत, जापान में एक साथ जारी दिखाई दिए गए, जिनमें से एक रिक्रिए टाइम्स में 9 स्थान के दूसरे रूप में दी और उसके बाद अधिकारियों द्वारा की गई समस्या का कारण बड़ी संख्या में जान और माल की क्षति हुई।

इस जानकारी के बाद पुक्करीशा दिन के 10 रिक्रिएटोर में से 10 में दुर्भाग्यात्मक दृष्टिकोण जान और दूर उतारने की अनुमति के लिए उपयोग की गई।

इस वर्ष के दौरान भारत ने अपने क्षेत्रों के अंतरराष्ट्रीय में वह संयंत्रों के सत्ताओं का सम्प्रभुश्चित करने के लिए कोठिया गणना के कारण एक दिग्गज करार किया है।

हरियाणा के बाहर रूपा में वैकल्पिक नामांकन उक्षा समाप्त करते समय उच्चतम प्राधिकरण को सार्वजनिक दर्शन करने के लिए समय प्राधिकरण का विषय है।
भाभाटून दूर षिष्का (टेले थेरी) मशीन को आपूर्ति हेतु आईजई, तथा नामिंदव शर्मा के साथ एक विचारी समझौता जारी पर भी हल्काकर किया है। परमाणु ऊर्जा विभाग तथा डायोएं, संसूच राष्ट्र अमेरिका ने ल्याक के क्षेत्र तथा डिस्क्वरी साइंस हेल्टु कण संस्थाओं के अनुसंधान एवं विकास में सहयोग के लिए एक कार्यान्वयन कार्य कर हल्काकर किया है।

प्रिय सहयोगियों,
में, विभाग द्वारा रिपोर्ट के सीरो रिजल्ट बढ़े उपलब्धियों में से कुछ का उल्लेख किया है। आपके समाजिक तथा अर्थ व्यवस्था में परमाणु ऊर्जा विभाग पूरे उत्साह के साथ अपने कार्यक्रम को अग्रेस बढ़ाने में लगा है तथा अपने संस्थापत्य टीम। भारत के अधिकांश वर्षों का पुरा करने में सफल भी हुआ है। आपको यह दोहरा होगा कि इससे यह इस सर्वोत्तम से आपसे बाटता हुए में अपने भविष्य के दृष्टि का शक्ति ध्यान पर ढालने के काल है तथा वापस या यह कि इस सर्वोत्तम से वास्तविकता में बदलता होगा। इस दृष्टि में, नामिंदव विभाग सीलिन दृष्टि देखने चक, खाद्य सुरक्षा, स्वास्थ्य संबंधी देखभाल, राष्ट्रीय सुरक्षा के क्षेत्र में बढ़े पेमाने पर नामिंदव विभाग तथा प्रौद्योगिकी को साथ करना तथा देश में नई प्रतिभाओं को अनुसंधान के अलावा प्रदर्शन करना सम्मिलित था। यातायात में हम इस सभी क्षेत्रों में संसूचित रूप से आगे बढ़ रहे हैं।

इस रूप क्रान्ति से वैचिक नतया पर फिल्टरली तीन दसकर में न्यू विश्व में नामिंदव विभाग संबंधी ने बढ़ा भाविकाली कार्य विकास कर देने किया है। हिस्टर्ज में कई दसी में नामिंदव ऊर्जा अंक उत्पादन देखा गया है। पूर्ववर्ती वर्ष पहले है चेयर्सबलिबल दर्जन का उपरांत, नामिंदव विभाग संबंधी को सुरक्षा के बारे में लोगों के मन में एक विभाग बाहर हो रहा था। इसी माध्यम पर, मुकुरिया दर्जन के, एक अव्यक्त हो वही पेयेने पर वाही हटाए से स्वास्थ्य लोगों के मन में एक विभाग बाहर हो रहा था। एक अव्यक्त हो वही पेयेने पर वाही हटाए से स्वास्थ्य लोगों के मन में एक विभाग बाहर हो रहा था। इसी माध्यम पर, मुकुरिया दर्जन के, एक अव्यक्त हो वही पेयेने पर वाही हटाए से स्वास्थ्य लोगों के मन में एक विभाग बाहर हो रहा था। इसी माध्यम पर, मुकुरिया दर्जन के, एक अव्यक्त हो वही पेयेने पर वाही हटाए से स्वास्थ्य लोगों के मन में एक विभाग बाहर हो रहा था। इसी माध्यम पर, मुकुरिया दर्जन के, एक अव्यक्त हो वही पेयेने पर वाही हटाए से स्वास्थ्य लोगों के मन में एक विभाग बाहर हो रहा था। इसी माध्यम पर, मुकुरिया दर्जन के, एक अव्यक्त हो वही पेयेने पर वाही हटाए से स्वास्थ्य लोगों के मन में एक विभाग बाहर हो रहा था। इसी माध्यम पर, मुकुरिया दर्जन के, एक अव्यक्त हो वही पेयेने पर वाही हटाए से स्वास्थ्य लोगों के मन में एक वि
कार्य तम्बी पूरा हो सकेगा जब हमारे साथ हमारे पैरिवार के सदस्य भी सामाजिक महत्व की इन गतिविधियों में रूचि लेंगे। परमाणु क्षेत्र में तेल, प्रत्येक संयंत्र स्थल में चिकित्सा सुविधाओं, अनुसंधान के लिए बाहरी सहायता उपलब्ध कराने हेतु BRNS, आस-पास के विकास के लिए आकृति (AKRUTI) कार्यक्रम, शोधान्तिक संस्थानों के साथ संबंध, विकिरण द्वारा तेल के बीज का वितरण एवं मूल्यांकन अभ्यासों के प्रबंधन के रूप में हमारे अनेक सुरक्षित कार्यक्रम हैं। अपने पड़ोस के लोगों के समांतर विकास (Inclusive growth) के लिए इसे एक बेहतर रूप में तैयारी में करने की जरूरत है। यह तम्बी संभव हो सकता है जब हम सब समाज सेवा एवं जागरूकता के कार्यभाषण में सहभागी बने। संस्थापक दिवस के अवसर पर में आप सभी लोगों से यह आगाज करता हूँ कि आप अपने आपको लोगों को शिक्षा प्रदान करने, उन्हें स्वास्थ्य देखभाल संबंधी सुविधाओं को सहायता उपलब्ध कराने तथा रोजगार के उन्मुख से संबंधित कार्यक्रमों और मुख्य रूप से स्वास्थ्य जनता के साथ अपने आपको जोड़ें। मुझे पूरा विश्वास है कि ऐसा करने पर हम अपने जीवन को भी समृद्ध कर सकेंगे और अपने कार्यक्रम को उपलब्धियों के साथ-साथ हमें आत्मसंतीष भी प्राप्त होगा।

इसलिए, आज आप हम इस शुभ दिवस पर आपको नामिकीय क्षेत्र कार्यक्रम के माध्यम से राष्ट्र के निर्माण के प्रति और आपने देश के लोगों को आकांक्षाओं को पूरा करने हेतु अपने आपको पुनः समर्पित करें। अपने संस्थापक डॉ. भाभा तथा हमारे कार्यक्रम के कर्मचारी के प्रति यही हमारी सच्ची श्रद्धांजलि होगी।

धन्यवाद,
जय हिंद।"
Founder’s Day 2011

Address by
Dr. Srikumar Banerjee
Chairman, Atomic Energy Commission & Secretary to Government of India, Department of Atomic Energy

“Dear Colleagues,

I extend my warm greetings and compliments to all of you on the occasion of the 102nd birth anniversary of our beloved founder Dr. Homi Jehangir Bhabha. As is customary on this day, we take stock of the year gone by and rededicate ourselves for the cause of strengthening the Nation through various facets of our activities. As you know, our activities are directed towards meeting the national needs and priorities while maintaining excellence by global standards. The last year has been quite eventful with several achievements setting all time records in electricity generation, in nuclear fuel production and in reprocessing of spent fuel while facing some new challenges. I intend to share some of these with you in the next few minutes.

Since we met last year, construction of Unit 4 of Kaiga Generation Station was completed and it commenced commercial operation in January this year. With this we have 20 nuclear power reactors in the country with an installed capacity of 4780 MWe. The Unit 1 of KAPS was resynchronised with the grid after completing its upgradation including Enmasse Coolant Channel Replacement and Enmasse Feeder Tube Replacement.

The nuclear power generation during the year recorded an increase of about 40% over the previous year due to increased fuel availability, both indigenous and imported. In particular, the average capacity factor is more than 80%, while that of 7 reactors has exceeded 90%.

Construction of four PHWRs of 700 MWe each at Kakarapar and Rawatbhata has been launched. The construction of the 500 MWe PFBR at Kalpakkam has attained 80% completion.

In the field of uranium exploration, about 32,000 tonnes of additional uranium resources have been established enhancing the country’s total uranium reserve to more than 1,72,000 t of U$_3$O$_8$ as on date. Tummalapalle uranium deposit in Andhra Pradesh is the flag bearer, which alone has contributed a staggering more than 60,000 t of U$_3$O$_8$ up to a vertical depth of 500m, that too in the limited area of 15 km by 3 km explored in detail so far. This stretch with a number of unexplored blocks, once explored up to its full potential may establish Tumalapalle as one of world’s largest deposits. AMD has gone in a big way in Airborne geophysical exploration using Time Domain Electro Magnetic system covering more than 80,000 line Km during the year, in parts of Cuddapah, Kaladgi-Badami, Bijawar-Sonrai, North Delhi Fold Belt and Meghalaya Basins, which has identified favourable areas. Apart from uranium, AMD has also achieved augmentation of heavy mineral placer resources, rare minerals and rare metal resources.

The Tummalapalle Uranium Mining & Milling Project in Andhra Pradesh is nearing completion. Currently segment wise trials in the mill are underway and the mill is expected to be commissioned in the early 2012. Shaft sinking is nearly complete at the Exploratory Mining at Gogi in Karnataka. In the Mohuldih Uranium Mining Project in the Saraikela-Kharsawan district of Jharkhand, the decline has reached a depth of 50 m and the ore body has been intercepted.

At the Nuclear Fuel Complex, Hyderabad, all its plants have not only achieved the target production, but many of them have surpassed the targets and have established new production records. The Zirconium Complex at Pazhayakayal, in its first year...
of commercial operation has performed commendably. An all time high recovery exceeding 80% has been achieved in production of PHWR fuel and significant reduction in consumables has been achieved in zirconium oxide production. A 37 pin MOX Fuel test subassembly of PFBR was successfully irradiated in FBTR to a burn-up of 112.5 GWd/t against the target burn up of 100 GWd/t. The challenging task of circumferential butt welding of PFBR main vessel to roof slab of nearly 13 m diameter was successfully completed. An engineering scale facility was commissioned for demonstration of pyro-processing of uranium on kg scale. The feasibility of producing $^{89}\text{Sr}$ in FBTR by irradiation of yttria was demonstrated and the separation of Sr$^{89}$ from irradiated yttria was carried out in hot cells. A unique mini sodium experimental facility was commissioned for sodium fire studies. The Interim Fuel Storage Building for PFBR fuel has been commissioned and handed over to NFC for manufacturing fast reactor fuel subassemblies. The success of the fast reactor programme hinges on building capacity for reprocessing of spent fuel for closing the fast reactor fuel cycle. Towards this goal, a project on setting up of Fast Reactor Fuel Cycle Facility is cleared by AEC and is awaiting Cabinet approval. Realising the importance of the development of fast breeding fast reactor fuel in the rapid growth of fast reactor programme, development of metallic fuel has been initiated. Just a few days back, the first set of Sodium bonded U-Zr alloy test fuel pins has been fabricated in a joint programme between BARC and IGCAR and assembled into a capsule for irradiation in FBTR. The capsules will be loaded shortly in FBTR for testing.

Performance of all the heavy water plants, has been excellent and the Heavy Water Board achieved more than 100% capacity utilization. High grade enriched boron produced by HWB is being regularly supplied to BARC for conversion in to boron carbide pellets for PFBR control rod application. About 2/3rds of the total requirement of PFBR has already been met.

At HWP, Baroda, a 130 MT per annum TBP plant has been commissioned and target production has been achieved. An industrial scale technology demonstration plant for recovery of uranium from phosphoric acid has been commissioned at RCF, Chembur. Towards alternate uses of Heavy Water and deuterium, laboratory scale preparation of D-labelled compounds is being continued at HWP, Baroda.

INDUS-2 Synchrotron has been operating regularly on round the clock basis at 2 GeV at 100 mA current. It has achieved beam life time of 20 hours. With the help of 30 kW RF power from solid state amplifiers developed indigenously, the INDUS operation has been enhanced to 2.3 GeV and 100 mA current.

The Homi Bhabha National Institute has completed five years of its existence. During the last year, more than 100 degrees and diplomas were awarded. In the Ph.D programme more than 50 students completed their academic requirements. The number of enrolments has increased to nearly 3000 including more than 1200 for Ph.D.

I am happy to inform you that the Government of Tamil Nadu has recently allocated land for the India based Neutrino Observatory programme in Theni district near Madurai. This will immensely help the High Energy Physics Community to achieve their cherished goal of setting-up this unique underground laboratory.

This year in March, Japan was hit by a twin tragedy in the form of an earthquake of level 9 on the Richter scale followed by tsunami of unprecedented height causing wide ranging damages to human lives and property. The tragedy was followed by accidents in four of the 10 nuclear power reactors located at Fukushima. After the accident at Fukushima, Prime Minister of India had underlined that safety of nuclear power plants is a matter of highest priority for the Government while implementing the national nuclear programme. Several steps have been taken in this regard and many of the recommendations of
Dear colleagues,

I have just highlighted some of the major achievements that have been accomplished by the Department during the last year. Through your dedicated and untiring efforts, the Department of Atomic Energy, is pursuing its programme with full vigour and has been successful in realising most of the dreams our founder Dr. Bhabha. If you recall, while talking to you last year from this very podium, I had painted a scenario of our future and had mentioned that we will have to convert this scenario into a reality. This scenario included large scale deployment of nuclear science and technology in sectors like nuclear power including the entire fuel cycle, food security, health care, national security and research opportunities to fresh talents in the country. We are in fact poised to move forward in all these areas.

Similarly in the global arena, Nuclear power plants all-over-the world recorded a very impressive performance in the last three decades. The resurgence of nuclear power has been in the horizon in many countries. After the Chernobyl accident which occurred a quarter of Century back, the confidence in the safety of the nuclear power plants was building up in the minds of people. At this juncture, the Fukushima accident has shaken the confidence on the safety of nuclear power plants when exposed to an external event of a very high magnitude. We are now facing a new challenge to restore this confidence. Safety statistics is all in favour of nuclear industry as we may recall that the world has logged 14000 reactor years of nuclear electricity generation in about 30 nations. Major accidents and casualties caused are far fewer when compared to any other energy generating technology over a sustained period. India has recorded over 350 reactor years of safe operation of nuclear power plants with only one event, namely Narora fire which was of level-III on IAEA event scale. In Fukushima, there has been no casualty due to radiation exposure though the total causality in Japan exceeded 20,000 due to earthquake and tsunami. These statistics will not
satisfy a common man and it is our duty to explain issues related to safety of nuclear power plants and to regain their confidence. We must ensure that nuclear installations have no adverse impact on the livelihood of the people around while they can bring about significant improvement in the quality of life of the people in the region and an all-round development of the country.

Let me do a loud thinking on how to enhance our outreach programme so that a greater appreciation comes from our neighbourhood in all our operating as well as our proposed plant sites. First and foremost, we must integrate ourselves with the people around. To achieve this, it would be necessary for us to be proactive in providing education, healthcare and other social services in the neighbourhood, participation of large number of our scientific and other staff in the neighbourhood activities, initiating our departmental activities having social relevance such as nuclear agriculture, food preservation, waste-to-wealth programme, etc. for the benefit of the people. I must mention here that several such activities are already in place in many of our operating plant sites. What is needed is to multiply them manifold so that the benefit reaches a much larger community.

We have our own education and healthcare programmes. Though difficult, but it may not be impossible to extend some of these facilities at least to a limited number of people in the neighbourhood. Such an enormous task cannot be fulfilled unless all of us including our family members take interest in the activities having social relevance.

We do have structured programmes such as education through our Atomic Energy Education Society, healthcare through the medical facilities, providing extra-mural support through Board of Research in Nuclear Sciences, development of neighbourhood through AKRUTI, links with educational institutions, agricultural programme through distribution of radiation mutated seeds for multiplication and management of municipal waste. For an inclusive growth of neighbourhood, there is a need to intensify these activities to a great extent and that is possible only if all of us participate in social service and awareness programmes. On the occasion of Founder’s Day, I make an appeal to all of you in this regard and I can assure you that by involving ourselves in imparting education, supporting healthcare facilities, helping employment generation and most importantly integrating ourselves with the local population will enrich our own lives and we will achieve a sense of fulfilment over and above our professional accomplishments. Let us therefore, on this auspicious day, rededicate ourselves to the cause of nation building through the nuclear energy programme and meet the great aspirations of our fellow countrymen. This would in fact be the most fitting tribute to our founder Dr. Homi Bhabha and other pioneers of our programmes.

Thank You

Jai Hind."
संस्थापक दिवस - 2011
शुक्रवार, 28 अक्टूबर, 2011

डॉ. आर. के. सिन्हा
संयोजक, भारत केंद्र
का संबोधन

डॉ. आर. के. सिन्हा द्वारा संबोधन

"परमाणु क्षेत्र आयोग के अध्यक्ष डॉ. चंद्रशेखर, परमाणु क्षेत्र विभाग परिषद के वरिष्ठ सदस्य, सम्पादक सहकार्यक, देवियों और सरजनों,

यह मेरा परम सोहाग्य है कि आज संस्थापक दिवस समारोह के शुभ अवसर पर मैं आप सब का हार्दिक स्वागत कर रहा हूँ।

यह हमारी परम्परा रही है कि प्रत्येक वर्ष दिनांक 30 अक्टूबर को हम अपने संस्थापक डॉ. होराकी जहांगीर भाभा के जन्मदिवस पर उन्हें प्रतापार्जीव कर्मचार करते हैं। चूँकि इस वर्ष डॉ. भाभा की जयंती सनातन के अंत में हो जाएगी, इसलिए हम आज शुक्रवार की सुबह यहाँ तक तक हुआ है। हम अवसर पर हम पिछले वर्ष के अपने कर्म निष्पादन तथा उपलब्धियों का अनुकूलन करते हैं और इसके साथ-साथ अपने देश तथा देश की विशाल जनसंख्या को नानाविविध विज्ञान संस्कृति विभिन्न सीमाओं का अधिकतम लाभ उपलब्ध कराने के लिए पुन्न्य अपने आपको समर्पित करते हैं।

मैं अपने केंद्र द्वारा हाल में किये गये कुछ महत्वपूर्ण विकास कार्य तथा प्रारंभ की पहले उपलब्धियों को इस्तेमाल में करने का कोष्ठक करूँगा ताकि हम अपने कर्म की विशेषताओं एवं प्रकृति पर एक दृष्टिवात कर सकें।

1. अनुसंधान रिएक्टर

दिसंबर 2010 को समाप्ति अनुसंधान रिएक्टर संयुक्त और भूवा के लिए महत्वपूर्ण रही। सामान्य प्रचालन का स्वायत्त ज्यांती और भूवा प्रचालन का रजत ज्यांती का समारोह बूथाईम द्वारा मनाया गया। आईसीटी अप्लाइड, पदवी विषय, अनुसंधान एवं मानव संसाधन विकास के लिए केंद्र के सभी रिएक्टर का समुच्चय प्रयोग किया गया। अनेक उद्यम कार्यों के लिए इस वर्ष अलग-आलग रेट्डाउन अवस्थाओं के बावजूद अनुसंधान रिएक्टर भूवा उच्च स्तरीय संरक्षण और लगभग 70% उपलब्धता पर प्रचालनरत रहा। उद्यम कार्यों में आधुनिक विश्लेषण द्वारा मुख्य नियंत्रण बहुत सुनिश्चित और मध्यम नियंत्रण पेटल का प्रतिस्थापन शामिल था। लंबी अवधि के स्टेजन के आउट परिस्थितियों को संभालने के लिए दूसरी राउंड डांजन इंजन चलाने पर कमीशन किया गया और इसका अच्छी कारण तीन रेखांतर का नाम जाना है।

भूवा रोडोयोज आईसीटी उपाल्य के आउट वर्ष के निर्माण क्षेत्र अनुसंधान हेतु राजस्थान सरकार के लिए प्रमुख सुविधा द्वारा रूप में बना। इसके पिछले वर्ष कूल 178 रोडोयोज आईसीटी अप्लाइड के नमूने सूची रखे गए। रोडोयोज आईसीटी उपाल्य को अरोड़ा बदाम के लिए एक
BABC NEWSLETTER

BARC CELEBRATES FOUNDER’S DAY

२०११ के मध्य में सी.एस. नोडिंग के प्रति समर्पित दिन

साल २०१० के ३१ अगस्त को सीएस नोडिंग टेलीफोनिक का ३० साली उम्र हुआ। 

बीपीएचव्यूएज डब्बो में नई नियंत्रण टाइम्स और पीडब्ब्यूआर डब्बो दोनों फैक्ट्री में प्रतिमात्मक विभागों के लिए संपादन पंजीकरण के लिए संगठित किया गया। 

2. नागरकीय विविध संबंधों अनुसंधान एवं विकास प्रचारण एवं निर्माण पाठ्य नागरकीय विविध संबंध

भारत परमाणु अनुसंधान केंद्र द्वारा संचालित वर्ष से पांच माहों में एनएडीआर कॉंसेप्ट (बाकबक) जो आयुक्त मंडल का संस्थापक कार्यकाल से हुआ। 

यह वर्ष अंतिम शुरुआत के लिए प्रारंभिक परिप्रेक्ष्य लाया गया और इसके कारण संचालन की कार्यान्वयन विभाग का विकास किया गया है। 

महत्वपूर्ण जानकारी है कि प्रतिमात्मक संरचना के कार्यान्वयन विभाग के प्रमुख भागों, पूर्व-प्रारंभिक के कारण अनुप्रभावित टाइम्स संरचना प्राथमिक संरचना से रिसाइकल अनुप्रयोग सूची के अंतर्गत हो और पारंपरिक आवश्यक की विवरण अवस्था में रखा जाएगा।
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3. नाभिकीय इलेक्शन

एफीआरएफ एवं बारियम इलेक्शन एलाक्सादियुआर के लिए ग्रांत इलेक्शन के विकास का दिशा में भारत परमाणु अनुसंधान केंद्र में अनेक ग्रांत मानविकियत खोज किया गया है। इस विकास में अभित्व अधिक इलेक्शन संरचना सुरक्षा का कारक, U-Pu भारतीय इलेक्शन अभिलेखण एवं जुड़ी वर्षों तक दोनों के पावर्क के साथ उनकी संगठन का मुद्दा भी शामिल किया गया।

एफीआरएफ हेतु समय इलेक्शन के विकास पर भी हम कार कर रहे हैं।

चूँकि धातुकी मार्ग द्वारा इलाक्सादियुआर कार्यक्रम के लिए, 8 से 22.5% तक UO2 यूक्स विविध संयोजन की ThO2-UO2 मिश्रित गुंटियों का संगठन किया गया है। इस इलेक्शन के रूप में भीतियों गुणधर्म का मुद्दा कार्यान्वयन किया गया है। इलेक्शन एलाक्सादियुआर (आईआई) का एक नया नाभिकीय प्रारंभ कर देने के लिए है। इस तकनीक में ThO2 गोल्की एवं पुरातत्त्विक क्षेत्रों का प्रारंभिक पावर्के के रूप में प्रामाण करते हैं। पुरातत्त्विक क्षेत्रों ने आधारित मिश्रित आक्साइड इलेक्शन मिश्रित गुंटियों का संगठन किया गया और इस प्रगति उद्घाटन कर दिया। इस प्रगति के प्रयोग से चूँकि हल्सन एवं पुरातत्त्विक-233 के हल्सन से जुड़े कार्यों में विकास की हुई है।

सामयर दाशिल्ज जल लूप में किरण कार्यक्रम की पारिवर्तन पर निर्भर विवरण पूरा किया गया। परिवर्तन नेतृत्व के रूप में किरण कार्यक्रम ने उपलब्धि उद्घाटन के संबंधी विभि समाज में विकास का प्रतिकृति होता है।

4. पुनर्रीत्वाण एवं अर्पण प्रबंधन

टीक एक वक्ता द्वारा, इसी अभिव्यक्ति पर मैंने तारापुर स्थित जी-3 इलेक्शन संरचना के असंगठित चलन के प्रारंभ के अनुसार अधिक किया जा रहा है। कल्पनाक्रम में पुनर्रीत्वाण संरचना जी-III का निर्माण करने के लिए आप चलन के उद्घाटन किया जा रहा है। कल्पनाक्रम स्थित विभिन्न अर्पण प्रबंधन सुविधाओं का कार्य भारत वर्ष पर ग्रांत होता है। इस कार्य का निर्माण जी-III का उद्घाटन किया जा रहा है।

जी-III विश्व उत्तर पुर्दल के (सीपी) एवं कल्पनाक्रम पुर्दल संरचना (जी-आरपी) भी संगठित एवं विकृतालाप प्राप्त करने का प्रयास कर रहे हैं। इसके अंतर्गत, बारियम अर्पण का संगठन किया गया एवं अर्पण निर्यात चलन संरचना (डब्ल्यू-आई) में परिवर्तन एवं उद्घाटन कार्य पूरा किया गया। अनुसंधान एवं विकास के क्षेत्र में, भूकंप प्रेमिक इलेक्शन से उपयुक्त पावर्के को पुनराभिव्यक्ति हमारी निभायें रखते हैं एवं जी-III का उद्घाटन किया जा रहा है।
5. व्यावसाय मोनिटर संस्था विकास पर नवीनता का मूल्यांकन

रक्षा मंत्रालय के माध्यम से एक संरक्षण नियम लागू करते हैं। व्यावसाय मोनिटर संस्था में भाग की जाने वाली सिस्टम नियमीय विकास के लिए एक अनुमान संरक्षण का मूल्यांकन किया जाता है।

6. सराहनीय विस्तार

सराहनीय विस्तार के लिए एक विवरणिक विकास का प्रतिनिधित्व किया जाता है। रूप विकसित किया जाता है जिसका नतीजा विकास के लिए उपयोगी होता है।

7. जीव-विस्तार

जीव-विस्तार के लिए एक विवरणिक विकास का प्रतिनिधित्व किया जाता है। रूप में विकसित किया जाता है जिसका नतीजा विकास के लिए उपयोगी होता है।

8. कोड्स का विकास

कोड्स का विकास के लिए एक विवरणिक विकास का प्रतिनिधित्व किया जाता है। रूप में विकसित किया जाता है जिसका नतीजा विकास के लिए उपयोगी होता है।
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10. **News Letter**

BARC celebrates Founder's Day

11. **News Letter**

BARC celebrates Founder's Day

12. **News Letter**

BARC celebrates Founder's Day

13. **News Letter**

BARC celebrates Founder's Day

14. **News Letter**

BARC celebrates Founder's Day

15. **News Letter**

BARC celebrates Founder's Day

16. **News Letter**

BARC celebrates Founder's Day

17. **News Letter**

BARC celebrates Founder's Day

18. **News Letter**

BARC celebrates Founder's Day

19. **News Letter**

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20. **News Letter**

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21. **News Letter**

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22. **News Letter**

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23. **News Letter**

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24. **News Letter**

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25. **News Letter**

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26. **News Letter**

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27. **News Letter**

BARC celebrates Founder's Day

28. **News Letter**

BARC celebrates Founder's Day

29. **News Letter**

BARC celebrates Founder's Day

30. **News Letter**

BARC celebrates Founder's Day

31. **News Letter**

BARC celebrates Founder's Day

32. **News Letter**

BARC celebrates Founder's Day
14. इलेक्ट्रोनिक्स एवं यंत्रीकरण
एस्एसईसीएस

0.35 यम CMOS प्रोजेक्टों में तीन नए एससीईसी-अनुसंधान, आपूर्ति एवं अपुर्ति का अभिकल्पन, विकास एवं सशस्त्र अंचल प्रकाश किया गया। आपूर्तियाँ आईएनआई (भारत स्थित न्यूज़ियन बेसेलाला) के रेजेंट्रिय फाइटर चेयर आर्थिक में हैं।

इलेक्ट्रोनिक्स के लिए निम्न शासक एंड रोडआउट है।

गहराई में सिवां दर्शन निषेधों के विभाजन सबसे बड़ा कार्य की सफाई के लिए 22 मोटर धारा लेने द्राप्रमित कोठरी एवं 1.1 मोटर फिल्टर कोठरी युक्त वांत का स्िय ऑलर्ट कंट्रोलर द्वारा द्राप्रमित की युक्त कोठरी को इसकी उड़ान क्षेत्र के लिए की गई और इसे संपादन करता गया। इस दृष्टि में बुंदोंतर के विभाजन एवं शहरता नेत्ररण करने के क्षेत्र में एक महत्वपूर्ण विकास है।

चोरा पहचानने की प्रणाली

प्रणाली नियंत्रण हेतु भ्रष्ट एंड एक्स-संचालक चेयर पहचानने की प्रणाली के उद्देश्य परिश्रम (केवल 0.7% गलत स्वीकृति) पूरा है। यह युक्त एक्स-एक्स के समक्षिक वायुक्षेत्रिक प्रणाली नियंत्रण प्रणालियों हेतु गहरी प्रकाश के रूप में महत्वपूर्ण है।

अंतर्गत वायुसेवनार्थी

महत्वपूर्ण आतिथ्य संचालित विकास के रूप में एक अंतर्गत वायुसेवनार्थी का विकास किया गया ताकि अप्रश्रय रेंज में मध्य वायुसेवनार्थी द्वारा सबसे अधिक आर्थिक तथा वायुसेवनार्थी के क्रम में अस्तित्व वायुसेवनार्थी द्वारा भित्ति का मापा जा सके।

इस महत्वपूर्ण विकास से कार्य क्षेत्र एवं आवृत्ति क्षेत्र में विशेष विश्लेषण विवरणों के अनुसार विवेक तात्पर्य एवं वायु परिस्थितियों में आति संसाधन कार्यनिष्ठ आर्थिक आर्थिक आर्थिक हुआ।

15. त्वरक एवं उच्चत्वक्षति इलेक्ट्रोनिकों

ह्यु-उजा संहं रेखीय त्वरकः

एससे-ए कारोबार अनुप्रयोगों हेतु 3/6 MeV ह्यु-उज्ज संहं रेखीय त्वरक का एक प्रकार रहा है। 85kV इलेक्ट्रोन गन एवं उसके मॉड्यूलेटर शक्ति आर्थिक, लाइटनिंग बैरिक, मेट्रिन्टेड संतर एवं मॉड्यूलेटर, फोक्सनिम-चुम्बक, एससे टार्गेट एवं कॉलोमेटर युक्त सहायता प्रणालियों का विकास किया गया और सहायता की समक्षता प्रकृति प्रति से है।

विद्युत-चुम्बक निम्नांकण प्रणाली

असामान्य धारता की शीत ब्लेड में प्रयोग हेतु 20kV, 40 किलो-जुल विद्युत चुम्बकीय निम्नांकण प्रणाली का विकास किया गया। अनेक विशेष घटक एवं लघू वाली इस प्रणाली का प्रयोग एससे एंड प्लग के साथ D-9 के उपक्रम ब्लेड नलिकाओं को जोडने और ODS ब्लेड नलिकाओं एवं प्लग को जोडने के भावी अनुप्रयोगों में प्रयुक्त किया जाएगा।

16. प्रगति प्रोद्योगिकियों

क्राइल-प्रोद्योगिकी

77K पर संदर्भ के लिए 250mW शीतलन उपलब्ध कराने हेतु नाइट विजन डिवाइज के लिए इलेक्द-रामण तापमान प्रतियोगिता के साथ स्थगित विकसित स्थूल क्राइल इकाई को सफलतापूर्वक समाप्त किया गया और सहायक हार्डवेयर के साथ इलेक्ट्राइकल, बॉडोंट को सुधार लिया गया।

निर्लाभीकरण

यूनिफॉर्म कम्पॉनेंट पोलीएमेक्स द्वारा प्रोद्योगिकी हेतु स्वदेशी श्रम का निर्माण को दिशा में, प्रतिपादनात्मक हेतु इस प्रकार का द्वारा इसकी को अपनी खेती लेना को रोक और इसे अभावित आकार प्रकाश के घटकों में कुछ आकार में रोल किया गया। इस घटकों में से छ: एनडोडोरी, कल्चरल स्थित प्रतिपादन संरचना में द्वारा प्रकाश को प्रतिस्थापित करने के लिए लेता है।

17. रोबोटिकी एवं सुदूरीकरण

स्वचालित पदार्थ अंतरण प्रणाली (एएमटीएस)

भारत केंद्र में एक ऑटोमेटेड गाइडेड उंचिकल (एएमटीएस) आधारित पदार्थ अंतरण प्रणाली का अभिकल्पन एवं विकास
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किया गया। यह प्रणाली किसी भी विनिमय संबंध में विशेष संबंध इंडाक्स के बीच पद्धति हस्ताक्षर के लिए मौल का सतत वातावरण काल भूलौंक करना है और तद्नुसार अपना रूप शोधनावर्त रूप से प्राथमिकता के अनुसार अंतरण करती है। इस प्रणाली का निर्देशन सम्मान प्रयोक्ताओं, निम्नांकन या तथ्यों, मोडल के लिए किया गया और अब इसे शोध ही आकृति, पूरा सिध्दित बनाए अंतरणालाइट में प्रयोग के तौर पर नियोजित किया जाएगा।

फॉर पीस समीकरण यूनिटर (एफईएसएम) भारत केंद्र द्वारा हाल ही में विकसित हुए पीस सभा में पुनर्नवीनीकरण लाइट केमिकल मास्टर स्लेट में पुनर्नवीनीकरण के लिए निर्देश दिए गए। इस प्रणाली का उपयोग करते हुए, यह प्राकृतिक यूनिटर यूनिटरों की तुलना में सरलता स्वरूप हरण कर सकते हैं।

स्वस्थ टेक्निकरों योगाभ्यास हेतु योगदान
भारत सेवा सेवा मण्डल (सीएसएस) के लिए अंतरण, अंतरण या विकास किया गया। चौथी उद्योग और चौथी उद्योग या कांग्रेस के लिए निर्देशन का विस्तृत परिशोध किया गया।

18. सामाजिक कार्य एवं प्रशिक्षण की हस्ताक्षर प्रशिक्षणीय की हस्ताक्षर

की क्रमशः उच्च और अवसंमाचार कार्यक्रम
I. आकृति कार्यक्रम के अंतर्गत अस्मितों का जित विषय निम्न के नामों लिखा गया, जो एक जल अभियान है, हेतु आईआईटी स्‍टेट में अवसंमाचार जनविश्वास तकनीक का प्रयोग करते हुए, 30,000 लेटर प्रति घंटे को क्षमता बढ़ाने नीति स्वाभाविक जल शोध को पहचाना गया।

II. 50,000 केले के पीले को क्षेत्र जलवायु सुरक्षा वाले उज्जवल संचालन प्रयोगों का कार्यक्रम किया गया एवं अग्रणी कर्मचारी, महाराष्ट्र के आकृति कार्यक्रम के अंतर्गत किये, पदार्थ को पहली खेम जिंदा निकाली गयी।

III. आकृति कार्यक्रम के अंतर्गत दो पर फंसी कामकाज को फंसी काम करने वाले हैं, जो अभिव्यक्ति कार्यक्रम के अंतर्गत किये, पदार्थ को पहली खेम में बोध दी गई।

IV. प्रमाण क्षेत्रों में और अत्यधिक क्रमबंध रूप से आकृति कार्यक्रम की विकास करने देने के लिए निर्देशन के लिए निर्देशन की विकास करने देने के लिए निर्देशन का इंस्ट्रक्टर एस. SVERI स्वयं संरचना स्वयं संरचना के साथ समाधान ज्ञापन पर उत्तरकाल किया गया तथा प्रदर्शन स्वामित्व शीर्षक SVERI केंद्र में कल्पना एवं रिसर्स डेवलर्स में इस्तेमाल किया गया।

19. आवृत्तिवर्ग सेवाएं
आवृत्तिवर्ग प्रभाव, भारत केंद्र द्वारा 390-विस्तार का असभ्यता, 12 क्षेत्रों और बांधालयों, नंबर विश्वास वास्तव केंद्रों और जीवनार्थ एवं कारकिस्म सुविधाओं के माध्यम से समय मुंबई स्थित थोएसैंस नामकांश नामकांश को स्वाभाविक देख-देख सुविधा प्रदान का जा रहा है। भारत केंद्र असभ्यता में नया स्वैच्छिक और उत्तराधिकारी है। निर्देशन 30 अगस्त, 2011 को नामांकन को कूल संख्या 87080 रही।

प्रविध साधनों
इसके समय में सामाजिक क्षेत्र में अपनी महत्वपूर्ण भूमिका का उल्लेख किया गया था। विश्वविद्यालय और प्रशिक्षणीय क्षेत्रों में कार्यरत 15000 से भी अधिक व्यक्तियों के योगदान को विभिन्न कार्य को समाधान करना असंभव है। इसके विश्वास में यह केवल समय के अभाव के कारण हुआ है और यह भी सरकार से उन सभी कारों की महत्व को कम नहीं करता है।

वर्ष 2011 केवल भारत में ही नहीं वर्तना विश्वम में नामीकरण कार्यक्रम और उद्योग जनरल के लिए चुनौतीपूर्ण रहा है। यह
BARC CELEBRATES FOUNDER’S DAY

मुख्तत्व इस वर्ष मार्च में जापान के फूलशिमा दर्शन-भोज में घटी दुर्भाग्यपूर्ण घटना के कारण हुआ है जो सर्वाधिक भूकम्प (रिक्टर स्केल पर 9.2) और सुनामी (15 मीटर की ऊंचाई तक) जैसी अभूतपूर्व दोहरी प्राकृतिक आपदाओं के परिणामस्वरूप हुआ। पहले हमें ऐसी घटनाओं के लिए पूर्वानुमान सचेत और स्थिरता से निपटने के लिए तैयार रहने की आवश्यकता है, फिर भी यह अनिवार्य है कि हम नाभिकीय क्षेत्र में विज्ञान और प्रौद्योगिकी के सामयिक और मूल सशक्तताओं के आधार पर हमारे सुविधाजनक कार्यक्रमों और समाजकर्मी नीतियों के प्रयोग निष्ठा से प्रतिवेद रहें। इस में नर्म दिनों की बढ़ती हुई माँग और समाज के माहौल से वेश्वर समय के माहौल और गृहहरित पूर्ण जीवन व्यापार में सत्ता प्रवृत्ति करते रहने हेतु यह नितंत्र आवश्यक है। हाल की घटनाओं से भी हमारे सामाजिक कार्यक्रम को मजबूती प्रदान करने पर बल दिया है। हम इस दिशा में सक्षम हैं और नई शुरुआत कर रहे हैं।

हमने, अभी हाल ही में बारहवी योजना के प्रस्तावों को योजना आयोग के समक्ष प्रस्तुत करने के लिए अंतिम रूप दिया है। निर्धारित लक्ष्यों और योजनाओं को हम सम्पूर्ण प्रायोगिक प्रयासों तथा विभिन्न विषयों और क्षेत्रों में सहजक्रम पूर्ण सहयोग के साथ ही प्राप्त कर सकते हैं। मैं यहां जोर देकर कहना चाहता हूँ कि हम विश्व धरोहर के अनुपालन के क्षेत्र में विश्वविद्यालयों के अनुपालन के क्षेत्र में जिस तेजी से प्रगति को कल्पना की गई है उसमें भावों योगदान करने में बहुत सी चुनौतियाँ हमारे सामने हैं। हमारे विश्वास का ईत्तिहास इस वात का गवाह है कि हम अपनी आल्मोनिया तथा सांस्कृतिक विकास और सुदृढ़ संकल्प से आपसी राह में आने वाली सभी वाणिज्य को अवश्य पा रहे हैं। मुझे पूरा विश्वास है कि हम सब अपने समर्पित प्रयासों के, अपनी व्यवसायिक और सांस्कृतिक परंपरा के अनुरूप इन स्थितियों का समानार्थ करने में सफल होंगे।

साथियों, अंत में, इस विशेष अवसर पर, आपेक्षिक वर्तमान संकल्प ले कि जबानियां को वेश्वर निर्माण के लिए नामिकीय विकास और प्रौद्योगिकी के अभावों के क्षेत्रों में अपनी श्रद्धा को सिद्ध करना जारी रखें।

धन्यवाद, जय हिन्द !”
“Dr. Banerjee, Chairman, AEC, Senior Members of the DAE Family, Esteemed Colleagues, Ladies and Gentlemen,

“It is my proud privilege to extend a warm welcome to all of you to the Founder’s Day functions scheduled today, to commence with this morning’s event here.

It has been our tradition to pay respectful homage to our Founder, Dr Homi Jehangir Bhabha, on his birth anniversary, the 30th October every year. The 102nd Birth Anniversary of Dr. Bhabha falls over the weekend this year and hence we are assembled here on this Friday morning for an introspection on our performance and achievements of the past year, as well as to rededicate ourselves to continue to do our best in providing the maximum benefits of all nuclear-related services to our nation and its very large population.

I will try to project a few glimpses of what BARC has achieved during the recent past, in various areas of our mandate, just to cite the typical range and nature of our work.

1. Research Reactors
The year ending December 2010 was a landmark year for the research reactors Cirus and Dhruba. The Golden Jubilee of Cirus operations and Silver Jubilee of Dhruba operations were celebrated in a befitting manner. All the reactors of this centre were utilised well for isotope production, material testing, research and human resource development.

Research reactor Dhruba continued to operate with a high level of safety and availability of about 70%, in spite of the additional shutdown requirements this year for several upgradeation tasks, that included the replacement of main control room panels and fuelling machine control panels by modern instrumentation. To take care of prolonged station black out scenario, trolley mounted diesel engine driven pumps have been commissioned and are maintained in poised state.

Dhruba continues to be the major facility for radioisotope production and national facility for neutron beam research. A total of 786 radioisotope samples were delivered last year. To further augment the radioisotope production, an additional tray rod has been incorporated. One hundred and twenty four samples were irradiated in pneumatic carrier facility for various research purposes. The facility continued to be utilised under the aegis of the UGC-DAE Consortium for Scientific Research and by a number of research scholars from various academic institutions.

After its permanent shutdown on 31st December 2010, the Cirus reactor has been defuelled and the heavy water moderator transferred to storage tanks. Various systems of this reactor are being operated in preservation mode.

Decommissioning of the Apsara reactor systems was completed. Activities pertaining to building a new pool type research reactor with 2 MW(Th) rated power at the site of Apsara are in progress. A recent evaluation has indicated that it will be necessary to construct a new reactor pool block, to be consistent with a design for increased static and seismic loading conditions.

The basic design of the new 30 MW thermal High Flux Research Reactor (HFRR) has been completed.
2. Nuclear Power Related R&D

NPPs Under Operation and Construction

Bhabha Atomic Research Centre had successfully commissioned BARC Containment (BARCOM) test model at Tarapur last year. During the year, four sequential over-pressure tests culminating in the functional failure of the containment have been successfully completed. The results have been made available for post-test analysis to fifteen Round Robin Participants, including 11 International Participants from seven countries. Such an extensively instrumented experiment has been done for the first time in the world.

An important finding is that, even after the functional failure of the primary containment, the leakage from primary containment with inherent tight cracks characteristics due to pre-stressing, the leakage rates are within manageable limits and the shielding cover will be retained in a stable manner.

Ultrasonic Phased Array technology has been developed to achieve better sensitivity and reliability in flaw detection and characterisation in critical nuclear power plant components such as PHWR pressure tubes, turbine blades, BWR pressure vessel and primary pipelines.

A test section for generation of two-phase pressure drop data for 700 MWe PHWR fuel channel components, including fuel bundles, has been installed.

Advanced in-service inspection probes were designed and tested for assessment of hydrogen ingress in pressure tubes. Scrape sampling for determination of hydrogen in operating pressure tubes was carried out in Kaiga-1.

An analysis has been carried out to study the behaviour of TAPS 1 & 2 under prolonged station blackout condition, to obtain information on gross behaviour of fuel temperature, RPV pressure, extent of clad oxidation and hydrogen generation during the progression of severe accident. Based on the analysis, the time line of the progression of accident was estimated and the findings indicated the availability of adequate time margins for external intervention.

The effectiveness of water injection into moderator side to mitigate the consequences of Station Black Out was assessed for a large PHWR.

AHWR Programme

To assess the robustness of AHWR design against any foreseeable accident scenarios, an extensive exercise was carried out. It was determined that on account of its advanced passive safety features, accidents such as those at Fukushima, Chernobyl and Three Mile Island would have practically no effect on fuel integrity.

The experimental programmes towards evaluation of design margins for AHWR continued with setting up of several new facilities and conduct of experiments in the existing ones. For example, an air-water loop has been installed and commissioned to study various thermal hydraulic phenomena associated with the steam drum of AHWR.

The Critical Facility (CF) for Advanced Heavy Water Reactor (AHWR) was operated on fifty seven occasions for various experiments. Reactivity measurements due to loading of a cluster containing Thoria and uranium (Th-U) pins and (Th-1 % Pu) MOX fuel at various lattice positions were carried out satisfactorily.

HTR Related Developments

Towards evaluation of alternate coolants for Indian High Temperature Reactor, a Molten Salt Natural Circulation Loop has been fabricated and installed to generate data on heat transfer and pressure drop. A computer code incorporating molten salt properties has also been developed.

3. Advanced Nuclear Fuels

Several new activities were carried out in BARC towards the development of advanced fuels for the FBRs, and the thorium fuelled AHWR. This work has covered the development of an innovative
metallic fuel fabrication facility, characterisation of U-Pu metallic fuel and assessment of its compatibility with zirconium liner bonded clad material. We are also working on the development of cermet fuels for FBRs.

For the AHWR programme, ThO\(_2\)-UO\(_2\) pellets of different compositions having UO\(_2\) from 8 to 22.5% were fabricated by powder metallurgy route. The evaluation of thermo-physical properties of these fuels is in progress. A new technique called Impregnation Agglomerate Process (IAP) for fabrication of thorium based mixed oxide fuel pellets using ThO\(_2\) spheroids and uranium nitrate solution as the starting materials has been initiated, with encouraging results. The use of this process will reduce powder handling and associated personnel radiation exposure when Uranium-233 is handled.

The Post Irradiation Examination (PIE) of experimental thoria-plutonia MOX fuel elements irradiated in CIRUS Pressurised Water Loop was completed. The findings demonstrate better retention of fission products in irradiated thoria (relative to uranium oxide based fuel elements).

4. Reprocessing and Waste Management

Exactly one year ago, on the same occasion, I had announced the start of cold run of PREFRE-2 Reprocessing Plant at Tarapur. The hot run with spent fuel was inaugurated by the Hon. Prime Minister of India on 7th January 2011. All systems in the plant are performing well and this plant is now producing plutonium for our programme. Additional Waste Tank Farm has also become operational at Tarapur. Construction activities for reprocessing plant PREFRE-III A at Kalpakkam are progressing in full swing. Infrastructure development for first Integrated Nuclear Recycle Plant, Tarapur is in progress.

The remote decommissioning of first Joule melter (AVS-I) at Tarapur has been completed. The second Joule melter AVS-II is being taken up for commissioning. Various waste management facilities at Kalpakkam are going through cold commissioning.

The Plutonium Plant (PP) at Trombay and Kalpakkam Reprocessing Plant (KARP) at Kalpakkam also continued to operate safely and efficiently. In addition, processing of Thoria waste was carried out and modification and augmentation work at Waste Immobilisation Plant (WIP), Trombay was completed. In the field of R&D, one of our responsibilities is to recover useful materials from spent fuel, which is internationally a very advanced field of research. Towards this end, we have made important achievements during the year with demonstration of recovery of strontium from thorium lean waste and synthesis of associated specific crown ether. A process has also been developed for production of caesium specific crown ether. Advances were made also in the development of continuous rotary dissolver and cold crucible induction melter.

5. Environmental Monitoring and Radiation Safety

Assessment of the Impact of the Fukushima Event

Using our computational models, preliminary estimates of the release rates of different radionuclides into the atmosphere and into the Pacific Ocean due to Fukushima Nuclear Accident were derived. Reasonable matching of the estimated release rates is observed with the values reported by different agencies.

All the Environmental Survey Laboratories in the country carried out special campaign to monitor very low level of radioactivity in the environmental matrices. The data from IERMON network was also analysed continuously at all the locations for atmospheric radioactivity. We were able to confirm that the Fukushima event has not caused any noticeable impact on India.

Monitoring of Environment

Environmental Radiation Monitors with solar powered systems, and GSM and LAN based communication have been developed. Mass production of 250 units has been completed with
the help of ECIL, Hyderabad. The units will be installed at various locations in the country under the Indian Environmental Radiation Monitoring Network (IERMON) programme of DAE.

Detailed baseline data for Atmospheric, Aquatic and Terrestrial Environment have been collected for the proposed BARC Campus at Vizag. Health and demographic status survey and marine survey, within an area of around 30 km radius, have been completed.

**Instrumentation for Radiation Detection:**

Inhalation dosimeter badges have been developed for directly monitoring the cumulative doses due to radon, thoron decay products using direct progeny sensors. These badges have been deployed in about 2000 places within the country and also in about 1000 locations in Europe, based on the request from several foreign institutions. Natural radiation burden from radon and thoron, especially in poorly ventilated dwellings is a known problem in several parts of the world, and the simple and effective development done at BARC is an important contribution.

**6. Physical Sciences**

Single crystals of copper and silver doped lithium-tetra-borate have been grown and they have been found suitable for dosimetry applications based on the optically stimulated luminescence technique.

**7. Chemical Sciences**

The feasibility study of in-house developed nano-diamond film as monitor of alpha activity of plutonium, in highly acidic medium, has been successfully completed.

A simple and inexpensive hydrogel-based material has been developed, which consists of nitrogen oxides releasing agarose gel, combined with citric acid loaded cotton gauze. It has excellent antimicrobial properties and has potential as a dressing material for ulcerative skin infections.

**8. Biological Sciences**

Towards developing radioprotector agents, an important finding has been made in experimental studies. 1,4-Naphthoquinone (NQ), a parent molecule for many anti-tumour natural compounds, protected lymphocytes and intestinal cells from mice against a dose of 4 Gy gamma radiation. In the mice, 2 mg/kg NQ given in-vivo restored radiation-induced bone marrow suppression.

**9. Codes Development**

A two-dimensional, multi-material Eulerian radiation-hydrocode, using Volume-of-Fluid tracking for material interfaces, has been developed, validated and applied to impact, penetration and ablative acceleration problems.

A code has been developed for generating equation-of-state (EOS) data covering orders of magnitude in density and temperature, necessary for radiation-hydrodynamics simulations. High-accuracy EOS data for expanded states of metals, required for modeling exploding wires, has been generated using ab-initio atomistic simulations.

**10. Food Technology**

The browning of cut fruits and vegetables is reduced in irradiated fruits and vegetables. For the first time, in a study conducted on pre-cut ready to cook ash gourd, it has been shown that gamma resorcylic acid liberated from its precursor during radiation processing acts as a natural inhibitor of polyphenol oxidase, the enzyme responsible for brown discoloration of cut fruits and vegetables.

Chips prepared from potatoes irradiated for sprout inhibition showed relatively lower levels of acrylamide (compared to non-irradiated potato controls), which is a neurotoxin and a probable carcinogen.

**11. Nuclear Agriculture**

A confectionary class large seed Trombay groundnut variety, TG 47, has been released for commercial cultivation in the name of Bheema for early kharif and rabi under irrigated conditions in all agro-climatic zones of Andhra Pradesh.

BARC produced 470 quintals of quality breeder seeds of recently released varieties and distributed...
to several state seed corporations, national institutes, state agricultural universities, NGOs and farmers for further utilisation.

Nisargruna technology was developed in BARC not only for disposing bio-degradable waste in an environment friendly manner, but also to produce high quality manure and fuel gas very efficiently. This technology has been widely deployed in our country. During the past year, 25 more such plants have become functional. This technology has now been extended to process large quantities of biological sludge generated in Effluent Treatment Plants (ETP) of textile, food and paper industries at Baddi (HP), Anjar (Gujarat), Kochi (Kerala) and Chandrapur (Maharashtra).

12. Isotope Applications

A dedicated 32 detector channel and Cs-137 radioisotope based process tomography imaging system, first of its kind in the country, was designed and developed in collaboration with the Indian Oil Corporation Limited (R&D Centre), Faridabad for applications in a packed cold-bed test reactor.

The first clinical use of BARC-produced Iodine-125 seeds for the treatment of prostate cancer was performed at the P.D. Hinduja National Hospital & Medical Research Centre, Mumbai on 29th September 2011 on a patient suffering from adenocarcinoma of prostate.

In collaboration with industry, radiation-grafted polypropylene based hydrophilic battery separator was developed by standardising various parameters. The separator was tested by the user industry and found suitable as a cost-effective import substitute.

13. Materials Programme

To qualify long design life of SS welds in advanced nuclear reactors (e.g. AHWR) and for life extension of existing reactors, the kinetics of low temperature embrittlement (LTE) was established for austenitic stainless steel welds. The electrochemical techniques developed to characterise the degree of LTE can be applied in a non-destructive manner and for in-situ use in plants.

In connection with the Indian contributions to the ITER project through Test Blanket Module (TBM) programme, BARC has developed pump-driven liquid metal loops for Pb-17Li and successfully operated them continuously for over 1000 hours. Pump and many of the key components for the loop have been fabricated in-house.

Towards commercial level development of Indian rare earth products, Nd-Fe-B alloy powder was synthesised for making permanent magnets in molybdenum crucible involving reduction-diffusion process.

14. Electronics & Instrumentation

ASICS

Three new ASICs - ANUSPARSH, ANUDRISHTI and ANUSUCHAK in 0.35 μm CMOS technology were designed, developed and tested successfully. The ANUSPARSH is front-end readout for Resistive Plate Chamber detectors of INO (India based Neutrino Observatory), the ANUDRISHTI is a monolithic photodiode and readout electronics for compact gamma detection probes and the ANUSUCHAK is low power front-end readout for silicon PIN Detectors.

To facilitate electromagnetic survey of deep seated mineral deposits, a Time Domain Electromagnetic (TDEM) system with 22 m dia transmitter coil and 1.1 m dia receiver coil has been tested using military helicopter DHRUVA of HAL for its airworthiness and found satisfactory. This is an important indigenous development to accelerate and support the expanded exploration of uranium in the country.

Face Recognition System

Face recognition systems developed by BARC for access control have shown highly promising results (with only 0.7% false acceptance). This is of high importance for a variety of integrated biometric access control systems as defence-in-depth.

Differential Micro Barometer

As an important import substitute, a Differential
Micro Barometer to measure very small atmospheric pressure variations of the order of microbars around the mean atmospheric pressure in infrasonic range has been developed. This important challenging development, benchmarked against intervening specifications in time-domain and frequency domain, has given highly satisfactory performance on evaluation under varying temperature and wind conditions.

15. Accelerator & High Power Electronics

**Dual Energy Compact Linear Accelerator:**
A 3/6 MeV dual energy compact linear accelerator for X-ray cargo scanning applications is in an advanced stage of development. The sub-systems consisting of a 85kV electron gun and its modulator power supplies, Linac cavity, magnetron source and modulator, focusing magnet, X-ray target and collimator have been developed and sub-system integration is in progress.

**Electromagnetic Manufacturing System**
A 20kV, 40 kilo-joule Electromagnetic Manufacturing System for use in cold welding of dissimilar metals has been developed. The system consisting of several special components and features will be used for joining FBR clad tubes of D9 alloy with SS end plugs, and future applications of joining ODS clad tubes and end plugs.

16. Advanced Technologies

**Cryo-Technology**
In-house developed micro cryo-cooler unit was integrated successfully with Hand Held Thermal Imager meant for night vision device to provide 250 mW cooling for the sensors at 77 K and handed over to EME School, Baroda, along with supporting hardware.

**Desalination**
Towards building indigenous capability for Thin Film Composite Polyamide membrane technology, the first batch of such membranes for reverse osmosis has been prepared and spirally rolled to commercial size elements. Six of these elements are now ready for replacing the membrane elements in reverse osmosis plant at NDDP, Kalpakkam.

17. Robotics and Remotisation

**Automated Material Transfer System (AMTS)**
An Automated Guided Vehicle (AGV) based material transfer system has been designed and developed in BARC. It performs continuous real-time assessment of demand for transfer of materials between various processing units in a manufacturing plant, and accordingly plans, prioritises and executes transfers autonomously. The system demonstrated to potential users, manufacturers and media will be deployed shortly on an experimental basis at Bajaj Auto Plant at Akurdi, Pune.

**Four-Piece Servo Manipulator (FPSM)**
Four-Piece Servo Manipulator (FPSM) recently developed by BARC is a novel design of servo manipulator, that can be used in place of any telescopic mechanical master slave manipulator. Using this easily maintainable FPSM, operators can handle objects in hot cells with less effort, compared to mechanical manipulators.

**Contribution to Indigenous Teletherapy System**
Prototype of a fully automatic, Multileaf Collimator (MLC) has been designed and developed for Bhabhatron-II telecobalt machine. The performance of the MLC was comprehensively tested on Bhabhatron-II telecobalt machine at ACTREC.

18. Societal Outreach and Technology Transfer

**Technology Transfer**
Two new technologies, namely, Quadrupole Mass Spectrometer and Dip and Drink Membrane Pouch were transferred to industry. Eight technology licenses to industry were renewed.

**DAE Societal Initiative and Infrastructure Programme**

1) Underground water source with capacity of 30,000 l/h has been identified, using Isotope
Hydrology technique in a village called Nimkhed in Amravati District, a water-scarce area (under AKRUTI Programme).

ii) Tissue culture laboratory with field hardening facility of 50,000 banana plantlets has been made operational and first batch of hardened plantlets have been sown in the field in AKRUTI programme at Amravati, Maharashtra.

iii) A Brackish Water RO plant with 300 l/h capacity has been set up in a coastal village called Farare in Dapoli through AKRUTI programme. The villagers have been trained to operate, run and maintain the plant.

iv) To promote AKRUTI programme in the rural sector in a more structured way, BARC has signed MoU with Shri Vithal Education Research Institute-‘SVERI’ Pandharpur to set up DAE Outreach Centre in the form of Rural Human and Resource Development Institute (RHRDI) at Pandharpur in SVERI campus.

19. Medical Services

Medical Division, BARC is providing healthcare facilities to entire Mumbai based CHSS beneficiaries through its 390-bed hospital, 12 zonal dispensaries, 2 occupational health centers, and 24-hour Casualty facility. New facilities and upgrades continue to be added at the BARC hospital. The total number of beneficiaries as on 30th September 2011 stands at 87,080.

Dear Colleagues,

Coverage of the highlights of contributions by more than 15,000 persons, spanning across all scientific and technological disciplines, and even without a mention of our considerable role in the strategic domain, is impossible in a short time. All omissions in my speech are purely due to time constraints and do not in any way undermine the importance and the value of all such work.

The year 2011 has been a challenging year for the entire nuclear programme and industry, not only in India, but also the world over. This has been mainly due to the unfortunate events in Japan – Fukushima Dai-ichi that was a consequence of the unprecedented natural twin disasters - massive earthquake, (9.2 on Richter scale), and Tsunami (of over 15 m height) - that struck Japan in March this year. While we need to remain fully cognizant and objectively responsive to these developments, it is imperative yet that we remain firmly committed to our well-established programmes and strategies based on our scientific and technological strengths and core competencies in the nuclear field. This is extremely essential to meet the country’s growing energy demands as well as making sustained advances in the standard of living and quality of life for the society at large. Recent events have also highlighted the necessity to further strengthen our societal outreach programme. We are active in this direction and taking new initiatives.

We have recently finalised XII-plan project proposals for submission to the Planning Commission. The envisaged targets and plans can only be achieved by dedicated team efforts and multi-disciplinary collaboration and co-operation. I would like to reiterate that we have plenty of challenges ahead in effectively contributing to the envisaged massive growth in the nuclear power and radiation technology applications sector in the country. The history of our Department bears ample testimony to the fact of our coming on top of all hurdles that came our way through determination and strength borne out of our ingrained culture of self-reliance. With the synergetic effort of all of us, I am sure, we can, and we shall rise to the occasion to meet these challenges in a manner consistent with our professional and cultural tradition.

Friends, on this very special day, let us yet again firmly resolve and rededicate ourselves to continue our pursuit of excellence and relevance in the frontier areas of nuclear science and technology for the betterment of life of our people.

Thank you – Jai Hind.”
23rd DAE All India Essay Writing Contest

The DAE All India Essay Writing Contest in Nuclear Science and Technology for students at the undergraduate level, was started by the department in the year 1989. Up till now, around 16,500 students have participated in this contest.

For this year’s essay contest, the three topics selected were:

Topic [1] - Relevance of Nuclear Power for future energy needs of India
Topic [2] - Radioisotopes and radiation technology for improving the quality of life

A total number of 267 essays were received, out of which, 253 were in English and the remaining 14 were in Hindi and other Indian regional languages. As has been the practice in the past, the essays were evaluated by a team of evaluators, forming 7 groups drawn from BARC and NPCIL. After preliminary evaluation, the essays were subjected to a normalization process within the groups. Depending on the ranking, some of the essays were short-listed and these essays were further evaluated for the final round of normalization. (Incidently, this year all the award winning essays were in the English language catagory.)

The first 12 contestants in the merit list for Topics 1 & 2 and 7 contestants in the merit list for Topic 3 were invited to Mumbai, to visit various facilities of the Department of Atomic Energy and also to make an oral presentation of their essays. Due to ongoing semester examinations of some engineering and science courses, 4 students could not be present...
Topic 1: Relevance of Nuclear Power for Future Energy Needs of India

I Prize winner

Mr. S. Royal Prince  B. Tech. II  Coimbatore

II Prize winner

Mr. Samrat Bhattacharjee  B. Sc. II  Kolkata

III Prize winner

Mr. Pratyay Raha  B. Sc. II  Kolkata

Consolation Prize Winners

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Name of Essayist</th>
<th>Student of</th>
<th>Place</th>
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<tbody>
<tr>
<td>1</td>
<td>Mr. Mandar Dilip Bhagwat</td>
<td>B.E. II</td>
<td>Amravati</td>
</tr>
<tr>
<td>2</td>
<td>Miss Deepti Gehlot</td>
<td>B.E. IV</td>
<td>Jodhpur</td>
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<tr>
<td>3</td>
<td>Mr. B. Vamsi Krishna</td>
<td>B.Tech. III</td>
<td>Vijayawada</td>
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<tr>
<td>4</td>
<td>Mr. A. Ramesh Pandian</td>
<td>B.Sc. III</td>
<td>Tiruchendur</td>
</tr>
<tr>
<td>5</td>
<td>Mr. Y. Sai Saketh</td>
<td>B.Tech. IV</td>
<td>Shamshabad</td>
</tr>
<tr>
<td>6</td>
<td>Miss H. Sindhuja</td>
<td>Bio. Tech. III</td>
<td>Chennai</td>
</tr>
<tr>
<td>7</td>
<td>Mr. Manas P. Thube</td>
<td>B.Sc. III</td>
<td>Mumbai</td>
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Topic 2: Radioisotopes and Radiation Technology for Improving the Quality of Life

I Prize winner

Miss Poulomi Ghosh  M.B.B.S. II  Kolkata

II Prize winner

Mr. Afsal K.  B.Sc. II  Malappuram

III Prize winner

Mr. Mirza Yaseem Baig  B. Tech. II  Coimbatore
Consolation Prize Winners

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<td>B.E. IV</td>
<td>Amravati</td>
</tr>
<tr>
<td>2</td>
<td>Miss Sayali Atul Bhatkar</td>
<td>B.Sc. I</td>
<td>Ratnagiri</td>
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<tr>
<td>3</td>
<td>Miss Bhoomi Choukse</td>
<td>B.E. III</td>
<td>Indore</td>
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<tr>
<td>4</td>
<td>Miss Safna Banu K.</td>
<td>B.Sc. II</td>
<td>Malappuram</td>
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<td>5</td>
<td>Miss Arsina Rahman K. K.</td>
<td>B.Sc. II</td>
<td>Malappuram</td>
</tr>
<tr>
<td>6</td>
<td>Miss Paloma Noronha</td>
<td>B. Sc. II</td>
<td>Mumbai</td>
</tr>
<tr>
<td>7</td>
<td>Miss Dike Manasee Shantaram</td>
<td>B.Sc. II</td>
<td>Ratnagiri</td>
</tr>
</tbody>
</table>


I Prize winner

| Mr. Indranil Chakraborty | B.SC. II | Kolkata |

II Prize winner

| Miss G.L. Sampoorna | B.E. IV | Secundrabad |

III Prize winner

| Miss Joanna D. Philips | B. Sc. III | Rajkot |

Consolation Prize Winners

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<tr>
<td>1</td>
<td>Ms Angel Kuriakose</td>
<td>B.Sc. III</td>
<td>Malappuram</td>
</tr>
<tr>
<td>2</td>
<td>Ms V. Nagarathinam</td>
<td>B.Sc. III</td>
<td>Madurai</td>
</tr>
<tr>
<td>3</td>
<td>Ms Juhika Nagrale</td>
<td>B.Tech. IV</td>
<td>Hyderabad</td>
</tr>
<tr>
<td>4</td>
<td>Ms A. Monica Viji</td>
<td>B.Sc. II</td>
<td>Kovilpatti</td>
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Industrial Safety Awards-2010

As part of safety promotional activities, the Industrial Hygiene and Safety Section of Radiation Safety Systems Division (RSSD), HS&EG, BARC has introduced an Industrial Safety Award Scheme in the form of Director’s Safety Shield on rotation, exclusively for BARC units.

The entries from the various Divisions/Sections/Units of BARC for the year 2010 were invited from three different categories of units/facilities, namely:

A: Operating Plants
B: R&D Labs and Industrial Units
C: Engineering, Projects and Support Units

On the occasion of the entries made and a comparative study of all the entries in each Category was carried out, based on the different parameters in respect of Safety Statistics and Safety Management Indicators including that of training and motivational efforts.

On the occasion of the Founder’s Day Programme at the Central Complex Auditorium, BARC, Shri N.D. Sharma, Controller, BARC and Chairman, Industrial Safety Award Scheme Committee and Conventional and Fire Safety Review Committee announced the winning units of the industrial safety awards for the year 2010 as follows:

A. **Operating Plants**: Centralised Waste Management Facility (CWMF), Kalpakkam.

B. **R&D Labs and Industrial Units**: FOTIA Facility, LEHIPA Project.

Representatives from the respective units received the shield from Dr. R.K. Sinha, Director, BARC. The award comprised one Rotating Shield and a small replica for retention by the respective winning units.

On behalf of CWMF, Kalpakkam, Shri Kanwar Raj, Head, WMD, Dr. P.K. Sinha, Plant Superintendent, CWMF, and Smt. S. Chitra, Safety Coordinator, CWMF received the shield.

Dr. Pitamber Singh, Project Manager, LEHIPA Project received the shield on behalf of FOTIA Facility (LEHIPA Project).

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Category A: Operating Plants: Dr. P.K. Sinha, Plant Superintendent, CWMF, Shri Kanwar Raj, Head, WMD and Smt. S. Chitra, Safety Coordinator, CWMF receiving the Safety Shield at the hands of Dr. R.K. Sinha, Director, BARC.

Category B: R&D Labs and Industrial Units: FOTIA Facility, LEHIPA Project: Dr. R.K. Sinha, Director, BARC giving away the Safety Shield to Dr. Pitamber Singh, Project Manager, LEHIPA Project.
BARC CELEBRATES FOUNDER’S DAY

Release of the Founder’s Day Special issue of the BARC Newsletter

As a tribute to our founder Dr. Homi Jehangir Bhabha, the Scientific Information Resource Division publishes the Founder’s Day Special Issue of the BARC Newsletter every year. This issue carries the R&D achievements of BARC scientists and engineers, which have received awards and honours at various national and international fora, during the preceding year. The 2011 issue carried a record number of 102 award winning papers, out of which 47 were DAE Scientific & Technical Excellence Award papers in Science, Engineering and Technology and others were Merit Award papers. The special feature of this special issue has been a substantial reduction in the use of paper. All the award winners uploaded their papers directly through a special weblink created on the BTS. As in the previous year, this issue has been brought out only in the CD format. Dr. R.K. Sinha, Director, BARC, released the CD containing the Founder’s Day Special issue of the BARC Newsletter.

From R-L: Dr. R.K. Sinha, Director, BARC, releasing the CD containing the Founder’s Day Special issue of the BARC Newsletter, Dr. S. Banerjee, Chairman, Atomic Energy Commission and N.D. Sharma, Controller, BARC
Nuclear energy as a source of electric power has had a very promising start; it promised an unlimited, safe and environmentally benign source of energy. Making a small beginning in 60s, it had a phenomenal growth in 70s and early 80s with about 18 power reactors being commissioned every year. By 1987 the world had 300 power reactors operating with an installed capacity of about 285 GWe. However, over this period, it also started facing an unique and essentially non-technical problem; a problem of perception. On the one hand there continued to be claims that nuclear energy is safe and environmentally benign. On the other hand, a perception had developed that it is disastrous to the environment and detrimental to the safety of the workers and public of not only the present generation but also that of our progeny. Added to this, around this period, two severe accidents occurred in nuclear power stations, the Three Mile Island (TMI) in USA in 1979 and Chernobyl in USSR in 1986. Consequently the nuclear power programme slowed down considerably with only a few reactors being added in 90s. By 2000, the number of nuclear power reactors in the world stagnated around 440. Around this time, the perceptions started getting changed again. So far, the fossil-fuelled power stations, particularly the coal-fired ones, have been the mainstay for electricity generation in the world. The gigantic release of CO$_2$ from these plants has been leading to continuous increase in the concentration of CO$_2$ in the atmosphere. Because of the fear that such an increase can result in global warming with disastrous consequences, there has been a serious rethinking of energy options. This has led to the rediscovery of nuclear energy as a viable and environmentally benign option and nuclear power programme was getting revived in several countries where it had been stopped or slowed down. India too, because of its compulsion to meet the power requirements of its galloping industrial progress and also to ensure energy security, embarked on an ambitious expansion of its nuclear power programme. It is at this stage that the incident at Fukushima– Daiichi nuclear power plant in Japan has occurred, creating considerable concern amongst the public. It is
necessary to address such concerns and reservations, as to what extent they are fact and experience based and to what extent they have come about because of our perceptions and assumptions.

Since all the public concern about nuclear energy has been essentially due to very large quantities of radioactivity with the associated ionising radiation in the power reactors and their effects on living systems. Of the two known classes of radiation effects, deterministic and stochastic, the deterministic effects, resulting from massive cell killing, occur due to high, acute exposures that are seen in major accidents or in medical treatment. Besides, there is a threshold of exposure only above which they occur. Hence this has not caused much of public concern. The second class of effects, called stochastic effects, arises out of the ‘mutagenic’ action of ionising radiation. In a biological cell the ‘Deoxyribonucleic acid (DNA)’, a macromolecule residing inside the nucleus, is the repository of all the information required for the cell functioning and its replication. The information in DNA is written in the form of a long sequence of certain chemical species called nucleotides. Ionising radiation can alter this sequence, either directly or indirectly interacting with DNA, and such an alteration is called mutation. If the mutation occurs in a germinal cell, it may be carried on to the progeny leading to genetic effects and if it is in a non-germinal cell, it may result in the loss of control over cell replication leading to cancer induction. The mutational effect is supposed to be cumulative over all the exposures for an individual, and over all the individuals for a community. Because of the high redundancy in the biological information and resilience of the biological systems, not every mutation will necessarily lead to detrimental effects. Hence it is dealt in terms of probabilities and risk coefficient/ factor. Risk coefficient is the number of defects likely to be introduced into the community due to unit community dose. A very crucial assumption made here is that the detriment is linearly proportional to the total exposure and that there is no threshold for this effect to manifest; that is, unlike in deterministic effect, which does not occur below a particular radiation exposure, however small the exposure is, the risk of stochastic effects exists. It is linearly proportional to the exposure and it is cumulative. This is called ‘Linear No Threshold (LNT)’ model. Despite the existence of a large amount of experimental as well as epidemiological data contradicting this assumption, it is made only ‘to be on the safe side’. Unfortunately, this ‘to be on the safe side’ assumption has resulted in undue scare in the minds of public.

The context of all the above arises due to the radiation exposures that could arise from nuclear power reactors. The exposures could be to the occupational workers or to the public and due to normal operations or accidents. Regarding the exposures during normal operation, enormous data has been acquired and analysed over the years and it is shown to be of insignificant detriment to the society. There have been three major accidents in nuclear power reactors- TMI in 1979 in USA, Chernobyl in 1986 in USSR and Fukushima - Daiichi, very recently in Japan. In the TMI accident, the reactor core did melt but the containment was intact and prevented the escape of radioactivity to the environment. Hence there was no accidental radiation exposure. However, in Chernobyl accident, the reactor core did melt, containment did not exist and there was a very large release of radioactivity to the environment. Hence there was no accidental radiation exposure. While discussing in detail about this accident and its health consequences, the point to be particularly noted is that based on the extensive measurement and analysis of the spread of radioactivity and consequent exposures, about 4000 excess leukemia and solid cancer deaths were projected to occur within 15 to 20 years of the accident. But so far, no death due to excess cancer has been observed. The large difference between the projection (prediction) and the actual observation appears to be a direct consequence of the LNT hypothesis used in the estimation of radiation effects. Amongst the public, 4000 cases of thyroid cancer which could be
attributed to the accident were reported, which, after treatment, have resulted in fifteen fatalities. Regarding the environmental impact of Chernobyl accident, in the highly contaminated area, amongst the plant species initially needle falling and inhibition of growth were observed; but over a short period, they completely recovered. There has been no loss of any plant or animal species and they continue to survive under chronic irradiation conditions. The area which is marked as exclusion zone because of it high level contamination has paradoxically become a sanctuary for biodiversity.

The incident that occurred at Fukushima - Daichi nuclear power plant in Japan was triggered by the unprecedented tsunami of dooms day proportions on March 11, 2011 and resulted in the partial melting of fuel in the reactor and damage to fuel in the storage bay. This led to the environmental release of very large quantities of radioactivity, about 10% of that of Chernobyl accident, a large part of which was released to the Pacific Ocean. It did result in a large scale terrestrial and air contamination in Japan. Large scale loss of life, about 15000 dead and 5000 missing, was reported following the tsunami incident, but not a single one of that could be attributed to radiation. Extensive measurements and analyses of the contamination, resulting radiation fields and consequent health effects are under progress now. Considering the Chernobyl experience and the fact that activity release in Fukushima accident was only 10% of that of Chernobyl, significant health effects are not likely. However the incident has created intense concern the world over and seriously affected the public confidence in nuclear power. One reason for the great scare in the minds of public about nuclear energy is our own ultra-conservative set of assumptions, such as LNT, in risk estimation. While it might have been justified earlier as a ‘to be on the safe side’ hypothesis, with large experience gained and data obtained so far, we need to have a re-look at such assumptions.

Experience so far, with routine operations of nuclear power reactors, as well as from the few accidents that have occurred, shows that its detrimental effects are far insignificant compared to its benefits to the society. Hence, while projecting risks of nuclear power, it is necessary to make a quantitative analysis of the risks against benefits in this option. Such an analysis touched upon in the talk will help arriving at objective conclusions and not be carried away by undue fear.

The full text of the paper in PPP form can be obtained from Dr. Gopinath at dvgopinath@gmail.com
The DAE awards scheme was instituted in the year 2006 to recognize outstanding accomplishments and exceptional achievements of the DAE staff, who are engaged in scientific research, technology development, engineering/project implementation, teaching, healthcare and support services.

These awards are given annually.

The awards for the year 2010 were given on the eve of Founder’s Day (October 30) which was celebrated this year on October 28, 2011 in BARC. These were presented to the winners by the Chief Guest, Dr. R. Chidambaram, Principal Scientific Advisor to the Government of India.

These Awards were in the following categories:

1. Homi Bhabha Science & Technology Awards
2. Scientific & Technical Excellence Awards
3. Young Applied Scientist / Technologist Awards
4. Young Scientist Awards
5. Young Engineer Awards
6. Group Achievement Awards
7. Special Contributions Awards
8. Meritorious Service Awards

1. Homi Bhabha Science & Technology Award carries a Cash award of Rs 5 Lakh, a Citation and a Medal. There were Seven award winners: Five from BARC and one each from VECC and IGCAR. Following were the award winners from BARC:

1. Shri R.M. Suresh Babu, CnID, E&IG, BARC

Shri Suresh Babu was awarded for his excellent contributions in the “Development of Safety Critical Software for Nuclear Power Plants”. Shri Suresh Babu, in the recent times, has been the lead developer of the LWR simulator for project B, which is a full-scope training simulator intended to familiarize and qualify the crew in the operation of the nuclear propulsion plant under normal, transient and accident conditions. Formidable challenges were overcome in developing this simulator and it was commissioned ahead of schedule. He leads the team engaged in developing software for the light water reactor (LWR) plant of project B1/B2 also.

2. Dr. Hirendra Nath Ghosh, RPCD, CG, BARC

Dr. Ghosh was awarded for his excellent research contributions in the field of “Ultrafast Laser Spectroscopy of Nano-structured Materials”. He carried out Femtosecond transient absorption studies detecting in the visible to mid-infrared region, which has been developed by him for the first time in India to gain deeper physico-chemical understanding of the nanostructured and quantum-dot material based solar cells.
He carried out Interfacial electron transfer studies on dye-nanoparticle-quantum dot systems in ultrafast domain.

3. **Shri Prashant P. Marathe**, CnID, E&IG, BARC

He was awarded for his excellent contributions in the field of “Control & Instrumentation for compact Light Water Reactors”. Shri Marathe executed under his leadership several important projects over the years. He is the principal architect of the main power plant control system (MPPCS) of the compact light water reactor (LWR) plant of project B1/B2.

He has been a key figure in finalizing MPPCS requirements for project B and also in finalizing the procedure for factory acceptance tests and in carrying out these tests at supplier’s premises.

4. **Dr. K.S. Pradeep kumar**, RSSD, HS&EG, BARC

He was awarded for his excellent contributions in the area of “Radiological Safety and Emergency Preparedness”. Dr Pradeep Kumar made immense contributions in conceptualization and planning for development of instrumentation, system integration, data collection & processing software and analysis methodologies required to develop a well planned emergency response mechanism to respond to nuclear disasters as well as nuclear/radiological emergencies both at nuclear facilities and in public domain. He was actively involved in setting up ERCs at 20 locations in the country which would go a long way in handling nuclear/radiological emergencies in public domain.
5. **Dr. P.K. Vijayan, RED, RDDG, BARC.**

Dr. Vijayan was awarded for his excellent contributions in the field of “Thermal Hydraulics of Indian Nuclear Reactor Systems”. His contributions are in thermal-hydraulic design and validation of nuclear reactors like AHWR, CHTR and PHWR-700 being developed in India. He established several major test facilities like ITL and FISBE which helped in finalizing the design of several passive safety features incorporated in the AHWR design. His contributions in the field of natural circulation loops, especially the generalized equation for the steady state flow is well recognized internationally. He played a key role in developing techniques for stabilizing natural circulation flow including a novel technique using nanoparticles.

Dr. R. Chidambaram, presenting the Homi Bhabha Science & Technology Award 2010 to Dr. P.K. Vijayan

2. **Scientific & Technical Excellence Award**

Carries a Cash award of Rs 1 Lakh, a Citation and a Medal. There were thirty eight award winners: Thirty two from BARC and Two each from IGCAR and VECC and one each from RRCAT and NFC. Following were the award winners from BARC:

1. Shri Anupkumar B., WSCD, CG, BARC
2. Dr. Y. K. Bhardwaj, RTDD, RC&IG, BARC
3. Shri Probal Chaudhury, RSSD, HS&EG, BARC
4. Dr. Niharendu Choudhury, TCS, CG, BARC
5. Dr. (Smt.) Nandini Garg, HP&SRPD, PG, BARC
6. Shri O.D. Jayakumar, ChD, CG, BARC
7. Shri K. Jayakumar, SO/G, LWRD/RPG/BARC
8. Dr. T. Jayasekharan, SO/E, ApSD/PG/BARC
10. Dr. Awadesh Kumar, SO/G, RPCD/CG/BARC
11. Shri Kundan Kumar, SO/G, RED/RDDG/BARC
12. Shri Ranajit Kumar, SO/H, CnID/E&IG/BARC
13. Shri Soumitra Kundu, SO/G, L&PTD/ BTDG/ BARC
14. Shri P.K. Limaye, SO/G, RTD/RDDG/BARC
15. Shri Vinay Kumar Mishra, SO/F, CDM/DMAG/ BARC
16. Dr. Subhankur Mitra, SO/F, SSPD/PG/BARC
17. Shri Dipankar Mukherjee, SO/G, QAD/NFG/ BARC
18. Shri D. Narain, SO/G, LWRD/RPG/BARC
20. Dr. Ashok Kumar Pandey, SO/G, RCD/RC&IG/ BARC
21. Dr. Harish Jagat Pant, SO/G, IAD/ RC&IG/BARC
22. Dr. P.N. Pathak, SO/F, RCD/RC&IG/BARC
23. Dr. Suprasanna P, SO/G, NABTD/BMG/BARC
24. Dr. R.C. Rannot, SO/H, ApSD/PG/BARC
25. Smt. Shilpi Saha, SO/F, CnID/E&IG/BARC
26. Dr. Debasis Sen, SO/F, SSPD/PG/BARC
27. Dr. Anubha Sharma, SO/G, BOD/CG/BARC
28. Dr. Aradhana Shirivastava, SO/F, NPD/PG/BARC
29. Shri Pawan Kumar Singh, SO/F, RSD/HS&EG/ BARC
30. Shri G. Sreekumar, SO/G, FRD/NRG/BARC
31. Dr. V. Sudarsan, SO/F, CD/CG/BARC
32. Dr. A. Vinodkumar, SO/G EAD/HS&EG/BARC.

3. **Young Applied Scientist / Technologist Award**

Carries a Cash award of Rs 50,000/-, a Citation and a Medal. There were nine award winners: four from BARC, two each from IGCAR and VECC and one from RRCAT. Following were the award winners from BARC:

1. Shri Kiran T. Badgujar, SO/F, TDD/ NRG/ BARC
2. Shri Soumitra Kar, SO/D, DD/ ChEG/ BARC
3. Shri Arshad Khan, SO/E & Shri Sanjay Singh, SO/D, RSSD/ HS&EG/ BARC
4. Shri Saurabh B. Pandharikar, SO/E, RTD/ RDDG/ BARC.

4. **Young Scientist Award** carries a Cash award of Rs 50,000/-, a Citation and a Medal. There were six award winners: five from BARC and one from RRCAT. Following were the award winners from BARC
   1. Dr. S.A. Ansari, SO/D, RCD/ RC&IG/ BARC
   2. Dr. Sharmistha Dutta Choudhury, SO/E, RPCD/ CG/ BARC
   3. Dr. Amit Kunwar, SO/D, RPCD/ CG/ BARC
   4. Dr. Dharmendra Kumar Maurya, SO/E, RB&HSD, BMG, BARC
   5. Dr. Rahul Tripathi, SO/E, RCD, RC&IG, BARC.

5. **Young Engineer Award** carries a Cash award of Rs 50,000/-, Citation and a Medal. There were seventeen award winners: twelve from BARC, each from VECC and IGCAR and one from BRIT. Following were the award winners from BARC
   1. Dr. Chandra Bhanu Basak, SO/E, MSD, MG, BARC
   2. Shri Monesh Chaturvedi, SO/E, RTD, RD&DG, BARC
   3. Shri Subrata Chatterjee, SO/E, RED, RD&DG, BARC
   4. Shri Dhirendra Kumar Jha, SO/E, A&CED/ESG/ BARC
   5. Shri K. V. Mani Krishna, SO/E, MSD, MG, BARC
   6. Shri Chirag A. Patel, SO(E), LWRD/RPG/BARC
   7. Shri Dipak D. Patel, SO/E, RCnD/E&IG/BARC
   8. Shri M. Kumar Raja, SO/E, RMP Mysore, BARC
   9. Shri Jitendra Kumar Sonber, SO(D), MPD, MG, BARC
   10. Shri A. Srivastava, SO/F, RSD, RDDG, BARC
   11. Shri A.K. Upadhyay, SO(E), DRHR / DMAG / BARC
   12. Dr. Abhijeet Mohan Vaidya, SO/E, RED, RD&DG, BARC.

6. **Group Achievement Award** winners received cash awards, a medal and a Citation. A total number of fifty nine Groups received these awards. Out of these, forty groups were from BARC, eight from IGCAR, four from RRCAT, two from NFC, two from VECC and one each from BRIT and HWB. One award was shared jointly by IGCAR and NFC. Following were the Group Leaders from BARC, who received the awards for their groups:
   1. Dr. M.G.R. Rajan, Head, RMC, BMG, BARC
   2. Dr. A.K. Ghosh, Director, HS&EG, BARC
   3. Shri R.P. Singh, Director, NFG, BARC
   4. Shri H.S. Kamath, Former Director, NFG, BARC
   5. Shri Surender Kumar, SO(H+), WMD, NRG, BARC
   6. Shri Kanwar Raj, Head, WMD & Dr. P.K. Sinha, Plant Supt., CWMF, NRG, BARC
   7. Dr. S. Kailas, Director, PG, BARC
   8. Dr.(Smt.) Grace Samuel, SO(G) Radiopharmaceuticals Division, RC&IG, BARC
   9. Shri V.K. Mehra, Director, ESG, BARC
   10. Dr. S. C. Gupta, Head, APD & Project Manager, EHPPL, BARC
   11. Dr. D.J. Biswas, SO/H, L&PTD, BTDG, BARC & Dr. J. P. Panakkal, Head, AFFF, NFG, BARC
   12. Dr. K.C. Mittal, OS, Project Manager, EBC, BTDG, BARC
   13. Shri P.K. Gupta, SO/H+, ChEG, BARC
   14. Dr. V.K. Suri, OS, ChTG, BARC
   15. Shri G. Gouthaman, Associate Director, CTG BARC
   16. Dr.(Smt.) S.R. Bharadwaj, SO/H+, Chemistry Division, CG, BARC
   17. Shri S.B. Jawale, Head, CDM, DM&AG, BARC
   18. Shri S.K. Parulkar, SO/H+, Computer Division, E&IG, BARC
   19. Dr. Shashank Chaturvedi, Head, Computational Analysis Division, E&IG, BARC-Vizag
   20. Shri Ram Kishan, OS, TSD, ESG, BARC
   21. Shri S. Soundararajan, Head, IHS Section RSSD, HS&EG, BARC
   22. Dr. K.S. Pradeepkumar, SO/H, RSSD, HS&EG, BARC
BARC CELEBRATES FOUNDER’S DAY

23. Shri S.K. Satpati, SO/F, UED, MG, BARC
24. Shri B.G. Naik, Dy. Manager, SMMF, MG, BARC
25. Dr. P.K. Pal, SO/H, DRHR, MG, BARC
26. Shri R.P. Singh, Director, NFG, BARC
27. Shri M.N.B. Pillai, SO/H, RMD, NFG, BARC
28. Shri V.K. Savarkar, SO/H+, NRB, BARC
29. Smt. Uma Devi, SO/F, TNRPD, NRB, BARC
30. Dr. G. Sugilal, SO/G, TDD, NRG, BARC
31. Dr. Amar Sinha, SO/H+, Project Manager, NXP, PG, BARC
32. Shri V. Nataraju, SO/G, TPD, PG, BARC
33. Dr. Ashutosh Dash, SO/H, RPhD, RC&IG, BARC
34. Dr. S.V. Godbole, SO/H, RCD, RC&IG, BARC
35. Shri K.S.S. Sarma, Head, EBPS, RTDD, RC&IG, BARC
36. Dr. N.K. Maheshwari, SO/H, RED, RDDG, BARC
37. Shri D.S. Pilkhwal, SO/H, RED, RDD, BARC
38. Shri A. Bhowmik, SO/H+, Refining Facility, RMP, BARC
39. Shri I.S. Girigoudar, SO/H, RMP Mysore, BARC
40. Shri T.K. Bera, Director, CTG, BARC, Demonstration Facility, RMP, BARC

7. Special Contributions Award carries a cash award of Rs. 50,000/-, a Citation and a Medal. There were eighty five award winners; eighty one were from BARC, three from DAE and one from DCSEM. Following were the award winners from BARC:

1. Shri P. Nagaraju, TSD, BARC
2. Shri V.K. Savarkar, NRB, BARC
4. Shri D.K. Lalsare, NRB, BARC
5. Shri Hanmanth Rao, ChED, BARC
6. Shri A.S. Kalsi, CTD, BARC
7. Shri Rajendra S. Menon, Cryo-Tech. Dn, BARC
8. Shri S.P. Srivastava, CDM, BARC
9. Shri C.P. Mahajan, CDM, BARC
10. Shri J. Yadav, CDM, BARC
11. Shri K.N. Patnaik, ESD(V), BARC
12. Ms. P.D. Sawant, HPD, BARC
13. Shri D.S. Kurkure, SMMF, BARC
14. Shri M.M. Hussain, AFD, BARC
15. Shri G.W. Diwan, AFD, BARC
16. Shri B.N. Rajesh, AFFF, BARC
17. Shri R.B. Bhatt, AFFF, BARC
18. Shri A.B. Kamble, ED&D, BARC
19. Shri K.B. Deore, ED&D, BARC
20. Shri V.N. Garje, ED&D, BAEC
21. Shri R.B. Saindane, ED&D, BARC
22. Shri Rajesh Singh, ED&D, BARC
23. Shri S.R. Mhatre, ED&D, BARC
24. Shri Rajendra Prasad, MFD, BARC
25. Shri B.N. Sen, MFD, BARC
26. Shri R.K. Jha, MFD, BARC
27. Shri A.A. Coutinho, MFD, BARC
28. Shri S.D. Patil, MFD, BARC
29. Shri A. Waseem, MFD, BARC
30. Shri S. Murugaiah, TMU, BARC
31. Shri G.K. Prasad, FCD, BARC
32. Shri K.B. Modi, PDD, BARC
33. Shri A.V. Patil, PDD, BARC
34. Shri S.P. Kulkarni, PDD, BARC
35. Dr. S.K. Mukherjee, FCD, BARC
36. Shri M.Y. Ali, RCD, BARC
37. Dr. T.K. Seshagiri, RCD, BARC
38. Dr.(Smt) Neelam Goyal, RCD, BARC
39. Shri R.K. Mahajan, LWRD, BARC
40. Shri H. Krishnan, LWRD, BARC
41. Shri P. Kelkar, RED, BARC
42. Shri V. Padmanabhan, Director’s Off. BARC
43. Shri P.C. Krishnakumar, Director’s Off. BARC
44. Shri A.M. Rawool, APD, BARC
45. Shri A.V. Patil, APD, BARC
46. Shri A.B. Kalsarpe, APD, BARC
47. Shri H.C.M. Pillay, HPD, BARC
48. Shri M.B. Baiju, WMD, BARC
49. Shri G.P. Verma, RSSD, BARC
50. Shri J.K. Divkar, RSSD, BARC
51. Shri H.D. Badgujar, MFD, BARC
52. Shri D.G. Mishra, HPD, BARC
53. Shri P. Krishnakumar, RSSD, BARC
8. **Meritorious Service Awards** carry a cash prize of Rs. 20,000/-, a citation and a medal. There were 25 Award winners. Sixteen were from BARC, 6 from IGCAR and one each from DPS, RRCAT and DAE Secretariat. Following were the award winners from BARC:

1. Smt. Pratibha J. Achrekar, Assistant, PD, Adm. Group, BARC
2. Shri I.K. Agarwal, T/H, DRHR/DM&AG/BARC
3. Shri Subhash Narayan Bhosle, T/G, RED/RDDG/BARC
4. Shri Parshotam Dass J., F/B, PD/BARC
5. Shri David Edwards, Technical Supervisor (B), ED&DD/ NFG/ BARC
6. Shri K. Gopidhas, Sr. Technician/H, RRMD/ RG/ BARC
7. Shri K.U. Johnson, T/G, Fab. & Maint. Section/ RMP/ BARC
8. Shri K.D. Koli, F/B, RMD/ NFG/ BARC
9. Shri M.J. Naidu, F/B, CDM/ DMA/ BARC
10. Shri R.R. Nair, SA/G, FRD/ NRG/ BARC
11. Shri Tukaram P. Patil, F/B, ROD/ RG/ BARC
12. Shri P.V. Radhakrishnan, F/C, AFD/ NFG/ BARC
13. Shri Pratap Singh Ramsaran, Driver Gr.I, Director’s Office, BARC
14. Shri A.R. Singh, Dr. Grade-I, Transport/ PD/ BARC
15. Smt. Sangita R. Wadaskar, AAO, AD/ Adm. Group/ BARC
16. Shri P.A. Wagh, AF/M, TP&PED/PG/BARC
Aluminium Foam Fabrication by Powder Metallurgy Route

C. Umashankar, Kaushal Jha and K.N. Mahule
Engineering Design & Development Division
and
T.R.G. Kutty
Radiometallurgy Division

Abstract
Aluminium foams play a key role in providing a cushion for absorption of shock and impact. They have also found increasing applications in a wide range of structural and functional products, due to their exceptional mechanical, thermal, acoustic, electrical and chemical properties and offer great potential for lightweight structures. Aluminium foam structures have densities only fractions of that of a solid structure and have high specific strength and stiffness. They have excellent properties for absorption of impact energy, vibration and sound. In this paper, a process for development of aluminium foam by powder metallurgy route has been discussed. The metal foaming process is based on a procedure where uniform mixing of aluminium powder and foaming agent is done and compacted in a cold isostatic press. The compacted billet is extruded. The extruded billet is heated up to foaming temperature. The heating process leads to partial metal melting with the release of the foaming gas. Aluminium foam having a density of around 0.3 g/cm$^3$ have been fabricated. The effects of various fabrication parameters like compaction pressure, extrusion ratio, foaming temperature are discussed. The above-mentioned, Aluminium foams are characterized in terms of density, microstructure, porosity content. It is necessary to obtain various mechanical properties like yield strength, tensile strength and impact energy for metal foam to understand the behaviour of foam under different conditions.

Keywords: Aluminium Foams, Cellular Microstructure, and Compressive behaviour

Introduction
Metal foam has a lot of promising industrial applications and most important among them is shock mitigation. Among the metal foams, Aluminium foam deserves a special place as it has high specific strength and higher stiffness than other contemporary packaging materials.

The Aluminium foams were not manufactured indigenously in the past. Their cost of procurement is exorbitant. Therefore, development of Aluminium foam by indigenous means has become a necessity. The foam is defined as a uniform dispersion of gas bubbles in a liquid, separated by thin film of liquid making a cell or pore. This morphology when preserved in solid state is known as solid foam or cellular solid. If we consider the structural aspects of metal foam, there are three most common cell structures, namely, open cell structure, closed cell structure and the combination of the above two. Recently, a novel structure has been developed, which is known as lotus-type growth structure consisting of long cylindrical pores aligned in one direction. The open cell structures incorporate interconnected pores, whereas, in closed cell structures, a metallic thin wall surrounds pores.

Solid metallic foams are known for their interesting combinations of physical, mechanical, thermal, electrical and acoustic properties such as high stiffness in conjunction with very low specific weight or high compression strengths combined with good
energy absorption characteristics. They are a newclass of materials, offer potential for lightweight structures, for energy absorption and for thermal management. Aluminium foams are isotropic porous materials with several unusual properties that make them especially suited for engineering applications. Due to their low densities between 0.3 g/cm$^3$ and 0.8 g/cm$^3$ the foams can float in water (in case of closed porosity). They exhibit a reduced conductivity for both heat and electricity. The strength is lower than conventional dense aluminium and declines with decreasing density. Foams are stable at temperatures up to the melting point. The metal foaming process is based on a procedure consisting of a base metal and a foaming agent, which are mixed by milling and pre-compacted by cold isostatic pressing. This is followed by cold/warm extrusion. The extruded piece is then heated up to a foaming temperature. The heating process leads to partial melting as well as the release of the hydrogen gas and consequently leads to the material foaming in the semi-solid state.

**Experimental**

In this process, aluminium powder is weighted and mixed with 2-3.5% TiH$_2$ powder. The powders are milled in a High-Energy Stirred Ball mill at 100 rpm for 6 hours. The milled powder is removed, packed and sealed inside silicon rubber mould. The weighing, mixing and sealing operation is carried out inside an inert atmosphere enclosure. The tapped density of the powder as calculated analytically, was 76% of theoretical value.

The sealed mould is cold isostatically compacted to a pressure of 2500-3000 bar for 1 min. The density obtained is nearly 96% of theoretical density. For, better and uniform mixing and to achieve a density as close as to theoretical density, the isostatically compacted billet is extruded in an extrusion machine with an extrusion ratio of 1:16. The extruded billet was sealed and stored in an inert atmosphere to prevent oxidation. The billets are cut into 100mm long pieces, which are to be heated in an induction furnace. The furnace was pre-heated to 740°C before starting the foaming operation. The extruded pieces are kept inside a one end closed quartz tube having an inside diameter of 35 mm. The quartz tube is inserted inside the furnace. The furnace temperature drops due to the quartz tube insertion. The furnace is allowed to stabilize to 740°C. The foaming starts immediately once the temperature of billet reaches 740°C. The foam expands and takes the shape of quartz tube. Once the foam touches the wall of the quartz tube, it is immediately withdrawn from the furnace. The quartz tube is cooled immediately to get good quality foam.

The foaming was tried at different temperatures and the best foaming temperature obtained is 740°C. The holding time also has been varied. It was found at lower holding time of < 60sec the density was higher and if holding is >120sec the drainage of the melt occurs resulting an increase in density. Hence, the optimum holding time established was 60 to 120s.

To conclude, the best foaming parameters in this study are as given below:

- Compaction pressure: 2500-3000 bar
- Extrusion: 200-250°C
- Extrusion ratio: 1:16
- Foaming temperature: 740°C
- Holding time: 60 to 120 sec
- Cooling: water quenching

**Characterisation**

The powder route is the best method to obtain good quality foam with relative densities as low as 10%. The microstructures of Aluminium foam obtained using powder route are shown in the figures below. The density of the foam obtained using powder process was found to be in the range of 0.2 to 0.3 g/cc depending upon the fabrication parameters. From the figures, it is evident that pores are uniformly distributed and their size varies from 2 to 5 mm. The shape of the pores was irregular in most cases. Typical cell structures showing the pore shape and size distribution are shown in Fig. 1.
The exact cell wall thickness measurements were carried out using SEM. Some typical SEM pictures are given in Fig. 2.

The Figure shows a low magnification image depicting the pore distribution and the cell walls in the aluminium matrix. It was observed that the cell wall thickness was not uniform and found to vary between 200-500 μm.

**Density measurement**

The overall density of a porous material is determined by Archimedes’ principle. The density of the foam obtained using powder metallurgy route was found to be in the range of 0.2 to 0.9 g/cc depending upon the fabrication parameters.

**X-ray radiography**

The defects in the cellular metals can be detected by simple X-ray radiography techniques. X-ray radiography as shown in Fig. 3 reveals some of the very large pores, but it is impossible to resolve most of the small pores. The radiography also revealed the absence cracks and the uniform distribution of pores in the Al matrix.

**Compression Test results**

Ideal energy absorbers have a long flat stress–strain (or load-deflection) curve like those of Figs. 4a & b. The absorber collapses plastically at a constant nominal stress, called the plateau stress, $\sigma_{pl}$, up to a limiting nominal strain, $\varepsilon_D$. Energy absorbers for packaging and protection are chosen such that, the plateau stress is just below which shall cause damage to the packaged object. The best choice is then the one, which has the longest plateau, and therefore absorbs most energy before reaching $\varepsilon_D$.

The area under the curve, roughly $\sigma_{pl}\varepsilon_D$, measures the energy the foam can absorb, per unit initial volume, up to the end of the plateau. Foams which have a stress–strain curve like that shown in Fig. 4 perform well in this $\sigma_{pl}$ function [1-6].

The characteristics of aluminium foam are best described by the material from which it is made, its relative density, $r/r_s$ (the foam density, $r$, divided by that of the solid material of the cell wall, $r_s$) and stating the pores/cell being closed or open. The foam properties are influenced by structure, particularly by anisotropy and defects. The structure of foam is like those of soap films: polyhedral cells with thin cell faces bordered by thicker cell edges (plateau...
borders). The features are governed by surface energy, as they are in soap films[10-11].

Compression testing is carried out using an Instron machine. The samples used for compression testing are of 35mm in diameter, and length varying from 35 mm to 70mm. In short, we used sample with L/D ratio varying from 1 to 2. Fig. 5 Shows some of the samples with relative densities in the range of 0.2-0.3 gm/cc on which the compression tests were carried out. The tests were carried out with a cross head speed of 60mm/min.

### Results and discussion

Aluminium foams are isotropic porous materials with several unusually properties that make them especially suited for some applications. They are incombustible, non-toxic and 100% recyclable. Due to their cellular structure, foams behave differently in testing when compared to conventional metal. The test that gives meaningful results is the compression test. A typical compressive stress-strain diagram for cellular materials consists of three parts:

- In foams irreversible (plastic) deformations can occur at low stresses.

<table>
<thead>
<tr>
<th>S.No</th>
<th>Description</th>
<th>Dimensions (mm)</th>
<th>Density g/cc</th>
<th>Relative density</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Al + 2-3.5% TiH₂</td>
<td>D=35L=70</td>
<td>0.29</td>
<td>0.11</td>
</tr>
<tr>
<td>2</td>
<td>Al + 2-3.5% TiH₂</td>
<td>D=35L=52</td>
<td>0.27</td>
<td>0.10</td>
</tr>
<tr>
<td>3</td>
<td>Al +20%Mg + 2-3.5% TiH₂</td>
<td>D=35L=46</td>
<td>0.23</td>
<td>0.08</td>
</tr>
<tr>
<td>4</td>
<td>Al + 2-3.5% TiH₂</td>
<td>D=35L=35</td>
<td>0.37</td>
<td>0.13</td>
</tr>
</tbody>
</table>

a) The first stage is not only caused by an elastic deformation as it is in the case of dense metals.

Fig. 4(a): Ideal Force-Displacement (b) Ideal Stress-Strain Curves for foam

Fig. 5: Aluminium foam samples used for compression testing (Front view)

Fig. 6: Stress-strain curve for different alloys of aluminium
b) The plateau is caused by a homogeneous plastic deformation.

c) The steep increase is caused by the collapse of the cells. The opposing cell walls begin to touch each other.

The properties of the foam are influenced by the following factors:

a) The properties of the solid of which the foam is made.

b) The topology (connectivity) and shape of the cells.

c) The relative density $\frac{n}{n_s}$ of the foam.

In most foam production technologies the properties can be varied over a wide range by controlling the production parameters. It shows a linear increase of stress at the beginning of deformation and a plateau regime of nearly constant stress in the middle, followed by a steep increase in flow stress at the end.

Aluminium foams made by Powder metallurgy route, the length of the plateau increases with decreasing density as show in Fig. 7. The energy absorption of Aluminium foam is 0.15kJ. The compressive strength as observed is 1-3 MPa at a densification strain of 70 to 90%. As, observed during compression testing the Young's modulus of foams increase with increasing density. Therefore, one can fabricate the foams having different plateau stress and Young's modulus.

Acknowledgements

I thank Shri H.S. Kamath, Ex-Director, NFG, Shri R.P. Singh, Director NFG and Head Atomic Fuels Division, Shri M.M. Hussain, Head Mechanical Working Section, AFD and Shri Arun Singh, of Mechanical Working Section, AFD, Dr. G.P. Kothiyal, Head Glass and Advanced Ceramics Division, Dr. S. Ramanathan, Head Advanced Ceramic Section, Shri M.R. Gonal, of Advanced ceramic Section for their continued help and support in the fabrication of aluminium foams. I would like to thank, Dr. K.B. Khan, Head Process control and NUMAC Section, Radio metallurgy, and all staff members of NFG for their cordial help and support.

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8. A.R. Kennedy, Advanced Materials Research Group, Report Manufacturing Engineering and Management University of Nottingham, NG7 2RD, UK
Velocity Field Measurements Using Digital Particle Image Velocimetric System

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Reactor Engineering Division
and
R.K. Singh
Scientific Information Resource Division

Abstract

Particle Image Velocimetry (PIV) is a non-intrusive technique for simultaneously measuring the velocities at many points in a fluid flow. Several case studies related to nuclear reactor were performed with the PIV system. Some of the cases like flow in circular tube, submerged jet, natural convection in a water pool and Fluidic Flow Control Device (FFCD) used in advanced accumulator of Emergency Core Cooling System (ECCS) have been studied using PIV system. Theoretical studies have been performed and comparisons with PIV results are also given in this article.

Introduction

Most innovative nuclear reactor systems under development are single-phase systems. Present day Computational Fluid Dynamics (CFD) codes are considered to be robust for single-phase systems and hence increasing application of these codes is expected for such reactors. However, verification and validation of CFD codes for reactor systems and components is not adequate. For verification and validation of CFD codes, one must be able to measure the multi-dimensional velocity, temperature and concentration fields. Simple experimental techniques are intrusive in nature and make measurements at few selected points only. In the past decade or so, techniques for practically non-intrusive measurement of the field variables have become possible, thanks to successful development of Particle Image Velocimetry (PIV), Planar Laser-Induced Fluorescence (PLIF), etc. A 2D PIV facility has been set-up for flow mapping in BARC. Such a facility plays important role in basic research, design optimisation, (CFD) code development and validation. Flow in circular tube, submerged jet, natural convection in a water pool and fluidic flow control device (FFCD) used in advanced accumulator of Emergency Core Cooling System (ECCS) have been studied using PIV system. Theoretical analysis has also been performed. This article deals with the experimental setups, results obtained by using PIV. The theoretical analysis performed has been compared with results obtained with the PIV system.

PIV system

Particle Image Velocimetry (PIV) is a non-intrusive optical technique for the measurement of flow velocity at many points (typically at thousands of locations) in a flow field simultaneously. It measures instantaneous vector field and displays velocity vectors in real-time [1]. The PIV system used is comprised of Nd:YAG laser source, CCD (Charged Coupled Device) camera, synchronizer (timing controller to control the laser and camera) and analysis software. The setup is shown in Fig. 1. Laser has very short pulse duration (~5-7 ns), which can freeze any motion. To synchronize the laser source and camera, a synchronizer is provided. The flow
measurement technique involves seeding the flow field with tracer particles, illuminating the region under the investigation and capturing two images in rapid succession. Velocity vectors are obtained from the displacement of tracer particles in the time interval between two images captured [2]. For the experiments, glass hollow spheres having density of 1.1 g/cm³ (close to water) and size of 10 μm are used as tracer particles. 2D PIV system can be used to calculate various derived parameters like vector length, vector components, two dimensional divergence, two dimensional vorticity, swirling strength, shear strength, strain, strain rate etc.

Flow pattern studies

Flow in a circular tube, submerged jet, natural convection in a water pool and fluidic flow control device (FFCD) used in advanced accumulator of Emergency Core Cooling System (ECCS) have been studied using PIV system. The various experimental setups and results for each are described in following sections.

Flow in circular tube

The test facility consists of a test section, pump, rotameter and sump. The test section is comprised of a glass tube having inner diameter of 22 mm and a square glass enclosure around the glass tube filled with water. The purpose of water filled square glass enclosure is to minimise the image distortion from the curved surface of pipe. Test section used is shown in Fig. 2a. Experiments were carried out for different flow rates. Figs. 2b (i) and (ii) show the velocity profile for flow rate of 0.4 lpm and 30 lpm respectively at different axial locations. The Reynolds numbers calculated for these flow rates are 480 and 36000 respectively. It can be seen from the Fig. 2b that measurement taken by PIV system gives parabolic velocity profile for laminar region and flat velocity profile for turbulent region. Figs. 2c (i) and (ii) depict comparison of measured non-dimensionised axial velocities as a function of non-dimensionised radial distance with the computed by CFD. The axial locations at which these profiles are shown are at a distance of 13D and 6.25D from inlet for laminar and turbulent flow respectively, where D is inner diameter of the circular tube.
**Submerged water jet**

In the secondary shutdown system of Pressurised Heavy Water Reactor (PHWR) and Advanced Heavy Water Reactor (AHWR), liquid poison is injected into moderator in Calandria vessel through perforated tubes to shutdown the reactor. Poison coming out from the perforated tubes is in the form of submerged jets. It is important to know the velocity pattern of submerged jet in presence of calandria tubes. As a first step, single submerged jet without any obstacles is studied using PIV. Experiments are performed on the submerged jet issuing from a tube of inner diameter of 6.5 mm. Fig. 3a shows the test setup which comprises of water tank with circular tube. Fig. 3b shows the velocity pattern obtained by using PIV system. Fig. 3c shows the variation of axial velocity as a function of axial length. Comparison of PIV measurement with CFD and analytical [3] results is shown in Fig. 3c. Fig. 3d shows the velocity contours of jet obtained by PIV system.

![Fig. 3a: Schematic of Nozzle in water tank](image1)

![Fig. 2c: Comparison of velocity at pipe cross section by PIV and CFD code](image2)

![Fig. 3b: Velocity profile at different axial distances of submerged water jet by PIV system](image3)

![Fig. 3c: Variation of axial velocity as a function of axial length.](image4)
Natural convection in water pool due to vertical plate heater

In advanced nuclear reactors, large water pools have been employed for removal of core decay heat passively during reactor shut down. Heat exchangers connected to primary circuit are immersed in these pools. The heat exchanger transfers heat from primary circuit to water pool by buoyancy driven natural convection phenomena. During heat transfer process, thermal stratification with a steep temperature gradient along the vertical plane occurs in the water pool.

Natural convection flow pattern in water pool due to vertical plate heater is studied using PIV system. The experimental setup consists of vertical heater plate immersed in a water tank as shown in Fig. 4a. The heater plate was given electrical power of 313 W. As the plate is heated, boundary layer flow develops adjacent to the plate. PIV measurements for flow pattern are taken after 15 s of switching on the heater. CFD analysis has been also carried out to compare with experimental data.

Figs. 4b and 4c show the flow pattern obtained by using PIV system and aluminium particles respectively. Both flow patterns match closely. It can be further observed from Figs. 4b and 4c that fluid moves up along the vertical heater to the free surface. At the free surface, the detaching boundary layer is reflected downwards. However, due to its higher temperature (lower density), it is found to rise back to the free surface and flows along the free surface horizontally towards the wall of the container. Comparison of resultant velocities from PIV and CFD results as a function of distance from vertical heater is given in Figs. 4d and 4e for 5 mm and 50 mm below free surface respectively.

Fluidic Flow Control Device

Emergency Core Cooling System (ECCS) is provided to limit the fuel temperature rise within acceptable
limits in the event of Loss Of Coolant Accident (LOCA). The advanced accumulators in advanced heavy water reactor inject large amount of cold water by passive means, at high pressure, directly into the core for short period of time and then a relatively small amount of cold water for large period of time to quench the core. For this, it was proposed to incorporate a Fluidic Flow Control Device (FFCD) at the bottom of accumulator tank as shown in Fig. 5a, which reduces the flow after some time, by passive means. This feature enables to extend the accumulator discharge. During initial period, the water level in the advanced accumulators is above the stand pipe, the water enters the vortex chamber of the FFCD through both stand pipe (radial) and side connection (tangential) as shown in Fig. 5b (i), and after some time when the water level in the accumulators falls below the top of the stand pipe, the water enters the chamber through the side pipe only, which is tangential to the vortex chamber as shown in Fig. 5b (ii). This causes the formation of vortex, which increases the flow resistance, and hence reduces the flow rate passively.

For PIV experiment, FFCD was made of glass. Only the side pipe and outlet are considered for study the vortex in FFCD as vortex study is of our interest. The experiments were conducted for various flow rates. Circular mid plane is studied using the PIV system for velocity pattern and Fig. 5c shows the stream line plot generated by PIV software. Fig. 5d shows the variation of non dimensional tangential velocity with non-dimensional radius using PIV.
The tangential velocity profile obtained is similar to profile obtained from empirical correlation proposed by Vatistas et al. [4].

Concluding Remarks

Flow pattern studies have been carried out for various geometries pertaining to nuclear reactor systems. Further work on computational fluid dynamics studies for these components/systems are in progress for comparison purpose. Up-gradation of 2D PIV system to 3D PIV and procurement of additional components for two phase flow measurement are in progress.

Reference

Detection of Radioactive Material in Public Places: BARC’s Handheld Tele Radionuclide Detector


Electronics Division

and

Venkat Subramanian

IGCAR, Kalpakkam

Abstract

Electronics Division, BARC has developed a compact and portable system for detection of radioactive nuclides like Co$^{60}$, Cs$^{137}$ etc. with high levels of radioactivity. These radioactive sources, because of their long life and relative ease of availability, have the potential of being used in radiological dispersion devices (dirty bombs) for panic creation in public places. The unit comprises of a compact CsI detector, photo diode and front-end electronics, micro-controller, a GPS module and Blue-tooth connectivity. The application software running on the mobile phone provides the interface as well as transmission of data to remote server. This is highly suitable for covert operations. The person, who carries this instrument, suitably camouflaged, also has a mobile phone in his pocket, which is connected to the system via blue tooth. On detection of activity above set limit, the system sends an alarm to the mobile phone. The mobile phone can be kept in vibration mode in order to avoid any undue attention. The graphical display on screen of mobile phone provides an indication of activity and the isotope identification. Simultaneously, the mobile phone sends information about the activity detected and source identification automatically along with the location of the instrument (longitude and latitude), provided by the GPS module in the instrument, to a remote server. The remote server provides radiation information on a map with position-coordinates. Based on this, necessary action can be initiated by the security personnel.

Introduction

In today’s climate of terrorist threat, long lived radio-isotopes like Co, Cs, Ba, Am etc. have the potential of being used in public places for creating panic. The activity may not be really high to cause any damage to the human beings but this information of radioactive material present in crowded place results in panic followed by stampede. To avoid this kind of situation, it is necessary that a close surveillance is kept at public places without attracting attention of the public. The radio-nuclide detector should be small enough to be carried in the pocket or small hand bag and sensitive enough to detect the presence of any radionuclide in a short time of two to three seconds. It should also have tele-connectivity to a remote server so that corrective action can be initiated immediately rather than waiting for instructions from the person carrying the instrument. Since the mobile phone has become universal, anybody carrying mobile phone which receives the details of the radio nuclide present and the counts per second (CPS) information with graphical display on the mobile screen will not raise any undue attention.

Sodium Iodide (NaI (Tl)) crystal is commonly used solid state scintillator detector for gamma rays as it is more efficient than gas detectors. It has good intrinsic and light conversion efficiency of 10%
combined with energy resolution of about 8% and a short decay time of around 250 nano seconds\(^1\). However it needs coupling with a photo-multiplier tube, needing high voltage supply (2KV, 1mA) for converting light pulse into a voltage pulse. The requirement of photo multiplier tube and input voltage supply puts limitation on the size of detector instrument and therefore is considered unsuitable for intended covert operation. Though Cesium Iodide (CsI(Tl)) has 1/3\(^{rd}\) efficiency as compared to that of NaI, with six fold increase in decay time, it can be coupled to a PIN diode for light to voltage conversion with the result that it operates with low voltage supply (typically +/-12V). It is therefore, ideally suited for intended covert operation. The details of this development are summarized below.

The Nuclide Detection System

Fig. 1 shows the photograph of the instrument developed at Electronics Division, BARC along with the detector and a mobile phone. The schematic diagram of the system is given in Fig. 2. The pulses from the detector are counted in a multichannel analyzer implemented using a 12-bit ADC, yielding a resolution of 1024 channels, and a microcontroller. The Region of Interest for Nuclides like Co\(^{60}\), Cs\(^{137}\) etc are identified during calibration phase with due correction of high energy contribution in different regions of interest (ROI). This information is stored in the system. The system is programmed for a counting time of three seconds for making a decision. At the end of every 3 seconds, the Count Rate (CR) per 3 seconds is computed for the selected ROIs and checked for alarms against programmable limit. At the end of three seconds, the counts are reset and a fresh counting is started for the next cycle.

On detection of alarms, the CR information and the nuclide identified using the ROI is sent to the mobile phone via Bluetooth. The mobile phone is optionally kept in vibration mode. The application running on the mobile phone will display the nuclide name and the CR information. The bar graphs provided will mimic the intensity as the detection system approaches the source in order to properly identify the location.
Hardware Description

Fig. 3 shows the schematic description of the hardware of the system. The gamma rays falling onto the CsI Scintillator produces photons that are sensed by the photodiodes and with the help of charge sensitive pre-amplifier gets converted into equivalent voltage pulses. These voltage pulses are of very short duration and cannot be given directly to the ADC. Therefore they are passed through pulse shaping circuit so as to give it a Gaussian shape and then through the baseline restorer circuit for removal of offset. The height of the shaped pulse is compared with Lower Level Discriminator (LLD) and Upper Level Discriminator (ULD), which is set by the microcontroller. If the height of the pulse is more than the LLD and less than ULD, the peak value is stretched so as to give enough time to ADC for conversion.

Fig. 4 shows the 1-minute spectrum of Co\(^{60}\) (25Ci) kept at a distance of about 3 inches from the detector. Since in actual practice, the counting time is kept as low as 3 seconds, to avoid false detection an 11-point smoothing operation is performed in the microcontroller for higher accuracy.

Bluetooth Communication

The instrument communicates with the mobile phone via Bluetooth connectivity. On the mobile phone, J2ME provides API for bluetooth communication known as JSR 82\(^{[3]}\) (Java Specification Review). The mobile phone application searches for the Tele Radionuclide Detectors Bluetooth device, connects to it by exchanging secret PIN number. Once connection is established the instrument transfers acquired spectrum and location coordinates to mobile phone every 3 seconds using Bluetooth.

Fig. 3: Hardware Schematic

Fig. 4: Averaged output with Co\(^{60}\) for 1 min
The GPS – Global Positioning System

Low power, compact GPS Module with built in smart antenna has been interfaced to the microcontroller via serial port. The module communicates using the NMEA 0183 protocol. The NMEA 0183 standard defines an electrical interface and data protocol for communications between marine instrumentation. The instrument sends $GPGGA packet which is described below.

GPS Based location Identification Scheme

The security personal during surveillance with this instrument will have a J2ME enabled mobile phone having an application which will communicate with instrument on Bluetooth network. It will receive the data from Radio Nuclide Detector on alarm. This data in addition to being displayed on the mobile phone is automatically sent to a central server using TCP/IP communication. For this IP access-point is provided by service providers like MTNL. If access-point is not available, this data can also be sent using port based SMS. In order to send the SMS without user intervention a latest mobile like Nokia N97/C7 need to be used. The server, using the longitude and latitude data, provides the information in a map in several ways.

A sample application worked out shows the picture of BARC mod-labs region. See Fig. 5.

The yellow dots correspond to detection of radionuclide (in this case Cs$^{137}$) as it is moved for the demonstration and these dots are connected by the application. The red dot indicates the most recent point. The location is behind the mod-labs near Electronics Division. On the left side, the nuclide identified and CR data is shown. The table describes the longitude and latitude at which radiation is detected using the sample source and the information related to the source.
Conclusion

The increased threat perception from usage of radioactive materials necessitates the indigenous development of compact portable devices to detect, identify and locate the presence of such material in public domain. The system developed uses an imported sensor but equivalent sensors have already been developed by Technical Physics Division, BARC. The coupling of these sensors with the system discussed above would result in fully indigenous units.

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Processing Food for Convenience: Challenges and Potentials
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Abstract
Minimally processed convenience foods like ready to cook (RTC) and ready to eat (RTE) products have gained prominence in recent years due to busy lifestyle of consumers resulting in demand for foods that can be readily cooked and served. Hurdle technology employing combination of several mild treatments is widely used to develop various shelf stable RTC and RTE products. Gamma irradiation is an effective process for microbial disinestation and shelf life extension of fresh products. In the present work hurdle technology involving combination of modified atmosphere packaging (MAP), low temperature storage, weak organic acids and gamma radiation was successfully employed to develop shelf stable RTC Indian vegetables.

Key words: Ready -To-Cook (RTC), Indian vegetables, Radiation processing, MAP.

Introduction
Worldwide demand for convenience foods such as minimally processed fresh cut fruits and vegetables has increased considerably in the past few years. Changing lifestyles and eating habits as well as preference for products with lesser additives have resulted in an increased demand for such products. Processed ready-to-eat (RTE) fresh fruits or ready-to-cook (RTC) vegetables provide convenience without significantly changing their fresh-like properties. Commercial production of RTC vegetables include washing, sorting and grading according to size, peeling, cutting, packaging, and finally, storage at refrigerated temperatures. However, these products have a short shelf life of 2-3 days.

When subjected to peeling / cutting or shredding during minimal processing, the plant cellular fluids are released causing browning and providing a nutritive medium for microbial growth. Thus, fresh cut vegetables support microbial growth and several outbreaks of food-borne illnesses have been found to be associated with these products. Psychrotropic bacteria, such as Listeria monocytogenes and Clostridium botulinum are known to grow at low temperature even under modified atmosphere packaging. Further, minimal processing results in elevated respiration and transpiration rate resulting in greater water loss from plant tissues. This leads to dehydration, loss of firmness, and reduced shelf life of these products.

Disinfectants presently employed in commercial processing lines, such as chlorine has limited effect (approx. 1 log reduction) on microbial populations and can not be relied to eliminate pathogenic microorganisms like L. monocytogenes. These disinfectants cannot prevent damage due to elevated respiration and transpiration rates of minimally processed products. In addition it is believed that they may form carcinogenic derivatives in water (e.g. chloramines and trihalomethanes) [1]. Therefore, there is a need for research on alternative treatments suitable for use on fresh-cut products. New protocols for maintaining quality while inhibiting undesired microbial growth are required for the production and distribution chain, as microorganisms adapt to survive in the presence of previously effective routinely employed control methods.

Newer methods available for preservation of RTC products can be classified in two categories- chemical...
and physical. Chemical methods involve use of chlorine dioxide, organic acids, hydrogen peroxide, calcium based solutions, ozone, electrolyzed water and natural preservatives. Under physical methods of food preservation, high pressure processing, pulsed white light, ultra violet light, pulsed electric field, oscillating magnetic fields and ionizing radiation are the recent techniques used widely.

**Chemical preservatives**

Among the chemical methods, chlorine dioxide with a better oxidation capacity than chlorine, hydrogen peroxide, a strong oxidizing agent and ozonated water have been used for reducing microbial populations and shelf life extension of fresh produce. Efficacy of ClO₂ in the inactivation of *Listeria monocytogenes* and *Salmonella Typhimurium* [2] and H₂O₂ solution in reducing microbial populations on fresh-cut bell peppers, cucumber, zucchini, cantaloupe, and honeydew melon, without alteration in sensory characteristics [3] have been reported. Although, antimicrobial activity of ozone is widely known, there is little information available about its efficacy against food borne pathogens like *Shigella sonnei*. Higher corrosiveness of ozone and initial capital cost for its generation are the main disadvantages in its use compared to other chemical preservatives.

Calcium is extensively used to extend the shelf life of fruits and vegetables. It helps maintain the vegetable cell wall integrity by interacting with pectin to form calcium pectate. Different salts of calcium used in food industry include calcium chloride, calcium lactate and calcium propionate. Antibacterial properties have been reported for calcium propionate for the treatment of honeydew melon, due to its ability to uncouple microbial transport processes [4]. Acidic electrolyzed water (pH 2.1-4.5) has a strong bactericidal effect against pathogens and spoilage microorganisms. It is more effective than chlorine due to its high oxidation reduction potential (ORP). A higher effectiveness of electrolyzed water in reducing viable aerobes than ozone on whole lettuce has been demonstrated [5].

No adverse effects were noted on surface colour, pH or general appearance of fresh-cut vegetables.

Reluctance of consumers towards the use of chemical preservatives has resulted in recent years in the use of natural antimicrobials as preservatives. Organic acids such as lactic, citric, acetic and tartaric acids are used as strong antimicrobial agents against psychrophilic and mesophilic microorganisms in fresh-cut fruits and vegetables. The antimicrobial action of organic acids is due to pH reduction in the environment, disruption of membrane transport and/or permeability, anion accumulation, or a reduction in internal cellular pH by the dissociation of hydrogen ions from the acid.

**Physical methods of preservation**

Several physical methods are currently used for preservation of minimally processed plant produce. Modified atmosphere packaging (MAP) for example aims at producing low O₂ and high CO₂ in the atmosphere surrounding fresh cut produce. These conditions reduce respiration rate thus delaying senescence and extending shelf life. In passive MAP the package is sealed under normal atmospheric conditions and desired composition is obtained due to produce respiration and film gas permeability. In active MAP the package is flushed with a gas mixture of preset composition and once closed, no further control of the gas composition is exercised. However, expensive equipment and materials (gases and packaging) are required for MAP generation.

Ultraviolet (UV) light is another physical treatment widely employed in industry. UV irradiation causes up to 4 log cycle reduction in bacterial, yeast and viral counts by inducing DNA damage. Major advantage of this technique is the availability of relatively inexpensive and easy to use equipment. Among the other technologies, treating products with millisecond pulses (1–20 flashes/sec) of broad spectrum white light, about 20,000 times more intense than sunlight holds promise. Pulsed white light inactivates microorganisms by combination of photochemical and photothermal effects, requires very short treatment times and has a high throughput. The above methods, however, have
lower efficiencies due to their lower penetration and are thus mostly used for surface sterilization.

Radiation processing with ionizing radiation is a non-thermal technology that effectively eliminates food-borne pathogens in various foods, including fresh vegetables without compromising the nutritional properties or sensory qualities of food. Treatment of food products by ionizing radiation is a physical process involving direct exposure to electromagnetic γ-rays or electron beam for improvement in food safety and shelf life. The irradiation technology is approved by FAO/IEAE/WHO joint committee on wholesomeness of food and currently this technology is commercially practiced in several countries. Being a cold process it can efficiently decontaminate or sterilize food without significantly affecting the sensory and nutritional quality of treated food. The non residual feature of ionizing radiation is an important advantage making it an effective alternative to chemical treatments.

**Hurdle technology**

Concept of hurdle technology has been developed recently. Hurdle technology provides a framework for combining a number of milder preservation techniques to achieve an enhanced level of product safety and stability. Complex interactions of various factors such as temperature, pH, water activity, MAP and antimicrobials are employed to design series of hurdles to ensure microbial safety of food products.

Use of hurdle technology with irradiation as one of the hurdles for control of microorganisms and extending shelf life of minimally processed produce has shown considerable potential for commercial exploitation. Efficacy of gamma irradiation in combination with other preservation techniques like MAP for reducing the microbial population and extension of shelf life while maintaining nutritional quality of minimally processed vegetables has been demonstrated [6].

In our laboratory, protocols have been standardized for the use of hurdle technology involving radiation as one of the hurdles for enhancing shelf life of fresh cut Indian vegetables. Several shelf stable RTC Indian vegetables were developed employing hurdle technology. Low temperature storage, GRAS (Generally Recognized as Safe) organic acids like citric acid, modified atmosphere packaging in PVC cling films and gamma radiation were the various hurdles employed to develop minimally processed vegetables. Levels of these hurdles as optimized for various products are shown in Table 1. Schematic diagram of various processing steps employed for minimal processing of vegetables is shown in Fig. 1.

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**Fig. 1. Schematic of processing steps involved in manufacture of RTC products.**
Process parameters were optimized using multivariate statistical optimization technique known as response surface methodology (RSM). RSM explores the relationships between several explanatory variables and one or more response variables. The main idea of RSM is to use a sequence of designed experiments to obtain an optimal response. It is a statistical method that uses quantitative data from an appropriate experimental design such as central composite rotatable design (CCRD) to fit a first-or-second order polynomial by least squares technique. When many factors and interactions affect desired response, RSM is an effective tool for optimization of process. Microbial safety along with sensory quality in terms of color, texture, aroma and taste are determining factors for consumer acceptability of any RTC product. In our studies RSM was successfully employed to mathematically model effects of various process parameters on quality and sensory characteristics of fresh vegetables (Fig. 2). Radiation dose resulted in decreased microbial load as

![Table 1: Shelf life extension of RTC vegetables at optimized radiation doses](image)

<table>
<thead>
<tr>
<th></th>
<th>Optimized radiation dose (kGy)</th>
<th>Optimum storage temp. (°C)</th>
<th>Extension in shelflife (Days)</th>
<th>Total shelf life of irradiated dose vegetables</th>
</tr>
</thead>
<tbody>
<tr>
<td>French beans</td>
<td>1</td>
<td>10</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Ash gourd</td>
<td>2</td>
<td>10</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>Pumpkin</td>
<td>2</td>
<td>10</td>
<td>14</td>
<td>21</td>
</tr>
<tr>
<td>Drumstick</td>
<td>1</td>
<td>10</td>
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![Fig. 2. Effect of process parameters on quality attributes of RTC French beans.](image)

well as firmness in vegetables [Fig. 2 (1 & 2)]. During initial storage period sensory scores for aroma and taste decreased with radiation dose but at end of storage period better sensory scores were observed at higher doses [Fig. 2 (3 & 4)].

An enhanced content of some odor active compounds such as acetoin and 3-hexen-1-ol in ash gourd and drumstick, respectively, was noted. These changes were correlated to enhanced radiolytic breakdown of their glycosidic precursors [7]. No changes in aroma profiles of french beans [8] and pumpkin was, however, observed after radiation treatment. Developed products (Fig. 3) demonstrate acceptable microbial safety, sensory and visual quality during entire intended storage period.

**Conclusion**

Radiation treatment of RTC vegetables, in combination with low temperature storage and MAP resulted in extension of shelf life of ash gourd, pumpkin, drumstick and french beans. Radiation processing can be used for development of microbially safe products without use of chemical preservatives. For manufacturers, radiation technology can be useful as it can result in shelf life extension of RTC products, thereby, reducing post harvest spoilage losses.

**References**


An Engineered Forbidden Zone for Light

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Abstract
A snapshot of opportunities and challenges in the field of nanophotonics emphasizing on controlling the light emission and propagation are discussed. A holy grail of nanophotonic research is the realization of photonic band gap. The basic physics of photonic band gap formation and its consequences in the photon density of states is discussed. We also present some of our recent experimental results of photonic band gap research activities.

Introduction
The quest for controlling light emission and propagation has the history of more than a century. With the introduction of the term ‘photon’ in 1926 and subsequently the advent of lasers in 1960’s, there has been an unprecedented progress in our understanding of light and its propagation, which has been accompanied by several technological breakthroughs. There have been incredible discoveries in the areas of linear and nonlinear optics, quantum optics, cooling and trapping of atoms, degenerate atomic gases, ultra-precision measurements, quantum metrology, chemical dynamics, optical communications, imaging sciences and even medical physics. At the origin of these great strides is our ability to exercise a reliable control over photons and their propagation.

Much before the research community started to understand how to control propagation of photons, scientists and engineers had developed knowledge and technology to control motion of electrons. This is evident from the remarkable discoveries and progress made in the field of semiconductor materials and devices. This understanding led to the invention of transistors and integrated devices, and gifted us unparallel miniaturization of devices in the field of computers, cell phones, lighting and entertainment.

Today we all appreciate that these unimaginable applications are possible due to the control of motion of electrons using functional semiconductors.

In this context, it is interesting to ask a simple question; can we mimic the functionalities offered by electrons in semiconductors using photons; the fastest information carrier. Is a semiconductor for photons possible? The search for finding the answer has given birth to periodic nanostructures for photons or the photonic band gap (PBG) materials. PBG materials are structures where the dielectric constant (refractive index) is periodically altered; the period is of the order of wavelength of light. The underlying structure has translational periodicity and therefore these structures are also called as photonic crystals. This is similar to atomic crystals where the atoms are arranged periodically with a period of the order of Å. This periodicity of atom in crystals provides the necessary potential for electrons resulting in series of allowed and forbidden bands for electrons. The same concept is also applicable for PBG structures where the potential is created using the difference in the refractive index leading to energy bands that can be described as propagating or forbidden for photons. We thus enter into the new and exciting field of research – nanophotonics, which is a buzz word amongst scientists and technologist today.
Physics and applications of photonic band gap materials

The PBG materials are artificial nanostructures where the refractive index is periodically altered with period of the order of wavelength. The periodicity can results in one-dimensional (1D), two-dimensional (2D), and three-dimensional (3D) PBG materials [1]. These materials also form a class of meta-materials where the properties of the structure depends on the way one arrange it rather than its own intrinsic material properties. The simplest case is 1D system and serves the purpose of introducing the essential concept of PBG formation.

The 1D system is shown in Fig. 1 (a) where alternating layers of two materials with refractive index $n_H$ and $n_L$ (H=high, L=low) are repeated along the z-direction with thickness of $d_H$ and $d_L$, respectively. The period is $\Delta = d_H + d_L$. The structure is homogenous in the x- and y-directions. Fig. 1(b) shows the 2D systems where the refractive index is varied along the y- and z-directions whereas the structure is homogenous along the x-direction. For 3D systems the refractive index is varied along all the three orthogonal x, y, z-directions as seen in Fig. 1(c). The 3D PBG structures are the most promising as they tailor light propagation and emission in a remarkable way due to 3D confinement of photons [2].

When light is incident on a PBG structure, a certain band of wavelength is reflected back and the transmission for those wavelengths is forbidden. This forbidden zone, for certain wavelength, is called the photonic stop gap. This means that the structure essentially becomes an insulator for photons. The wavelength of forbidden region is decided by the lattice period, refractive index contrast, light polarization, and angle of incidence of light. The wavelength of forbidden zone can be approximately calculated using the Bragg condition. When the light wave is incident on the structure, at the stop gap wavelength two waves are generated; one is the forward propagating incident wave and the other is the backward reflected light from each dielectric interface. These two waves form a standing wave inside the structure. One of these waves concentrates its energy in the high index medium whereas the other wave in the low index medium. This generates frequency separation, for an incident wavelength, at the stop gap and results in a forbidden region for frequencies where no light mode is allowed to couple to the PBG structure. This is shown in Fig. 2(a) together with the dispersion relation (green dashed line) for vacuum ($\omega = ck$). Note here that the behavior in vacuum is linear whereas that in a PBG material shows discontinuity when the incident wave vector reaches the Bragg plane (i.e., at the Bragg condition). The Bragg diffraction of light is thus the genesis of photonic stop gap [2]. The width of the stop gap represents the strength of interaction between the incident waves and the structure, and
is called the photonic strength. The photonic strength is strongly dependent on the refractive index contrast; larger the contrast higher the photonic strength. When this forbidden zone is observed (for the same frequency range) along all the three orthogonal directions for different polarization of light, a 3D forbidden zone is obtained [3]. It is an extremely challenging task to realize the 3D forbidden zone for light and some success have been achieved recently [3]. The important hurdles in realization of 3D PBG is due to constrains on the symmetry and index contrast of the underlying structure. The two symmetries that have been proposed are face centered cubic (fcc) and diamond lattice with an index contrast of 2.8 and 2.0, respectively. These theoretical studies open door for experimentalist to fabricate and measure the 3D PBG.

As we have seen that at the forbidden zone frequency, light cannot couple to the structure as there exists no mode in the structure for coupling. This indicates that the density of states (DOS) for photons is zero for those forbidden frequencies. A schematic picture of DOS is given in Fig. 2(b) in a homogenous medium (dotted line) and PBG structure (solid line), respectively. It is seen that the DOS goes to zero inside the PBG and enhances near the band edges. Alternatively a light source embedded inside the PBG structure which is being excited externally, e.g. using a laser for instance, and if the emitted light frequency is within the forbidden zone, the light emission is forbidden as there no states available (DOS ~0) for the photons and the photons are excited forever! This is the pillar idea of the seminal paper on PBG materials published by Eli Yablonovitch in Physical Review Letters in 1987 [5]. In addition to the suppression, an enhancement of DOS is also possible near the band edges as may be seen in Fig. 2(b). This is due to the reduced group velocity of light near the band edge. It is this aspect of suppression and enhancement of DOS, in these engineered nanophotonic structures, has provided a great impetus for fabricating such structures and understanding the light propagation, thereby providing avenues for exotic phenomena in quantum optics, optical communication, dispersion characteristics and low-threshold lasing or even threshold-less lasing [2, 6].

Similar to semiconductors, defects and impurities in an otherwise perfect PBG material can give rise to localized states inside the band gap. This is another pillar idea that throws open the possibility of observation of Anderson localization for photons, as proposed by Sajeev John in Physical Review Letters in 1987 [7]. It is argued that a PBG structures with controlled amount of disorder is an ideal platform for experimentalist to fabricate and measure the 3D PBG.

![Fig. 2: (a) Dispersion relation for light in free space (green dashed line) and in a photonic band gap structures (solid line). When the wave vector reaches the Bragg plane, diffraction results in a forbidden zone for certain frequencies as shown using two bounded dotted line. (b) The schematic representation of density of states showing a quadratic dependence on frequency in a homogenous medium (dotted line) and suppression of the density of states inside the photonic band gap and enhancement near the band edges for photonic band gap materials (solid line).](image-url)
for Anderson localization modes, a hypothesis still to be verified experimentally. Line defects caved on PBG materials can act as waveguides to route photons in optical circuits. In conventional waveguides light confinement within the core takes place due to the total internal reflection at the core/cladding interface whereas in a PBG waveguides light confinement within the core is due to the PBG of the surrounding cladding material. This is already being commercialized as photonic crystal fibers [8]. Planar or point defect in PBG structures can give rise to localized states within the forbidden zone with high quality factor (Q), which signifies how strongly a photon can be trapped inside the cavity. When an emitter, e.g. a quantum dot, whose emission frequency coincides with that of the cavity mode is place in PBG structure, an enhancement of emission occurs due to the so-called Purcell effect. This can ideally lead to threshold-less lasers, a contemporary area of active research. Up to now, we have seen the interesting physical concepts and opportunities in these emerging fields of nanophotonics. In the remaining, we show how such nanophotonic structures can be realized and shed some light on our recent results.

Realization of PBG structures

Fabricating 1D PBG structures are quite straightforward as it is routinely done in thin film technology. They exert limited control on tuning the DOS but work as excellent filters and omnidirectional reflectors. 2D PBG structures can be realized using nanostructure fabrication methods, such as reactive ion etching and e-beam lithography. The race for tailoring the DOS for applications is steadily progressing well using the 2D PBG structures. The most appealing structure is 3D PBG structure where the light confinement is possible in all directions.

It is an extremely challenging task to fabricate the 3D PBG structure and the field is still in an infant stage. But there exists an alternative route which is to mimic the nature. 3D PBG structures exist in nature called opals or gemstones. These structures consist of close packed silica spheres which are sediment through a self-assembling process involving time span of years. The beautiful colors appearing, when viewed at different angles, are due to the Bragg diffraction along different crystal directions. The big question is; can we mimic it in our laboratory? Thanks to the progress in colloidal chemistry, 3D PBG structures of superior optical quality can be made by self-assembling process utilizing mono-disperse spherical particles made of organic or inorganic materials that are nowadays available commercially. These particles are the building blocks of 3D PGB structures. The main drawbacks of such self-assembled PBG structures are the absence of a 3D PBG due to the lower refractive index contrast and uncontrollable disorder which can hamper the light interaction [9].

Experimental results

We have synthesized self-assembled 3D PBG structures using mono-disperse polystyrene spheres with different diameters to realize photonic stop gaps in different spectral ranges. Scanning electron microscope (SEM) image of the synthesized PBG structure is shown in Fig. 3 (a) and 3(b). Very good ordering of spheres is evident on the surface and in the depth of the PBG structure. These structures are known to crystallize in the fcc lattice, the thermodynamically stable phase, with the (111) plane of the lattice parallel to the substrate [10]. Other crystalline planes can be probed through an angle resolved photonic stop gap measurements. Reflectivity and transmittance measurements are the standard technique to probe the stop gap properties of PBG structure along a particular direction. At the stop gap wavelength, the peak in reflectivity spectrum is accompanied by a trough in transmission indicating that neither the light is allowed to couple to the structure nor the light is absorbed, but it is simply reflected. This is the photonic stop gap along that direction. The photonic stop gap measured from the (111) plane is given in Fig. 4(a). In reciprocal
space this corresponds to the Å-L direction of the fcc Brillouin zone. The stop gap around 600 nm is clearly visible with a width of 42 nm and on the either side of the stop gap the structure behaves like a homogenous medium with high transmission and low reflectivity. This is the forbidden zone for light of wavelength from 580 to 630 nm. The experimentally observed stop gap wavelength and photonic strength are in good agreement with theoretical calculations, which exemplifies the superior quality of our PBG structure. As we see that no light can couple to the structure externally, therefore, we expect no light to come out from an internally excited source inside the PBG structure. To verify this hypothesis, we conducted experiments where dyes entrapped inside the PBG structure (photonic sample) are excited using 532 nm light from an Nd: YAG laser. We choose dyes (e.g., Rhodamine B) so as to overlap the emission frequency with that of photonic stop gap. We also measured the emitted light from a proper reference (non-photonic) which is a PBG structure where the stop gap frequency does not overlap with that of emission. The intensity ratio; which is the ratio of the emission spectra of the photonic sample to the non-photonic sample is given in Fig. 4(b). Ideally the ratio is equal to unity, but in Fig. 4(b) a clear trough is visible around 600 nm which is due to the existence of photonic stop gap. The spontaneous emission from dyes is suppressed due to the vanishing of DOS along the [111] direction of the PBG structure.

Fig. 3: (a,b): Scanning electron microscope image of self-assembled photonic crystals synthesized using polystyrene spheres of diameter of 803 nm. The image confirms the very good ordering on the surface and in the depth of the photonic crystals.

Fig. 4: (a) Measured reflectivity and transmittance indicating the photonic stop gap at a wavelength of 600 nm. One either side of the stop gap the structure behaves like a homogenous medium (b) Intensity ratio between the dye emission from the photonic sample and non-photonic sample (reference). The suppression of spontaneous emission of dye embedded inside the photonic band gap structure can be seen around 600 nm.
We have thus shown that we can tailor the light propagation through engineering the forbidden zone for photons. This capability offers several unprecedented applications in mirror-less and low-threshold lasing, cavity quantum electrodynamics, communications, biological sensors, and solar cells. The field of 3D PBG structures is still in the infant stage. It opens a new way to control light propagation and emission at nano-scale and provides a versatile platform for fundamental science as well as exotic applications.

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References

BARC Scientists Honoured

Name of the Scientists: Y.S. Rajpurohit and H.S. Misra, Molecular Biology Division
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Name of the Award: FEMS-2011 Young Scientist Grant Award to Y.S. Rajpurohit

Name of the Scientist: H.S. Misra, Molecular Biology Division
Honour: Elected as a Member of the Guha Research Conference (GRC) (an elected body of Biological Scientists in India)
Announced at: Annual Meeting of the GRC-2010, held at Aurangabad.
Golden Mahogany

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