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BARC NEWSLETTER

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From the Editor's Desk

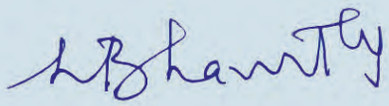
The Founder's Day is celebrated every year at BARC on the occasion of the birth anniversary of Dr. Homi Jehangir Bhabha. This year it was celebrated on the 28th of October 2011. This issue covers all the major events that were a part of the Founder's Day celebrations.

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 अक्तूबर, 2011

डॉ. श्रीकुमार बॅनर्जी
अध्यक्ष, परमाणु ऊर्जा आयोग एवं
सचिव, भारत सरकार, परमाणु ऊर्जा विभाग
का संबोधन

डॉ. श्रीकुमार बॅनर्जी द्वारा संबोधन

"प्रिय साथियों,

अपने प्रिय संस्थापक डॉ. होमी जहांगीर भाभा की 102वीं जयंती के अवसर पर मैं आप सबका हार्दिक अभिवादन करता हूँ और बधाई देता हूँ। जैसी कि हमारी परंपरा रही है आज के दिन हम पिछले वर्ष की उपलब्धियों का मूल्यांकन करते हैं और अपनी विभिन्न गतिविधियों के माध्यम से अपने राष्ट्र को और सशक्त करने के लिए अपने आपको एक बार फिर समर्पित करते हैं।

जैसा कि आप सभी जानते हैं, हमारी गतिविधियां अपने क्षेत्र में, विश्व स्तर के मानदंडों के अनुरूप श्रेष्ठता के साथ अपनी राष्ट्रीय जरूरतों और प्राथमिकताओं को पूरा करने की ओर उन्मुख होती हैं। पिछला वर्ष अनेक उपलब्धियों के साथ घटनाओं से भरा हुआ वर्ष रहा है। इस दौरान बिजली के उत्पादन, नाभिकीय ईंधन के उत्पादन एवं भुक्तशेष ईंधन (स्पेंट फ्यूल) के पुनर्संसाधन में अब तक का श्रेष्ठ रिकार्ड बनाया गया है, जबकि कुछ नई चुनौतियां भी सामने आयी हैं। आगे कुछ मिनटों में इनमें से कुछ की चर्चा मैं आपके सामने करूंगा ।

पिछले वर्ष जब हम मिले थे, उसके बाद से कैगा उत्पादन केंद्र की चौथी इकाई का निर्माण कार्य पूरा हो चुका है और इस वर्ष जनवरी में इसका वाणिज्यिक प्रचालन प्रारंभ हो चुका है। इसके साथ ही अब हमारे देश में कुल 20 नाभिकीय रिएक्टर हो गये हैं जिनकी स्थापित क्षमता 4780 MWe है। केएपीएस की इकाई 1 के उन्नयन, जिसमें सामूहिक शीतलक चैनल प्रतिस्थापन तथा सामूहिक फीडर ट्यूब प्रतिस्थापन शामिल है, के बाद इसे फिर से ग्रिड के साथ सिंक्रोनाइज कर दिया गया है।

स्वदेशी और आयातित, दोनों प्रकार से ईंधन की उपलब्धता में वृद्धि होने के फलस्वरूप नाभिकीय विद्युत उत्पादन में पिछले वर्ष की तुलना में लगभग 40% की वृद्धि दर्ज की गई है। विशेष रूप से, औसत क्षमता गुणक 80% से अधिक है जबकि 7 रिएक्टरों का यह गुणक 90% से अधिक हो गया है। काकरापार और रावतभाटा में 700 MWe के चार थबित भारी पानी रिएक्टरों (पीएछाडब्ल्यूआर) का निर्माण कार्य प्रारंभ कर दिया गया है। कलपक्कम में 500 MWe के पीएफबीआर के निर्माण कार्य का 80% कार्य पूरा हो गया है।

यूरेनियम अन्वेषण के क्षेत्र में, लगभग 32,000 टन अतिरिक्त यूरेनियम संसाधनों की विद्यमानता स्थापित की जा चुकी है। इसके फलस्वरूप देश में आज की तारीख तक का कुल यूरेनियम भंडार 1,72,000 t U_3O_8 तक हो गया है। इसमें आंध्रप्रदेश का तुमलापल्ली स्थित यूरेनियम निक्षेप सबसे आगे है जिसका अकेले का अभी तक का योगथन 60,000 t U_3O_8 से भी अधिक हो चुका है। यहां 15 किमी x 3 किमी के सीमित क्षेत्र में 500 मी. ऊर्ध्वाधर (वर्टिकल) गहराई तक विस्तृत अन्वेषण किया जा चुका है और अभी तक अन्वेषित नहीं किए ब्लॉकों में जब यह अन्वेषण उनकी पूरी क्षमता तक हो जाएगा तो तुमलापल्ली विश्व के सबसे बड़े निक्षेपों में से एक बन सकता है। एएमडी ने चिन्हित संभावित क्षेत्रों-कडप्पा, कालादगी-बाथमी, बीजावार-सोनराई के भागों, उत्तरी दिल्ली फोल्ड बैल्ट तथा मेघालय द्रोणी में 80,000 लाइन कि.मी. से अधिक क्षेत्र में समय प्रक्षेत्र (टाइम डोमेन) विद्युत चुबंकीय प्रणाली का उपयोग करते हुए भू-भौतिकी अन्वेषण में काफी आगे कदम बढ़ाए हैं। एएमडी ने यूरेनियम के अतिरिक्त भारी खनिज प्लेसर संसाधनों, विरल खनिजों तथा विरल धातु संसाधनों में भी वृद्धि की है।

आंध्रप्रदेश में तुमलापल्ली यूरेनियम खनन एवं पेषण परियोजना लगभग पूरी होने वाली है। वर्तमान में मिल में खंडों के अनुसार परीक्षण जारी है और मिल के 2012 के प्रारंभ में कमीशन किये जाने की संभावना है। कर्नाटक में गोगी में अन्वेषणात्मक खनन में शाफ्ट सिंकिंग का कार्य लगभग पूरा होने वाला है। झारखंड के सरायकेला-खरसावान जिले में माहुलडिह यूरेनियम खनन परियोजना की ढलान 50 मी गहराई तक पहुंछा चुकी है और अयस्क पिंड अंतर्रोधित (इंटरसेप्ट) किये गये हैं।

नाभिकीय ईंधन सम्मिश्र, हैदराबाद में इसके सभी संयंत्रों ने न केवल उत्पादन के लक्ष्य प्राप्त किये हैं बल्कि उनमें से कुछ ने तो अपने लक्ष्य से आगे बढ़ कर उत्पादन के नए कीर्तिमान स्थापित किए हैं। पझयकयाल स्थित जर्कोनियम कॉम्प्लेक्स ने अपने वाणिज्यिक प्रचालन के प्रथम वर्ष में प्रशंसनीय कार्य किया है। पीएचडब्ल्यूआर ईंधन के उत्पादन में अभी तक की सर्वश्रेष्ठ पुनर्प्राप्ति 80% है तथा जर्कोनियम ऑक्साइड के उत्पादन में उपभोज्यों (कन्ज्यूमेबल्स) में उल्लेखनीय कमी अर्जित की गयी है।

एफबीटीआर में पीएफबीआर की 37 पिन मॉक्स ईंधन परीक्षण उप-एसेम्बली को 100 GWd/t के लक्ष्य बर्न-अप के मुकाबले 112.5 GWd/t बर्नअप से सफलतापूर्वक किरणित किया गया। पीएफबीआर के मुख्य पात्र से छत की स्लैब तक के लगभग 13 मी. व्यास के परिधिक बट वेल्डिंग के चुनौतीपूर्ण कार्य को सफलतापूर्वक पूरा किया गया। किलोग्राम पैमाने पर यूरेनियम के ताप संसाधन (Pyro Processing) के प्रदर्शन हेतु एक अभियांत्रिकी स्केल सुविधा कमीशन की गयी। एफबीटीआर में इट्रिया के किरणन द्वारा 89 Sr के उत्पादन की संभावना को प्रर्थशित किया गया तथा विकिरण कक्षों में किरणित इट्रिया से Sr-89 के पृथक्करण का कार्य पूरा किया गया। सोडियम अग्नि के अध्ययन के लिए एक अनोखी लघु सोडियम प्रयोगात्मक सुविधा कमीशन की गयी। पीएफबीआर ईंधन के लिए एक अंतरिम ईंधन भंडारण सुविधा का कमीशनन किया गया और उसे फास्ट रिएक्टर ईंधन उप-असेम्बलियों के विनिर्माण हेतु एनएफसी को सौंप दिया गया। फास्ट रिएक्टर कार्यक्रम की सफलता, फास्ट रिएक्टर ईंधन चक्र को पूरा करने हेतु भुक्त शेष (स्पेंट) ईंधन के पुनर्संसाधन की निर्माण क्षमता पर निर्भर है। इस लक्ष्य की दिशा में, फास्ट रिएक्टर ईंधन चक्रण सुविधा की स्थापना के लिए परियोजना को परमाणु ऊर्जा आयोग की मंजूरी मिल चुकी है और मंत्रिमंडल के अनुमोथन की प्रतीक्षा है। फास्ट रिएक्टर कार्यक्रम के तेजी से वृद्धि में फास्ट ब्रीडिंग फास्ट रिएक्टर ईंधन के विकास के महत्व को महसूस करते हुए, धात्विक ईंधन का विकास प्रारंभ किया गया है। कुछ दिनों पहले ही, बीएआरसी तथा आईजीकार के संयुक्त कार्यक्रम के तहत सोडियम परिबद्धित U-Zr मिश्रधातु परीक्षण ईंधन पिनों के पहले सेट का विनिर्माण कर एफबीटीआर में किरणन के लिए उसे एक कैप्सूल में संयोजित किया गया है। कैप्सूल को शीघ्र ही परीक्षण के लिए एफबीटीआर में लोड किया जाएगा।

सभी भारी पानी संयंत्रों का कार्य निष्पादन उत्कृष्ट रहा है तथा भारी पानी बोर्ड ने अपनी 100% से अधिक क्षमता का उपयोग किया है। पीएफबीआर नियंत्रण छड़ों के अनुप्रयोग के लिए बोरोन कार्बाइड पैलेटों में परिवर्तित करने हेतु भारी पानी बोर्ड द्वारा उत्पादित उच्च श्रेणी के संवर्धित बोरोन की बीएआरसी को लगातार आपूर्ति की जा रही है। पीएफबीआर की कुल

आवश्यकताओं में से लगभग थे तिहाई जरूरतों को पहले ही पूरा किया जा चुका है। भारी पानी संयंत्र, बडौदा में प्रति वर्ष 130 MT क्षमता का एक टीबीपी संयंत्र कमीशन किया गया है तथा लक्ष्य उत्पादन प्राप्त कर लिया गया है। फास्फोरिक अम्ल से यूरेनियम की पुनर्प्राप्ति हेतु आरसीएफ, चेम्बूर में एक औद्योगिक स्तर का प्रौद्योगिकी प्रदर्श संयंत्र कमीशन किया गया है। भारी पानी तथा ड्यूटीरियम के वैकल्पिक उपयोगों की दिशा में भापासं, बडौदा के डी-लेबल्ड यौगिकों के प्रयोगशाला स्तर की तैयारी जारी रही।

इंडस-2 सिंक्रोट्रॉन का 100 mA धारा पर 2 GeV पर राउंड द क्लॉक आधार पर नियमित रूप से प्रचालन किया जा रहा है। इसने 20 घंटे का बीम लाइफ टाइम अर्जित कर लिया है। स्वदेशी रूप से विकसित ठोस अवस्था के एम्पलीफायरों से 30 KWRF विद्युत की सहायता से इंडस का प्रचालन 2.3 GeV एवं 100 mA धारा तक बढ़ाया गया है।

होमी भाभा राष्ट्रीय संस्थान की स्थापना को पांच वर्ष पूरे हो गये हैं। पिछले वर्ष के दौरान 100 से अधिक उपाधियां तथा डिप्लोमा प्रदान किए गए। पीएचडी कार्यक्रम में 50 से अधिक छात्रों ने अपनी शैक्षणिक अपेक्षाएं पूरी कीं। नामांकनों की संख्या में लगभग 3000 तक की वृद्धि हुई है जिसमें 1200 से अधिक पीएचडी के लिए हैं।

मुझे आपको यह बताते हुए खुशी होती है कि तमिलनाडु सरकार ने हाल ही में भारत आधारित न्यूट्रिनो वेधशाला कार्यक्रम के लिए मदुरै के पास थेनी में जमीन आबंटित की है। इससे इस अद्वितीय भूमिगत प्रयोगशाला की स्थापना के लक्ष्य को प्राप्त करने में उच्च ऊर्जा भौतिकी समुदाय को बड़ी सहायता मिलेगी।

इस वर्ष मार्च में, जापान में एक साथ थे त्रासदियां हुईं, जिनमें से एक रिक्टर पैमाने पर 9 स्तर के भूकंप के रूप में थी और उसके बाद अप्रत्याशित ऊंचाई की सुनामियों के कारण वहां बड़ी संख्या में जान और माल की क्षति हुई। इस त्रासदी के बाद फुकुशिमा स्थित 10 रिएक्टरों में से चार में दुर्घटनाएं हुई। फुकुशिमा दुर्घटना के बाद भारत के प्रधानमंत्री ने इसे रेखांकित किया था कि राष्ट्रीय नाभिकीय कार्यक्रम को लागू करते समय नाभिकीय विद्युत संयंत्रों की सुरक्षा सरकार के लिए उच्चतम प्राथमिकता का विषय है। इस संबंध में कई कदम उठाए गए हैं और एनपीसीआईएल के कार्यदलों तथा एईआरबी द्वारा संचालित सुरक्षा पुनर्विलोकनों की सिफारिशों में से कई सिफारिशें पहले ही लागू की जा चुकी हैं। शेष सिफारिशों को लागू करने के लिए एक कार्य योजना भी तैयार की गयी है। नाभिकीय विद्युत संयंत्रों की सुरक्षा तथा विनियामक प्रणाली की उच्चस्तरीय समीक्षा के लिए आईएईए मिशनों, नामत: प्रचालनीय सुरक्षा पुनर्विलोकन टीम (ओएसएआरटी) तथा एकीकृत विनियामक पुनर्विलोकन सेवा (आईआरआरएस) को आमंत्रित करने का निर्णय लिया गया है। हमारी सभी नाभिकीय सुविधाओं में आपातकालीन कार्रवाई तथा तैयारी के उपायों को और अधिक मजबूत किया गया है। राष्ट्रीय सुरक्षा विनियामक प्राधिकरण को सांविधिक दर्जा प्रदान करने के लिए संसद में एक विधेयक पुर:स्थापित किया गया है।

हम ग्यारहवीं पंचवर्षीय योजना की समाप्ति की ओर अग्रसर हैं। ग्यारहवीं योजना का कुल व्यय लगभग रु.46,000 करोड़ था। ग्यारहवीं योजना की कई परियोजनाएं पूरी की जा चुकीं हैं तथा कुछ अगली योजना में जारी रहेंगी। हम अभी बारहवीं योजना के प्रस्तावों को अंतिम रूप दे रहे हैं। बारहवीं योजना के प्रस्तावों को तैयार करते समय इन पर जोर दिया गया है - बहु रिएक्टर प्रौद्योगिकियों की खोज, अभिकल्पन पर आधारित घटनाओं से परे अन्य घटनाओं का सामना करने हेतु सुरक्षा का उन्नयन, सामाजिक लाभों के लिए नाभिकीय प्रौद्योगिकियों के अनुप्रयोग पर अधिक जोर, जन स्वीकार्यता को बढ़ाने के लिए बाह्य सम्पर्क कार्यक्रमों तथा विश्वविद्यालयों एवं राष्ट्रीय प्रयोगशालाओं के साथ संबंधों को मजबूत करना।

इस वर्ष के दौरान भारत ने परमाणु ऊर्जा के शांतिपूर्ण उपयोग में सहयोग के लिए कोरिया गणराज्य के साथ एक द्विपक्षीय करार किया है। हरियाणा के बहादुरगढ़ में वैश्विक नाभिकीय ऊर्जा सहभागिता केंद्र स्थापित किया जा रहा है जो प्रचुर उद्भवन प्रतिरोधी रिएक्टर प्रौद्योगिकियों, नाभिकीय सुरक्षा प्रौद्योगिकियों, विकिरण सुरक्षा तथा विकिरण प्रौद्योगिकी अनुप्रयोगों के विकास पर ध्यान केंद्रित करेगा। परमाणु ऊर्जा विभाग ने नामीबिया को

भाभाट्रोन दूर चिकित्सा (टेली थैरेपी) मशीन की आपूर्ति हेतु आईएईए तथा नामीबिया सरकार के साथ एक त्रिपक्षीय समझौता ज्ञापन पर भी हस्ताक्षर किए हैं। परमाणु ऊर्जा विभाग तथा डीओई, संयुक्त राज्य अमेरिका ने त्वरक के क्षेत्र तथा डिस्कवरी साइंस हेतु कण संसूचकों के अनुसंधान एवं विकास में सहयोग के लिए एक कार्यान्वयन करार पर हस्ताक्षर किए हैं।

प्रिय साथियों,

मैंने, विभाग द्वारा विगत वर्ष के दौरान प्राप्त बड़ी उपलब्धियों में से कुछ का उल्लेख यहां किया है। आपके समर्पित तथा अथक प्रयासों के माध्यम से परमाणु ऊर्जा विभाग पूरे उत्साह के साथ अपने कार्यक्रम को आगे बढ़ाने में लगा हुआ है तथा अपने संस्थापक डॉ. भाभा के अधिकांश सपनों को पूरा करने में सफल भी हुआ है। आपको याद होगा कि पिछले वर्ष इसी मंच से आपसे बात करते हुए मैंने अपने भविष्य के दृश्य का खाका खींचा था तथा बताया था कि हमें इस खाके को वास्तविकता में बदलना होगा। इस दृश्य में, नाभिकीय विद्युत सहित पूरे ईंधन चक्र, खाद्य सुरक्षा, स्वास्थ्य संबंधी देखभाल, राष्ट्रीय सुरक्षा के क्षेत्र में बड़े पैमाने पर नाभिकीय विज्ञान तथा प्रौद्योगिकी को सन्नध करना तथा देश में नई प्रतिभाओं को अनुसंधान के अवसर प्रदान करना सम्मिलित था। वास्तव में हम इन सभी क्षेत्रों में संतुलित रूप से आगे बढ़ रहे हैं।

इसी प्रकार से वैश्विक स्तर पर पिछले तीन दशकों में पूरे विश्व में नाभिकीय विद्युत संयंत्रों ने बहुत प्रभावशाली कार्य निष्पादन दर्ज किया है। क्षितिज में कई देशों में नाभिकीय ऊर्जा का पुनरूत्थान देखा गया है। पच्चीस वर्ष पहले हुई चैरनोबिल दुर्घटना के उपरांत, नाभिकीय विद्युत संयंत्रों की सुरक्षा के बारे में लोगों के मन में एक विश्वास बहाल हो रहा था। इसी मोड़ पर, फुकुशिमा दुर्घटना ने, एक अत्यंत ही बड़े पैमान पर बाहरी घटना से प्रभावित होने के बाद, नाभिकीय विद्युत संयंत्रों की सुरक्षा के बारे में लोगों के विश्वास को हिला दिया है। हम अब इस विश्वास को बहाल करने की एक नई चुनौती का सामना कर रहे हैं। सुरक्षा आँकड़े पूरी तरह से नाभिकीय उद्योग के पक्ष में हैं। हमें यह नहीं भूलना चाहिए कि विश्व ने लगभग 30 राष्ट्रों में नाभिकीय बिजली उत्पादन में 14000 रिएक्टर वर्ष पूरे कर लिए हैं। लगातार इतनी अवधि तक, इसके कारण हुई मुख्य दुर्घटनाओं तथा जनहानि की, ऊर्जा उत्पादन के किसी अन्य स्रोत से तुलना की जाय तो वह काफी कम है। भारत ने नाभिकीय विद्युत संयंत्रों के सुरक्षित प्रचालन के लगभग 350 रिएक्टर वर्ष पूरे कर लिए हैं और इस दौरान केवल एक घटना घटी जो नरौरा में हुई अग्नि दुर्घटन थी। यह आईएईए के घटना पैमाने पर, स्तर-III की घटना थी। फुकुशिमा के विकिरण उद्भासन के कारण कोई जनहानि नहीं हुई है जबकि जापान में भूकंप और सुनामी के कारण कुल 20,000 से भी अधिक की जनहानि हुई है। ये आँकड़े एक आम आदमी को संतुष्ट नहीं कर सकते और नाभिकीय विद्युत संयंत्रों की सुरक्षा से संबंधित मामलों को समझाना और उनके विश्वास को दुबारा जीतना हमारा कर्त्तव्य है। हमें यह सुनिश्चित करना चाहिए कि नाभिकीय संस्थापनाओं का उसके आस-पास रह रहे लोगों की जीविका पर कोई प्रतिकूल प्रभाव नहीं पड़े और वे उस क्षेत्र के लोगों के जीवन की गुणवत्ता को सुधारने तथा देश के चहुंमुखी विकास में उल्लेखनीय योगदान कर सकें।

हमें इस पर विस्तार से विचार करना चाहिए कि हम अपने सभी प्रचालनरत संयंत्रों व प्रस्तावित संयंत्रों की साइटों के आस-पास की जनता तक अपने कार्यक्रम को किस प्रकार पहुंचाएं कि हमें उनकी सराहना प्राप्त हो। सबसे पहले हमें स्थानीय जनता के साथ जुड़ना होगा। इसके लिए हमारे लिए यह आवश्यक होगा कि हम उन्हें आगे बढ़ाकर शिक्षा, स्वास्थ्य संबंधी देख-रेख एवं अन्य सामाजिक सेवाएं उपलब्ध करायें। इन सामाजिक गतिविधियों में एक बड़ी संख्या में हमारे वैज्ञानिक एवं अन्य कर्मचारी भाग लें। हम नाभिकीय कृषि, खाद्य संरक्षण, अपशिष्ट से धन (Waste-to-wealth) आदि जैसे सामाजिक महत्व के कार्यक्रम प्रारंभ करें, जिसका लाभ लोगों को मिले। मैं यहां इस बात का उल्लेख करना चाहूँगा कि हमारे अनेक प्रचालनरत संयंत्रों में पहले से ही ऐसी गतिविधियों चल रही हैं। जरूरत इस बात की है कि हम उनका लाभ एक बड़े समुदाय तक पहुंचाएं ।

शिक्षा और स्वास्थ्य का हमारा अपना कार्यक्रम है। हमें अपनी इन सेवाओं का लाभ स्थानीय जनता में कम से कम कुछ लोगों तक पहुंचाना होगा। यह कठिन तो है, पर असंभव नहीं है। यह

कार्य तभी पूरा हो सकेगा जब हमारे साथ हमारे परिवार के सदस्य भी सामाजिक महत्व की इन गतिविधियों में रूचि लेंगे। परमाणु ऊर्जा शिक्षण सोसाइटी, प्रत्येक संयंत्र स्थल में चिकित्सा सुविधाओं, अनुसंधान के लिए बाहरी सहायता उपलब्ध कराने हेतु BRNS, आस-पास के विकास के लिए आकृति (AKRUTI) कार्यक्रम, शैक्षणिक संस्थानों के साथ संबंध, विकिरण द्वारा तैयार बीजों का वितरण एवं म्युनिसिपल अपशिष्ट के प्रबंधन के रूप में हमारे अनेक सुगठित कार्यक्रम हैं। अपने पड़ोस के लोगों के समावेशी विकास (Inclusive growth) के लिए इसे एक बेहतर रूप में कार्यान्वित करने की जरूरत है। यह तभी संभव हो सकता है जब हम सब समाज सेवा एवं जागरूकता के कार्यक्रमों में सहभागी बनें। संस्थापक दिवस के अवसर पर मैं आप सभी लोगों से यह अपील करता हूँ कि आप अपने आपको लोगों को शिक्षा प्रदान करने, उन्हें स्वास्थ्य देखरेख संबंधी सुविधाओं की सहायता उपलब्ध कराने तथा रोजगार के सृजन से संबंधित कार्यक्रमों और मुख्य रूप से स्थानीय जनता के साथ अपने आपको जोड़ें। मुझे पूरा विश्वास है कि ऐसा करने पर हम अपने जीवन को भी समृद्ध कर सकेंगे और अपने कार्यक्षेत्र की उपलब्धियों के साथ-साथ हमें आत्मसंतोष भी प्राप्त होगा।

इसलिए, आइए आज हम इस शुभ दिवस पर अपने आपको नाभिकीय ऊर्जा कार्यक्रम के माध्यम से राष्ट्र के निर्माण के प्रति और अपने देश के लोगों की आकांक्षों को पूरा करने हेतु अपने आपको पुनः समर्पित करें। अपने संस्थापक डॉ. भाभा तथा हमारे कार्यक्रम के कर्णधारों के प्रति यही हमारी सच्ची श्रद्धांजलि होगी।

धन्यवाद,

जय हिन्द."

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_3O_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_3O_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}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 Facilitiy 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 2/3rd 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

the safety reviews conducted by the NPCIL task forces and by AERB have already been implemented. A road map has also been prepared for implementing the remaining recommendations. It has been decided to invite IAEA missions, namely, Operational Safety Review Team (OSART) and Integrated Regulatory Review Service (IRRS), for peer review of safety of nuclear power plants, and of the regulatory system, respectively. The emergency response and preparedness measures have been further strengthened in all our nuclear facilities. A bill to confer statutory status to the national safety regulatory authority has been introduced in the Parliament.

We are coming to the end of the XI 5-year plan. The total outlay of the XI plan was around Rs. 46,000 Crores. Many of the projects in the XI plan have been completed and some of them are being continued in the next plan. We are currently finalising the proposals for the XII Plan. The emphasis while preparing the XII plan proposals has been – pursuit of multiple reactor technologies, safety upgrades to address beyond design basis external events, increased emphasis on applications of nuclear technology for societal benefits, outreach programmes to enhance public acceptance and strengthening of linkages with universities and national laboratories.

During the year, India has entered into bilateral agreement with Republic of Korea for cooperation in peaceful uses of Atomic Energy. Global Centre for Nuclear Energy Partnership being set up at Bahadurgarh, Haryana will focus on development of proliferation resistant reactor technologies, nuclear security technologies, radiological safety and radiation technology applications. DAE also signed tripartite MoU with IAEA and Government of Namibia for supply of a Bhabhatron Tele-therapy machine to Nambia. An Implementing agreement between DAE and DOE, USA was signed for corporation in the area of accelerator and particle detectors R&D for discovery science.

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 in to 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."

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संस्थापक दिवस - 2011

शुक्रवार, 28 अक्तूबर, 2011

डॉ. आर.के. सिन्हा

निदेशक, भापअ केंद्र
का संबोधन

डॉ. आर.के. सिन्हा द्वारा संबोधन

" परमाणु ऊर्जा आयोग के अध्यक्ष डॉ. बॅनर्जी, परमाणु ऊर्जा विभाग परिवार के वरिष्ठ सदस्यगण, सम्मानित सहकर्मिकों, देवियों और सज्जनों,

यह मेरा परम सौभाग्य 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 अक्तूबर को हम अपने संस्थापक डॉ. होमी जहांगीर भाभा के जन्मदिवस पर उन्हें श्रद्धांजलि अर्पित करते हैं। चूंकि इस वर्ष डॉ. भाभा की जयंती सप्ताह के अंत में रविवार को पड़ रही है, इसलिए हम आज शुक्रवार की सुबह यहाँ इकट्ठे हुए हैं। इस अवसर पर हम पिछले वर्ष के अपने कार्य निष्पादन तथा उपलब्धियों का अवलोकन करते हैं और इसके साथ-साथ अपने देश तथा देश की विशाल जनसंख्या को नाभिकीय विज्ञान संबंधी सभी सेवाओं का अधिकतम लाभ उपलब्ध करवाने के लिए पुन: अपने आपको समर्पित करते हैं ।

मैं अपने केंद्र द्वारा हाल में किये गये कुच महत्वपूर्ण विकास कार्य तथा प्राप्त की गई उपलब्धियों की झलक प्रस्तुत करने की कोशिश करूंगा ताकि हम अपने कार्य की विशिष्टताओं एवं प्रकृति पर एक दृष्टिपात कर सकें ।

1. अनुसंधान रिएक्टर

दिसंबर 2010 की समाप्ति अनुसंधान रिएक्टर सायरस और ध्रुवा के लिए महत्वपूर्ण रही । सायरस प्रचालन की स्वर्ण जयंती और ध्रुवा प्रचालन की रजत जयंती का समारोह धूमधाम से मनाया गया। आईसोटोप उत्पादन, पदार्थ परीक्षण, अनुसंधान एवं मानव संसाधन विकास के लिए केंद्र के सभी रिएक्टरों का समुचित प्रयोग किया गया । अनेक उन्नयन कार्यों के लिए इस वर्ष अतिरिक्त शटडाउन आवश्यकताओं के बावजूद अनुसंधान रिएक्टर ध्रुवा उच्च स्तरीय संरक्षा और लगभग 70% उपलब्धता पर प्रचालनरत रहा। उन्नयन कार्यों में आधुनिक यंत्रीकरण द्वारा मुख्य नियंत्रण पैनलों तथा ईंधनन मशीन नियंत्रण पैनलों का प्रतिस्थापन शामिल था। लंबी अवधि के स्टेशन ब्लैक आउट परिदृश्य को संभालने के लिए ट्राली मांउन्टेड डीज़ल इंजन चालित पंपों का कमीशनन किया गया और इनका अच्छी तरह रखरखाव किया जा रहा है।

ध्रुवा रेडियोआईसोटोप उत्पादन एवं न्यूट्रॉन किरणपुंज अनुसंधान हेतु राष्ट्रीय सुविधा के लिए प्रमुख सुविधा के रूप में बना रहा। पिछले वर्ष कुल 786 रेडियोआईसोटोप के नमूने सुपुर्द किए गए। रेडियोआईसोटोप उत्पादन को और भी बढ़ाने के लिए एक

अतिरिक्त ट्रे रोड को समाहित किया गया। विभिन्न अनुसंधान प्रयोजनों के लिए एक सौ चौबीस नमूनों को वतिल वाहक सुविधा में किरणित किया गया। वैज्ञानिक अनुसंधान हेतु यूजीसी-डीएई संकाय के तत्वावधान के अंतर्गत और अनेक शैक्षणिक संस्थाओं से अनुसंधान के छात्रों द्वारा सुविधा का प्रयोग किया जा रहा है।

सायरस रिएक्टर के दिनांक 31 दिसंबर 2010 को स्थायी शटडाउन के पश्चात उसे ईंधन रहित किया गया तथा भारी पानी मंदक को भंडारण टंकियों में स्थानातरित किया गया । इस रिएक्टर की विभिन्न प्रणालियों को परिरक्षण पद्धति में प्रचालित किया जा रहा है।

सायरस रिएक्टर प्रणालियों का संपूर्ण विकमीशनन किया गया। अप्सरा के स्थल पर 2MW(th) रेटेड शक्ति वाले एक नए कुंड प्रकार के अनुसंधान रिएक्टर के निर्माण से संबंधित गतिविधियां जारी हैं। हाल ही के मूल्यांकन से पता चला है कि बढ़ी हुई स्थैतिक एवं भूकंपीय भारण स्थितियों हेतु नये रिएक्टर कुंड ब्लाक के निर्माण की आवश्यकता होगी ।

नवीन 30 MW तापीय उच्च फ्लक्स अनुसंधान रिएक्टर (एचएफआरआर) का मूलभूत अभिकल्पन किया जा चुका है।

2. नाभिकीय विद्युत संबंधी अनुसंधान एवं विकास

प्रचालन एवं निर्माणाधीन नाभिकीय विद्युत संयंत्र

भाभा परमाणु अनुसंधान केंद्र द्वारा पिछले वर्ष तारापुर में बीएआरसी कंटेन्मेंट (बारकॉम) जांच मॉडल का सफलतापूर्वक कमीशनन किया गया। वर्ष के दौरान चार श्रृंखलात्मक अतिदाब परीक्षण किए गए जिसके कारण संरोधन की कार्यात्मक विफलता हुई और यह जांच सफल रही। जांच के परिणाम सात देशों से 11 अंतर्राष्ट्रीय प्रतिभागियों सहित पंद्रह राउंड रॉबिन प्रतिभागियों को जांच पश्च विश्लेषण उपलब्ध करवाए गए। इस प्रकार का विस्तृत यंत्रीकृत प्रयोग विश्व में पहली बार किया गया ।

महत्वपूर्ण जानकारी यह है कि प्राथमिक संरोधन की कार्यात्मक विफलता के पश्चात भी, पूर्वप्रतिबल के कारण अंतरनिहित टाइट क्रैकस सहित प्राथमिक संरोधन से रिसाव अनुमेय सीमा के अंदर ही था और परिरक्षण आवरण को भी स्थिर अवस्था में रखा जाएगा।

पीएचडब्ल्यूआर दाब नलियों, टर्बाइन ब्लेड, पीडब्ल्यूआर दाब पात्र और प्राथमिक पाइप लाइनों जैसे क्रांतिक नाभिकीय विद्युत संयंत्र घटको में त्रुटि संसूचन एवं अभिलक्षणन में बेहतर संवेदनशीलता एवं विश्वसनीयता प्राप्त करने के लिए परा-श्रव्य प्रवस्था व्यूह प्रौद्योगिकी विकसित की गई ।

ईंधन गुच्छों सहित 700 मेगावॉट पीएचडब्ल्यूआर ईंधन वाहक घटकों के लिए द्विकला दाब बिंदु डाटा उत्पादन हेतु एक जाँच सेक्शन का स्थापन किया गया।

दाब नलियों में हाइड्रोजन इनग्रेस के मूल्यांकन प्रगत सेवाकालीन निरीक्षण अन्वेशियों का अभिल्पन एवं जाँच की गई। कैगा-1 में प्रचालनरत दाब नलियों में हाइड्रोजन के निर्धारण हेतु स्क्रेप सैम्पलिंग की गई।

दीर्घकालीन स्टेशन ब्लैक आउट स्थिति के अंतर्गत टीएपीएस 1 एवं 2 के सकल गतिविधि के अध्ययन के लिए एक विश्लेषण किया गया ताकि ईंधन तापमान, आरपीवी दाब, गंभीर दुर्घटनाक्रम के दौरान क्लैड आक्सीकरण एवं हाइड्रोजन उत्पादन के विस्तार पर सूचना प्राप्त की जा सके। विश्लेषण के आधार पर दुर्घटनाक्रम की समय रेखा का अनुमान लगाया गया और इससे बाहरी हस्तक्षेप के लिए पर्याप्त समय अंतर की उपलब्धता की जानकारी होती है।

बृहत पीएचडब्ल्यूआर हेतु स्टेशन ब्लैक आउट के परिणामों को दूर करने के लिए मंदक पक्ष में जल के इंजेक्शन के प्रभाव का मूल्यांकन किया गया।

एएचडब्ल्यूआर कार्यक्रम

एएचडब्ल्यूआर अभिकल्पन की किसी पूर्वानुमानित दुर्घटना के परिदृष्य में इसकी सशक्तता के मूल्यांकन के लिए विस्तृत अभ्यास किया गया। यह निर्धारित किया गया कि इसकी प्रगत निष्क्रिय संरक्षा लक्षण के कारण, फुकुशिमा, चेर्नोबिल एवं थ्री माइल आयलैंड जैसी दुर्घटनाओं का ईंधन विश्वसनीयता पर वास्तव में कोई प्रभाव नहीं पड़ता।

एएचडब्ल्यूआर के लिए अभिकल्पन अंतर के मूल्यांकन के प्रति प्रयोगात्मक कार्यक्रम अनेक नयी सुविधाओं के स्थापन एवं वर्तमान सुविधाओं में प्रयोगों के माध्यम से जारी रहा। उदाहरण के लिए एक वायु-जल लूप का स्थापन एवं कमीशनन किया

गया ताकि एएचडब्ल्यूआर के वाष्प ड्रम से जुडे अनेक ऊष्मीय द्रव चालित प्रतीयमान का अध्ययन किया जा सके।

विभिन्न प्रयोगों के लिए सत्तावन अवसरों पर प्रगत भारी पानी रिएक्टर (एएचडब्ल्यूआर) क्रांतिक सुविधा का प्रचालन किया गया। विभिन्न जालक स्थितियों पर थोरिया और यूरोनियम (Th-U) पिन एवं (Th-१%Pu) मॉक्स ईंधन युक्त गुच्छों के भरण के कारण सक्रियता मापन संतोषजनक रूप से किया गया ।

एचटीआर संबंधी विकास कार्य

भारतीय उच्च तापीय रिएक्टर हेतु वैकल्पिक शीतलक के मूल्यांकन की दिशा में, एक मॉल्टेन सॉल्ट नैचुरल सर्कुलेशन लूप का संविरचन एवं स्थापन किया गया ताकि ऊष्मा अंतरण एवं दाब पात्र पर डाटा निर्मित किया जा सके। माल्टेन सॉल्ट के गुणधर्मों को समाहित करते हुए एक कंप्यूटर कोड का विकास किया गया।

3. प्रगत नाभिकीय ईंधन

एफबीआर एवं थोरियम ईंधनित एएचडब्लयूआर के लिए प्रगत ईंधन के विकास की दिशा में भाभा परमाणु अनुसंधान केंद्र में अनेक गयी गतिविधियां चलाई गईं। इस कार्य में अभिनव धात्विक ईंधन संविरचन सुविधा का विकास, U-Pu धात्विक ईंधन अभिलक्षणन एवं जर्कोनियम लाइनर बॉन्डेड कैल्ड पदार्थ के साथ उसकी संगतता का मूल्यांकन भी शामिल किया गया। एफबीआर हेतु सर्मेट ईंधन के विकास पर भी हम कार्य कर रहे हैं ।

चूर्ण धातुकी मार्ग द्वारा एएचाडब्लयूआर कार्यक्रम के लिए, 8 से 22.5% तक UO_2 युक्त विविध संयोजन की ThO_2-UO_2 गुटिकाओं का संविरचन किया गया। इन ईंधनों के ताप भौतिकी गुणधर्मों का मूल्यांकन कार्य प्रगतिपर है। इम्प्रेग्नेशन ऐग्लोमरेट प्रोसेस (आईएपी) नामक एक नई तकनीक प्रारंभ की गई है। इस तकनीक में ThO_2 गोलक एवं यूरेनियम नाइट्रेट घोल को प्रारंभिक पदार्थ के रूप में प्रयोग करते हुए थोरियम आधारित मिश्रित आक्साइड ईंधन गुटिकाओं का संविरचन किया गया और इसका परिणाम उत्साहजनक रहा। इस प्रक्रिया के प्रयोग से चूर्ण हस्तन एवं यूरेनियम-233 के हस्तन से जुड़े कार्मिकों में विकिरण उद्भासन कम होगा।

सायरस दाबित जल लूप में किरणित प्रयोगात्मक थोरिया-प्लूटोनिया मॉक्स ईंधन घटकों का पश्च किरणन परीक्षण पूरा किया गया। परिणामों से यह निदर्शित किया गया है कि किरणित थोरिया (यूरेनियम आक्साइड आधारित ईंधन घटकों से संबंधित) विखंडन उत्पादों में बेहतर अवधारण होता है ।

4. पुनर्संसाधन एवं अपशिष्ट प्रबंधन

ठीक एक वर्ष पहले, इसी अवसर पर मैंने तारापुर स्थित प्रिफ्री-2 पुनर्संसाधन संयंत्र के असक्रियता चालन के प्रारंभ किए जाने की घोषणा की थी। भुक्तशेष ईंधन के साथ रेडियोसक्रिय परीक्षण का दिनांक 7 जनवरी 2011 को भारत के माननीय प्रधान मंत्री द्वारा उद्घाटन किया गया ।

संयंत्र की सभी प्रणालियां सचारू रूप से कार्यरत हैं एवं संयंत्र द्वारा अब अपने कार्यक्रम के लिए प्लूटोनियम का उत्पादन किया जा रहा है। कलपाक्कम में पुनर्संसाधन संयंत्र प्रिफ्री-IIIA का निर्माण कार्य तेजी से आगे बढ़ रहा है। प्रथम समाकलित नाभिकीय पुनश्चक्रण संयंत्र, तारापुर हेतु अवसंरचना विकास का कार्य प्रगति पर है।

तारापुर स्थित पहले जूल गावक (AVS-I) का सुदूर विकमीशनन पूरा हो चुका है। दूसरा जूल गालक AVS-II का कमीशनन कार्य हाथ में लिया जा रहा है। कलपाक्कम स्थित विभिन्न अपशिष्ट प्रबंधन सुविधाओं का कोल्ड कमीशनन किया जा रहा है।

ट्रांबे स्थित प्लूटोनियम संयंत्र (पीपी) एवं कलपाक्कम पुनर्संसाधन संयंत्र (केएआरपी) भी संरक्षित एवं कुशल रूप से प्रचालनरत रहे। इसके अतिरिक्त, थोरिया अपशिष्ट का संसाधन किया गया एवं अपशिष्ट निश्चलन संयंत्र (डब्ल्यूआईपी) में परिवर्तन एवं उन्नयन कार्य पूरा किया गया। अनुसंधान एवं विकास के क्षेत्र में, भुक्तशेष ईंधन से उपयुक्त पदार्थ की पुन:प्राप्ति हमारी जिम्मेदारियों में से एक है जो अंतरराष्ट्रीय तौर पर अनुसंधान का अति प्रगत क्षेत्र है। इस दिशा में, हमने वर्ष के दौरान महत्वपूर्ण उपलब्धियां प्राप्त की हैं जिसके अंतर्गत थोरियम लीन अपशिष्ट से स्ट्रॉंशियम की प्राप्ति एवं सहचारी विशिष्ट क्राउन ईथर संश्लेषण का निदर्शन शामिल है। सीजियम विशिष्ट क्राउन ईथर के उत्पादन के लिए भी प्रक्रिया का विकास किया गया है। सतत घूर्णी विलयनित्र एवं कोल्ड क्रूसिबल प्रेरण गालक के विकास में भी प्रगति की गई।

5. पर्यावरण मॉनीटरन एवं विकिरण संरक्षा

फुकूशिमा घटना के प्रभाव का मूल्यांकन

हमारे परिकलनात्मक मॉडलों का प्रयोग करते हुए, पर्यावरण एवं प्रशांत महासागर में फुकूशिमा नाभिकीय दुर्घटना के कारण विविध रेडियो न्यूक्लाइडों को उन्मोचन दरों का प्रारंभिक अनुमान प्राप्त किया गया।

अनुमानित उन्मोचन दरों की उचित तुलना विविध एजेन्सियों द्वारा रिपोर्ट किए गए मानों से की गई।

देश की सभी पर्यावरण सर्वेक्षण प्रयोगशालाओं द्वारा पर्यावरणीय मेट्रिक्स में अति निम्नस्तरीय विकिरण सक्रियता को मॉनीटर करने के लिए विशेष अभियान चलाया गया। वातावरण में रेडियोसक्रियता के लिए सभी स्थानों पर IERMON नेटवर्क से प्राप्त डाटा का भी लगातार विश्लेषण किया गया। इससे हम यह पुष्टि कर पाए कि फुकूशीमा घटना से भारत पर कोई विशेष प्रभाव नहीं पड़ा।

पर्यावरण मॉनीटरन

सौर ऊर्जित प्रणालियाँ एवं जीएसएम तथा लैन आधारित संचार सहित पर्यावरण विकिरण मॉनीटरों का विकास किया गया। ईसीआईएल, हैदराबाद की सहायता से 250 यूनिट द्रव्यमान उत्पादन किया गया। इन यूनिटों को प.ऊ.वि. के भारतीय पर्यावरण विकिरण मॉनीटरन नेटवर्क (IERMON) कार्यक्रम के अन्तर्गत देश के विभिन्न स्थानों पर स्थापित किया जाएगा।

वैज़ाग में प्रस्तावित भापअ केंद्र कैम्पस हेतु वायुमंडलीय, जलीय एवं पार्थिव पर्यावरण के लिए विस्तृत बेस लाइन डाटा एकत्रित किया गया। तीस किलोमीटर त्रिज्या वाली परिधि के क्षेत्र में स्वास्थ्य एवं जनसंख्यिक स्थिति का सर्वेक्षण और समुद्री सर्वेक्षण पूरा किया गया।

विकिरण संसूचन हेतु यंत्रीकरण

प्रत्यक्ष संतति स्पंदकों का प्रयोग करते हुए रेडान, थोरान क्षय उत्पादों के कारण संचित मात्रा के प्रत्यक्ष मॉनीटरन के लिए अंत:श्वसन मात्रामापी बैजों का विकास किया गया है। इन बैजों को देश के अंदर लगभग 2000 स्थानों में और अनेक विदेशी संस्थाओं के अनुरोध पर यूरोप के लगभग 1000 स्थानों में परिनियोजित किया गया। विश्व के कई भागों में विशेषकर कम संवातन वाले घरों में रेडान और थोरान से प्राकृतिक विकिरण का प्रभाव एक जानी-मानी समस्या है एवं भापअ केंद्र में किया गया सरल एवं प्रभावपूर्ण विकास एक महत्वपूर्ण योगदान है।

6. भौतिक विज्ञान

तांबा और चांदी मादित लिथियम-टेट्रा-बोरेट के एकल क्रिस्टल निर्मित किए गए एवं उन्हें प्रकाश अनुकारित संदीप्ति तकनीक पर आधारित मात्रामिति अनुप्रयोगों के लिए उपयुक्त पाया गया।

7. रसायन विज्ञान

अति अम्लीय माध्यम में प्लूटोनियम की अल्फा सक्रियता के मॉनीटर के रूप में स्वगृहे विकसित नैनो-डायमंड के व्यवहार्यता अध्ययन पूरा किया गया। एक सरल एवं सस्ता हाइड्रोजन-आधारित पदार्थ का विकास किया गया, जिसमें सिट्रिक अम्ल युक्त कॉटन गेज वाले नाइट्रोजन ऑक्साइड मुक्त करने वाले एगरोस जे मौजूद है। इसमें उत्कृष्ट प्रति सूक्ष्मजैविक गुणधर्म हैं एवं व्रणकारी त्वचा संक्रमणों में मरहम-पट्टी के रूप में उपयोगी है।

8. जीव-विज्ञान

रेडियोसंरक्षी एजेंटों के विकास की दिशा में, प्रयोगात्मक अध्ययनों में महत्वपूर्ण खोज की गई। 1,4-नैफ्लोक्विनोन (एनक्यू), कई ट्यूमर प्रतिरक्षी प्राकृतिक संयोजक 4 Gy गामा विकिरण डोज पर चूहों के लिम्फोसाइट एवं आंतों की कोशिकाओं से संरक्षा देते हैं। चूहों में, जीवे प्रदत्त 2mg/kg एनक्यू से विकिरण प्रेरित अस्थि मज्जा दबाव को पुन: निर्मित किया गया।

9. कोड़ों का विकास

पदार्थ अन्तरा पृष्ठों हेतु वॉल्यूम-ऑफ-फ्लूइड ट्रेकिंग का प्रयोग करते हुए द्वि-विनीय, बहु-पदार्थ यूलेरियन विकिरण-हाइड्रोकोड का विकास, मान्यीकरण एवं अनुप्रयोग किया गया ताकि वे घन एवं अपक्षरणी त्वरण समस्याओं पर संघात कर सके।

विकिरण-जलगतिक अनुकारों हेतु आवश्यक घनत्व एवं तापमान में परिमाण को शामिल करते हुए ईक्वेशन-ऑफ-स्टेट (EOS) डाटा के निर्माण के लिए एक कोड का विकास किया गया। मूलाधार परमाण्विक अनुकारों का प्रयोग करते हुए विस्फोटक तारों के प्रतिरूपण हेतु आवश्यक धातुओं की विस्तारित स्थिति के लिए उच्च परिशुद्ध EOS डाटा का निर्माण किया गया।

10. खाद्य प्रौद्योगिकी

किरणित फलों और सब्जियों में कटे हुए फलों और सब्ज़ियों में भूरेपन को कम किया गया। पहली बार, पहले से ही कटे हुए व पकाने के लिए तैयार कद्दू पर किए गए अध्ययन से यह पाया गया है कि विकिरण संसाधन के दौरान उसके प्रीकर्सर से मुक्त गामा रिसॉरसिलिक अम्ल पालीफेनोल आक्सिडेस के प्राकृतिक संदमक के रूप में कार्य करता है जो कटे हुए फलों और सब्जियों के भूरे फीकेपन के लिए कारक इन्जाइम है।

अंकुर संदमन हेतु किरणित आलुओं से बनाए गए चिप्स में ऐक्रिलैमाइड का स्तर अकिरणित आलू नियंत्रण की तुलना में काफी कम पाया गया जो एक न्यूरोटाक्सिन होने के साथ-साथ संभाव्य कैर्सिनोजन भी है।

11. नाभिकीय कृषि

आंध्रप्रदेश के सभी कृषि मौसम क्षेत्रों में सिंचाई की स्थिति के अंतर्गत खरीफ़ और रबी से पहले भीमा के नाम से वाणिज्यिक कृषि के लिए मिष्ठान्न श्रेणी की ट्राम्बे मूंगफली किस्म का बड़ा बीज, टीजी 47 को जारी किया गया।

भापअ केंद्र द्वारा हाल ही में 470 क्विंटल उत्तम प्रजनक बीजों की किस्मों को जारी किया गया और आगे के प्रयोग के लिए अनेक राज्य बीज निगमों, राष्ट्रीय संस्थाओं, राज्य कृषि विश्वविद्यालयों, गैर सरकारी संस्थाओं और किसानों को वितरित किया गया।

भापअ केंद्र में निसर्गऋण प्रौद्योगिकी का विकास न केवल जैव निम्नीय अपशिष्ट का पर्यावरण अनुकूल रूप से निपटान के लिए किया गया है बल्कि उच्च गुणता वाली खाद और ईंधन गैस के सकुशल उत्पादन के लिए भी किया गया है। इस प्रौद्योगिकी का प्रयोग हमारे देश में व्यापक रूप से किया जा रहा है। पिछले वर्ष के दौरान इस प्रकार के 25 और संयंत्र कार्यरत हुए। इस प्रौद्योगिकी का प्रयोग बड्डी (एचपी), अंजट (गुजरात), कोच्ची (केरल) एवं चन्द्रपुर (महाराष्ट्र) के वस्त्र, खाद्य और काग़ज उद्योगों के बहि:स्त्राव उपचार संयंत्रों (ईटीपी) द्वारा उत्पन्न बृहत मात्रा के जैविक आपंक के संसाधन हेतु किया जा रहा है।

12. आईसोटोप अनुप्रयोग

पैक्ड कोल्ड बेड टैस्ट रिएक्टर में अनुप्रयोग के लिए इंडियन ऑइल कॉरपोरेशन लिमिटेड (आरएण्डडी केंद्र), फरीदाबाद के सहयोग से एक समर्पित 32 संसूचक चैनल एवं सीएस 137 रेडियोआईसोटोप आधारित प्रौसेस टामोग्राफ़िंग एमेंजिंग सिस्टम का अभिकल्पन एवं विकास किया गया जो देश में इस प्रकार का सर्वप्रथम सिस्टम है।

प्रौस्टेड कैंसर के उपचार हेतु भापअ केंद्र द्वारा उत्पादित आयोडिन-125 बीजों का पहला चिकित्सीय प्रयोग प्रोस्टेड के ऐडीनो कार्सीनोमा से पीड़ित रोगी पर मुंबई में दिनांक 21 सितंबर, 2011 को पीडी हिन्दुजा नेशनल हॉस्पिटल एण्ड मेडीकल रिसर्च सेंटर में किया गया।

उद्योग के सहयोग से, विभिन्न प्राचलों को मानकीकृत करते हुए रेडिएशन-ग्राफटेड पॉलीप्रोपाइलिन आधारित हाइड्रोफाइलिक बैटरी सैपरेटर का विकास किया गया। सैपरेटर की जाँच प्रयोक्ता उद्योग द्वारा की गई और कम लागत वाले आयात विकल्प के रूप में उपयुक्त पाया गया।

13. पदार्थ कार्यक्रम

प्रगत नाभिकीय रिएक्टरों (जैसे एएचडब्ल्यूआर) एवं वर्तमान रिएक्टरों की आयु में विस्तार के लिए एस.एस. वेल्डों की दीर्घ अभिकल्पन आयु की पुष्टि के लिए, ऑस्टेनाइटिक स्टेनलैस स्टील वल्डों हेतु निम्न तापमान एमब्रिटिलमैन्ट की गतिकी स्थापित की गई। एलटीई की डिग्री के अभिलक्षणन के लिए विकसित विद्युत रासायनिक तकनीक का अनुप्रयोग अविनाशी प्रकार से और संयंत्रों में स्वस्थाने प्रयोग के लिए किया जा सकता है।

टैस्ट ब्लैंकेट मॉडुल (टीबीएम)- कार्यक्रम के माध्यम से आईटीईआर के प्रति भारतीय योगदान के संबंध में भापअ केंद्र द्वारा Pb-17 Li हेतु पंप चालित द्रव धातु लूपों का विकास किया गया और इन्हें 1000 घंटों से भी अधिक समय तक लगातार सफलतापूर्वक प्रचालित किया गया। लूप के लिए पंप तथा अनेक मुख्य घटकों का संविरचन स्वगृहे किया गया।

भारतीय विरल मृदा उत्पादों के वाणिज्यिक स्तरीय विकास की दिशा में मॉलिब्डेनम क्रूसिबल में स्थायी चुम्बक के निर्माण हेतु Nd-Fe-B मिश्रधातु चुर्ण का संश्लेषण किया गया जिसमें अपचयन-विसरण प्रक्रम शामिल है।

14. इलेक्ट्रोनिक्स एवं यंत्रीकरण

एएसआईसीएस

0.35 µm CMOS प्रौद्योगिकी में तीन नए एएसआईसीज़ों- अणुस्पर्श, अणुदृष्टि एवं अणुसूचक का अभिकल्पन, विकास एवं सफलतापूर्वक परीक्षण किया गया। अणुस्पर्श आईएनओ (भारत स्थित न्यूट्रोनों वेधशाला) के रेजेस्टिव प्लेट चैम्बर संसूचकों हेतु फ्रंट एण्ड रीडआउट के लिए, अणुदृष्टि एक मोनोलिथिक फोटो डायोड एवं संहत गामासंसूचन अनुवेशियों के लिए रीडआउट इलेक्ट्रॉनिकी है तथा अणुसूचक सिलीकॉन पिन संसूचाकों के लिए निम्न शक्ति फ्रंट एण्ड रीडआउट है।

गहराई में स्थित खनिज निक्षेपों के विद्युत चुम्बकीय सर्वेक्षण की सहायता के लिए 22 मीटर व्यास वाले ट्रांसमीटर कॉइल एवं 1.1 मीटर रिसीवर कॉइल युक्त टाइम डोमेन इलेक्ट्रोमेग्नेटिक (टीडीईएम) प्रणाली की जाँच एचएएल के ध्रुवा सैनिक हैलीकॉप्टर को उसकी उड़ान क्षमता के लिए की गई और इसे संतोषजनक पाया गया। यह देश में यूरेनियम के विस्तृत अन्वेषण में तीव्रता एवं सहायता प्रदान करने के क्षेत्र में एक महत्वपूर्ण स्वदेशी विकास है।

चेहरा पहचानने की प्रणाली

प्रवेश नियंत्रण हेतु भापअ केंद्र द्वारा विकसित चेहरा पहचानने की प्रणाली के उत्तम परिणाम (केवल 0.7% गलत स्वीकृति) मिले हैं। यह अनेक प्रकार के समाकलित बायोमैट्रिक प्रवेश नियंत्रण प्रणालियों हेतु गहरी प्रतिरक्षा के रूप में महत्वपूर्ण है।

अन्तरीय सूक्ष्म वायुदाबमापी

महत्वपूर्ण आयात विकल्प के रूप में एक अन्तरीय सूक्ष्म वायुदाबमापी का विकास किया गया ताकि अपश्रव्य रेंज में माध्य वायुमंडलीय दाब के चारों ओर माइक्रोबार्स के क्रम में अतिसूक्ष्म वायुमंडलीय दाब भिन्नता को मापा जा सके।

इस महत्वपूर्ण विकास से काल क्षेत्र एवं आवृत्ति क्षेत्र में विशिष्ट विनिर्देशों के अनुसार विभिन्न तापमान एवं वायु परिस्थितियों में अति संतोषजनक कार्यनिष्पादन प्राप्त हुआ।

15. त्वरक एवं उच्चशक्ति इलेक्ट्रॉनिकी

द्वि-ऊर्जा संहत रेखीय त्वरक:

एक्स-रे कार्बोस्कैनिंग अनुप्रयोगों हेतु 3/6 MeV द्वि-ऊर्जा संहत रेखीय त्वरक विकास का एक प्रगत स्तर है। 85kv इलेक्ट्रॉन गन एवं उसके मॉडुलेटर शक्ति आपूर्ति, लाइनेक कैविटी, मैग्नेट्रॉन स्रोत एवं मॉडुलेटर, फोकसन-चुम्बक, एक्स-रे टार्गेट एवं कॉलीमेटर युक्त सहप्रणालियों का विकास किया गया और सहप्रणाली की समकलन प्रक्रिया प्रगति पर है।

विद्युत-चुम्बक निर्माण प्रणाली

असामान्य धातुओं की शीत वेल्डन में प्रयोग हेतु 20kv, 40 किलो-जूल विद्युत चुम्बकीय निर्माण प्रणाली का विकास किया गया। अनेक विशेष घटक एवं लक्षण वाली इस प्रणाली का प्रयोग एस एस एण्ड प्लग के साथ D-9 के एफबीआर क्लैड नलियों को जोड़ने और ODS क्लैड नलियों एवं प्लग को जोड़ने के भावी अनुप्रयोगों में प्रयुक्त किया जाएगा।

16. प्रगत प्रौद्योगिकियाँ

क्रायो-प्रौद्योगिकी

77K पर स्पंदकों के लिए 250mW शीतलन उपलब्ध करवाने हेतु नाइट विजन डिवाइस के लिए हस्त-धारित तापीय प्रतिबिम्बक के साथ स्वगृहे विकसित सूक्ष्म क्रायो शीतलक इकाई को सफलतापूर्वक समाकलित किया गया और सहायक हार्डवेयर के साथ ईएमई स्कूल, बड़ौदा को सुपुर्द किया गया।

निर्लवणीकरण

थिन फिल्म कम्पोज़िट पोलीएमाइड झिल्ली प्रौद्योगिकी हेतु स्वदेशी क्षमता के निर्माण की दिशा में, प्रतिपरासरण हेतु इस प्रकार की झिल्लियों की पहली खेप तैयार की गई और इसे वाणिज्यिक आकार के घटकों में कुण्डली आकार में रोल किया गया। इन घटकों में से छः एनडीडीपी, कल्पाक्कम स्थित प्रतिपरासरण संपन्न में झिल्ली घटकों को प्रतिस्थापित करने के लिए तैयार है।

17. रोबोटिकी एवं सुदूरीकरण

स्वचालित पदार्थ अंतरण प्रणाली (एएमटीएस)

भापअ केंद्र में एक ऑटोमेटेड गाइडेड वेहिकल (एजीवी) आधारित पदार्थ अंतरण प्रणाली का अभिकल्पन एवं विकास

किया गया। यह प्रणाली किसी भी विनिर्माण संयंत्र में विभिन्न संसाधन इकाइयों के बीच पदार्थ हस्तान्तरण के लिए माँग का सतत वास्तविक काल मूल्यांकन करती है और तद्नुसार अपनेआप योजनाबद्ध रूप से प्राथमिकता के अनुसार अंतरण करती है। इस प्रणाली का निदर्शन सम्भाव्य प्रयोक्ताओं, निर्माताओं तथा मीडिया के लिए किया गया और अब इसे शीघ्र ही आकुर्डी, पूना स्थित बजाज ऑटोप्लांट में प्रयोग के तौर पर नियोजित किया जाएगा।

फोर पीस सर्वोमैनीपुलेटर (एफपीएसएम)

भापअ केंद्र द्वारा हाल ही में विकसित फोर पीस सर्वो मॅनीपुलेटर (एफपीएसएम) सर्वोमेनीपुलेटर का एक अभिनव अभिकल्पन है जिसका प्रयोग किसी भी टेलीस्कोपिक मैकेनिकल मास्टर स्लेव मेनीपुलेटर के स्थान पर किया जा सकता है। रखरखाव में सरल इस एफपीएसएम को प्रयोग करते हुए प्रचालक यांत्रिक मेनीपुलेटरों की तुलना में रेडियोसक्रिय कक्ष में वस्तुओं का सुगमतापूर्वक हस्तन कर सकते हैं।

स्वदेशी टेलीथैरेपी प्रणाली हेतु योगदान

भाभाट्रॉन-II टेलीकोबॉल्ट मशीन हेतु एक पूर्ण स्वचालित मल्टीलीफ़ कॉलीमेटर (एमएलसी) के प्रोटोटाइप का अभिकल्पन एवं विकास किया गया। एक्ट्रेक स्थित भाभाट्रॉन-II टेलीकोबाल्ट मशीन पर एनएलसी के कार्य निष्पादन का विस्तृत परीक्षण किया गया।

18. सामाजिक कार्य एवं प्रौद्योगिकी हस्तांतरण

प्रौद्योगिकी हस्तांतरण

दो नई प्रौद्योगिकियां, यथा चतुर्ध्रुवी द्रव्यमान स्पेक्ट्रममापी एवं डिप एंड ड्रिंक मेंब्रेन पाउच का उद्योग को हस्तांतरण किया गया। उद्योगों को आठ प्रौद्योगिकी अनुज्ञप्तियों का नवीनीकरण किया गया।

पऊवि की सामाजिक पहल एवं अवसंरचना कार्यक्रम

I. आकृति कार्यक्रम के अंतर्गत अमरावती जिला स्थित निमखेड नामक गांव, जो एक जल अभाव क्षेत्र है, में आइसोटोप जलविज्ञान तकनीक का प्रयोग करते हुए, 30,000 लिटर प्रति घंटे की क्षमता वाले भूगर्भीय जल स्त्रोत को पहचाना गया।

II. 50,000 केले के पौधों की क्षेत्र कठोरन सुविधा वाली ऊतक संवर्धन प्रयोगशाला को प्रचालनरत किया गया एवं अमरावती, महाराष्ट्र के आकृति कार्यक्रम के अंतर्गत कठोर किए पादपों की पहली खेप खेत में बोयी गयी।

III. आकृति कार्यक्रम के अंतर्गत दापोली मे फरारी नामक तटीय गांव में 300 लीटर प्रति घंटे की क्षमता वाले खारे पानी आरओ संयंत्र का स्थापन किया गया। ग्रामवासियों को संयंत्र को प्रचालित करके चलाने एवं उसके रख-रखाव का प्रशिक्षण दिया गया।

IV. ग्रामीण क्षेत्रों में और अधिक क्रमबद्ध रूप से आकृति कार्यक्रम को बढावा देने के लिए भापअ केंद्र द्वारा श्री विठ्ठल एज्युकेशन रिसर्च इन्स्टिट्यूट- SVERI पंढरपुर के साथ समझौता ज्ञापन पर हस्ताक्षर किया गया ताकि पंढरपुर स्थित SEVRI कैंपस में रूरल ह्यूमन एंड रिसोर्स डेवलपमेंट इन्स्टिट्यूट (RHRDI) के रूप में पऊवि आउटरीच केंद्र स्थापित किया जा सके।

19. आयुर्विज्ञान सेवाएं

आयुर्विज्ञान प्रभाग, भापअ केंद्र द्वारा 390-बिस्तर का अस्पताल, 12 क्षेत्रीय औषधालयों, दो व्यावसायिक स्वास्थ्य केंद्रों और चौबीसों घंटे आकस्मिक सुविधा के माध्यम से समग्र मुंबई स्थित सीएचएसएस लाभार्थियों को स्वास्थ्य देख-रेख सुविधा प्रदान की जा रही है। भापअ केंद्र अस्पताल में नयी सुविधाएं और उन्नयन जारी हैं। दिनांक 30 सितंबर, 2011 को लाभार्थियों की कुल संख्या 87080 रही।

प्रिय साथियों

इतने कम समय में सामरिक क्षेत्र में अपनी महत्वपूर्ण भूमिका का उल्लेख किए बिना विज्ञान और प्रौद्योगिकी के क्षेत्रों में कार्यरत 15000 से भी अधिक व्यक्तियों के योगदान की विशिष्टताओं को शामिल करना असंभव है। मेरे भाषण में यदि कुछ छुट गया है तो यह केवल समय के अभाव के कारण हुआ है और किसी भी तरह से उन सभी कार्यों की महत्ता को कम नहीं करता है।

वर्ष 2011 केवल भारत में ही नहीं वरना विश्वभर में नाभिकीय कार्यक्रम और उद्योग जगत के लिए चुनौतीपूर्ण रहा है। यह

मुख्यतया इस वर्ष मार्च मे जापान के फुकुशिमा दाई-ची में घटी दुर्भाग्यपूर्ण घटना के कारण हुआ है जो भयानक भूंकप (रिक्टर स्केल पर 9.2) और सुनामी (15 मीटर की ऊंचाई तक) जैसी अभूतपूर्व दोहरी प्राकृतिक आपदाओं के परिणामस्वरूप हुआ। यद्यपि हमें ऐसी घटनाओं के लिए पूर्णतया सचेत और स्थिति से निपटने के लिए तैयार रहने की आवश्यकता है, फिर भी यह अनिवार्य है कि हम नाभिकीय क्षेत्र में विज्ञान और प्रौद्योगिकी के सामर्थ्य और मूल सक्षमताओं के आधार पर हमारे सुव्यवस्थित कार्यक्रमों और सामरिक नीतियों के प्रति पूर्ण निष्ठा से प्रतिबद्ध रहें। देश में ऊर्जा की बढ़ती हुई मांग और समाज के लिए बेहतर और गुणवत्तापूर्ण जीवन यापन में सतत प्रगति करते रहने हेतु यह नितांत आवश्यक है। हाल की घटनाओं ने भी हमारे सामाजिक कार्यक्रम को मजबूती प्रदान करने पर बल दिया है। हम इस दिशा में सक्रिय हैं और नई शुरुआत कर रहे हैं।

हमने, अभी हाल ही में बारहवीं योजना के प्रस्तावों को योजना आयोग के समक्ष प्रस्तुत करने के लिए अंतिम रूप दिया है। निर्धारित लक्ष्यों और योजनाओं को हम समर्पित सामूहिक प्रयासों तथा विभिन्न विषयों और क्षेत्रों में सूझबूझ पूर्ण सहयोग के साथ ही प्राप्त कर सकते हैं। मैं यहां जोर देकर कहना चाहूंगा कि देश में परमाणु ऊर्जा तथा विकिरण प्रौद्योगिकी के अनुप्रयोगों के क्षेत्र में जिस तेजी से प्रगति की कल्पना की गई है उसमें प्रभावी योगदान करने में बहुत सी चुनौतियां हमारे सामने हैं। हमारे विभाग का इतिहास इस बात का गवाह है कि हम अपनी आत्मनिर्भरता की सांस्कृतिक विरासत और सुदृढ़ संकल्प से अपनी राह में आने वाली सभी बाधाओं को अवश्य पार कर लेते हैं। मुझे पूरा विश्वास है कि हम सब अपने सम्मिलित प्रयासों से, अपनी व्यावसायिक और सांस्कृतिक परंपरा के अनुरूप इन चुनौतियों का सामना करने में सफल होंगे।

साथियों, अंत में, इस विशेष अवसर पर, आइए हम दृढ़तापूर्वक संकल्प लें कि जनमानस की बेहतर जिंदगी के लिए नाभिकीय विज्ञान और प्रौद्योगिकी के अग्रणी क्षेत्रों में अपनी श्रेष्ठता को सिद्ध करना जारी रखेंगे।

धन्यवाद, जय हिन्द !"

Founder's Day 2011

Address by

Dr. R.K. Sinha
Director, BARC

"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 Dhruva. The Golden Jubilee of Cirus operations and Silver Jubilee of Dhruva 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 Dhruva 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 upgradation 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.

Dhruva 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. Acivities 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-IIIA 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

i) 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

Topic [3] - Role of Power Beams in enabling Science and Technology in the Twenty-first Century: contributions to healthcare, materials processing, environment and energy sectors

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

A Group Photograph of contestants

for the final presentation. 10 contestants from Topics 1 & 2 and 7 contestants from Topic 3 made their presentations on 27th October, 2011.

Based on the assessment of the panel of judges and the evaluators, the list of the prize winners has been finalized. In addition to the first, second and third prizes for each topic, consolation prizes were also given to the remaining contestants, who were invited to make oral presentations.

Dr. S. Banerjee, Chairman, AEC awarded the prizes to the winners.

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

Sr. No.	Name of Essayist	Student of	Place
1	Mr. Mandar Dilip Bhagwat	B.E. II	Amravati
2	Miss Deepti Gehlot	B.E. IV	Jodhpur
3	Mr. B. Vamsi Krishna	B.Tech. III	Vijayawada
4	Mr. A. Ramesh Pandian	B.Sc. III	Tiruchendur
5	Mr. Y. Sai Saketh	B.Tech. IV	Shamshabad
6	Miss H. Sindhuja	Bio. Tech. III	Chennai
7	Mr. Manas P. Thube	B.Sc. III	Mumbai

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	Coinbatore

Consolation Prize Winners

Sr.No.	Name of Essayist	Student of	Place
1	Miss Aasawari D. Bhagwat	B.E. IV	Amravati
2	Miss Sayali Atul Bhatkar	B.Sc. I	Ratnagiri
3	Miss Bhoomi Choukse	B.E. III	Indore
4	Miss Safna Banu K.	B.Sc. II	Malappuram
5	Miss Arsina Rahman K. K.	B.Sc. II	Malappuram
6	Miss Paloma Noronha	B. Sc. II	Mumbai
7	Miss Dike Manasee Shantaram	B.Sc. II	Ratnagiri

Topic 3: Role of Power Beams in Enabling Science and Technology in The Twenty-First Century: Contributions to Healthcare, Materials Processing, Environment and Energy Sectors

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

Sr. No.	Name of Essayist	Student of	Place
1	Ms Angel Kuriakose	B.Sc. III	Malappuram
2	Ms V. Nagarathinam	B.Sc. III	Madurai
3	Ms Juhika Nagrale	B.Tech. IV	Hyderabad
4	Ms A. Monica Viji	B.Sc. II	Kovilpatti

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).

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

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

Founder's Day Guest Lecture

Radiation Effects, Linear No-Threshold Hypothesis and Nuclear power

D.V. Gopinath
Energy & Environment
Mysore 570 009

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

D.V. Gopinath delivering the Guest Lecture on the occasion of Founder's Day

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. 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 - Daiichi 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

DAE (Excellence in Science, Engineering & Technology) Awards 2010

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

   Mr. 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.

Dr. R. Chidambaram, presenting the Homi Bhabha Science & Technology Award 2010 to Shri R.M. Suresh Babu

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.

Dr. R. Chidambaram, presenting the Homi Bhabha Science & Technology Award 2010 to Dr. Hirendra Nath Ghosh

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.

Dr. R. Chidambaram, presenting the Homi Bhabha Science & Technology Award 2010 to Shri Prashant Marathe

Dr. R. Chidambaram, presenting the Homi Bhabha Science & Technology Award 2010 to Dr. K.S. Pradeep kumar,

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
9. Shri M.K. Kapoor, SO/G, FRD/NRG/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
19. Smt. Manjiri Milind Pande, SO/G, TPD/PG/ 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 Shrivastava, 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, two 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

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, NXPF, 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 Rajendran 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&DD, BARC
19. Shri K.B. Deore, ED&DD, BARC
20. Shri V.N. Garje, ED&DD, BAEC
21. Shri R.B. Saindane, ED&DD, BARC
22. Shri Rajesh Singh, ED&DD, BARC
23. Shri S.R. Mhatre, ED&DD, 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

54. Shri M.V.R. Narsaiah, RSSD, BARC
55. Shri P.S. Sorate, RSSD, BARC
56. Shri M.K. Kamble, RSSD, BARC
57. Shri Pankaj Kumar, HPD, BARC
58. Shri Anil Gupta, HPD, BARC
59. Shri Praveen Dubey, RSSD, BARC
60. Shri Kamlesh, HPD, BARC
61. Shri Mridulendu Pandey, HPD, BARC
62. Shri V.J. Pawar, RSSD, BARC
63. Shri D.K. Patre, RSSD, BARC
64. Shri A.R. Mhatre, FRD, BARC
65. Shri S.L. Patil, RSSD, BARC
66. Shri S.A. Yadav, RSSD, BARC
67. Shri Vaidyanath Mahato, TSD, BARC
68. Shri A.K. Nayak, RSSD, BARC
69. Shri M.T. Valvi, RSSD, BARC
70. Shri J.P.N. Pandey, HPD, BARC
71. Shri Nitin A. Bhosale, RSSD, BARC
72. Shri Sanjay Kumar Singh, RSSD, BARC
73. Shri M.P.Jayan, RSSD, BARC
74. Shri Prasad S. Sajin, RSSD, BARC
75. Shri S.S. Deolekar, RSSD, BARC
76. Shri C. Sunil, HPD, BARC
77. Shri R.R. Bhingare, RSSD, BARC
78. Shri D. P. Rath, RSSD, BARC
79. Shri Jagjit Singh, PD, BARC
80. Shri D.J. Kambli, PD, BARC
81. Shri K.K. Sharma, PD, 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/ DMAG/ 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

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and

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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 structureconsisting 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 1min. 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 with drawn 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 s
- 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.

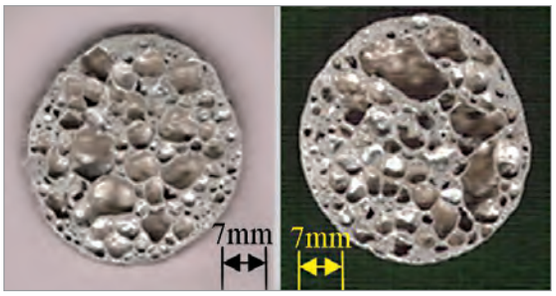

Fig. 1: Typical structure of Aluminium foam showing poresize distribution at different cross-sections

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

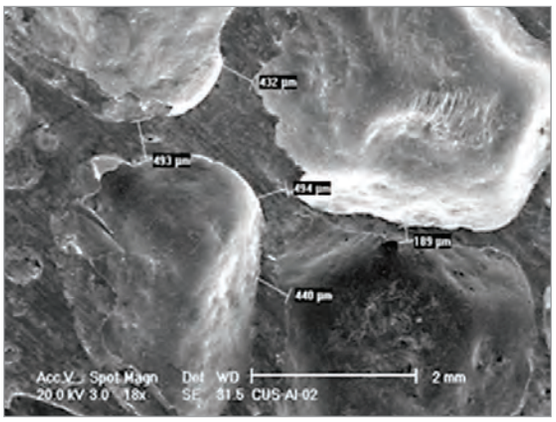

Fig. 2: Microstructure of Aluminium foam showing the cell wall thickness.

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

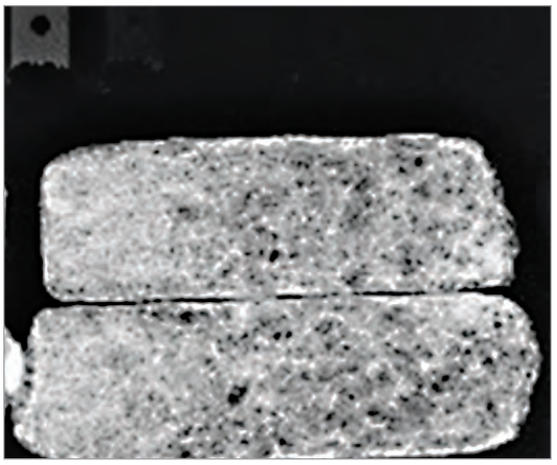

Fig. 3: X-ray radiographyof Aluminium foamed samples

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, σ_{pl}, up to a limiting nominal strain, ε_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 å$_D$. 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 σ_{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

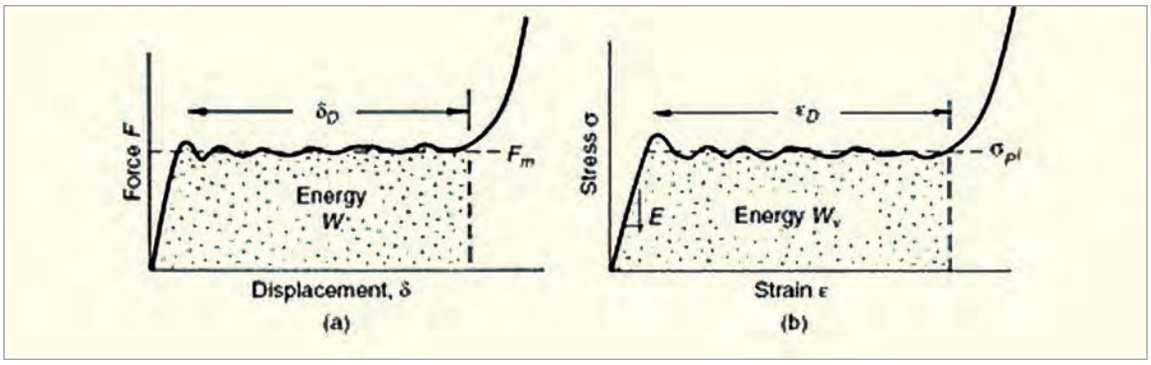

Fig. 4(a): Ideal Force-Displacement (b) Ideal Stress-Strain Curves for foam

borders). The features are governed by surface energy, as they are in soap films[10-11].

Compression testing is carried out using aInstron 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.

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

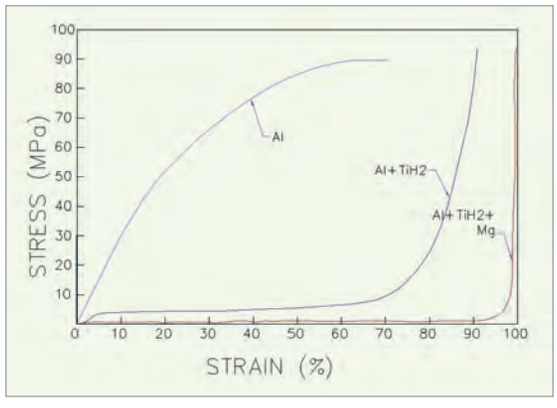

Fig. 6: Stress- strain curve for different alloys of aluminium

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.

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

Table 1: Densities of various samples taken for Compression test

S.No	Description	Dimensions (mm)	Density g/cc	Relative density
1	Al + 2-3.5% TiH_2	D=35L=70	0.29	0.11
2	Al + 2-3.5% TiH_2	D=35L=52	0.27	0.10
3	Al +20%Mg+ 2-3.5% TiH_2	D=35L=46	0.23	0.08
4	Al + 2-3.5% TiH_2	D=35L=35	0.37	0.13

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 $\tilde{n}/\tilde{n}_s$ 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.

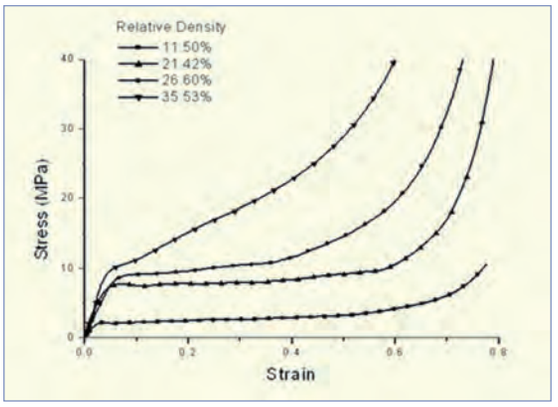

Fig. 7: Stress-Strain curves for different relative densities.

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.

I thank Shri R.K.Mittal, for helping me in fabricating and commissioning induction power source setup and control system. I also, thank Staff members of ED&DD for helping me in carrying out the experiments and laying out the facility at M/s BARC, Mumbai.

References

1. M.F. Ashby, A. Evans et al., Metal foams- a design guide
2. J Banhart, *JOM* 52, 22-27 (2000)
3. J Banhrat, *JOM* 52(12)(2000)
4. J Banhart, *Prog. Mater. Sci.* 46 (2001) 559-632
5. John Banhart, Department of Materials Science, Hahn-Meitner-Institute Berlin, Germany Discusses on the Metal foams-from fundamental research to applications.
6. J Banhart, et.al.,(1997), *Mat. Design*. Vol.18, Nos.4/6,pp.217-220
7. L.N.Padurets, Zh.V.Dobrokhotova, A.L.Shilov, *International Journal of Hydrogen Energy* 24(1999) 153-156
8. A.R.Kennedy, Advanced Materials Research Group, Report.Manufacturing Engineering and Managemen University of Nottingham, NG7 2RD, UK
9. B. Matijasevic-Lux, et al., *Acta Materialia* 54 (2006) 1887-1900
10. E.Andrews, W.Sanders, L.J.Gibson, *Materials Science and Engineering* A270 (1999) 113-124
11. E.Koza., et al., *Materials letters* 58(2003) 132-135, ELSEVIER.

Velocity Field Measurements Using Digital Particle Image Velocimetric System

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and

R.K. Singh
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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/cm^3 (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.

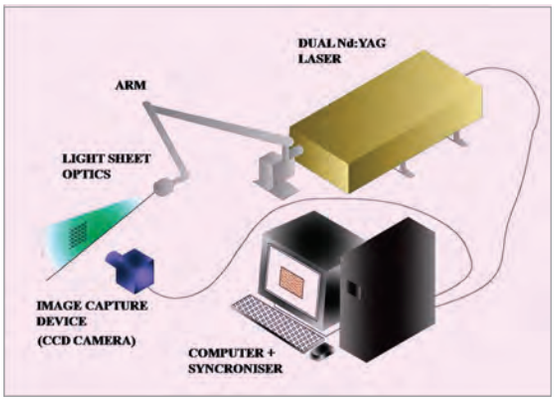


Fig. 1: Typical 2D PIV Setup

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.

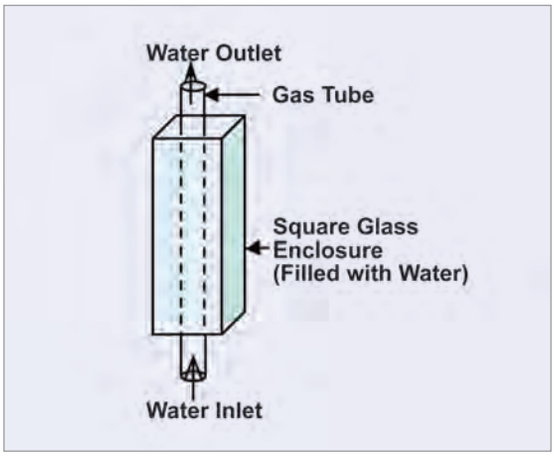


Fig. 2a: Test section for flow through circular tube

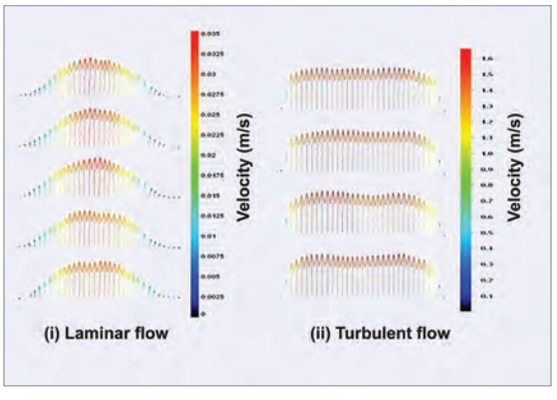
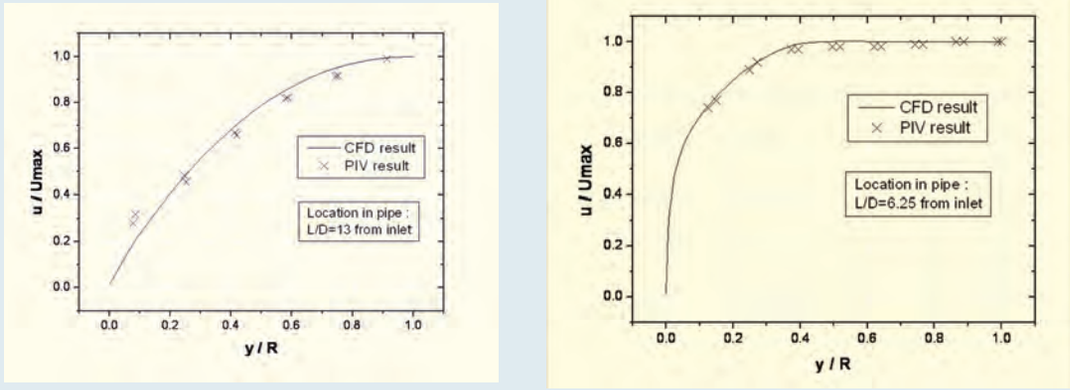


Fig. 2b: Velocity profile in a pipe by digital PIV at different axial locations



(i) Laminar Flow (ii)Turbulent Flow

Fig. 2c: Comparison of velocity at pipe cross section by PIV and CFD code

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.

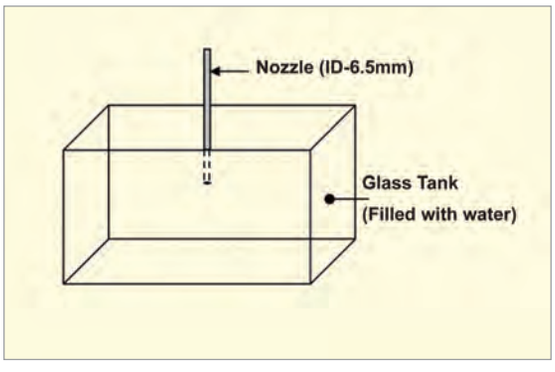


Fig. 3a: Schematic of Nozzle in water tank

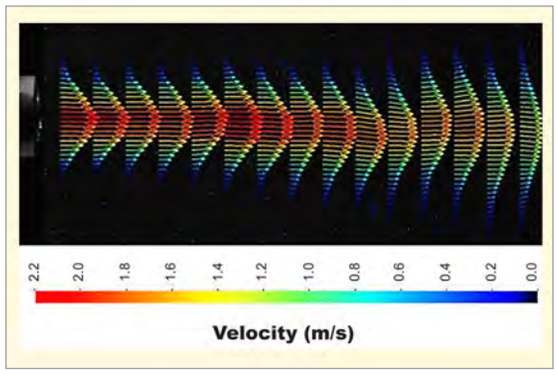


Fig. 3b: Velocity profile at different axial distances of submerged water jet by PIV system

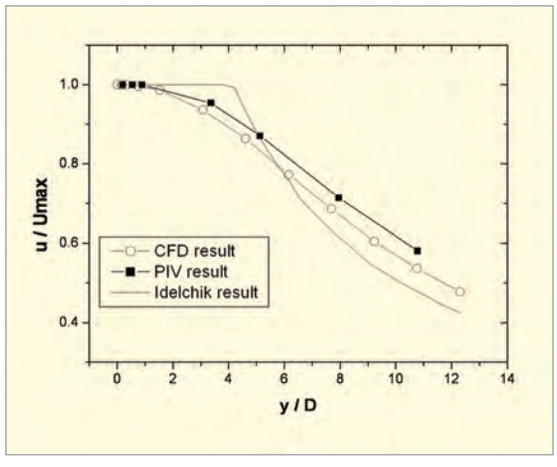


Fig. 3c: Variation of axial velocity as a function of axial length.

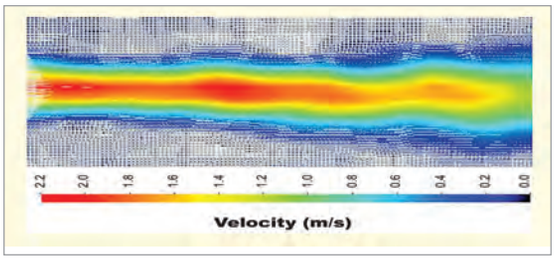


Fig. 3d: Velocity Contours of submerged water jet by PIV system

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

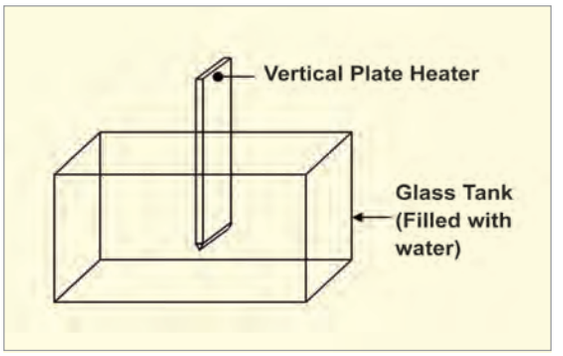


Fig. 4a: Schematic of vertical heater in glass tank

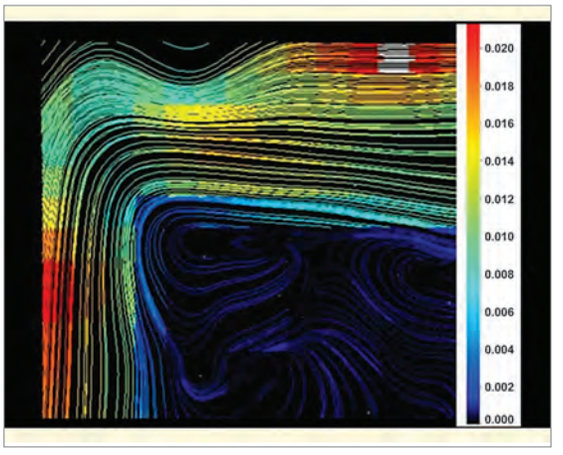


Fig. 4b: Velocity stream lines and contours by digital PIV

Fig. 4c: Flow visualization with aluminium particles

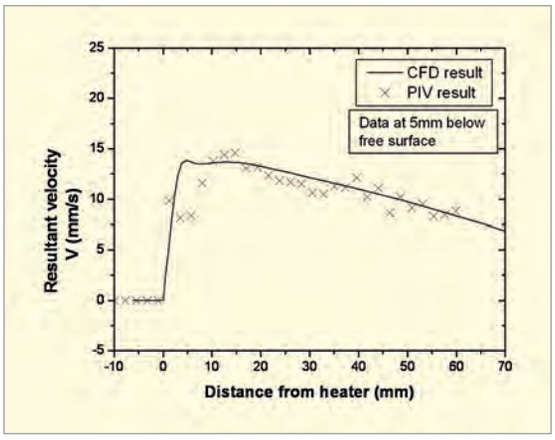


Fig. 4d: Comparison of PIV and CFD results at 5 mm below free surface of water

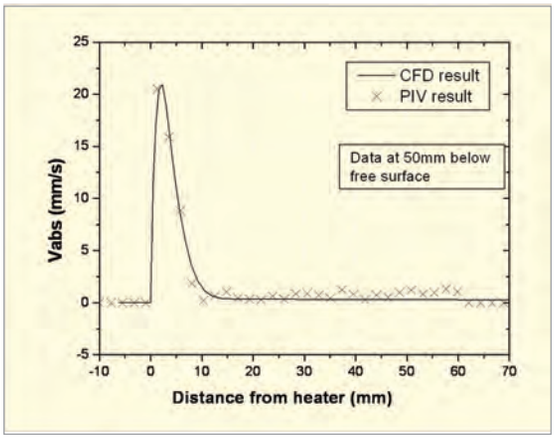


Fig. 4e: Comparison of PIV and CFD results at 50 mm below free surface of water

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

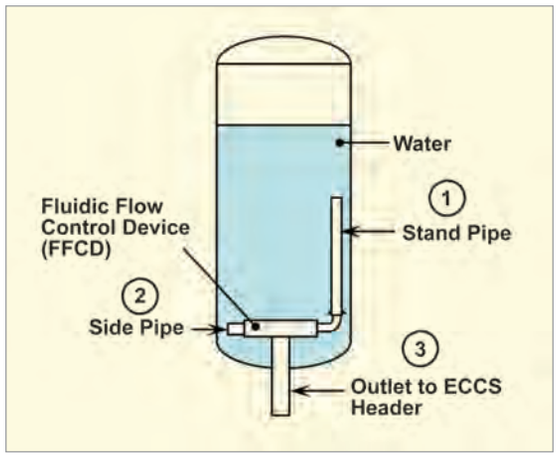


Fig. 5a: Accumulator tank with Fluidic Flow Control Device (FFCD)

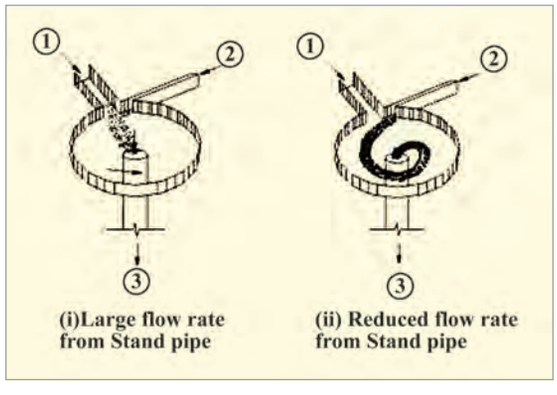


Fig. 5b: Details of FFCD

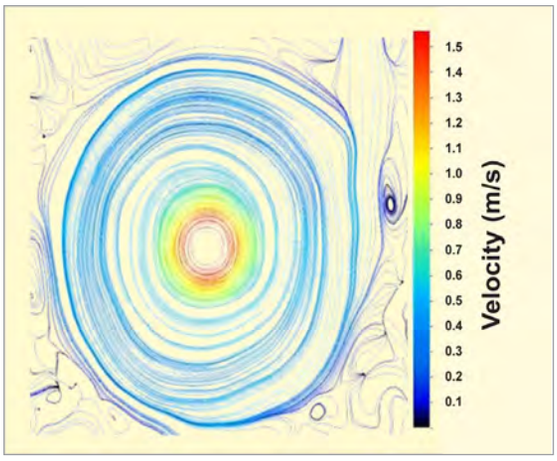


Fig. 5c: Velocity stream line and contour using PIV system

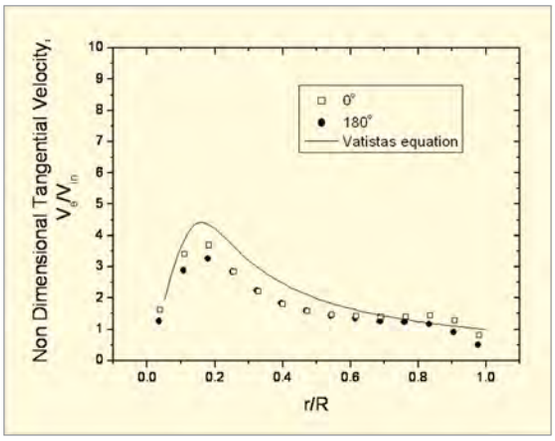


Fig. 5d: Tangential velocity distribution using PIV system

system. Results show that tangential velocity increases to peak value with radius then decreases. 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

1. M. Raffel, C. Willert and J. Kompenhans, "Particle Image Velocimetry", A Practical Guide, Springer Verlag, Berlin, 1998.
2. R. J. Adrian "Twenty years of particle image velocimetry", 12th International symposium on applications of laser techniques to fluid mechanics, Lisbon, July 12-15, 2004.
3. G. N. Abramovich, "The Theory of Turbulent Jets", The Massachusetts Institute of Technology Press, 1963.
4. Georgios H. Vatistas, V. Kozel and W.C. Mih, "A Simpler Model for Concentrated Vortices", *J. Experiments in Fluids*, Vol 11,73-76, 1991

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

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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 1/3rd 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.

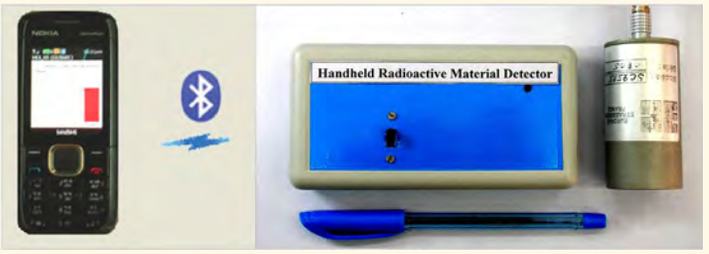

Fig. 1: Handheld Tele Radionuclide Detector with controlling mobile phone.

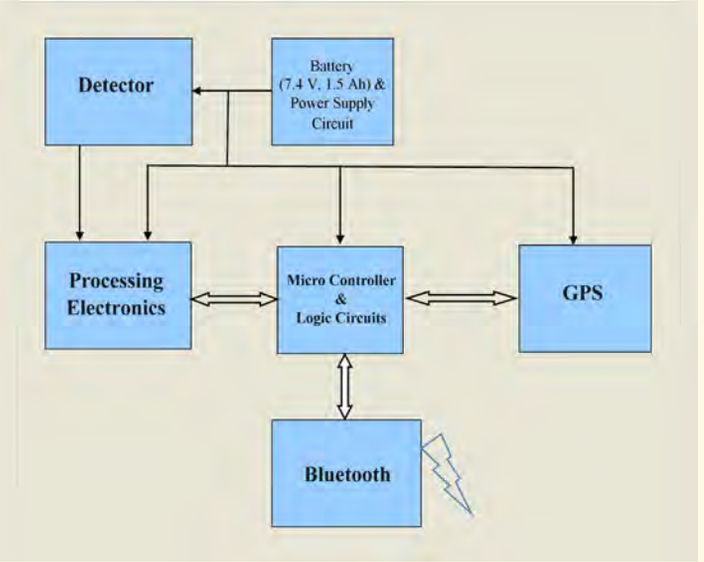

Fig. 2: Schematic Diagram of Handheld Radionuclide Detection System

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.

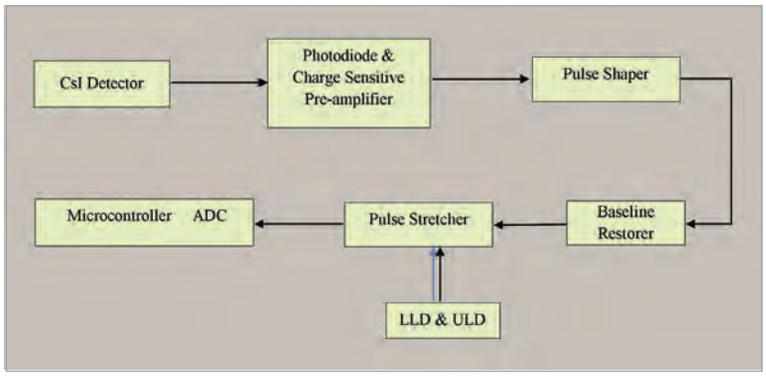

Fig. 3: Hardware Schematic

Fig. 4 shows the 1-minute spectrum of Co^{60} (25iCi) 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.

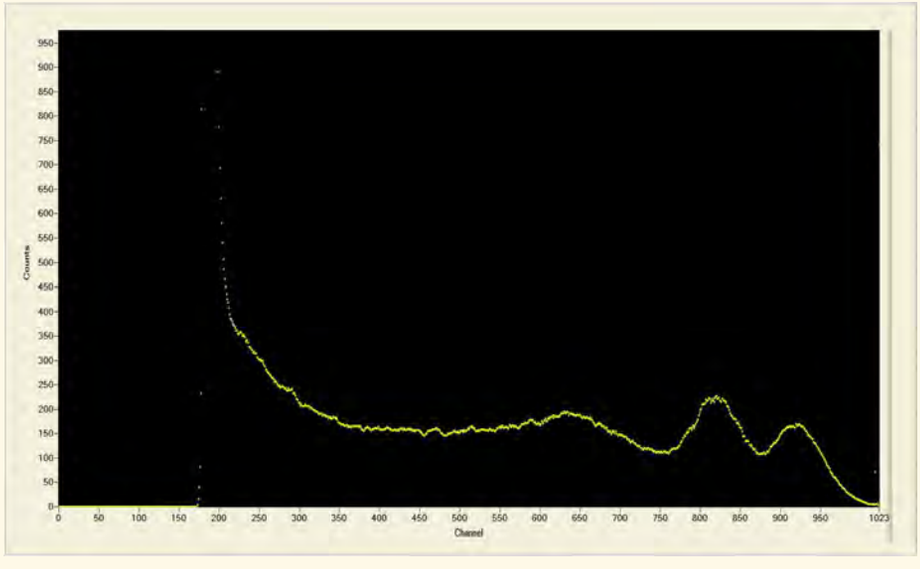

Fig. 4: Averaged output with Co^{60} for 1 min

GGA Global Positioning System Fix Data. Time, Position and fix related data for a GPS receiver

```
                                                      11
      1         2       3 4        5 6 7  8   9  10 |  12 13  14   15
      |         |       | |        | | |  |   |   | |  |  |   |    |
$--GGA,hhmmss.ss,llll.ll,a,yyyyy.yy,a,x,xx,x.x,x.x,M,x.x,M,x.x,xxxx*hh
```

1) Time (UTC)
2) Latitude
3) N or S (North or South)
4) Longitude
5) E or W (East or West)
6) GPS Quality Indicator,
   0 - fix not available,
   1 - GPS fix,
   2 - Differential GPS fix
7) Number of satellites in view, 00 - 12
8) Horizontal Dilution of precision
9) Antenna Altitude above/below mean-sea-level (geoid)
10) Units of antenna altitude, meters
11) Geoidal separation, the difference between the WGS-84 earth ellipsoid and mean-sea-level (geoid), "-" means mean-sea-level below ellipsoid
12) Units of geoidal separation, meters
13) Age of differential GPS data, time in seconds since last SC104 type 1 or 9 update, null field when DGPS is not used
14) Differential reference station ID, 0000-1023
15) Checksum

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[4]. 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.

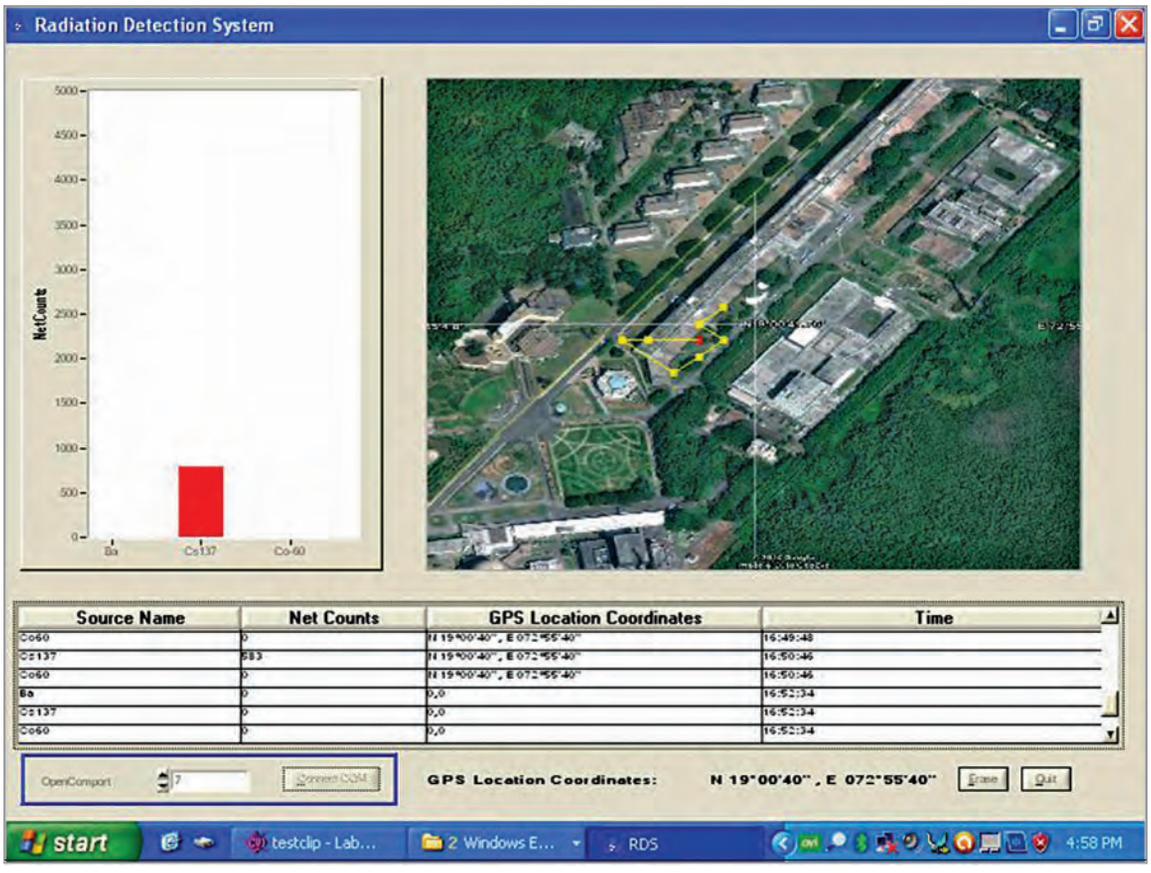

Fig. 5: Screenshot of Radionuclide Detection System Server

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.

Acknowledgement

The authors gratefully acknowledge helpful suggestions, deep interest and involvement of Shri G.P. Srivastava, Director E&I Group, BARC; Shri R.K. Patil, Associate Director E&I (C) Group, BARC; and Dr. P.R. Vasudeva Rao, Director, Chemistry Group, IGCAR.

We also acknowledge the technical help provided by Shri S.K. Parulkar & Mrs. Renuka Ghate of Computer Division.

Processing Food for Convenience: Challenges and Potentials

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Food Technology Division

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 disinfestation 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 ClO_2 in the inactivation of *Listeria monocytogenes* and *Salmonella Typhimurium* [2] and H_2O_2 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 O_2 and high CO_2 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.

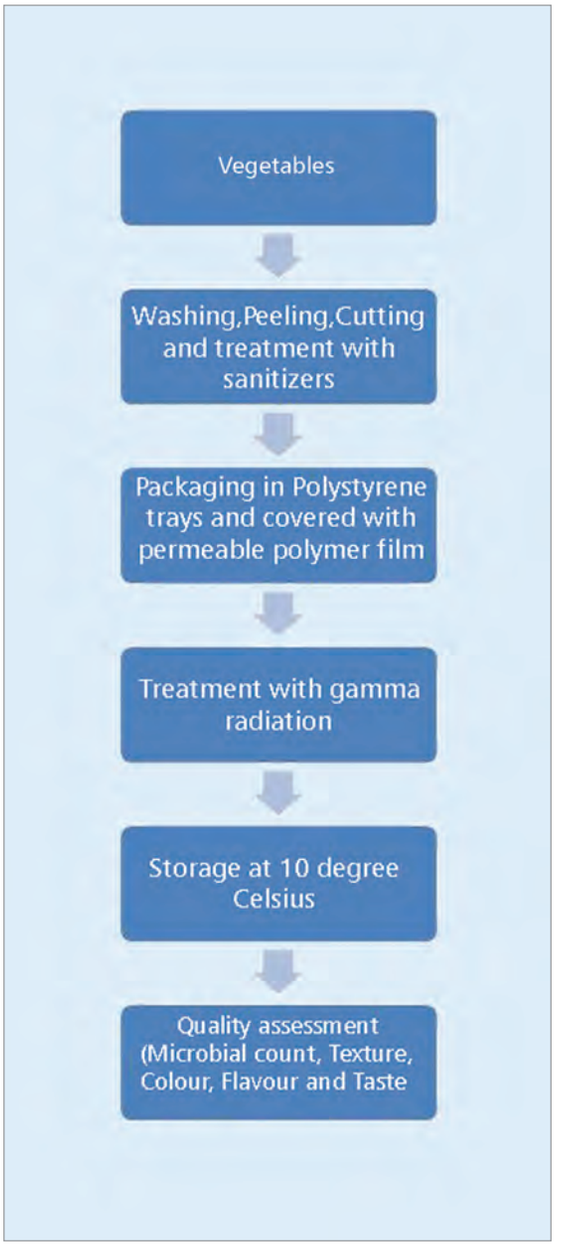

Fig. 1. Schematic of processing steps involved in manufacture of RTC products.

Table 1: Shelf life extension of RTC vegetables at optimized radiation doses

	Optimized radiation (kGy) dose	Optimum storage temp.(°C)	Extension in shelflife (Days)	Total shelf life of irradiated dose vegetables
French beans	1	10	10	15
Ash gourd	2	10	8	12
Pumpkin	2	10	14	21
Drumstick	1	10	5	10

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

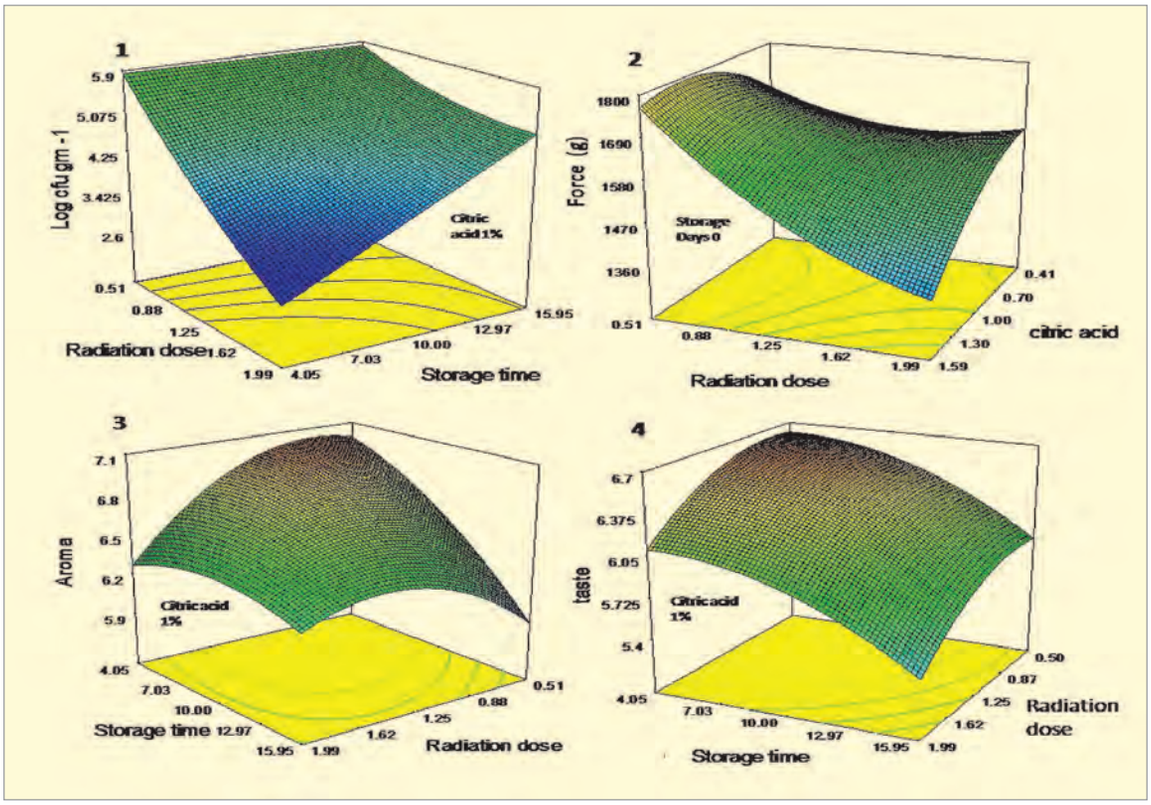

Fig. 2. Effect of process parameters on quality attributes of RTC French beans.
Effect on 1. Microbial load, 2. Texture, 3. Aroma and 4. Taste.

Fig. 3: Extension in shelf life of (a) French beans; (b) Pumpkin; (c) Drumstick and (d) ash gourd. C- Control; I- Irradiated

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

1. Wei, C. I., Huang, T. S., Kim, J. M., Lin, W. F., Tamplin, M. L., & Bartz, J. A. Growth and survival of Salmonella Montevideo on tomatoes and disinfection with chlorinated water. *Journal of Food Protection*, 58, 829-836, 1999.
2. Lee, S. Y., Costello, M., & Kang, D. H. Efficacy of chlorine dioxide gas a sanitizer of lettuce leaves. *Journal of Food Protection*, 67, 1371-1376, 2004.
3. Park, C. M., & Beuchat, L. R. Evaluation of sanitizers for killing Escherichia coli O157:H7, Salmonella and naturally occurring microorganisms on cantaloupes, honeydew melons, and asparagus. Dairy, *Food and Environmental Sanitation*, 19, 842-847, 1999.
4. Saftner, R. A., Baj, J., Abbott, J. A., & Lee, Y. S. Sanitary dips with calcium propionate, calcium

chloride, or calcium amino acid chelates maintain quality and shelf stability of fresh-cut honeydew chunks. *Postharvest Biology and Technology*, 29, 257-269, 2003.

5. Koseki, S., Yoshida, K., Isobe, S., & Itoh, K. Decontamination of lettuce using acidic electrolyzed water. *Journal of Food Protection*, 64, 652-658, 2001.
6. Arvanitoyannis, I. S., Stratakos, A., C., Tsarouhas, P., Irradiation Applications in Vegetables and Fruits: A Review, *Critical Reviews in Food Science and Nutrition* 49, 427–462, 2009.
7. Sharma, J., Chatterjee, S., Kumar, V., Variyar, P. S., and Sharma, A., Analysis of free and glycosidically bound compounds of ash gourd (Benincasa hispida): Identification of key odorants, *Food Chemistry*, 122, 1327-1332, 2010.
8. Chatterjee S., Sharma, J., Variyar, P., S., and Sharma A., Free and glycosidically bound volatiles of some common Indian vegetables, *Electronic journal of Environmental, agricultural and food chemistry*, 8, 613-620, 2009.

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 $\triangle = d_H + d_L$. 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

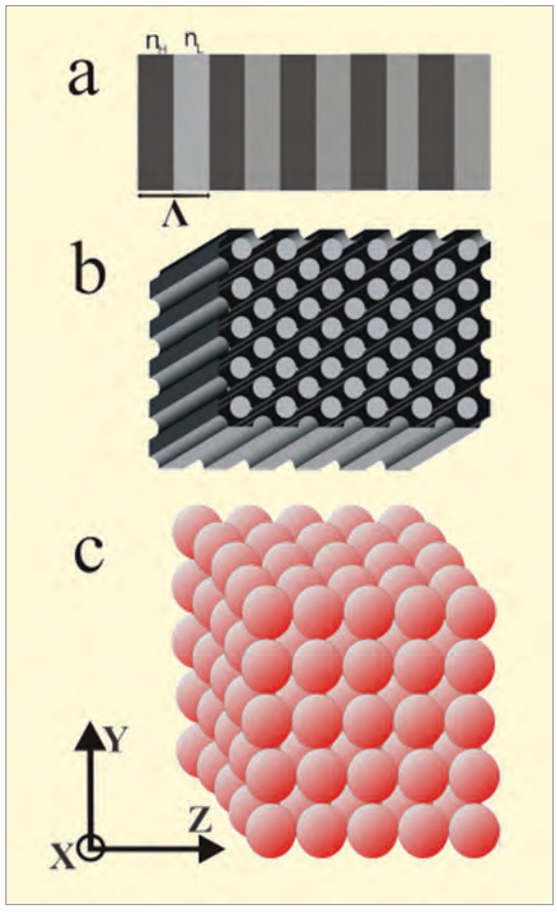

Fig.1: Schematic illustration of (a) 1D, (b) 2D and (c) 3D photonic band gap structures.

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 $(\omega \approx ck)$. 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

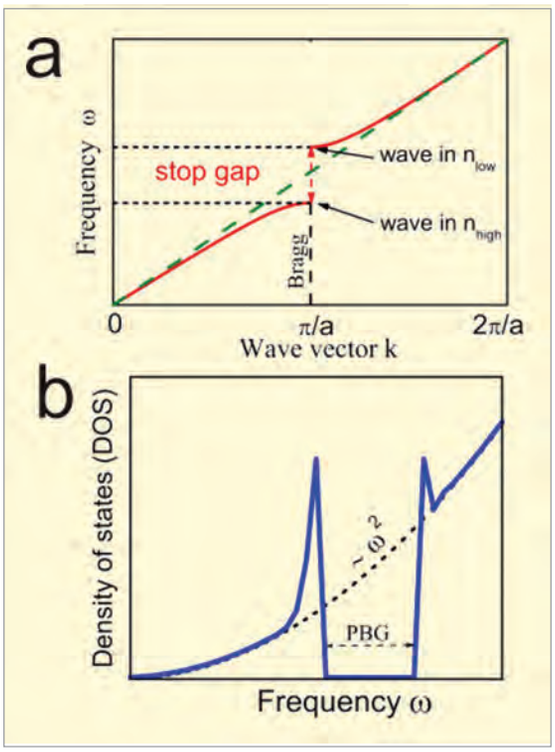

Fig. 2: (a) Dispersion relation for light in free space (green dashed line) and in a photonic band gap structures (solid line). When the wave vector reaches the Bragg plane, diffraction results in a forbidden zone for certain frequencies as shown using two bounded dotted line. (b) The schematic representation 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).

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 straight forward 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

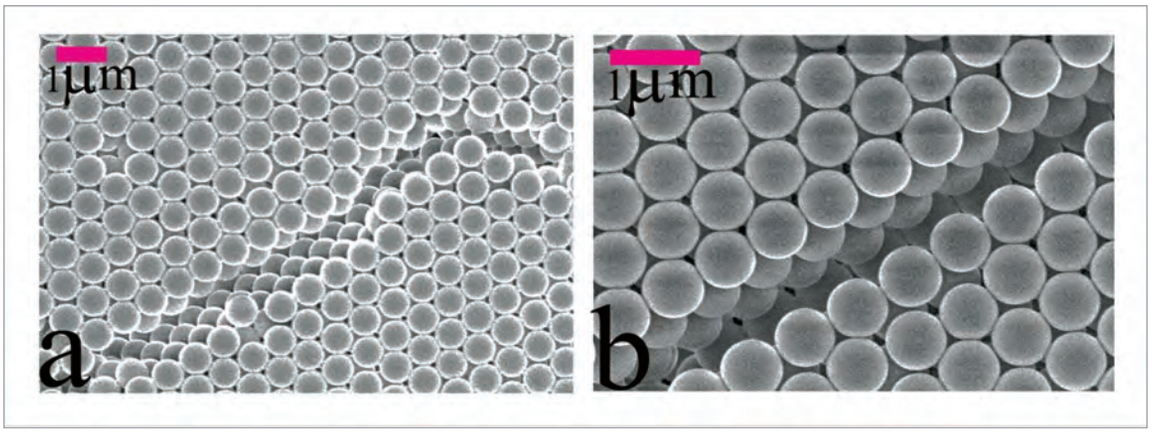

Fig. 3:(a,b):Scanning electron microscope image of self-assembled photonic crystals synthesized using polystyrene spheres of diameter of 803 nm. The image confirms the very good ordering on the surface and in the depth of the photonic crystals.

space this corresponds to the Ã-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.

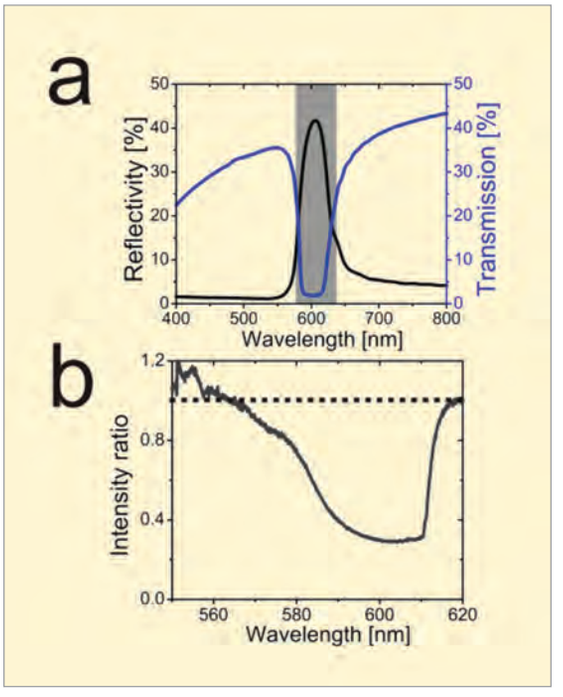

Fig. 4: (a) Measured reflectivity and transmittance indicating the photonic stop gap at a wavelength of 600 nm. One either side of the stop gap the structure behaves like a homogenous medium (b) Intensity ratio between the dye emission from the photonic sample and non-photonic sample (reference). The 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

1. C. Lopez, *Adv. Mater*. 15, (2003) 1679-1704.
2. M. Notomi, *Rep. Prog. Phys*. 73, (2010) 096501-1-50.
3. S. R. Huisman, R. V. Nair, L. A. Woldering, M. D. Leistikow, A. P. Mosk, and W. L. Vos, *Phys. Rev*. B 83, (2011) 205313-1-7.
4. R. V. Nair and R. Vijaya, *Phys. Rev.* A 76, (2007) 053805-1-7.
5. E. Yablonovitch, *Phys. Rev. Lett*., 58, (1987) 2059-2062.
6. K.Sakoda, "Optical properties of photonic crystals," Springer-Verlag, Berlin (2001).
7. S. John, *Phys. Rev. Lett*., 58, (1987) 2486-2489.
8. P. Russell, *Science*, 299, (2003) 358-362.
9. P. Lodahl, A. F. van Driel, I. Nikolaev, A. Irman, K. Overgaag, D. Vanmaekelbergh, and W.L. Vos, *Nature* 430, (2004) 654-657 (2004)
10. R. V. Nair, R. Vijaya, K. Kuroda, and K. Sakoda, *J. Appl. Phys*. 102, (2007) 123106 -1-

BARC Scientists Honoured

Name of the Scientists:	**Y.S. Rajpurohit and H.S. Misra, Molecular Biology Division**
Title of the Paper:	Characterization of radiation-inducible eurokaryotic type serine / threonine protein kinase from Deinococcus radiodurans
Name of the Award:	FEMS-2011 Young Scientist Grant Award to Y.S. Rajpurohit
Presented:	4th FEMS Congress of European Microbiologists-2011 (FEMS-2011), held at Geneva, Switzerland, from June 26-30, 2011

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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