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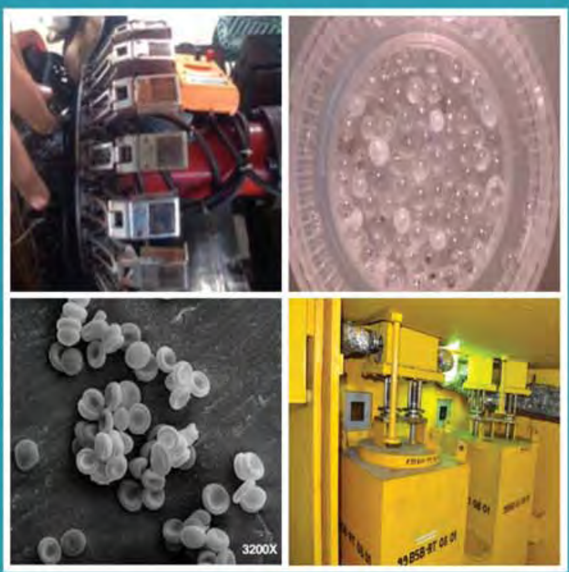
BARC NEWSLETTER

भाभा परमाणु अनुसंधान केंद्र

BHABHA ATOMIC RESEARCH CENTRE



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From the Editor's Desk

Welcome to the last issue of this year. This issue carries two major events. The first is the visit of the President of India to BARC on November, 15, 2013. During his visit, Shri Pranab Mukherjee inaugurated five advanced facilities set up by BARC and also dedicated to the Nation the most popular variety of BARC-developed mutant groundnut, TAG 24 (Trombay - Akola - Groundnut). He addressed the august gathering of Senior Scientists from DAE and gave away the Homi Bhabha Prizes to the graduating officers of the BARC Training School.

The Second major event is the coverage of Founder's Day 2013. A report of all the programmes held on 30th October, 2013, has been published under the caption "BARC Celebrates Founder's Day".

Apart from these two events, the issue carries five articles, two Brief Communications and also the annual index of all the articles published in 2013.

We would like to thank all our colleagues at BARC who have contributed to the seven issues of the BARC Newsletter in 2013. In addition, I would like to thank all the reviewers for spending their valuable time. We hope to receive the same response from you in the coming year too.

Wishing you all a very happy and productive new year!

Dr. K. Bhanumurthy
On behalf of the Editorial Committee

The President Visits BARC

The Graduation Function of the BARC Training School is an annual event organized by the HRDD for the successful completion of the training programme by the Graduating Officers. Toppers from various disciplines are also conferred the Homi Bhabha Prizes. The Hon'ble President of India, Shri. Pranab Mukherjee, was the Chief Guest at the function this year, held on November 15, 2013 at the Central Complex Auditorium, BARC, Trombay. Shri K. Sankaranarayanan, Governor of Maharashtra, presided over the function. Shri Prithviraj Chavan, Chief Minister of Maharashtra graced the function. The President awarded the Homi Bhabha prizes to the top ranking Officers in each discipline. Dr. R.K. Sinha, Chairman, AEC delivered the welcome address. On this occasion the President also inaugurated (by remote control) the five following advanced facilities that have been recently set up by BARC. Shri. Sekhar Basu, Director, BARC, briefly described the facilities and requested the President to inaugurate them.

1. The integrated facility for Proving Advanced Reactor Thermal Hydraulics (PARTH), built jointly by BARC and NPCIL at Tarapur. This will demonstrate the effectiveness of the various advanced safety systems (emergency core cooling; natural circulation) and performance of the refuelling system incorporated in the design of the Advanced Heavy Water Reactor (AHWR), a technology demonstrator for thorium utilization.

2. The hot commissioning of the Waste Immobilization Plant at Kalpakkam. This large comprehensive facility, co-located with reprocessing plant of BARC at Kalpakkam, facilitates the management of all types of radioactive wastes generated during reprocessing of spent fuel. Besides vitrification of high level liquid waste, this facility also addresses handling and management of intermediate level waste, separation of residual uranium from high level liquid waste, management of organic waste etc.

3. The Actinide Separation Demonstration Facility at Tarapur, addresses the challenging technology of separating long-lived minor actinides from high level liquid waste generated during reprocessing. This cross-cutting technology referred as "Partitioning of High Level Liquid Waste" would not only lead to substantial reduction in the radio-toxicity of long lived high level wastes, but also reduce the volume

The Honourable President of India addressing the gathering

Dr. R.K. Sinha, Chairman AEC, presenting a memento of a 3D printed model of Cirus and Dhruva Research Reactors to the President

to nearly one tenth of its present level for ultimate disposal in a geological repository.

4. The Experimental Accelerator-Driven sub-critical System (Ex-ADS) at Trombay, BARC, is the key first step in the Indian ADS roadmap. A sub-critical reactor operated with a stream of non-fission neutrons can resolve the main global concerns about nuclear power and also transmute nuclear waste. This experimental facility will verify and validate various reactor physics parameters through computations. India becomes one of the very few countries in the world to have such an experimental low power ADS facility.

5. Radiation-aided chemical removal of pollutants in flue gases arising from burning fossil fuel has been recently demonstrated, in collaboration with BHEL (Ranipet), at the Electron Beam Centre, BARC. The acidic oxides of nitrogen and sulphur present in the flue gases, when exposed to a beam of electrons, are converted (by radiolytic reactions) in to non-polluting ammonium salts (nitrate and sulphate), which are also useful as fertilisers. An indigenous DC electron accelerator (1 MeV) developed by BARC has been used for this purpose.

In addition to the above, the President also dedicated to the Nation the most popular variety of BARC-developed mutant groundnut, TAG 24 (Trombay - Akola - Groundnut). To date, BARC has developed 41 improved crop mutant varieties, especially of pulses and oil seeds, which have been released for commercial cultivation.

स्थापना दिवस 2013

(बुधवार, 30 अक्टूबर 2013)
डॉ. रतन कुमार सिन्हा,
अध्यक्ष परमाणु ऊर्जा आयोग एवं
सचिव परमाणु ऊर्जा विभाग का संबोधन

प्रख्यात वरिष्ठजन, प्रिय साथियों, देवियों और सज्जनों, आज हम यहाँ पर डॉ होमी जहांगीर भाभा के 104 वें जन्म दिवस के अवसर पर एक दिवसीय समारोह हेतु एकत्र हुए हैं। हमारी सुदीर्घ परंपरा के अंश के रूप में हम इस दिन की शुरुआत, हमारे इस महान स्वप्रदृष्टा द्वारा 06 दशक पूर्व लगाए गए वृक्ष के फलों के रूप में, हमारी कुछ नवीनतम उपलब्धियों को पुन: याद कर, अपने प्रिय संस्थापक को श्रद्धांजलि देने से कर रहे हैं।

पिछले एक वर्ष के दौरान प्राप्त किये गये कुछ उल्लेखनीय लक्ष्यों में से, मैं सबसे नवीनतम प्राप्त लक्ष्य से बात शुरू करना चाहूंगा। कुडनकुलम न्यूक्लियर पावर प्लांट यूनिट-1 ने अपनी प्रथम क्रांतिकता 13 जुलाई 2013 को प्राप्त की और सभी आवश्यक कमीशनिंग टेस्टों को पूरा करने के बाद इसे दिनांक 22-10-2013 को 02-45 बजे 160 मेगावाट पावर-लेवल पर पहली बार ग्रिड के साथ टेस्ट-सिंक्रोनाइज किया गया। द्वितीय सिंक्रोनाइजेशन 25 अक्टूबर को 21.45 बजे किया गया। आज की सुबह तक 230 MWe पर प्रचालित रहने के बाद स्ट्रेनर्स की पूर्व नियोजित सफाई के लिए विद्युत-जनन को रोक दिया गया। कुछ और परीक्षणों तथा योजनाबद्ध मेंटेनेंस गतिविधियों और चरण-बद्ध विनियामक क्लीयरेंसों के बाद विद्युत का स्तर क्रमश: आगे बढ़ाया जाएगा। यह आशा की जाती है कि इस यूनिट का वाणिज्यिक प्रचालन दिसंबर 2013 में शुरू हो जाएगा। आज भारत की सबसे बड़ी ऊर्जा-उत्पादक इस यूनिट का निर्माण एवं कमीशनिंग इस देश के नाभिकीय विद्युत उत्पादन क्षमता के विकास के त्वरित विकास के मार्ग पर एक बड़ा माइलस्टोन है। दूसरी यूनिट कमीशनिंग की आखिरी चरण में है ओर इसका भी छह महीने बाद कमीशनिंग होना अपेक्षित है।

मुझे आपको यह सूचित करते हुए प्रसन्नता है कि स्वदेशी और अंतरराष्ट्रीय श्रोतों से यूरेनियम की सप्लाइ में सुधार होने के कारण हमारा नाभिकीय विद्युत उत्पादन लगातार बढ़ता जा रहा है। हमारे देश के नाभिकीय बिजली संयंत्रों से उच्चतम वार्षिक उत्पादन पिछले वर्ष प्राप्त हुआ, जिसमें समग्र क्षमता गुणांक 80% और वार्षिक उपलब्धता गुणांक % था। हमारे रिएक्टरों में से 06 (छह) ने वर्ष के दौरान 300 दिन से अधिक का लगातार प्रचालन किया है। आज कुल मिला कर एनपीसीआईएल छह अलग-अलग स्थलों पर बीस नाभिकीय रिएक्टर, बेदाग संरक्षा रिकॉर्ड के साथ संचालित कर रहा है।

हमारे प्रचालनाधीन नाभिकीय विद्युत संयंत्रों की संरक्षा के बारे में मैं आपको बताना चाहूंगा कि राजस्थान RAPS यूनिट 3-4 हेतु पहली आई.ए.ई.ए. ऑपरेशनल सेफ्टी रिव्यू टीम (OSART) का भारत में पहला मिशन

29 अक्टूबर से 14 नवंबर 2012 तक चला। OSART मिशन टीम ने कई अच्छी संरक्षा आदतों/व्यवहारों की रिपोर्ट दी तथा कुछ क्षेत्रों में और आगे सुधार हेतु सुझाव दिए। आज की तारीख में, एनपीसीआईएल ने संरक्षित प्रचालन के 385 रिएक्टर वर्ष से अधिक पूरे कर लिए हैं। एनपीसीआईएल द्वारा अपने संयंत्रों को संरक्षापूर्णक चलाने के अनुभव की OSART के प्रेक्षणों ने भी पुष्टि की है।

काकरापार, गुजरात व रावतभाटा, राजस्थान में पहले से विकसित स्थलों पर स्वदेशी रूप से डिजाइन किए गए 700-700 मेगावाट के 04 दाबित भारी पानी रिएक्टर (PHWR) लगाए जा रहे हैं। इनमें से क्रमश: दो-दो रिएक्टर लगाए जा रहे हैं। इन रिएक्टरों की प्रगति कार्यक्रम के अनुसार चल रही है। एन.पी.सी.आइ.एल. देश के अंदरूनी भागों में 5 (पाँच) विभिन्न स्थलों पर 700 मेगावाट के 16 और दाबित भारी पानी रिएक्टर (PHWR) का क्रमिक रूप से निर्माण करने की योजना बना रहा है। इनमें से आठ दाबित भारी पानी रिएक्टर (PHWR),यानि चार अलग-अलग स्थलों पर 700 मेगावाट के दो-दो प्लांट हरियाणा में गोरखपुर यूनिट 1 और 2, मध्य प्रदेश में चुटका यूनिट 1 और 2,राजस्थान में माही बांसवाड़ा यूनिट 1 और 2 तथा कैगा यूनिट- 5 और 6 को 12वीं पंचवर्षीय योजना के दौरान शुरू किया जाना प्रस्तावित है।

हमारे नाभिकीय विद्युत कार्यक्रम के द्वितीय चरण के प्रौद्योगिकी प्रदर्शन संयंत्र के रूप में कलपाक्कम के निकट 500 मेगावाट के प्रोटोटाइप फास्ट ब्रीडर रिएक्टर (PFBR) का निर्माण पूरा होने के निकट है। सभी स्थायी क्रोडित (in-core) संघटकों की संस्थापना पूरी कर ली गयी है। निर्माण एवं स्थापन गतिविधियां 95% से अधिक तक पूरी हो चुकी है। द्वितीय सोडियम लूप में शीघ्र ही सोडियम भरा जाना प्लान किया गया है और द्रुत प्रजनक टेस्ट रिएक्टर (FBTR) द्वारा प्रथम क्रांतिकता सितंबर 2014 में प्राप्त किया जाना अपेक्षित है। XIIवीं पंचवर्षींययोजना के दौरान द्रुत प्रजनक रिएक्टर की दो यूनिटों (FBR 1 & 2) का निर्माण प्रारंभन की गतिविधियाँ शुरू किया जाना प्रस्तावित है।

थोरियम आधारित ईंधन से चालित एवं प्रगत संरक्षा फीचर्स युक्त प्रगत भारी पानी रिएक्टर (AHWR), हमारे नाभिकीय विद्युत कार्यक्रम के तीसरे चरण हेतु एक प्रौद्योगिकी प्रदर्शन संयत्र होगा, जिसे XII वीं योजना अवधि के दौरान लॉंच किया जाना प्रस्तावित है।

प्रिय मित्रों,

डॉ. भाभा ने स्वदेशी अनुसंधान कार्यक्रमों से प्रौद्योगिकियों की प्राप्ति की आधारशिला रखी। अनुसंधान, विकास, प्रदर्शन और तैनाती की उनकी विचारधारा ने हमें नाभिकीय ऊर्जा के उपयोग के प्रतीक क्षेत्र में खास प्राप्तियों की एक बड़ी रेंज प्रदान करने, और इस क्षेत्र में स्वनिर्भर बनने के लिए स्वदेशी प्रौद्योगिकियाँ विकसित करने की शक्ति दी है। इन कार्यक्रमों ने हमारे उद्योगों के विकास और वृद्धि में मदद की है तथा कई अनुसंधान एवं शिक्षण संस्थानों को न केवल हमारे विभाग की जरूरतों को पूरा करने, बल्कि समग्र देश की जरूरतों को पूरा करने में मदद की है।

यह बड़े संतोष का विषय है कि आज दुनिया भारत को एक प्रगत नाभिकीय प्रौद्योगिकी वाले देश के रूप में मान्यता दे रही है और हमारे नाभिकीय विद्युत कार्यक्रम में सहकार करने हेतु आगे आ रहे है। अभी तक असैन्य नाभिकीय सहयोग हेतु संयुक्त राज्य अमेरिका, फ्रांस, रूस, मंगोलिया, नामिबिया, अर्जेटीना, यूनाइटेड किंगडम, कनाडा, दक्षिण कोरिया, कजाकिस्तान के साथ अंतर-सरकारी संधियाँ या समझौता ज्ञापनों पर हस्ताक्षर किए गए हैं। इसके अलावा चेक गणराज्य के साथ एक पुरानी संधि को पुनर्नवीकरण किया गया है। जापान, आस्ट्रेलिया और ऐसे अन्य देशों के साथ सहयोग की संभावना वाले देशों के साथ चर्चा चल रही है। विदेशी नाभिकीय विद्युत संयंत्र सप्लायर जैसे फ्रांस के अरेवा, संयुक्त राज्य अमेरिका के वेस्टिंगहाउस और जनरल इलेक्ट्रिक के साथ एनपीसीआईएल के साथ बातचीत प्रगत

चरण में है। हाल ही में NPCIL ने संयुक्त अमेरिका की वेस्टिंगहाउस इलेक्ट्रिक कंपनी (डब्ल्यू ई. सी) के साथ तीन पैकेजों यानि (i) प्रारंभिक संरक्षा विश्लेषण रिपोर्ट (ii) संयंत्र डिजाइन की परमाणु ऊर्जा नियामक परिषद (एईआरबी) कोड/गाइडों और संरक्षा एप्रोच के साथ संगतता और (iii) रेडियोलॉजिकल डिजाइन विकास से युक्त एक "पूर्व-प्ररंभिक-कार्य समझौता" या "प्रारंभिक ठेका" पर हस्ताक्षर किए हैं।

अंतराष्ट्रीय सहयोग से अन्य चार अलग-अलग स्थलों पर यानि तमिलनाडु में कुडनकुलम में (के. के. 3 & 4), जैतापुर, महाराष्ट्र में (जेएनपीपी – 1 & 2), कोवाडा, आंध्रप्रदेश में यूनिट 1 & 2, तथा गुजरात के मीठी विर्दी यूनिट 1 & 2 में 1000 मेगावाट या अधिक के सामान्य पानी रिएक्टर (एलडब्ल्यूआर) XII वीं योजना के दौरान शुरू किए जाने की योजना है।

यूरेनियम अन्वेषण के क्षेत्र में हमारे विभाग का परमाणु खनिज अन्वेषण एवं अनुसंधान निदेशालय देश में यूरेनियम अन्वेषण के अपने अथक प्रयासों में रत है। प्रगत प्रौद्योगिकियों का उपयोग करने के फलस्वरूप हम यूरेनियम के नये संसाधनों की पहचान करने में सफल रहे हैं। पिधले वर्ष हमारे रिजर्व की मात्रा में 5% की वृद्धि हुई है। प.ख.नि. ने अप्रैल से सितंबर 2013 के दौरान U_3O_8 के 7,324 टन और XII वीं योजना अवधि (सितंबर 2013 तक) में कुल 22,611 टन के बराबर स्व-स्थाने संसाधन सिद्ध किये हैं। देश के स्व-स्थाने यूरेनियम संसाधन 1,67,582 टन से बढ़ कर अब 1,97,621 टन U_3O_8 हो गये हैं । इसमें काफी बड़ा योगदान आंध्रप्रदेश के तुम्मलपली क्षेत्र से व उसके बाद सिंहभूम थ्रस्ट बेल्ट झारखंड, महाडेक, मेघालय तथा रोहिल राजस्थान से आया है।

परमाणु खनिज निदेशालय ने कूलंबाइट-टैंटलाइट (Nb-Ta) के उत्पादन हेतु मर्लगल्ला, जिला मांडया, कर्नाटक में, और जेनोटाइम (इट्रियम-एक विरल मृदा तत्व) के उत्पादन हेतु सीरी नदी, जशपुर जिला, छत्तीसगढ़ में विरल धातु एवं विरल मृदा (आरएमआरई) निष्कर्षण संयंत्र स्थापित किए है।

यूरेनियम कार्पोरेशन ऑफ इंडिया ने तुम्मलपल्ली, आंध्र प्रदेश में पाँच वर्ष के रिकॉर्ड समय में एक नयी भूमिगत खान और एक प्रोसेसिंग संसयंत्र कमीशन किया है। तुरमडीह खदान की क्षमता-विस्तरण की परियोजना पूरी कर ली गयी है तथा खदान को शीघ्र ही कमीशनित कर लिया जाएगा। झारखंड में मोहुलडीह खदान को कमीशनित कर दिया गया है। समय के साथ स्वदेशी यूरेनियम की समग्र आपूर्ति काफी सुधर गयी है, और तुम्मलपली में प्रचालनों के सुस्थिर होने के साथ आई.ए.ई.ए. सुरक्षोपाय बाह्य रिएक्टरों के लिए यूरेनियम की आपूर्ति भी सुधर जाएगी, जिससे रिएक्टरों के क्षमता-गुणांक में वृद्धि होगी, फलत: विद्युत उत्पादन भी बढ़ेगा।

इंडियन रेअर अर्थ्स लि. ओडिसा सैंड्स कांप्लेक्स छत्रपुर,ओडिसा (ऑस्काम) में 10,000 टन प्रतिवर्ष मोनाजाइट प्रोसेसिंग संयंत्र लगाने जा रहा है। इस संयंत्र के जनवरी 2014 तक कमीशन होने की संभावना है। ऑस्काम (सीईएमएमयू) उड़ीसा के खनन और खनिज पृथक्करण संयंत्र की क्षमता-विस्तरण का काम हाथ में लिया गया है। पृथकीकृत उच्चत: शुद्धीकृत विरल मृदा संयंत्र रेअर अर्थ्स, डिवीजन, अलुवा, केरल में स्थापित किया गया है। इसकी प्रतिवर्ष 2250 टन की क्षमता के 50 प्रतिशत को कमीशन कर दिया गया है। इस संयंत्र में उत्पादित मिश्रित विरल मृदा क्लोराइड को आइ.आर.ई.एल. के रेअर अर्थ्स डिवीजन में विद्यमान सुविधाओं का उपयोग कर, पृथकीकृत उच्च शुद्धता विरल मृदा ऑक्साइड को उत्पादित किया जाता है। ओडिसा सैंड कांप्लेक्स (आस्काम) ओडिसा व मानविलाकुरूचि, तमिलनाडु स्थित खनिज पृथक्करण यूनिटों की क्षमता विस्तरण के बाद खनिज उत्पादन क्षमता वर्तमान के 6.08 लाख टन प्रतिवर्ष से बढ़कर 8.70 लाख टन प्रतिवर्ष हो जाएगी।

जहां तक 2012-13 में दाबित भारी पानी रिएक्टर -ईंधन के उत्पादन का सवाल है, नाभिकीय ईंधन

सम्मिश्र ने 8122 मिलियन टन के कुल उत्पादन के साथ अब तक का उच्चतम उत्पादन प्राप्त किया है, जो पिछले वर्ष से 8% से अधिक है। एन.एफ.सी ने दाबित पानी रिएक्टरों (पीडब्ल्यूआर) के स्टीम जनरेटर में उपयोग हेतु इन्कोनेल-718 और इन्कोनेल-690 सुपर एलॉय ट्यूबों के लिए एक्सट्रूजन प्रक्रिया विकसित कर ली है। इस उत्पाद के विश्वभर में हो रहे उपयोग के कारण इसका काफी वाणिज्यिक महत्व है।

तारापुर स्थित पावर रिएक्टर ईंधन प्रसंस्करण संयंत्र-2 (PREFRE-2) के साथ मिल कर प्रगत ईंधन संविरंचन सुविधा (AFFF) पी.एफ बी.आर हेतु आव्यक ईंधन-पिनों का उत्पादन एवं आपूर्ति कर रहे हैं।

द्रुत रिएक्टर ईंधन में पुनर्प्रसंस्करण और अपशिष्ट प्रबंधन के क्षेत्र में, आदिरूप द्रुत प्रजनक रिएक्टर (PFBR) से प्राप्त ईंधन को पुन:प्रसंस्कृत और पुन:संरोधित करने हेतु एक सह-अवस्थित द्रुत रिएक्टर ईंधन चक्र सुविधा (एफआरएफसीएफ), कलपाक्कम में स्थापित की जा रही है। हाल ही में इस परियोजना को सरकार ने वित्तीय और प्रशासनिक संस्वीकृति प्रदान कर दी है। आवश्यक स्थल अवसंरचना (इंफ्रास्ट्रक्चर) पहले ही सृजित की जा चुकी है तथा इस परियोजना को शुरू करने की तैयारियाँ प्राथमिकता स्तर पर शुरू की जा चुकी हैं।

हमारे भारी पानी संयंत्रों द्वारा उत्कृष्ट कार्य-निष्पादन किया गया है। वित्तीय वर्ष, के दौरान संयंत्रों ने न्यूनतम विशिष्ठ ऊर्जा खपत के साथ भारी पानी का अब तक का उच्चतम उत्पादन प्राप्त किया है। पिछले वित्तीय वर्ष के दौरान भारी पानी बोर्ड ने यू.एस.ए., फ्रांस, दक्षिण कोरिया के 10 मिलियन से अधिक की कीमत के भारी पानी ऑर्डर पूरे किये हैं। भारी पानी बोर्ड ने यू.एस. और फ्रांस को भारी पानी सप्लाइ करने के लिए यू.एस. डॉलर 15 मिलियन से अधिक की कीमत के पांच और निर्यात-आदेश भी प्राप्त किए है। इन आदेशों की पूर्ति मार्च 2014 से पहले कर दी जाएगी।

भारी पानी बोर्ड, हमारे द्वितीय चरण के नाभिकीय विद्युत कार्यक्रम के लिए जरूरी विलायक (solvent) और कच्ची सामग्री के विकास और सुपुर्दगी के कार्य में रत है। विलायकों का उत्पादन वार्षिक लक्ष्य को पार कर चुका है। यह विलायक पुन:प्रसंस्करण और अपशिष्ट प्रबंधन में भी प्रयुक्त होते है। बोर्ड की अधीनस्थ उत्पादन इकाइयों ने तात्विक बोरोन के उत्पादन की प्रौद्योगिकी को सुपुष्ट कर लिया है, तथा संयंत्र की उसकी क्षमता के 100% से अधिक पर प्रचालित किया है। पाइलट-स्तंभ में ऑक्सिजन का संवर्द्धन 95.5% ऑक्सिजन - 18 (O^{18}) तक प्राप्त कर लिया गया है। ऑक्सिजन-18, चिकित्सकीय अनुप्रयोगों हेतु फ्लूरिनेटिंग (fluorinating) के उत्पादन के लिए एक लक्ष्य आइसोटोप है। अब O^{18} के उत्पादन हेतु एक औद्योगिक स्तर का संयंत्र, भापासं, मणुगुरू में लगाए जाने की योजना है।

हमारे इंदिरा गांधी परमाणु अनुसंधान केंद्र (IGCAR) में द्रुत प्रजनक परीक्षण रिएक्टर (FBTR) सुचारु रूप से प्रचालित होता रहा, जिससे महत्वपूर्ण अनुभव के साथ-साथ भारत के द्रुत रिएक्टर कार्यक्रम हेतु तकनीकी जानकारियां भी मिलती रहीं। आदिरूप द्रुत प्रजनक रिएक्टर (पीएफबीआर) हेतु ईंधन परीक्षण-उप-असेंबली, जिसे FBTR में किरणित किया गया था, की पश्च-किरणन परीक्षा ने महत्वपूर्ण डाटा प्रदान किया है और द्रुत प्रजनक रिएक्टर (एफबीआर) ईंधन के डिजाइन एवं निर्माण हेतु विश्वास पैदा किया है। मार्क-1 कार्बाईड ईंधन के सोलिडियस लिक्विडस तापमान का एक नयी स्पॉट तकनीक से सीधा निर्धारण किया जाना पहली बार संपन्न किया गया। स्वदेशी रूप से विनिर्मित सोडियम बांडेड धात्विक ईंधन पिनों का किरणन और स्फीयर-पाक मॉक्स ईंधन पिन के किरणन व्यवहार तथा उसके विलगन को समझने हेतु अध्ययन शुरू किए गए।

प्लाज्मा अनुसंधान संस्थान (IPR) में स्टेडी स्टेट अतिचालक टोकोमैक (SST-1) को, इस सुविधा में प्रथम प्लाज्मा प्राप्ति के साथ 20 जून 2013 को

सफलतापूर्वक कमीशन किया गया। इस उपलब्धि के साथ भारत उन चुनिंदा देशों के समूह में जुड़ गया है, जहां अभी अतिचालक टोकोमैक पर अनुसंधान किये जा रहे हैं।

संलयन रिएक्टर प्रौद्योगिकी के विकास संबंधी हमारे कार्यक्रम तथा गतिविधियाँ, फ्रांस में बनाए जा रहे अतंरराष्ट्रीय ताप नाभिकीय प्रायोगिक रिएक्टर (आईटीईआर) परियोजना जैसे सर्वाधिक बड़े वैज्ञानिक सहकार्य परियोजना में भारत के जुड़ने की प्रेरक तत्व रही है। यह परियोजना सूर्य में हो रही पारमाण्विक प्रतिक्रिया संलयन के द्वारा परमाणु की ऊर्जा को दोहन करने का लक्ष्य रखती है। आइटीईआर यह प्रदर्शित करने हेतु कि नियंत्रित संलयन प्रतिक्रिया की पर्याप्त अवधि तक बनाए रखा जा सकता है, डयूटीरियम-ट्रिशियम (डीटी) संलयन प्रतिक्रिया का उपयोग करती है। आईटीईआर मशीन का दूसरा संरोधन बैरियर है क्रायोस्टेट, जिसके अंतर्गत निर्वात वैसल (Vessel), अतिचालक क्वाइलें और कई अन्य उप-प्रणालियाँ स्थित है। इसका व्यास लगभग 28 मी. और ऊंचाई 28 मीटर है। निर्मित होने पर, यह संबंधित नाभिकीय संरक्षा मानकों को पूरा करने वाला विश्व का सबसे बड़ा निर्वात वैसल होगा। आइटर परियोजना में भारतीय हिस्सेदार यानि आइटर-इंडिया जो परमाणु ऊर्जा विभाग के अंतर्गत एक स्वायत्त संस्था प्लाज्मा अनुसंधान संस्थान द्वारा चालित है , को आइटर की इस बड़ी प्रणाली के डिजाइन, विकास और आपूर्ति की जिम्मेदारी सौंपी गयी है। वैश्विक प्रतिस्पर्धात्मक बोली प्रक्रिया का अनुसरण करते हुए इस उच्च प्रौद्योगिकी उपस्कर के निर्माण का ठेका एक बड़े भारतीय औद्योगिक प्रतिष्ठान को दिया गया है। यह काम भारतीय उद्योग द्वारा ऐसे जटिल निर्माण कार्यों को हाथ में लेने की क्षमता को दर्शाता है। क्रायोस्टेट के निर्माण पर काम शुरू हो चुका है।

उच्च निष्पादन वाली नवतर संरचनात्मक सामग्रियों के स्वदेशी विकास के प्रयासों के भागरूप में आइटर के टेस्ट-ब्लैंकेट मॉड्यूल हेतु भारत-सापेक्ष रिड्यूस्ड एक्टिवेसन फैरेटिक-मार्टिनिस्टिक (आइ एन आर ए एफ एम) स्टील का विकास आइ जी सी ए आर में पूरा कर लिया गया है। यह आइ पी आर, आइजी सी ए आर और उद्योग जगत का सहकारी कार्य है।

राजा रामण्णा प्रगत प्रौद्योगिकी केंद्र (आरआरकेट), इंदौर में इंडस-2 सिंक्रोट्रान विकिरण स्रोत ने 24 जनवरी 2013 को इंडस-2 के 158 mA करंट पर 2.5 GeV की डिजाइन ऊर्जा के प्रचालन के साथ एक महत्वपूर्ण उपलब्धि हासिल की है। इंडस-2 को 150 mA करंट पर 2.5 GeV ऊर्जा के बीम-करेंट पर लगातार तीन पारियों में प्रचालित किया जा रहा है।

आरआरकेट में, इंडस-2 की 10 बीम लाइनें एवं इंडस-1 की 5 बीम लाइनें प्रचालनरत हैं और ये आरआरकेट में बड़ी संख्या में एम.टेक एवं पीएचडी विद्यार्थियों के लिए तथा पूरे देश भर से शोधकर्ताओं के लिए भी उपलब्ध हैं। जनवरी 2012 से, इन बीम लाइनों का उपयोग करके किये गये कार्य पर आधारित 95 प्रकाशन पीअर समीक्षित अंतरराष्ट्रीय जर्नलों में प्रकाशित हुए हैं।

आर आर केट ने अद्वितीय सॉलिड स्टेट आरआर एंप्लिफायरों को स्वदेशी रूप से विकसित कर लिया है। पिछले एक वर्ष के दौरान सॉलिड स्टेट आरएफ एंप्लिफायरों की आउट-पुट शक्ति को 200KW तक बढ़ा लिया गया है। इससे आयातित क्लाइस्टॉर्न पर हमारी निर्भरता खत्म हो गयी है। इंडस-2 को अब नियमित रूप से इन सॉलिड स्टेट एंप्लिफायरों द्वारा प्रचालित किया जाता है।

भापअकेंद्र द्वारा एनपीसीआईएल को अनुसंधान एवं विकास सहायता के एक भाग के रूप में, टीएपीएस-2 के हाल ही के 23 वें पुनर्चक्रण आउटेज के दौरान तारापुर परमाणु बिजलीघर (टीएपीएस-2) में सुधारित Mak-2 (MK-2) वेल्ड इनस्पेक्शन मैनीपुलेटर (डब्ल्यूआईपी-2) को सफलतापूर्वक लगाया गया है। इस मैनीपुलेटर का उपयोग करके अल्ट्रासोनिक जांच तकनीक से टीएपीएस-2 रिएक्टर प्रेशर-वैसल की जांच की गई। कुडनकुलम

नाभिकीय विद्युत संयंत्र (के के एन पी पी) के इमर्जेंसी कोर कूलिंग सिस्टम (ई सी सी एस) के डबल-चेक वाल्वों के कुछ घटकों (कंपोनेंट्स) की असफलता के मूल कारण को ढूंढने में तथा उसका हल पाने मे एन.पी.सी.आइ.एल. को तकनीकी सहायता दी गयी। स्वदेशी रूप से डिजाइन किये गये घटकों से सुधारित डिजाइन वाला वाल्व पूरी तरह उपयुक्त पाया गया और रिएक्टर में स्थापित कर दिया गया।

एक स्वदेशी रूप से अभिकल्पित एवं विकसित रेडियो आवृत्ति चतुर्ध्रुव (आरएफक्यू) भापअकेंद्र में कमीशन किया गया है। यह भारत में त्वरक चालित प्रणाली (एडीएस) हेतु एक विशेष उपलब्धि है। इस आर.एफ.क्यू. द्वारा एक प्रोटोन बीम को 70% ट्रांसमिसन के साथ 200 KeV तक सफलतापूर्वक त्वरित किया गया, तथा इसके परिणाम, डिजाइन मानपंडों के साथ उत्कृष्ट तरीके से मेल खा रहे हैं।

एडीएस के विकास के अंतर्गत, एक स्वदेशी रूप से विकसित पूर्णिमा ड्यूटेरान त्वरक चालित एक उपक्रांतिक न्यूट्रान मल्टिप्लाइंग असेंबली भापअकेंद्र में सफलतापूर्वक विकसित की गई है। मापित बहुगुणक कारक (Keff) 0.89 की पूर्वनिर्धारित वेल्यू पर स्थिर है। बी.ए.आर.सी. के पूर्णिमा भवन में स्थित यह प्रायोगिक सुविधा ईंधन के रूप में यूरेनियम धातु को, मंदक के रूप में पॉलिथिन को, एवं परावर्तक (रिफ्लैक्टर) के रूप में बेरिलियम ऑक्साइड को प्रयुक्त करती है। त्वरक चालित प्रणाली (ए डी एस) की दिशा में चल रहे प्रायोगिक अनुसंधान की दिशा में यह पहला कदम है। न्यूट्रान जेनरेटर और इसकी एलाइनमेंट प्रणाली बी.ए.आर.सी. के डिजाइन एवं निर्माण केंद्र (सी डी एम) द्वारा डिजाइन, विनिर्मित एवं स्थापित की गयी।

उच्च ऊर्जा भौतिकी के क्षेत्र में टी.आइ.एफ.आर. वैज्ञानिकों के जुड़ाव की सशक्त अंतरराष्ट्रीय सहकार्यों की परिणति, सर्न, जेनेवा में लार्ज हैड्रॉन कोलाइडर (एल.एच.सी.) की स्थापना में हुई। भारत-आधारित न्यूट्रिनों वेधशाला (आइ एन.ओ.) हेतु संसूचकों के एक आवश्यक भाग रेसिस्टिव प्लेट चेंबर्स (आर पी.सी) का विनिर्माण शुरू हो गया है।

स्वास्थ्य देखभाल, पानी, उद्योग और पर्यावरण बचाव में नाभिकीय और विकिरण प्रौद्योगिकी के गैर-विद्युतीय अनुप्रयोगों का हमारे समाज के कल्याणकारी कामों में महत्वपूर्ण योगदान है।

बी.ए.आर.सी. उच्च तापमान रिएक्टरों और हाइड्रोजन उत्पादन प्रोसेस हेतु प्रौद्योगिकी विकसित कर रहा है। विद्यमान अनुसंधान एवं विकास गतिविधियों का लक्ष्य उच्च तापमान के नाभिकीय रिएक्टर, जो प्रोसेस ऊष्मा को 1000^{0}C पर सप्लाई कर सकें, तथा उच्च दक्षता वाली हाइड्रोजन उत्पादन प्रक्रियाएं जैसे ताप-रसायनिक प्रक्रियाएं और उच्च तापमान स्टीम इलेक्ट्रोलाइसिस हैं। इसके अलावा बी.ए.आर.सी. हाइड्रोजन भंडारण सामग्रियों के साथ ही साथ परिवहन एवं विद्युत उत्पादन सेक्टरों में अनुप्रयोग हेतु ईंधन-सेल भी विकसित कर रहा है। नाभिकीय हाइड्रोजन उत्पादन से संबंधित आई.ए.ई.ए. गतिविधियों में योगदान के रूप में "हीप" (एचईईपी) हाइड्रोजन इकॉनामिक इवैल्यूएशन प्रोग्राम नामक सॉफ्टवेयर टूल आई.ए.ई.ए. हेतु भारत में विकसित किया गया है। यह टूल नाभिकीय हाइड्रोजन उत्पादन के आर्थिक विश्लेषण हेतु उपयोग किया जा रहा है ताकि विभिन्न विकल्पों की तुलना की जा सके।

विकिरण एवं आइसोटोप प्रौद्योगिकी बोर्ड (ब्रिट) ने प्रचालनरत दो विकिरण संसाधन संयंत्रों के अलावा, निजी क्षेत्र में नौ विकिरण संसाधन संयंत्रों के डिजाइन, निर्माण एवं प्रचालन में भी सहायता की है। छह (06) ऐसे संयंत्र निर्माणाधीन है और अन्य आठ (8) उद्यमियों के साथ समझौता ज्ञापन हस्ताक्षरित किये गये हैं। ये संयंत्र निर्जर्मीकरण एवं मसाले, पशु खाद्य और आयुर्वेदिक एवं जड़ीबूटी परिरक्षण के लिए इस्तेमाल योग्य चिकित्सा सामग्रियों को संसाधित कर रहे हैं। इस साल ब्रिट ने सतारा, महाराष्ट्र के निकट विकिरण उत्पादों के

निर्जर्मीकरण हेतु एक संयंत्र में 900 kci के बराबर की CO-60 पेंसिल स्थापित करके कोबाल्ट-60 (CO-60) आइसोटोप की सप्लाई के एक सबसे बड़े आर्डर को पूरा किया है।

ब्रिट ने स्वदेशी रूप से एक निष्कर्षण टूल को विकसित किया तथा प्रत्यर्पण उद्देश्यों हेतु कैंडी, श्रीलंका में एक पुराना गामा चैंबर फ्लास्क से C0-60 स्रोतों का स्थानांतरण सफलतापूर्वक पूरा किया।

स्वास्थ्य संरक्षा के क्षेत्र में, टाटा स्मारक केंद्र (टीएमसी) भारत में सामान्य कैंसरों के लिए कम लागतवाली प्रभावी उपचार प्रणाली को विकसित करने के लिए अनुसंधान कार्य कर रहा है। कम लागत वाली स्क्रीनिंग मॉडेलिटी का पहला ऐसा उदाहरण एसिटिक एसिड का उपयोग करके ग्रीवा (cervix) का नेत्रीय निरीक्षण करना था। टीएमसी में, नवीनतम कम लागत वाली उपचार पद्धति के परीक्षण ने महिलाओं में ग्रीवा कैंसर से होने वाली मृत्यु दर में 31% कमी की संभावना दर्शायी है। इस प्रौद्योगिकी एवं प्रशिक्षकों को प्रशिक्षण के प्रोसीजर में स्वास्थ्य एवं परिवार कल्याण मंत्रालय के साथ राष्ट्रव्यापी कार्यान्वयन हेतु सहभागिता की जा रही है। यह अपेक्षा की जा रही है कि इसके कार्यान्वयन के बाद यह प्रतिवर्ष भारत में 20,000 स्त्रियों एवं विश्व में 75,000 स्त्रियों की जान बचा सकती है। टाटा स्मारक केन्द्र द्वारा कृत एक अन्य विकास के अंतर्गत सीने के कैंसर की सर्जरी से पूर्व लगाया जाने वाले एक कम लागत वाला इंजेक्शन दिया जाता है। इससे विक्षेपी संक्रमण (Metastases) के कारण होने वाली मृत्युओं में 28% की कमी आ सकी है।

बी.ए.आर.सी. ने स्वदेशी टेलीथेरेपी प्रणाली भाभाट्रॉन के सशक्त पूरक के रूप में एक स्वदेशी प्रौद्योगिकी आधारित "इमेजिन" नामक डिजिटल रेडियोथेरेपी सिम्युलेटर (डीआरएस) विकसित किया है। तीन डी. आर.एस. यूनिटों में से एक टाटा स्मारक केन्द्र में स्थापित की गयी है। डी.आर.एस. की प्रौद्योगिकी को व्यापक प्रगति हेतु एक निजी उद्योग को हस्तांतरित कर दिया गया है।

सितंबर 2013 में टाटा स्मारक अस्पताल (टीएमएच) से सटकर स्थित रेडिएशन मेडिसिन सेंटर (आरएमसी) ने नाभिकीय औषधि के क्षेत्र में सतत सेवा के 50 वर्ष पूरे किये। आरएमसी में प्रशिक्षित चिकित्सक और प्रौद्योगिकीविद केवल भारत भर में ही नहीं वरन विश्व के अन्य कई देशों में सेवा कर रहे हैं।

बहुचरणीय फ्लैश वाष्पीकरण प्रौद्योगिकी पर चलने वाला कल्पाक्कम स्थित नाभिकीय निर्लवणीकरण संयंत्र, मद्रास परमाणु बिजलीघर की जरूरतों को पूरा करने हेतु उच्च गुणवत्ता वाले गैरआयनीकृत पानी की आपूर्ति कर रहा है।

नाभिकीय कृषि कार्यक्रम के एक भाग के रूप में, वर्ष 2013 में ट्रांबे मूंगफली किस्मों के 286 क्विंटल प्रजनक बीज की आपूर्ति की गई। वर्ष 2013 के दौरान एक बृहत बीज, ट्रांबे ब्लैक ग्राम वैरायटी TU40 जारी कर दी गई है। इसके साथ ही ट्रांबे फसल किस्मों की संख्या अब 41 हो गयी है।

मानव संसाधन विकास एक और क्षेत्र है, जहां हम डॉ. भाभा की दूरदृष्टि से अत्यधिक लाभान्वित हुए हैं। तथापि हमारे कार्यक्रमों में आगे नजर आने वाले बड़े विस्तरण से उत्पन्न चुनौतियाँ, नई प्रौद्योगिकी क्षेत्र जिन पर हमें काम करना है तथा बाहरी आकर्षणों के कारण, हमें नई पहल करने की जरूरत है। होमी भाभा राष्ट्रीय संस्थान में पीएचडी कार्यक्रम में बड़ी संख्या में वैज्ञानिक और इंजीनियर पंजीकृत हो रहे हैं।

"नाभिकीय ऊर्जा सहभागिता हेतु वैश्विक केन्द्र" का निर्माण इस साल के अंत में शुरू होगा, जबकि कैम्पस-बाह्य गतिविधियाँ पहले ही शुरू हो गयी हैं, जिनमें विभिन्न प्रशिक्षण कार्यक्रमों का गठन शामिल है। रेडियोलॉजिकल खतरों के निरोधन एवं प्रत्युत्तर पर एक राष्ट्रीय कार्यक्रम का आयोजन GCNEP में 26-30 अगस्त

2013 में किया गया था। चालू वर्ष में दो अन्य कार्यक्रम, एक आइसोटोपों के अनुप्रयोग (खाद्यान्न किरणन) और दूसरा रेडियोलॉजिकल संरक्षा पर आयोजित किये गये ।

प्रिय साथियों,

राष्ट्रीय सुरक्षा के क्षेत्र में, अरिहंत के नाभिकीय रिएक्टर की क्रांतिकता तथा विद्युत प्रचालन की उपलब्धि से एक बहुत बड़ा मुकाम हासिल कर लिया गया है।

उपलब्ध अल्प समय में, मैंने गत एक वर्ष के दौरान परमाणु ऊर्जा विभाग द्वारा हासिल की गयी मुख्य उपलब्धियों की एक झलक प्रस्तुत करने का प्रयास किया है। आज इस प्रौद्योगिकी के प्रति नकारात्मक रवैया होने के बावजूद हमारे द्वारा अकेले दम पर इस क्षेत्र में आत्म निर्भरता के साथ प्राप्त की गयी दृढ़ता के आधार पर हमें गर्व है कि हम अपनी उपलब्धियों के बल पर अंतरराष्ट्रीय समुदाय में अपनी एक पहचान बनाने में कामयाब हुए है और हमारा कद ऊंचा हुआ है। हम इस दिशा में काफी उन्नत हुए हैं और हमारे देश ने विश्व में प्रगत नाभिकीय क्षमता प्राप्त देशों की सूची में अपना स्थान बनाया है। परमाणु ऊर्जा विभाग का यह उत्तरदायित्व है कि वह ऊर्जा सुरक्षा, खाद्य सुरक्षा, जल सुरक्षा, स्वास्थ्य सुरक्षा तथा राष्ट्रीय सुरक्षा जैसे विषयों में आवश्यक समाधान उपलब्ध कर भारतीय जनता के जीवन की गुणवत्ता बढ़ाए तथा औद्योगिक विकास, वैज्ञानिक अनुसंधान तथा शिक्षा के क्षेत्र में अप्रतिम योगदान प्रदान करे । हम इन सभी क्षेत्रों में अपनी प्रतिबद्धताओं को पूरा कर रहे हैं। हमारी उपलब्धियाँ सर्वज्ञात हैं ही, फिर भी परमाणु ऊर्जा विभाग की प्रतिबद्धताओं तथा इसकी सफलताओं को स्पष्ट तथा ठोस रूप में संप्रेषित किया जाना होगा, ताकि इस विषय के विशेषज्ञों द्वारा दी गयी रिपोर्टों तथा भारत के माननीय

उच्चतम न्यायालय द्वारा दिए गए अधिनिर्णय के बावजूद भी सैद्धांतिक रूप से परमाणु ऊर्जा के विरोधी कुछ समूहों द्वारा परमाणु ऊर्जा के बारे में भयभीत करने वाली भ्रांतियों के प्रचार को रोका जा सके। इस चुनौती को भी हमने बहुत ही गंभीरता से लिया है। इस संदेश को प्रभावी ढंग से जनमानस तक पहुंचाने के लिए विभाग तथा इसकी कई यूनिटों ने बड़े पैमाने पर एक आउटरीच कार्यक्रम की शुरुआत की है।

इस पब्लिक आउटरीच कार्यक्रम के अंतर्गत हमारा लक्ष्य देश के सभी भागों में स्थित भारत की जनता को विभाग की विभिन्न गतिविधियों से होने वाले लाभों की जानकारी प्रदान करना है, साथ ही इन गतिविधियों में दिल से सहयोग करना है और इन्हें सहज और सुकर बनाना है।

हाल ही में विभाग के अलग-अलग यूनिटों ने अपने-अपने पब्लिक आउटरीच कार्यक्रमों को बड़े पैमाने पर विस्तारित किया है और इसके काफी अच्छे परिणाम मिले हैं। उदाहरण के रूप में पिछले एक वर्ष के दौरान एनपीसीआईएल ने जिला वैयक्तिक संपर्क कार्यक्रमों के माध्यम से 958 स्थल भ्रमण कार्यक्रमों तथा 48 प्रदर्शनियों का आयोजन कर परमाणु ऊर्जा के लाभों के बारे में 7 लाख 20 हजार से अधिक व्यक्तियों को जानकारी दी है।

प्रिय मित्रों,

1940 के दशक में, अपनी महज 30 वर्ष की उम्र में ही डॉ. होमी जहांगीर भाभा में अपने राष्ट्र की उन्नति के लिए परमाणु ऊर्जा के क्षेत्र में भारत को अग्रणी स्थान पर ले जाने की दूरदर्शिता थी। उस समय साक्षरता में कमी, गरीबी तथा भूख से बेहाल देश की बड़ी आबादी के सामने ऐसी संकल्पना प्रस्तुत करना एक असंगत तो नहीं पर एक साहसिक कार्य था। फिर भी, युवा डॉ. भाभा ने लक्ष्य को व्यवस्थित और साकार करने के लिये पूर्ण क्षमता एवं दृढ़ संकल्प से इसे चुनौती के रूप में स्वीकार किया। इतिहास इसका गवाह है कि डॉ. होमी जहांगीर भाभा इसमें सफल हुए और साल-दर-साल, हम सभी इस बात के गवाह हैं कि डॉ. होमी भाभा की दूरदर्शिता सफल होती गयी और आज भी सफल सिद्ध हो रही है।

धन्यवाद,

जय हिंद

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Founder's Day 2013

Address by
Dr. Ratan Kumar Sinha
Chairman, Atomic Energy Commission &
Secretary to Government of India, Department of Atomic Energy

"Distinguished Seniors, dear Colleagues, Ladies and Gentlemen,

We have assembled here this morning to launch the day long celebrations on the occasion of the 104th birth anniversary of Dr. Homi Jehangir Bhabha. As a part of the longstanding tradition, we start this day by paying homage to our dear Founder by recounting some of our recent achievements that symbolise the fruits of the tree that was planted by this great visionary more than six decades ago.

Among the many remarkable goals realised during the last one year, I would like to begin with the latest one. Kudankulam Nuclear Power Plant Unit-1 achieved its first criticality on 13th July 2013, and after completing all necessary commissioning tests, was test synchronised to the grid, for the first time on 22nd October 2013 at 02.45 hrs at 160 MW power level. The second test synchronisation was carried out at 21.43 hrs. on the 25th October. After operating at 234 MWe till this morning the electricity generation has been suspended for planned cleaning of strainers. After a few more tests, and planned maintenance activities, and step-wise regulatory clearances, the power level will be progressively raised. Commercial operations of this unit are expected to start in December 2013. The construction and commissioning of this unit, which is the largest capacity electricity generation unit in the country today, is a major milestone on the path of accelerated growth of nuclear power generation capacity in our country. The second unit is in an advanced stage of commissioning, and is expected to follow suit about six months later.

I am happy to inform you that nuclear power generation continues to grow due to the improvement in supply of uranium from domestic as well as international sources. The highest annual generation from nuclear power plants in our country was attained last year with the overall capacity factor of 80% and availability factor of 90%. Six of our reactors have logged continuous operation of more than 300 days during the year. In all, today, Nuclear Power Corporation of India Ltd. (NPCIL) is operating twenty nuclear power reactors at six different sites, with unblemished safety record.

On the safety of our operating nuclear power plants, I wish to inform you that the first IAEA Operational Safety Review Team (OSART) mission to India for Rajasthan Atomic Power Station (RAPS) units - 3&4, took place during October 29 to November 14, 2012. The OSART mission team reported a number of good safety practices and gave suggestions to further improve in some areas. As of today, NPCIL has registered over 385 reactor years of safe operation. The observations of OSART endorse the rich experience of NPCIL in operating its plants safely.

The construction of four indigenously designed 700 MWe PHWRs, two each at existing sites of Kakrapar in Gujarat and Rawatbhata in Rajasthan, is progressing on schedule. NPCIL is planning to progressively construct sixteen more PHWRs of 700 MWe at five different inland sites. Eight of these PHWRs, two plants of 700 MW capacity each at four different sites, viz Gorakhpur Units -1&2 in Haryana, Chutka Units -1&2 in MP, Mahi Banswara Units - 1&2 in Rajasthan and Kaiga Units - 5&6 are proposed to be launched during the XII Plan.

As a technology demonstration plant of our second stage of nuclear power programme, the construction of the 500 MWe Prototype Fast Breeder Reactor (PFBR) is nearing completion at Kalpakkam. Erection of all permanent in-core components has been completed. The construction and installation activities have reached over 95%. Filling of sodium in the secondary sodium loop is planned shortly and PFBR is expected to achieve first criticality in September 2014. It is also proposed to initiate activities towards the launch of construction of two units of Fast Breeder Reactors (FBR-1&2), during the XII five year plan.

For the third stage of our nuclear power programme, Advanced Heavy Water Reactor (AHWR), which would be a technology demonstration plant utilising thorium based fuel and with advanced safety features, is also proposed to be launched during the XII Plan.

Dear Friends,

Dr Bhabha laid the foundation of delivering technologies from indigenous Research programmes. His philosophy of Research, Development, Demonstration and Deployment have given us the strength to provide a vast range of key deliverables in all the aspects of use of nuclear energy, and develop indigenous technologies for becoming self-reliant in this field. These programmes have helped the development and growth of our industries and also several research and academic institutions to cater not only to the needs of our Department, but also to the requirements of the country at large.

It is a matter of great satisfaction that the world today recognises India as a country with advanced nuclear technology and is coming forward to collaborate in our nuclear power programme. Till date, Inter Governmental Agreements or Memorandum of Understanding for Civil Nuclear Co-operation have been signed with USA, France, Russia, Mongolia, Namibia, Argentina, United Kingdom, Canada, South Korea and Kazakhstan. In addition, an old agreement has been revalidated with Czech Republic. Discussions are going on with countries like Japan, Australia and other countries with potential for mutual benefit with cooperation. The discussions of NPCIL with foreign nuclear power plant suppliers, like Areva of France and Westinghouse and General Electric Hitachi of USA, are in an advanced stage. Recently, NPCIL signed a "Pre-Early-Works Agreement" or "Preliminary Contract" with Westinghouse Electric Company (WEC), USA comprising three packages, i.e. (i) Preliminary Safety Analysis Report; (ii) Compatibility of plant design with Atomic Energy Regulatory Board (AERB) codes / guides and safety approach; and (iii) Radiological design development.

Light Water Reactors (LWRs), with international cooperation, each of capacity 1000 MW or more, at another four different sites, viz Kudankulam in Tamil Nadu (KK-3&4); Jaitapur in Maharashtra (JNPP-1&2); Kovvada Unit-1&2 in Andhra Pradesh; and Mithi Virdi Unit-1&2 in Gujarat, are planned to be launched during the XII Plan.

In the area of Uranium exploration, the Atomic Minerals Directorate for Exploration and Research (AMD) of our Department has continued its rigorous efforts in the exploration of Uranium in the country. As a result of using advanced techniques, we have been able to identify new resources of Uranium. During the last year, our reserves have registered an increase of about 5%. AMD has established in-situ resource amounting to 7,324 tonne U3O8 during April to September 2013, and a total of 22,611 tonne in XII Plan period (till September, 2013). The country's in-situ uranium resources have now grown to 1,97,621 tonne U3O8 corresponding to 1,67,582 tonne Uranium. A major contribution comes from the Tummallapalle area, Andhra Pradesh followed by Singbhum Thrust Belt, Jharkhand, Mahadek, Meghalaya and Rohil, Rajasthan.

AMD has established Rare Metal and Rare Earth (RMRE) Recovery plants at Marlagalla, Mandya district, Karnataka for production of Columbite tantalite (Nb-Ta) and at Siri River, Jashpur district, Chhattisgarh for production of Xenotime (Yttrium, a Rare Earth Element).

Uranium Corporation of India Ltd. has commissioned a new underground mine and a processing plant in record time of five years, at Tummalapalle in Andhra Pradesh. The project for capacity expansion of Turamdih mine has been completed and the mine will be commissioned soon. Mohuldih underground mine in Jharkhand has also been commissioned. The overall supply of indigenous uranium has improved over time, and with the stabilisation of operations at Tummalapalle, the supply of uranium to the non-IAEA safeguarded reactors will improve, thereby leading to increase in their capacity factors, and in turn, improved generation.

The Indian Rare Earths Limited (IREL) is setting up a 10,000 ton per annum Monazite processing plant at Odisha Sands Complex, Chatrapur, Odisha (OSCOM). The plant is expected to be commissioned by January 2014. Capacity Expansion of Mining & Mineral Separation Plant of OSCOM (CEMMU), Odisha has been taken up. Separated High Pure Rare Earths plant has been set up at Rare Earths Division, Aluva, Kerala. Fifty percent of its 2250 tonnes per annum plant capacity has been commissioned. A part of the mixed rare earths chloride produced in the Plant will be processed by IREL's Rare Earths Division, Aluva, Kerala, by using the existing facilities there for producing separated high purity rare earth oxides. Increase in mineral production capacity from existing level of 6.08 lakh tonne per annum (tpa) to 8.70 lakh tpa will be achieved after expansion of capacities of mineral separation units at Odisha Sand Complex (OSCOM), Odisha and Manavalakurichi, Tamilnadu.

As regards the production of PHWR fuel, in the year 2012-13, Nuclear Fuel Complex (NFC) has recorded the highest ever production with a total production of 812 Metric Tonnes (MT), which is an increase of 8% over the previous year. NFC has also developed extrusion process for Inconel-718 and Inconel-690 super alloy tubes for use in steam generators of PWRs. This is of significant commercial importance because of worldwide application of this product.

The Power Reactor Fuel Reprocessing Plant – 2 (PREFRE-2), along with the Advanced Fuel Fabrication Facility (AFFF) at Tarapur have been producing and delivering fuel pins required for the PFBR.

In the field of reprocessing and waste management of Fast Reactor Fuel, a co-located Fast Reactor Fuel Cycle Facility (FRFCF), to reprocess and re-fabricate the fuel from PFBR, is being set up at Kalpakkam. Recently, Government has given Financial and Administrative sanction to this project. Necessary site infrastructure has already been created and preparations for launching this project have been taken up on priority.

Excellent performance has been recorded by our Heavy Water Plants during the last financial year. The plants have recorded the highest ever production of heavy water with lowest specific energy consumption. The Heavy Water Board (HWB) has executed five export orders for supply of heavy water worth more than USD 10 million to USA, France and South Korea. The Heavy Water Board has also bagged five more export orders, worth more than USD 15 million, for supply of heavy water to the U.S. and France. These orders will be executed before March 2014.

Heavy Water Board is also engaged in the development and delivery of critical solvent and raw materials for our second stage nuclear power programme. The production of solvents has also exceeded the targeted annual production. These solvents are used in reprocessing and waste management. The production units under the Board have consolidated technology for production of elemental Boron, and have operated the plant at more than 100% of its capacity. Enrichment of oxygen to an extent of 95.5% Oxygen-18 (O18) has been achieved in a pilot column. Oxygen-18 is a target isotope for production of fluorinating for medical applications. An industrial scale plant to produce O18 is now planned to be set up at HWP, Manuguru.

At our Indira Gandhi Centre for Atomic Research (IGCAR), the Fast Breeder Test Reactor (FBTR) has continued to operate smoothly, providing valuable operating experience as well as technical inputs to India's fast reactor programme. Post-irradiation examination of the test fuel subassembly for the Prototype Fast Breeder Reactor (PFBR), which was irradiated in FBTR, has provided valuable data and generated confidence in the design and manufacture of the FBR fuel. The direct determination of solidus-liquidus temperatures of MARK-I carbide fuel by a novel spot technique has been accomplished for the first time. Irradiation of indigenously fabricated sodium bonded metallic fuel pins and studies to understand the irradiation behaviour of the sphere-pac MOX fuel pin including segregation have also been initiated.

Steady State Superconducting Tokamak (SST-1) at the Institute for Plasma Research (IPR) has been successfully commissioned with the attainment of the first plasma in this facility on June 20, 2013. With this achievement, India now joins the select group of countries, where research in `Superconducting Tokamak' is currently being carried out.

Our programmes and activities relating to the development of Fusion reactor technology had been the driver for India joining the largest scientific collaboration project International Thermonuclear Experimental Reactor (ITER) project being built in France. This project aims at harnessing the energy in atoms by the same atomic reaction 'fusion' as taking place in the Sun. ITER uses the Deuterium-Tritium (DT) fusion reaction to demonstrate that controlled fusion reaction can be sustained for long enough duration. The Cryostat is the 2nd confinement barrier of the ITER machine which holds the vacuum vessel, the superconducting coils and many other sub-systems. It is roughly 28m in diameter and 28m tall. Once built, this will be the biggest vacuum vessel in the world meeting relevant nuclear safety standards. The Indian partner in the ITER Project viz. ITER-India, hosted by the Institute of Plasma Research (IPR), an autonomous institution under DAE, has been given full responsibility for the design, development and supply of this major system of the ITER. Very recently, contract for manufacture of this very high technology equipment has been awarded to a major Indian industrial house following a globally competitive bidding process. This demonstrates the prowess of Indian industries for undertaking such complex manufacturing work. The work for manufacturing cryostat has already started.

As part of the efforts towards indigenous development of newer high performance structural materials, development of India specific reduced activation ferritic-martenistic (INRAFM) steel for test blanket module of ITER has been completed at IGCAR. This is an IPR, IGCAR and Industry collaboration work.

An important milestone of Indus-2 synchrotron radiation source at Raja Ramanna Centre for Advanced Technology (RRCAT), Indore was reached on January 24, 2013 with the operation of Indus-2 at 158 mA current at design energy of 2.5 GeV. Indus-2 is being operated regularly in three shifts at a beam current up to 150 mA at 2.5 GeV energy.

At RRCAT, ten beamlines on Indus-2 and five beamlines on Indus-1 are operational, and the same are available to researchers from all over the country, besides a large number of M.Tech. and PhD students at RRCAT. Since January 2012, 95 publications have appeared in peer-reviewed International Journals based on the work done using these beamlines.

RRCAT has indigenously developed unique Solid State RF amplifiers. During the last one year, the output power of solid state RF amplifiers has been enhanced to 200 kW. This has eliminated our dependence on imported klystrons. Indus-2 is now regularly operated with the support of these solid state RF amplifiers.

As a part of R&D support to the NPCIL by BARC, the improved Mak-2 (MK-2) Weld Inspection Manipulator (WIM-2) was successfully deployed in the Tarapur Atomic Power Station Unit-2 (TAPS-2) during the current 23rd refueling outage of TAPS-2. TAPS-2 Reactor Pressure Vessel was inspected using this manipulator with Ultrasonic Inspection technique. Technical support was also provided to NPCIL, to find the root cause of the failure of some components of Double check valves of Emergency Core Cooling System (ECCS) of Kudankulam Nuclear Power Plant (KKNPP) and working out solutions. Modified design of valve with indigenously designed components has been fully qualified and installed in the reactor.

An indigenously designed and developed Radio Frequency Quadrupole (RFQ) has been commissioned at BARC. This is a significant milestone in the Indian road-map for Accelerator Driven System (ADS). A proton beam was successfully accelerated to 200 keV through this RFQ, with a transmission of 70%, with the results being in excellent agreement with the design values.

Towards the development of ADS, a subcritical neutron multiplying assembly driven by an indigenously developed Purnima deuteron accelerator has been successfully commissioned at BARC. The measured multiplying factor (Keff) is consistent with the predicted value of 0.89. This experimental facility at Purnima building, BARC, uses natural uranium metal as fuel, polythene as moderator and beryllium oxide as reflector. This is the first step towards implementing experimental research leading to Accelerator Driven System (ADS). The Neutron Generator and its Alignment System was designed, manufactured and installed by Centre for Design and Manufacture (CDM), BARC.

In high energy physics, strong international collaborations involving TIFR scientists culminated in the installation of the outer hadron calorimeter at the Large Hadron Collider (LHC) in CERN, Geneva. Fabrication of Resistive Plate Chambers (RPCs), an essential part of the detectors for the India-based Neutrino Observatory (INO), has begun.

Non-power applications of nuclear and radiation technologies in the area of health-care, water, industry and environmental protection are extremely important contributions to the welfare of our society.

BARC is developing technologies for high temperature reactors and hydrogen production processes. The current R&D activities target technologies for high temperature nuclear reactors, capable of supplying process heat at 1000 °C, and high efficiency hydrogen production processes such as thermo-chemical processes and high temperature steam electrolysis. In addition, BARC is also developing hydrogen storage materials as well as fuel cells for applications in transport and power generation sectors. As a contribution to IAEA activities related to nuclear hydrogen production, a software tool called HEEP, which stands for Hydrogen Economic Evaluation Programme, has been developed in India for the International Atomic Energy Agency (IAEA). This tool is being used for economic analysis of nuclear hydrogen production so as to compare various options.

The Board of Radiation and Isotope Technology (BRIT), apart from operating two Radiation processing plants, has helped in the design, construction and operation of nine radiation processing plants in the private sector. Six such plants are under construction and MoUs have been signed with another eight private entrepreneurs.

These plants are processing disposable medical items for sterilisation and hygienisation of spices, pet feed and ayurvedic and herbal products for preservation. This year, BRIT executed the single largest order for supply of Cobalt-60 (Co-60) isotope by installing about 900 kCi worth of Co-60 pencils in a plant for sterilisation of medical products near Satara, Maharashtra.

BRIT indigenously developed an extraction tool and successfully completed transfer of Co-60 sources from an old gamma chamber flask at Kandy, Sri Lanka for repatriation purpose.

In the area of health care, Tata Memorial Centre (TMC) has been carrying out research to evolve cost-effective treatment for common cancers in India. The first such example is the low cost screening modality by visual inspection of cervix using acetic acid (VIA). Trials of the innovative low cost approach carried out in TMC have shown a potential for 31% reduction in mortality arising out of cervical cancer in women. This technology and the procedure of training trainers have been shared with the Ministry of Health & Family Welfare for nation-wide implementation. It is anticipated that once implemented, it could save over 22,000 lives of women in India every year and more than 75,000 lives globally. Another important development carried out by TMC has led to a modality of a low cost injection given prior to surgery of breast cancer. This could reduce fatalities arising out of metastases by 28 percent.

BARC has developed an indigenous technology based Digital Radiotherapy Simulator (DRS) "Imagin" as a vital supplement to the indigenous teletherapy system, Bhabhatron. One of the three DRS Units has been installed at Tata Memorial Centre (TMC). The technology of DRS has been transferred to a private industry for its wider deployment.

In September 2013, the Radiation Medicine Centre (RMC) of BARC, located alongside the Tata Memorial Hospital (TMH) in Mumbai completed 50 years of sustained service in the field of nuclear medicine. RMC-trained physicians and technologists are not only serving all over India, but in several other countries across the world.

The nuclear desalination plant at Kalpakkam, employing the technology of multi-stage flash evaporation, has been supplying high quality de-ionised water to cater to the requirements of the Madras Atomic Power Station.

As part of nuclear agriculture programme, 286 Quintals of Breeder Seed of Trombay Groundnut Varieties has been supplied in the year 2013. During 2013, a large seed Trombay Black Gram variety TU40 has been released. With this, total number of Trombay crop varieties released so far are 41.

Human resource development is another area where we have immensely benefited from the foresight of Dr. Bhabha. However, the challenges posed by the major expansion that we foresee in our programme, new technological areas that we need to work on and the external attractions necessitate new initiatives. Homi Bhabha National Institute (HBNI) continues to register large number of our scientists and engineers for the PhD programme.

The construction of Global Centre for Nuclear Energy Partnership (GCNEP) will start later this year, while off-campus activities are already taking place, involving organisation of different training programmes. A National Programme on Prevention and Response to Radiological Threats was organised from 26-30 August 2013 at GCNEP. During the current year, two other programmes one on Application of Radioisotopes (Food Irradiation) and the second one on Radiological safety were organised.

Dear Colleagues,

In the field of national security, a very important milestone was reached with the achievement of criticality, as well as power operation,. of the nuclear reactor of Arihant.

In the available short time, I have tried to highlight a few of the major achievements attained by the Department of Atomic Energy during the last one year. Today, we stand proud and tall in the international community, solely on the basis of strength acquired through self-reliance. In spite of the technology denial regimes, we have moved ahead and acquired a status of becoming one among the very few countries in the world with advanced nuclear capabilities. The DAE has a mandate to contribute to enhancing the quality of life of the Indian population by providing solutions that address energy security, food security, water security, health security and national security while, on the way, making immense contributions in the domains of industrial growth, scientific research and education. We have been fulfilling our commitments in each of these areas. While our achievements speak for themselves, the message of DAE's commitment and successes has to be communicated loud and clear to counter the propaganda and scaremongering that is being indulged in by some groups ideologically opposed to nuclear energy, despite the unambiguous reports of all the expert groups, and the clear verdict of the Hon'ble Supreme Court of India. We have taken up this challenge, too, with the seriousness it deserves. To spread this message effectively, the DAE and its various units have launched public outreach programmes in a big way.

Our goal in the Public Outreach programme is to ensure that the Indian population, in all parts of the country, are not only convinced of the benefits flowing out of the activities of DAE, but also whole-heartedly support and facilitate these activities.

In the recent past, the different units of DAE have vastly enhanced their public outreach programmes with visible results. For example, during the last one year period, the NPCIL has organised various events and visits in which more than 7.2 lakh persons from different walks of life have been communicated the benefits of nuclear energy, through direct personal contact programmes, including 958 site visits and 48 exhibitions.

Dear Friends,

Way back in the early 1940s Dr. Homi Jehangir Bhabha, still in his early 30's had a vision of India taking a lead position in the field of atomic energy for the progress of our nation. At that time, with the backdrop of gross illiteracy, poverty and hunger affecting large populations in our country, such a thought could have sounded very strange, if not preposterous. Even so, the young Dr. Bhabha took it as his unwavering mission to systematically face the challenge and realise his vision through sheer grit and determination. History is witness to the fact that Dr. Homi Jehangir Bhabha did succeed. Year after year, while recalling the achievements of the great institution founded by him, we are witness to the fact that the spirit of Dr. Bhabha is still alive amongst us.

Thank you,

Jai Hind".

स्थापना दिवस 2013

(बुधवार, 30 अक्टूबर 2013)
श्री शेखर बसु, भापअ केंद्र के निदेशक
का संबोधन

सिन्हा, परमाणु ऊर्जा विभाग परिवार के वरिष्ठ सदस्यगण, विशिष्ट आमंत्रित अतिथिगण, मीडिया के प्रतिनिधिगण, मेरे प्रिय साथियों और दोस्तों।

मैं, संस्थापक दिवस के शुभ अवसर पर आप सभी का हार्दिक स्वागत करता हूँ। आज के दिन हम अपने स्वप्नद्रष्टा संस्थापक डॉ. होमी जहांगीर भाभा के 104 वें जन्मदिवस के अवसर पर उन्हें भावपूर्ण श्रध्दांजलि अर्पित करते हैं। हम यहां इसलिए एकत्रित हुए हैं ताकि हम अपने पिछले वर्ष के कार्य निष्पादन एवं उपलब्धियों का विश्लेषण कर सकें और नाभिकीय अनुप्रयोगों से अपने राष्ट्र को अधिक से अधिक लाभ पहुँचाने की अपनी प्रतिबध्दता के प्रति अपने आप को पुन: समर्पित कर सकें।

मैं सर्वप्रथम आपको पिछले वर्ष के दौरान केंद्र द्वारा किए गए महत्वपूर्ण कार्यों और प्राप्त उपलब्धियों के बारे में बताना चाहूंगा।

सबसे रोमांचक समाचार हमें 10 अगस्त 2013 को यह मिला कि नाभिकीय पनडुब्बी "अरिहंत" पर स्थापित रिएक्टर ने काम करना शुरू कर दिया है। राष्ट्रीय सुरक्षा की दिशा में यह एक महत्वपूर्ण उपलब्धि है। वर्तमान में इस पनडुब्बी पर बंदरगाह में परीक्षण किए जा रहे हैं। इस उपलब्धि के फलस्वरूप नाभिकीय पनडुब्बियों के श्रृंखलाबध्द उत्पादन की संभावना जागी है। इस परियोजना का शुभारंभ ट्रांबे परिसर में हुआ था। जिसके विकास में बीएआरसी, डीआरडीओ तथा नौसेना के बहुत से कार्मिक शामिल थे। सबने मिलकर लंबे समय तक पूरे समर्पण भाव से कार्य करके इस सपने को साकार किया। इस कार्यक्रम की पहली सफलता वर्ष 2006 में तब मिली थी जब स्थलीय प्रोटोटाइप ने कलपाक्कम में काम करना शुरू किया था। अब वह दिन दूर नहीं है जब भारत के पास, अपने महासागरों की पहरेदारी करने के लिए, परमाणु ऊर्जा से चलने वाले जहाजों का बेड़ा होगा।

प्रिय साथियों,

आज हम अपने अनुसंधान और विकास परियोजनाओं हेतु यथोचित परिणाम प्राप्त करने की ओर अपनी गतिविधियों को केंद्रित कर रहे हैं। इसमें हमारे कुछ उच्च प्रौद्योगिकी की गतिविधियों के लिए अनुसंधान और विकास के प्रयासों के आउटपुट को परिनियोजित करना और व्यावसायिक एवं समाजोपयोगी अनुप्रयोगों हेतु

प्रौद्योगिकी का अधिकतम उपयोग शामिल होगा।

ए.1 ईसीसीएस के डबल चेक वाल्वों में कंपोनेंट असफल हो जाने के मुख्य कारण का पता लगाने और कुडनकुलम नाभिकीय विद्युत संयंत्र में उसे बदलने के लिए उपयुक्त कंपोनेंट का विकास करने हेतु एनपीसीआईएल को तकनीकी सहयोग दिया गया। स्वदेश में अभिकल्पित कंपोनेंट सहित वाल्व के संशोधित डिजाइन को कलपाक्कम सुविधा के लिए उचित बताया गया।

ए.2 टैप्स-2 के 23वें पुन:ईंधन भरण आउटेज के दौरान इसमें उन्नत वेल्ड इंस्पेक्शन मैनिपुलेटर को सफलतापूर्वक लगाया गया। संरचनात्मक अखंडता मूल्यांकन के लिए निरीक्षण के आंकड़ों का विश्लेषण किया गया। इस मूल्यांकन के आधार पर एईआरबी ने यूनिट को दुबारा शुरू करने की अनुमति दी।

ए.3 कंप्यूटर आधारित 8-चैनल पराश्रव्य प्रतिबिंबन प्रणाली (अल्ट्रासोनिक इमेजिंग सिस्टम) का अभिकल्पन और विकास करके आईजीकार को इसकी आपूर्ति की गई। 180^0 सेंटीग्रेड पर अंडर-सोडियम डम्मी फ्यूल सब-असेंबली की वृध्दि और बहि:सरण (प्रोट्रूजन) का पता लगाने के लिए इस सिस्टम का सफलतापूर्वक परीक्षण किया गया।

ए.4 पीएफबीआर के लिए "इन्क्लाइन्ड फ्यूल ट्रांसफर मशीन" और "सेल ट्रांसफर मशीन" हेतु माइक्रोकंप्यूटर आधारित नियंत्रण प्रणाली की डिलीवरी की गई।

ए.5 समुद्री जल के निर्लवणीकरण के लिए अपशिष्ट ऊष्मा का उपयोग करके ताजे पानी के जनरेटर के निम्न ताप प्रौद्योगिकी को, परिनियोजन की संभावना में और विस्तार करने हेतु औद्योगिक गृह (इंडस्ट्रियल हाउस) को हस्तांतरित किया गया।

ए.6 0.01 ppm टर्बिडिटी वाले पैथोजन मुक्त पानी का उत्पादन करने के लिए, मेम्ब्रेन कार्ट्रिज पर आधारित एक परानिस्यंदन प्रणाली (अल्ट्राफिल्ट्रेशन सिस्टम) का विकास किया गया। यह प्रणाली किसी भी अस्पताल में परिनियोजित करने हेतु उपयुक्त है।

ए.7 पूर्व में प्रारंभ किए गए स्वदेशी टेलीथेरेपी सिस्टम, भाभाट्रॉन (34 यूनिट का उपयोग किया जा रहा है) के महत्वपूर्ण पूरक के रूप में डिजिटल रेडियोथेरेपी सिम्युलेटर (इमेजिन) का विकास किया गया। परेल स्थित टाटा मेमोरियल अस्पताल में स्थापित तीसरे इमेजिन का उद्घाटन, हाल ही में आईएइए के महानिदेशक ने किया।

ए.8 मेटास्टेटिक बोन कैंसर के उपशामक उपचार के लिए एक चिकित्सीय उत्पाद, ईडीटीएमपी (इथिलीनडाइमाइन टेट्रा मिथिलीन फास्फोनिक) के फ्रीज-ड्राइड कोल्ड किट्स और तुरंत उपयोगी Lu-177-EDTMP का विकास करके इसकी आपूर्ति शुरू की गई।

ए.9 ट्रांबे स्थित प्लुटोनियम प्लांट के निकट झील सं. 10 की डी-सिल्टिंग का काम पूरा किया

गया ताकि वर्षा जल संरक्षण के लिए झील की क्षमता में वृध्दि की जा सके।

ए.10 "प्रेरण-युग्मित प्लाज्मा द्रव्यमान (इंडक्टिवली कपल्ड प्लाज्मा मास) स्पेक्ट्रोमीटर (ICP-MS)" के लिए विकसित प्रौद्योगिकी को हैदराबाद के एक निजी एजेंसी को हस्तांतरित किया गया। यह एक सर्वतोमुखी विश्लेषणात्मक उपकरण है जो जलीय नमूने में अल्ट्रा-ट्रेस एवं आइसोटोप के अनुपात का विश्लेषण करने की क्षमता रखता है।

ए.11 साउथ साइट में स्थित यूरेनियम धातु अपचयन प्रौद्योगिकी सुविधा में "वैरिएबल रेफ्रिजरेन्ट वॉल्यूम" वातानुकूलन प्रणाली का कमीशनन किया गया।

ए.12 ~6% ऊर्जा रूपान्तरण की दक्षता वाले pbTe (P-टाइप सेमिकन्डक्टर) एवं TAGS (Te, Ag, Ge एवं Sb के n- टाइप सेमीकन्डक्टर मिश्रधातु) को रेडियोआइसोटोप जनरेटरों में अनुप्रयोग के संबंध में अनुकारित परीक्षण के लिए इसरो (ISRO) को इसकी आपूर्ति की गई।

ए.13 एक सस्पेंडेबल सर्वो-मैनिपुलेटर का विकास किया गया और टैप्स-3 एवं 4 के रिएक्टर डेक प्लेट पर आपातकालीन प्रचालनों के लिए एनपीसीआईएल को इसकी आपूर्ति की गई।

ए.14 ट्रांबे के डब्ल्यूआईपी में HEPA फिल्टरों के परीक्षण के लिए टेलीटेक्टर सहित ऑल-टेरेन रोबोट का हाल ही में प्रयोग किया गया।

ए.15 बोरोन, बेरिलियम और फ्लुओरीन जैसे तत्वों के संरचनात्मक पदार्थ में ppm क्रम के दस गुणांक तक सही आकलन लगाने के लिए प्रोटोन प्रेरित गामा उत्सर्जन (पीआईजीई) का प्रयोग करके एक नई तकनीक स्थापित की गई।

प्रिय साथियों

हमारी कुछ गतिविधियों में अच्छी प्रगति हुई है और हम उस अवस्था तक आ चुके हैं जहां हम विभिन्न क्षेत्रों में अनुप्रयोग के लिए इन पहलुओं के उन्नयन की ओर कार्य कर रहे हैं।

बी.1 एनएफसी के प्रस्तावित ट्विन गन 300 kW EB गलन भट्टी में परिनियोजित करने के लिए एक प्रोटोटाइप 100 kW अक्षीय इलेक्ट्रॉन बीम मेल्टिंग (ईबीएम) गन का विकास किया गया।

बी.2 स्वदेश में विकसित एक ड्यूटेरॉन त्वरक द्वारा चालित सबक्रिटिकल न्यूट्रॉन मल्टिप्लाइंग असेम्बली का भापअ केंद्र में कमीशनन किया गया। मल्टिप्लाइंग फैक्टर को मापने के बाद वह भविष्यवाणी किए हुए मान 0.89 से मेल खाता है। यह प्रायोगिक सुविधा, त्वरक चालित प्रणाली को क्रियान्वित करने की ओर एक कदम है।

बी.3 प्रोटोन (H^+) H_2^+ किरणपुंजों को त्वरित करके एक 400 KeV रेडियोआवृत्ति क्वाड्रूपोल (आरएफक्यू) का सफलतापूर्वक परीक्षण किया गया। 400 KeV RFQ का अभिकल्पन D^+

(H_2^+) किरणपुंज के लिए किया गया है। 99% से अधिक पॉवर कपलिंग वाले स्वदेश में विकसित एक RF कपलर के माध्यम से 60 kW टेट्रोड आधारित RF पॉवर स्रोत को RFQ के साथ युग्मित किया गया।

बी.4 निर्भय नामक एक ऐसी युक्ति का विकास किया गया जो संकट आने पर दूर से ही सतर्क करेगा। बड़ी मात्रा में इस युक्ति के उत्पादन के लिए इसकी प्रौद्योगिकी को ईसीआईएल में हस्तांतरित किया गया।

बी.5 वातावरण में और प्रतिकूल पर्यावरण में रासायनिक प्रजातियों के सूक्ष्म मात्रिक तत्व विश्लेषण और उन्हें दूर से मानीटर करने के लिए पिकोसेकंड्स सम-फ्रिक्वेंसी जनरेशन युक्त लेसर तकनीक तथा फेम्टोसेकंड लेसर-इंड्यूस्ड ब्रेकडाउन स्पेक्ट्रोस्कोपी का विकास किया गया।

बी.6 गुणात्मक न्यूट्रॉन और सिंक्रोट्रॉन बीम ट्रांसपोर्ट्स की आवश्यकताओं की पूर्ति के लिए अनेक परतों वाले सुपर-मिरर के संविरचन हेतु 9 मीटर लंबा एक बेलनाकार मल्टी-कैथोड मैग्नेट्रॉन स्पटर कोटर का कमीशनन किया गया। इस स्वचालित सिस्टम में यह क्षमता है कि यह अनेक किस्मों के सबस्ट्रेटों पर संतुलित मोटाई के साथ धातु, डाइइलेक्ट्रिक, सिरेमिक और संयुक्त पदार्थों के सैकड़ों सूक्ष्म परतों को जमा कर सकता है।

बी.7 मसकीटो-लार्विसाइडल प्रोटीन पर मूल जैव-भौतिकी अध्ययन करने से एक ऐसे नए प्रोटीन कांप्लेक्स का अभिकल्पन और संश्लेषण किया गया जो अब तक के किसी भी ज्ञात बाइनरी टॉक्सिनों के संयोजन से अधिक विषैला है।

बी.8 पदार्थ विज्ञान के अनुसंधान के लिए प्रकीर्णन प्रतिदर्शों (स्कैटरिंग सैम्पल) के डेप्थ रिजॉल्व्ड टोमोग्राफी इमेजिंग हेतु काल-प्रक्षेत्र (टाइम-डोमेन) पर आधारित एक लो-कोहेरेंस फाइबर - ऑप्टिक इंटरफेरोमीटर का विकास किया गया।

बी.9 माइक्रो-पोरस हॉलो फाइबर क्लस्टर में परिक्षेपण के प्रकार की द्रव झिल्ली का प्रयोग करके लीन-एसिडिक स्ट्रीम में से 60 लीटर प्रति घंटे के पैमाने पर यूरेनियम की पुन:प्राप्ति (रिकवरी) का सफलतापूर्वक निदर्शन किया गया।

बी.10 विशेष नाभिकीय पदार्थों के अविनाशी आमापन के लिए बृहत आयतन वाले एक कैलोरीमीटर का विकास किया गया।

बी.11 1 बार से 10E-12 बार तक लगातार दाब को मापने में सक्षम एक पूर्ण रेंज के निर्वात गेज का विकास किया गया।

बी.12 यूसीयूएफ परियोजना के प्रत्येक 9 किलोहर्ट्ज और 130 वाट पर प्रचालित तीन कॉपर वेपर लेसर, मास्टर ऑसिलेटर और पॉवर एम्प्लिफायर चेनों का कमीशनन किया गया।

बी.13 ताप-संदीप्ति (टीएल) और प्रकाशिक उद्दीपित संदीप्ति (ओएसएल-ऑप्टिकली स्टिमुलेटेड ल्युमिनेसेंस) फास्फरों पर आधारित वलय (रिंग) के जैसा फिंगर डोजीमीटर का अभिकल्पन और संविरचन प्लास्टिक रिंग और एडजस्ट करने योग्य बैंड/स्ट्रैप के रूप में किया गया है जिसका प्रयोजन शरीर के अंगों द्वारा प्राप्त डोजों को मापना है।

बी.14 भापअ केंद्र में 325 मेगाहर्ट्ज पर 5 किलोवाट के एक आरएफ एम्प्लिफायर और 7 और 10 किलोवाट पावर के एम्प्लिफायरों का निर्माण और परीक्षण किया गया।

बी.15 4% सामर्थ्ययुक्त 25 डाई सेंसिटाइज्ड सोलर सेलों वाले सोलर सेल अरे का संविरचन किया गया।

बी.16 एक 2.45 गीगाहर्ट्ज, 2 किलोवाट के माइक्रोवेव प्लाज्मा सीवीडी सुविधा का विकास किया गया और सिलिकॉन सबस्ट्रेटों पर डायमंड तनुपरतों के लगातार निक्षेपण का निदर्शन किया गया।

बी.17 0-35 माइक्रोन, CMOS प्रौद्योगिकी में चार चैनल वाले एक टाइम-टू-डिजिटल कन्वर्टर (टीडीसी) एएसआईसी का विकास किया गया।

प्रिय साथियों,

हम निम्नलिखित क्षेत्रों में भी कुछ प्रमुख परियोजनाएं शुरू कर रहे हैं:

सी.1 प्रगत भारी पानी रिएक्टर के लिए प्राकृतिक घटनाओं, सिस्मोटेक्टोनिक एवं फाउंडेशन स्थितियों के संबंध में तारापुर स्थल की उपयुक्तता की जांच की गई। इस पर एक रिपोर्ट पऊवि स्थल चयन समिति को प्रस्तुत की गई ताकि वे इस पर विचार करें। विशेष रूप से एएचडब्ल्यूआर के लिए टर्बाइन और स्टीम साइकल स्थितियों के विकास हेतु मेसर्स बीएचईएल (भेल) के साथ भी करार किया गया।

सी.2 इंडियन कांपैक्ट एलडब्ल्यूआर के विकास के अनुभव के आधार पर, 900 मेगावाट (MWe) के भारतीय दाबित पानी रिएक्टर का कंसेप्चुअल डिजाइन तैयार किया गया। भारतीय दाबित पानी रिएक्टर (आईपीडब्ल्यूआर), एनपीसीआईएल और भापअ केंद्र का एक संयुक्त प्रयास होगा। स्थल का चयन और विस्तृत डिजाइन कार्य किया जा रहा है।

सी.3 मदुरई में अंतर-संस्थानिक केंद्र के लिए अवसंरचनात्मक विकास प्रगति पर है जो पोट्टिपुरम स्थित भारतीय न्यूट्रिनो वेधशाला का एक अग्रदूत है।

भापअकेंद्र, वैकल्पिक ऊर्जा स्त्रोतों के विकास की ओर भी अपनी गतिविधियों का विस्तार कर रहा है।

डी.1 विद्युत उत्पादन के लिए पश्चिमी तट पर भू-तापीय ऊर्जा स्त्रोतों के विकास और उपयोग हेतु भू-तापीय स्प्रिंगों पर आइसोटोप जलविज्ञान परीक्षण का कार्य पुणे की एक निजी एजेंसी के

सहयोग से महाराष्ट्र के ट्रल, राजवाडी और चिपलुन में किया जा रहा है।

डी.2 भापअ केंद्र ने आईआईटी जोधपुर साइट में 2 मेगावाट (MWe) का सौर तापीय विद्युत संयंत्र की स्थापना का कार्य शुरू किया है। इस संयंत्र के अभिकल्पन में, गलित लवण में तापीय ऊर्जा के भंडारण की परिकल्पना की गई है। इसके लिए निधियों के अनुमोदन हेतु नवीन और नवीकरणीय ऊर्जा मंत्रालय को परियोजना की विस्तृत रिपोर्ट प्रस्तुत की गई है।

हम नाजुक क्षेत्रों में संपूर्ण समाधान करने की ओर भी प्रयासरत हैं। मैं साइरस से संबंधित उदाहरण का उल्लेख करना चाहूंगा।

ई.1 शटडाउन के बाद, साइरस के सभी भुक्तशेष ईंधन का पुनर्संसाधन किया गया।

ई.2 साइरस के किरणित 'J' रॉडों के अंतिम खेप को पुनर्संसाधित करने के लिए, यूरेनियम थोरियम पृथक्करण सुविधा (यूटीएसएफ) को भी साथ-साथ प्रचालित किया गया। 'J' रॉडों के पुनर्संसाधन के दौरान उत्पादित सभी थोरिया-लीन रैफिनेट वेस्ट का भी सफलतापूर्वक संसाधन डब्ल्यूआईपी में किया गया।

ई.3 पहली बार, तीनों उपलब्ध धात्विक प्रेरण तापन भट्टियों को साथ-साथ परिनियोजित करके 30-35 lph के संवेश-प्रवाह (थ्रूपुट) पर कांचीकरण के लिए उच्च स्तर द्रव अपशिष्ट का संसाधन किया गया।

ई.4 मध्यस्तरीय अपशिष्ट से भरे हुए एक टैंक का सफलतापूर्वक संसाधन किया गया।

ई.5 साइरस के भारी पानी में से ट्रीशियम का अंश हटाया जा रहा है ताकि अन्य रिएक्टरों में इसका पुन: उपयोग किया जा सके।

प्रिय साथियों,

भापअ केंद्र का विकिरण औषधि केंद्र(आरएमसी), इस वर्ष 3 सितंबर को अपनी सेवाओं के गौरवशाली 50 वर्ष पूरे कर चुका है। रोगियों की सेवा करने के अतिरिक्त नाभिकीय औषधि के क्षेत्र में नैदानिक प्रक्रियाओं के साथ-साथ मानव संसाधन विकसित करने में यह केंद्र अग्रणी रहा है।

रायल सोसायटी ऑफ केमेस्ट्री ने संस्थागत श्रेणी वर्ग में बीएआरसी को जनवरी 2012 से जून 2013 की अवधि में विभिन्न प्रकाशकों के जर्नलों में भारत भर से आलेख भेजने वालों में सर्वश्रेष्ठ घोषित किया है। इस दौरान हमारे केंद्र के वैज्ञानिकों ने रसायनशास्त्र में 660 आलेख प्रकाशित किए।

प्रिय साथियों,

पिछला तीन माह भापअ केंद्र के लिए अभूतपूर्व सफलता लेकर आया जब इसने परमाणु ऊर्जा विभाग के लक्ष्यों से जुडे क्षेत्रों में महत्वपूर्ण उपलब्धियां प्राप्त की।

F.1. पिछले माह कलपक्कम में प्रगत उन्नयन सुविधा संस्थापित की गई थी जो बहुत अच्छा कार्य कर रहा है।

F.2 अनुसंधान रिएक्टर ध्रुव लगभग 80% की उपलब्धता पर कार्य कर रहा है। हाल में रिएक्टर की शक्ति 70MW तक बढ़ाई गई ताकि विशेष गतिविधियों और रेडियोसमस्थानिकों के उत्पादन की गुणवत्ता को बढ़ाया जा सके। यह निर्णय हमारे देश के लोगों के स्वास्थ्य देखभाल के प्रति हमारा योगदान मुखर करता रहेगा।

F.3 'अरिहंत' के रिलोड कोर ने दिनांक 11 अक्तूबर से P4 सुविधा में कार्य करना आरंभ किया। कोर हेतु उपयोगी सामग्री एवं घटकों का उत्पादन मैसूर, हैदराबाद और ट्राम्बे सुविधाओं में किया गया।

F.4 प्रिफ्री संयंत्र से उच्च स्तरीय अपशिष्ट का कांचीकरण करने के लिए तारापूर स्थित प्रगत कांचीकृत प्रणाली ने प्रथम वर्ष में ही अपनी अभिकल्पन क्षमता से अधिक क्षमता पर कार्य किया।

F.5 इस सप्ताह इन्टरमीडियट स्तर के अपशिष्ट को KARP से कलपाक्कम स्थित अपशिष्ट अचलीकरण संयंत्र में हस्तांतरित किया गया जिसकी शुरूआत अपशिष्ट प्रबंधन सुविधा के हॉट कमीशनिंग से की गई।

F.6 एक्टीनाईड पृथक्करण प्रदर्शन सुविधा का हॉट कमीशनन आरंभ हुआ है। अब तक नोट किए गए उसके निष्पादन संबंधी पैरामीटर उत्कृष्ट रहे। इस प्रौद्योगिकी का निदर्शन सफल होने से उच्च स्तरीय अपशिष्ट, जिसका भंडारण लंबे समय तक करना पड़ता है, वह बहुत कम हो जाएगा।

F.7 भापअ केंद्र के विशाखापट्टणम परिसर में प्रथम चरण में बनाए जाने वाले भवनों और आधारभूत सुविधाओं का निर्माण कार्य शुरू किया गया।

F.8 बीएआरसी के विभिन्न परिसरों में फैले प्रशिक्षण विद्यालयों में प्रतिभाशाली प्रशिक्षणार्थियों को, युवा इंजिनियरों तथा विज्ञान के पोस्ट ग्रैज्युएटों को आकर्षित करने के लिए विशेष पहल की गई। इसके फलस्वरूप प्रशिक्षण विद्यालयों में प्रवेश पाने वालों की संख्या में 30% की वृध्दि हुई। इससे नाभिकीय ईंधन चक्र, रिएक्टर, त्वरक आदि के क्षेत्रों में प्रस्तावित विस्तार योजनाओं के लिए वैज्ञानिकों तथा इंजीनियरों की भारी कमी से निपटने में मदद मिलेगी। हम एक पखवाड़े के बाद होने वाले इस वर्ष के उपाधिग्रहण समारोह (ग्रैज्यूएशन फंक्शन) की प्रतीक्षा कर रहे हैं, जिसमें हम मुख्य अतिथि के रूप अपने माननीय राष्ट्रपति महोदय का स्वागत करेंगे।

F.9 तारापुर और कलपाक्कम स्थित पुनर्संसाधन संयंत्र ने वर्ष 2012 की Name Plate क्षमताओं को पार किया है और यह आशा है कि इस वर्ष भी इस की निष्पादकता वैसी ही होगी।

F.10 तारापुर स्थित प्रगत ईंधन संविरचन सुविधा भी सतत कार्य कर रही है। PFBR को शुरू करने के लिए 75% ईंधन संविरचित किया गया है।

F.11 तुमलापल्ली यूरेनियम उत्पादन संयंत्र स्थापित करने के संबंध में कुछ समस्याओं के समाधान हेतु हमारा केंद्र पिछले कुछ महीनों से UCIL के साथ मिलकर काम कर रहा है। इन सभी समस्याओं का समाधान कर लिया गया है और 4 टन प्रति माह की दर से यूरेनियम का प्रायोगिक उत्पादन प्रारंभ हो चुका है।

ये सभी हमारे कार्यक्रमों के लिए लंबी अवधि तक उपयोगी होंगे और आशा है कि पूरे वर्ष भर हमें इसी प्रकार की उपलब्धियां प्राप्त हो सके।

प्रिय साथियों

मैं प्रशासन, लेखा, स्वास्थ्य-सेवा, अग्निशमन सेवाओं, इंजीनियरी सेवाओं, सुरक्षा संगठनों, विभिन्न एसोशिएशनों तथा अन्य सभी सहयोगियों की तहेदिल से सराहना करता हूं जिन्होंने इन सभी उपलब्धियों को संभव किया है।

साथियों आइए, आज इस विशेष दिवस पर, हम अपनी अनुसंधान एवं विकास की उपलब्धियों को राष्ट्रहित के लिए और अधिक उपयोगी बनाने की दृष्टि से अपने प्रयासों को केंद्रित करने के लिए अपने आप को पुन:समर्पित करें।

आप सब को धन्यवाद !

Founder's Day 2013

Address by
Sekhar Basu
Director, BARC

"Dr Sinha, Chairman, AEC, Senior Members of the DAE Family, Distinguished Invitees, Media representatives, my Colleagues and friends,

I extend a warm welcome to all of you to this Founder's Day functions. On this day we pay respectful homage to our visionary Founder, Dr Homi Jehangir Bhabha, on his 104th birth anniversary. We have assembled here to reflect upon our performance and achievements in the past year, and rededicate ourselves to make best efforts in ensuring maximum benefit to the nation from nuclear applications.

To begin with let me tell you about the performance highlights and achievements of BARC during the last one year.

Most exciting news came on August 10, 2013, when reactor on board nuclear submarine 'Arihant' went critical; a major milestone in national security was achieved. The vessel presently undergoing harbour trials have opened up the possibility of serial production of nuclear submarines. The project, which originated at Trombay campus, involved a large number of personnel from BARC, DRDO and Navy, who worked with total dedication over a long period of time to make this dream come true. The programme saw its first success when the land based prototype at Kalpakkam became operational in 2006. The day is not far when India will have its nuclear fleet patrolling the oceans.

Dear colleagues,

Today we are focusing our activities towards achieving logical end to our R&D projects. This would involve deploying the output of our R&D efforts in some of our high technology activities and also exploit the technology for commercial and societal applications.

A.1 Technical support was provided to NPCIL to find the root cause of component failure in double check valves of ECCS and development of suitable components for replacement in Kudankulam Nuclear Power Plant. Modified design of valve with indigenously designed components was qualified at Kalpakkam facility.

A.2 The improved Weld Inspection Manipulator was successfully deployed in TAPS-2 during its 23rd refueling outage. The inspection data was analyzed for structural integrity assessment. AERB permitted restart of the unit based on this assessment.

A.3 Computer based 8-Channel Ultrasonic Imaging System has been designed, developed and supplied to IGCAR. The system has been successfully tested for detection of growth and protrusion of undersodium dummy fuel sub-assemblies at 1800C.

A.4 Microcomputer based Control Systems for "Inclined Fuel Transfer Machine" and "Cell Transfer Machine" for PFBR have been delivered.

A.5 The Low Temperature Technology of Fresh Water Generator utilizing waste heat for sea water desalination was transferred to an industrial house for expanding the deployment potential.

A.6 An ultra filtration system based on membrane cartridges was developed to produce pathogen free water with 0.01 ppm turbidity. This system is suitable for deployment in any hospital.

A.7 Digital Radiotherapy Simulator (Imagin) was developed as a vital supplement to the earlier launched indigenous teletherapy system, Bhabhatron (34 units are in use). The 3rd Imagin recently installed at Tata Memorial Hospital (TMH), Parel was inaugurated by Director General of IAEA.

A.8 Freeze-dried cold kits of EDTMP (Ethylenediamine Tetra Methylene Phosphonic) and ready-to-use Lu-177-EDTMP, a therapeutic product for palliative therapy of metastatic bone cancer, has been developed and supplies commenced.

A.9 De-silting of Lake No. 10 near Plutonium Plant at Trombay was completed for augmenting the capacity of the lake for rain water harvesting.

A.10 The technology developed for "Inductively Coupled Plasma Mass Spectrometer (ICP-MS)" has been transferred to a private agency in Hyderabad. This is a versatile analytical instrument capable of ultra-trace and isotope ratio analysis in aqueous samples.

A.11 "Variable Refrigerant Volume" air-conditioning system at Uranium Metal Reduction Technology facility at South Site has been commissioned.

A.12 Linear thermoelectric modules based on PbTe (p- type semiconductor) and TAGS (n- type semiconductor alloy of Te, Ag, Ge and Sb) with ~6% power conversion efficiency were supplied to ISRO for simulated testing with regard to application in radioisotope generators.

A.13 A suspendable servo-manipulator has been developed and supplied to NPCIL for emergency operations on the reactor deck plate of TAPS-3&4.

A.14 All-Terrain Robot with Teletector has recently been used for testing HEPA filters at WIP, Trombay.

A.15 A new technique, using Proton Induced Gamma Emission (PIGE), has been established for accurate estimation of elements like Boron, Beryllium and Fluorine in structural material to tens of ppm order.

Dear Colleagues,

Some of our activities have progressed well and has come to a stage where we are working towards up-gradation of these initiatives for application in various fields.

B.1 A prototype 100kW axial electron beam melting (EBM) gun has been developed for deployment at NFC in the proposed twin gun 300 kW EB melting furnace.

B.2 Subcritical neutron multiplying assembly driven by an indigenously developed deuteron accelerator has been commissioned at BARC. The measured multiplying factor is consistent with the predicted value of 0.89. This experimental facility is a step towards implementing the Accelerator Driven System.

B.3 A 400 keV Radio Frequency Quadrupole (RFQ) has been successfully tested by accelerating proton (H+) and H2 + beams. The 400 keV RFQ is designed for D+ (H2 +) beam. 60 kW tetrode based RF power source was coupled to the RFQ through an indigenously developed RF coupler with power coupling of more than 99%.

B.4 A Tele Distress Alarm Device, named Nirbhaya, has been developed. The technology of the device has been transferred to ECIL for mass production.

B.5 Laser techniques involving picoseconds sum-frequency generation, and femtosecond laser-induced breakdown spectroscopy, were developed for trace element analysis and for remote monitoring of chemical species in atmosphere and hostile environment.

B.6 A 9-meter long cylindrical multi-cathode magnetron sputter coater was commissioned for fabrication of multilayer Super-Mirrors catering to the needs of efficient neutron and synchrotron beam transports. The automated system has the capability to deposit several hundreds of nano layers of metal, dielectrics, ceramics and composite materials with graded thickness on varieties of substrates.

B.7 The basic biophysical studies on mosquito-larvicidal proteins had led to design and synthesis of a novel protein complex that is more toxic than any combination of binary toxins known so far.

B.8 A time-domain based low-coherence fiber-optic interferometer has been developed for depth-resolved tomography imaging of scattering samples for material science research.

B.9 Recovery of uranium from lean acidic stream at 60 litre/hour, using dispersion type liquid membrane in micro-porous Hollow Fiber cluster was successfully demonstrated.

B.10 A large volume calorimeter has been developed for nondestructive assay of special nuclear materials.

B.11 A Full-range vacuum gauge capable of measuring pressure continuously from 1 bar to 10E-12 bar has been developed.

B.12 Three Copper Vapour Laser, Master Oscillator and Power Amplifier chains of UCUF project, each operating at 9kHz and at about 130W have been commissioned.

B.13 Ring type Finger dosimeters based on Thermoluminescence (TL) and Optically Stimulated Luminescence (OSL) phosphors have been designed and fabricated in the form of plastic ring and adjustable band/strap for the measurement of the doses received by the body extremities.

B.14 A 5 kW RF amplifier and 7 & 10 KW power amplifiers at 325 MHz has been built and tested at BARC.

B.15 Solar cell arrays consisting of 25 dye sensitized solar cells with 4% efficiency were fabricated.

B.16 A 2.45 GHz, 2 kW, microwave plasma CVD facility has been developed, and deposition of continuous Diamond Thin Films on silicon substrates has been demonstrated.

B.17 A four channel Time-to-Digital Converter (TDC) ASIC has been developed in 0-35 micron, CMOS technology.

Dear Colleagues,

We are also initiating, some major projects in the following areas:-

C.1 Suitability of Tarapur site was examined for Advanced Heavy Water Reactor with regard to Natural Events, Seismo-tectonic & Foundation Conditions. A report has been submitted to DAE Standing Site Selection Committee for its consideration. Agreement has also been reached with M/s BHEL for the development of turbine and steam cycle conditions specific to AHWR.

C.2 Drawing upon the experience of the development of Indian compact LWR, conceptual design of 900 MWe Indian PWR was prepared. The IPWR will be a joint effort of NPCIL and BARC. Site selection and detailed design work is being taken up.

C.3 Infrastructure development for Inter-institutional Centre at Madurai, a forerunner to Indian Neutrino Observatory at Pottipuram is in progress.

BARC is also expanding its activities towards the development of alternate energy sources.

D.1 Isotope Hydrology Investigations on Geothermal Springs at Tural, Rajwadi and Chiplun in Maharashtra are underway in association with a private agency in Pune for development and exploitation of west coast geothermal energy sources for power generation.

D.2 BARC has initiated action for setting up a 2 MWe solar thermal power plant at the IIT Jodhpur site. The design of the plant envisages storage of thermal energy in molten salt. The detailed project report has been submitted to Ministry of New and Renewable Energy for approval of funds.

We are also concentrating our efforts towards total solution in critical areas. I would like to mention an example related to CIRUS.

E.1 After shutdown all the spent fuel from CIRUS has been reprocessed.

E.2 The Uranium Thorium Separation Facility (UTSF) was also operated simultaneously to reprocess the last lot of irradiated 'J' rods from CIRUS. All the Thoria-lean raffinate waste generated during reprocessing of the 'J' rods was also successfully processed at WIP.

E.3 For the first time, High Level Liquid Waste was processed for vitrification at a throughput of 30-35 lph deploying all the three available metallic induction heating furnaces simultaneously.

E.4 One tank full of Intermediate Level Waste has been successfully processed.

E.5 Heavy water from CIRUS is being detritiated for reuse in other reactors.

Dear Colleagues,

The Radiation Medicine Centre (RMC) of BARC reached the 50 year milestone of rendering services on 3rd September this year. The Centre has been pioneering development of clinical procedures in nuclear medicine, as well as human resources development, in addition to providing patient services.

Royal Society of Chemistry has declared BARC as the best contributor of articles across the publishers in India for the period January 2012 to June 2013 in the individual institute category. BARC scientists published 660 articles in Chemistry during this period.

Dear Colleagues,

Last three months have brought unprecedented success for BARC in terms of major accomplishments in areas critical to the goals of DAE.

F.1 Advanced up-gradation facility at Kalpakkam was commissioned last month and is performing very well.

F.2 Research reactor Dhruva continued to operate at an availability factor of about 80%. Recently power of the reactor was raised to 70 MW to increase the specific activity and quantity of radioisotope production. This step would go a long way in our contribution towards the health care for the people of our country.

F.3 The reload core for Arihant went critical on 11th October at P4 facility. Materials and components for the core were made at Mysore, Hyderabad and Trombay facilities.

F.4 Advanced vitrification system at Tarapur for vitrification of high level waste from PREFRE plant worked beyond design capacity in first year itself.

F.5 This week intermediate level waste was transferred from KARP to Waste Immobilisation Plant at Kalpakkam, beginning the hot commissioning of the waste management facility.

F.6 Hot commissioning of Actinides Separation Demonstration

Facility has been started. Performance parameters noted so far has been excellent. Successful demonstration of this technology will go a long way in major reduction of high level waste requiring long term storage.

F.7 Construction of Phase 1 buildings and infrastructural facilities was started at Vizag campus of BARC.

F.8 Special initiative was taken for attracting talents to BARC Training Schools spread in various campuses, which resulted in 30% increase in intake to the Training Schools. This will help in managing the chronic shortage of scientists and engineers for the expanding activities in the area of nuclear fuel cycle, reactor, accelerator, etc. We are waiting to receive Hon'ble President of India as the Chief Guest for this year's Graduation Function scheduled about a fortnight from today.

F.9 The Reprocessing Plant at Tarapur and Kalpakkam exceeded name plate capacity in 2012 and is performing equally well this year also.

F.10 Advanced Fuel Fabrication Facility at Tarapur is also working continuously. 75% of fuel for PFBR criticality has been fabricated.

F.11 Last few months BARC had been working with UCIL for addressing the issues related to commissioning of Uranium production plant at Tummalapalle. All these issues have been addressed and trial production of Uranium was started at a rate of 4T per month.

All of them have long term implication to our programmes and I wish we have similar achievements all year round.

Dear Colleagues,

I appreciate the excellent support from you in administration, accounts, health care, fire services, engineering services, security, association matters and other areas that made all these possible.

On this special day, let us rededicate ourselves towards achieving much more by focusing our efforts towards converting our achievements in research and development into a deliverable for the benefit of the nation.

Thank you"

25th DAE All India Essay Contest

DAE All India Essay Contest in Nuclear Science and Technology for students at under graduate level was started by the department in the year 1989. The essay contest has been very popular among the student community and about 17200 students have taken part till date. This year it was the 25th essay contest.

For this year's essay contest, the three topics chosen were:

Topic [1] - Nuclear Power – Inevitable Option for Energy Security in India

Topic [2] - Applications of Radioisotopes and Radiation Technology in Industry, Health Care and Agriculture

Topic [3] - Power Beams in Service of Humanity

In response, a total of 506 essays written in English, Hindi, and other regional languages were received. After evaluation and intergroup normalization by experts from BARC and NPCIL, a total of 35 students (12 contestants for Topic-1, 12 contestants for Topic-2 and 11 contestants for Topic-3) were invited to Mumbai to visit various facilities of the Department of Atomic Energy and make an oral presentation. 28 contestants made oral presentations on Tuesday 29th October, 2013 as 7 contestants could not reach for presentation due to various academic constraints.

Based on the assessment of panel of judges and the evaluators, the list of the prize winners was finalized. In addition to the first, second and third prizes for each topic, consolation prizes were awarded to the remaining contestants who were invited to make oral presentations. The winners were awarded by Dr. R. K. Sinha, Chairman, AEC on founder's day on 30th October 2013.

Few contestants expressed their views on the overall experience and information they received about nuclear power and application through the contest and visit to various units of DAE during their stay at Mumbai. The list of prize winners is given below.

Topic [1] - Nuclear Power – Inevitable Option for Energy Security in India

I Prize winner:

Name of Student	Student of	Place	Language
Ms. Ganga Budlakoti	B.Sc. 1st year	Nainital	Hindi

II Prize winner:

Name of Student	Student of	Place	Language
Mr. Suagata Roy	B.Sc. 3rd year	Kolkata	English

III Prize winner:

Name of Student	Student of	Place	Language
Mr. Swaroop R Pande	B.E. 3rd year	Amravati	English

Consolation prizes:

Name of Student	Student of	Place	Language
Mr. Jerin P G	B.Sc.(Phy.) 3rd sem.	Malappuram	English
Ms. Sweta Prakash	B.E. first year	Chennai	English
Mr. T S T Subba Rao	B.Tech. 3rd year	Calicut	English
Mr. J V Beni	B.Sc. 3rd year	Madurai	English
Mr. Anuj Kumar Choubey	B.Sc. Part - II	Durg	English
Mr. Mihir M Kapadia	B.Tech 2nd year	Surat	English

Topic [2] - Applications of Radioisotopes and Radiation Technology in Industry, Health Care and Agriculture

I Prize winner:

Name of Student	Student of	Place	Language
Mr. Sami Ullah Bhat	B.Tech. 2nd year	Coimbatore	English

II Prize winner:

Name of Student	Student of	Place	Language
Ms. A Alinda Shaly	B.Sc. 3rd year	Madurai	English

III Prize winner:

Name of Student	Student of	Place	Language
Ms. S Subhashini	B.Sc. first year	Coimbatore	English

Consolation prizes:

Name of Student	Student of	Place	Language
Ms. Aishwarya U Kudtarkar	B.Sc. first year	Sindhudurg	English
Ms. Lalitha S	B.Sc. (CS) 3rd year	Chennai	English
Ms. Kumari Manjula R Angadi	B.Sc. 5th sem	Belgaum	English
Mr. Kalyankrishnan A V	B.Sc. 2nd year	Kannur	English
Ms. Roshna Zamana	B.A. first sem.	Malappuram	English
Mrs. Farhana P	B.Sc. 5th sem	Malappuram	English
Mr. Azhar K	B.Sc. first sem.	Malappuram	English
Ms. B Sree Rekha	B.Sc. 3rd year	Coimbatore	English

Topic [3] - Power Beams in Service of Humanity

I Prize winner:

Name of Student	Student of	Place	Language
Ms. Shaniba K	B.Sc. 5th sem.	Malappuram	English

II Prize winner:

Name of Student	Student of	Place	Language
Mr. Harkishan Dua	B.Sc. 3rd sem.	Guwahati	English

III Prize winner:

Name of Student	Student of	Place	Language
Mr. D B K Reddy	B.Tech 2nd year	Coimbatore	English

Consolation prizes:

Name of Student	Student of	Place	Language
Ms. P Shahana	B.Sc. 3rd sem.	Malappuram	English
Mr. Mohammed Shafeeq P C	B.Sc. 3rd sem.	Malappuram	English
Ms. Sreerupa Chongdar	B.Sc. 2nd year	Durgapur	English
Ms. Thasneema K A	B.Sc. first sem.	Malappuram	English
Mr. Mohan A Umratkar	B.E (Final)	Amravati	English
Ms. Yogita K Bajaji	B.Sc. 2nd year	Sindhudurg	English
Ms. Anagha C	B.Tech 7th sem	Thrissur, Kerala	English

Industrial Safety Awards: 2012

Industrial Hygiene and Safety Section of HS&EG, BARC has introduced an Industrial Safety Award Scheme in the form of Director's Safety Shield on rotation, for BARC units.

The entries from the various Divisions/Sections/ Units of BARC for the year 2012 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

A thorough scrutiny of the entries was 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.

Dr. D. N. Sharma, Director, Health, Safety & Environment Group, BARC announced the winning units for the year 2012 as follows.

A: Operating Plants	Tarapur Reprocessing Plant (PREFRE-1, PREFRE-II, AWTF, SFSF), NRB, Tarapur
B: R&D Labs and Industrial Units	FOTIA Facility, LEHIPA Project
C: Engineering, Projects and Support Units	Kalpakkam based Nuclear Recycle Project Construction, NRB, Kalpakkam

Representatives from the respective units received the shield from Shri Sekhar Basu, Director, BARC. The award comprised one Rotating Shield and a small replica for retention by the respective winning unit.

On behalf of TRP, Shri Y. Kulkarni, Chief Superintendent, TNRPO, Shri S. Pradhan, Plant superintendent, TRP and Shri Hemant Kumar, Safety Coordinator, TRP, BARC, Tarapur received the shield.

Dr. Pitamber Singh, Head, Ion Accelerator Development Division, Shri S.K. Gupta, Head, FOTIA

Category A: Operating Plants:
Tarapur Reprocessing Plants (PREFRE-1, PREFRE-II, AWTF, SFSF), NRB: Shri Sekhar Basu, Director, BARC giving away the Safety Shield to Shri Y. Kulkarni, Chief Superintendent, TNRPO, Shri S. Pradhan, Plant Superintendent and Shri Hemant Kumar, Safety Coordinator, TRP, BARC, Tarapur

Category B: R&D Labs and Industrial Units:
FOTIA Facility, LEHIPA Project: Shri Sekhar Basu, Director, BARC giving away the Safety Shield to Dr. Pitamber Singh, Head, Ion Accelerator Development Division, Shri S.K. Gupta, Head, FOTIA Section, IADD and Shri Arun Agarwal, Safety Coordinator, IADD

Section and Shri Arun Agarwal, Safety Coordinator, IADD received the award on behalf of FOTIA Facility, LEHIPA Project.

On behalf of Kalpakkam based Nuclear Recycle Projects Construction, NRB, Kalpakkam, Shri Amitava Roy, Project director, KNRPC and Shri Biplab Das, Safety Officer, KNRPC received the award.

Category C: Engineering, Projects and Support Units:
KNRPC, Kalpakkam: Shri Sekhar Basu, Director, BARC giving away the Safety Shield to Shri Amitava Roy, Project director, KNRPC, BARC, Kalpakkam and Shri Biplab Das, Safety Officer, KNRPC, BARC, Kalpakkam

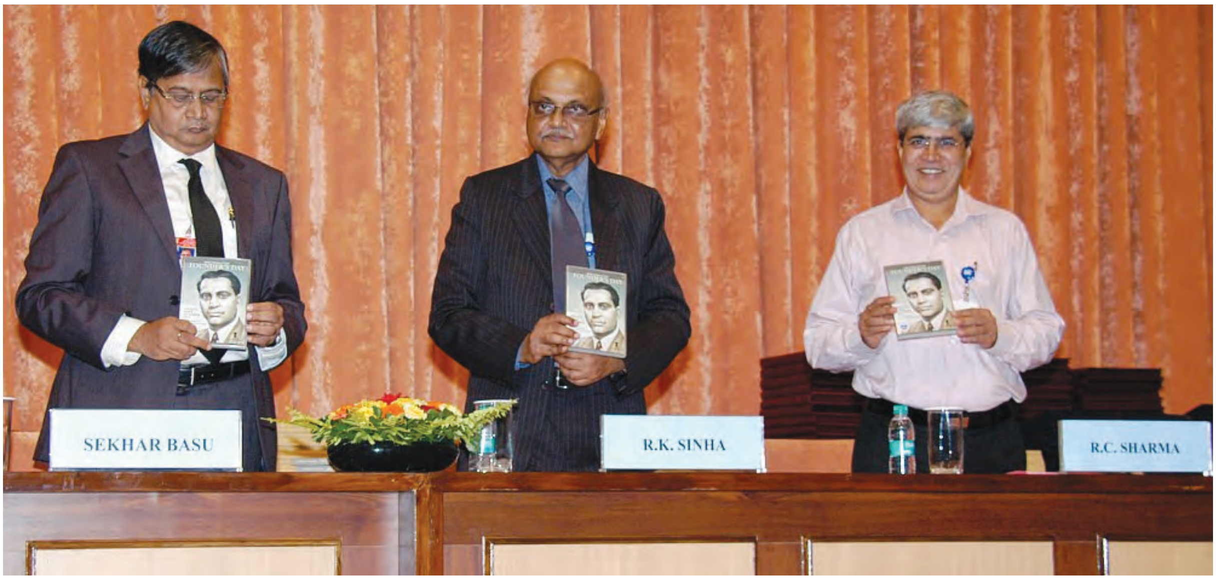
Release of the Founder's Day Special Issue of the BARC Newsletter

The CD of the Founder's Day Special Issue of the BARC Newsletter was released by Director, BARC on 30th October, 2013. This year, the Special issue carried 88 Award winning Papers; 56 DAE Excellence in Science, Engineering & Technology Awards for the year 2011 and 32 Merit Awards received by BARC Scientists & Engineers in 2012.

Out of the 56 DAE Award Papers, 7 papers were from Homi Bhabha Science & Technology Award winners, 12 from Scientific & Technical Excellence Award winners, 7 from Young Applied Scientist/ Technologist Award winners, 11 from Young Engineer Award winners, 5 from Young Scientist Award winners and 14 from Group Achievement Award winners.

The 32 Merit Awardees received Awards and Honours at various national and international seminars, symposia and conferences held in 2012.

As with the regular issues of the BARC Newsletter, the Founder's Day Special Issue can be accessed through BTS and Lakshya portals and on the BARC website.



From left to right: Shri Sekhar Basu, Director, BARC releasing the Founder's Day Special Issue of the BARC Newsletter, Dr. R.K. Sinha, Chairman, AEC and Shri R.C. Sharma, Director, Reactor Group, BARC

Founder's Day Guest Lecture

A.K. Anand

(Former Director, Technical Coordination & International Relations Group, BARC)

Shri Anand gave an interesting presentation on the history of submarines and their importance in strategic planning and warfare. Several attempts were made during the early Antiquity and the Middle Ages to build submersibles, but the first plan to build a submarine was developed by William Bourne, a Britisher in 1578. Later in 1620, the first successful submarine was built by Cornelius Jacobszoon Drebbel, a Dutchman in the service of James possibly based on Bourne's design. It was propelled by oars. Apart from underwater exploration, the military feasibility of submarines was recognized first by Bishop John Wilkins of Chester in Mathematical Magick in 1648. In 1653, a 72-foot-long "Rotterdam Boat," was designed by a Frenchman named DE SON. For propulsion, a spring-driven clockwork device was used to turn a central paddle wheel. Between 1690 and 1692, the French physicist Denis Papin, designed and built two submarines. David Bushnell an American developed a military submarine in 1776 called Turtle. It was the first verified submarine capable of independent underwater operation and movement, and the first to use screws for propulsion. It was in the year 1800, that Robert Fulton from France was encouraged enough to build the submarine he called "Nautilus." "Nautilus" was essentially an elongated "Turtle" with a larger propeller and mast and sail for use on the surface. The Irish inventor John Philip Holland built a model submarine in 1876 and a full scale one in 1878. Phillips was granted an 1852 patent for a "Steering Submarine Propeller." The innovation: steering (as well as up-and-down movement) was controlled by a hand-cranked propeller on a swivel joint. Between 1878 and 1890, several designs of submarines were developed around the world.

A landmark event in the 1890s was the development of the diesel engine by Rudolf Diesel a German engineer. The diesel engine and the electric battery remained the main power source for submarines. Most of the advances were made in armament, speed, periscopes etc, snorkel, radar, sonar, hull construction, hydrophones, rescue chamber etc. it was Germany's use of the U-boat in World War I that demonstrated the vital role the submarine would play in the next global conflict. After the first war, all-welded submarine, Sonar and radar technology matured during World War II. Between 1942 and 1944, Japan began construction of the 5,223-ton I-400 class of submarine aircraft carrier, each of which carried three dive-bomber seaplanes. As early as 1939, Dr. Ross Gunn of the US Naval Research Laboratory suggested that "fission chambers" using an isotope of uranium, U-235, could be used to power submarines. Thus in 1950, Nuclear Propulsion, the best Air Independent

Propulsion system was developed and in 1954 the first nuclear-powered submarine "Nautilus" went to sea. Today, six countries deploy some form of nuclear-powered strategic submarines: the United States, Russia, France, the United Kingdom, People's Republic of China and India.

In 1984, under the PRP Project, BARC took the first step in developing a nuclear submarine programme at Kalpakkam. It was a joint effort between the Indian Navy and BARC. The prototype reactor became critical on 11 November 2003. It was declared operational on 22 September 2006. Successful operation for three years yielded data and provided confidence leading to fabrication of the reactor and the propulsion plant for Arihant While the PRP was nearing completion; based on the its experience, the design of the submarine began. The role of Navy increased as weapons, radar, sonar, periscope, living accommodation and galley were added to it. Towards the end of nineties, while BARC completed the design of the Reactor Compartment, the Navy concentrated on other aspects. The Submarine was fitted out in Vizag. It underwent a long and extensive process of testing after its "launch" in July 2009. Arihant's reactor achieved criticality on August 10, 2013, a landmark for India and the Indian Navy.

DAE (Excellence in Science, Engineering & Technology) Awards 2012

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 2012 were given on the eve of Founder's Day on October 30, 2013 in BARC. These were presented to the winners by the Chief Guest, Dr. Srikumar Banerjee, Former Chairman, Atomic Energy Commission.

The Awards were in the following categories:

A. Homi Bhabha Science & Technology Awards

B. Exceptional Service Awards

C. Scientific & Technical Excellence Awards

D. Young Applied Scientist / Technologist Awards

E. Young Scientist Awards

F. Young Engineer Awards

G. Special Contributions Awards

H. Meritorious Technical Service Awards

I. Group Achievement Awards

J. Special Contributions Awards

K. Meritorious Service Awards

Apart from the awards in the above categories, this year, two new Awards were instituted; Exceptional Service Award and Meritorious Technical Support Award.

A. Homi Bhabha Science & Technology Award carries a Cash award of Rs 5 Lakh, a Citation and a Medal. There were Nine award winners: Eight from BARC and one from RRCAT. Following were the award winners from BARC:

1. Dr. Vinod Kumar Aswal , SO/G, SSPD, PG, BARC.

Awarded for his outstanding research contributions in the development of "Small-Angle Neutron Scattering (SANS) facility and its applications in delineating complex structure of soft matter". Dr. Aswal has been responsible for the development of the slit-collimation based SANS facility at Dhruva reactor. He has played a vital role in popularizing the use of the SANS technique among University scientists by helping several groups in planning, executing and analyzing in the collaborative SANS experiments. He has trained a large number of research students through these collaborations.

Dr. Vinod Kumar Aswal receiving the Homi Bhabha Science & Technology Award from Dr. Srikumar Banerjee, Chief Guest and Former Chairman, Atomic Energy Commission

2. Shri S. K. Jha , SO/H+, AFD, NFG, BARC

Shri Jha has made outstanding contribution in the design and development of processes and facilities for fabrication of dispersion-type fuel pins, burnable poison rods and photo-neutron pins for Compact

Light Water Reactors at PRP, Kalpakkam and Vizag. Performance of these components have been as per the design and with "Zero-Failure" so far. Shri Jha has also been responsible for fabrication of complete requirement of fuel pins and core components for BPR Calibration Facility at P-4, at Trombay. He has been a key member of the team responsible for the development and fabrication of metallic fuels for Fast Reactor and various components for strategic applications.

Shri S.K. Jha receiving the Homi Bhabha Science & Technology Award from Dr. Srikumar Banerjee, Chief Guest and Former Chairman, Atomic Energy Commission

3. Shri Gigi Joseph, SO/G, Computer Div., E&IG, BARC

Awarded for his contributions in the development of 'Cyber Security Systems'.

Shri Joseph has made significant contributions in the indigenization of the Networking & Security devices. Shri Joseph developed a Secure Network Access System (SNAS) which is an integrated comprehensive network security solution. It was launched as a commercial product in April 2012 and it is being accepted as an Intranet Security Solution in various organizations at national level. He has also significantly contributed in the design & development of indigenous network devices such as transport routers and switches.

Shri Gigi Joseph receiving the Homi Bhabha Science & Technology Award from Dr. Srikumar Banerjee, Chief Guest and Former Chairman, Atomic Energy Commission

4. Dr. P. D. Naik, SO/H+, RPCD, CG, BARC

Dr. Naik has been awarded for his pioneering research in the area of "Gas Phase Chemical Dynamics" in India. He has set up a chemical physics research laboratory of an international repute by developing indigenously several state-of-the-art experimental facilities. He has contributed substantially in understanding the microscopic

Dr. P.D. Naik receiving the Homi Bhabha Science & Technology Award from Dr. Srikumar Banerjee, Chief Guest and Former Chairman, Atomic Energy Commission aspects of chemical reactions, which include the disposal of exoergicity in the electronic states of the product molecule, intermolecular vibrational energy transfer, effect of translational energy and selective vibration excitation on reaction cross sections, photodissociation dynamics and correlation with the dissociative potential energy surfaces etc.

5. Shri P.R. Patil, SO/H+, RCnD , E&IG, BARC

Shri Patil has been awarded for his outstanding contributions in "the indigenous development of special sensors and instruments required for Compact Nuclear Reactor Plant and other strategic programs of the Department". These custom-built sensors are designed to meet the stringent operating environment of high pressure, high temperature, nuclear radiation, shock and vibration. With the transfer of technology to industry, he has brought-in self-reliance in one vital segment of our strategic programme. He was also instrumental in indigenous development of differential micro-barometer to measure very small atmospheric pressure variations of the order of microbars.

Shri P.R. Patil receiving the Homi Bhabha Science & Technology Award from Dr. Srikumar Banerjee, Chief Guest and Former Chairman, Atomic Energy Commission

6. Shri S. Pradhan , SO/H, LWRD, RPG, BARC.

Awarded for his outstanding contributions in the "Design and development of critical equipment and erection technology for Compact Reactor systems"

Shri Pradhan made significant contribution in introducing new material in the industry and perfecting the welding technology associated with it. Through meticulous, ingenious and focussed effort, he has evolved several procedures that have helped in achieving high quality products consistently in the strategic programme.

Shri S. Pradhan receiving the Homi Bhabha Science & Technology Award from Dr. Srikumar Banerjee, Chief Guest and Former Chairman, Atomic Energy Commission

7. Dr. N.K. Sahoo, OS & Head, ASpD, PG, BARC

Dr. Sahoo has been awarded for his outstanding contributions in the field of "Multilayer Thin film Science & Super Mirror Technology, Optics & Optical Nuclear Instruments, Photonics and Synchrotron Beamline Science & Technology." Most of his deliverables involve complex as well as unique technologies quite often serving as import ubstitutes. Various programmes pursued under his leadership, have not only fulfilled the essential needs of the Departmental projects but also drawn the attention of the international programs like BARC-ILL collaborations in neutron science research. He has played a leading role in establishing three synchrotron beamlines at Indus.

Dr. N.K. Sahoo receiving the Homi Bhabha Science & Technology Award from Dr. Srikumar Banerjee, Chief Guest and Former Chairman, Atomic Energy Commission

8. Dr. Raghvendra Tewari, SO/H, MSD, MG, BARC

Dr. Tewari has been awarded for his outstanding contributions in the "Fundamental as well as Applied research' involving development of Niobium based alloys which have potential applications in nuclear reactors, space technology and aerospace industry. In collaboration with NFC, he could develop the flow sheet for the fabrication of various components of the alloy for compact high temperature reactor application. He has also contributed significantly in the development of bulk metallic glass and composites which have very high penetration depth and required for strategic purposes.

Dr. Raghvendra Tewari receiving the Homi Bhabha Science & Technology Award from Dr. Srikumar Banerjee, Chief Guest and Former Chairman, Atomic Energy Commission

B. Exceptional Service Award carries a Cash award of Rs 5 Lakhs, a Citation & a Medal.

Dr. V. V. Kulkarni, RRF & Project Director, (NT), Director's Office, BARC was the only recipient of this Award. Awarded for his excellent contributions and exceptional Service in the "Strategic Programmes of the Country". During the initial part of his career, he had actively participated in the environmental studies programme of the department. Later on he was associated with operation 'Smiling Buddha' in 1974. He served in DRDO, on deputation for two years from 1996 to 1998 under the guidance of Dr. A.P.J. Abdul Kalam and was responsible for preparations at various levels for the Operation "Shakti" in 1998. He was involved in post shot drilling operation at the site of Operation "Shakti".

C. Scientific & Technical Excellence Award carries a Cash award of Rs 1 Lakh, a Citation and a Medal. There were Twenty eight award winners: Twenty from BARC and Two each from IGCAR and VECC, three from RRCAT and one from BRIT. Following were the award winners from BARC:

1. Dr. Tusar Bandyopadhyay, SO/G, TCS, CG, BARC.
2. Dr. (Smt.) Nalini Bhat, SO/G, MD, BMG, BARC.
3. Shri Sameer Bhatt, SO/G, CDM, DMAG, BARC.
4. Shri Tarun Kumar Dewangan, SO/E, PED, ChTG, BARC.
5. Dr. Sandip Dey, SO/F, Chemistry Division, CG, BARC.
6. Dr. I. Venkata Ramana , SO/E, CAD, MRG, BARC(Vizag) & Shri S. Madhavan, SO/E, CAD, MRG, BARC.Vizag)
7. Shri A.K. Jha, SO/F, NRPSED, NRB, BARC & Shri F.T. Qureshi, SO/F, TNRPO, NRB, BARC.
8. Dr. Amrit Prakash, SO/G, AFFF, BARC (Tarapur)
9. Shri Aseem Singh Rawat, SO/G, L&PTD, BTDG, BARC.
10. Dr. Aditi Ray, SO/G, ThPD, MRG, BARC.
11. Shri Rahul Vasudeo Sakrikar, SO/G, DRHR, DMAG, BARC
12. Shri Satyaranjan Santra, SO/G, NPD, PG, BARC.
13. Dr. Pranesh Sengupta, SO/F, MSD, MG, BARC.
14. Shri C. Uma Shankar, SO/F, ED&DD, MRG, BARC.
15. Shri P.S. Shetty, SO/G, TSD, ESG, BARC.
16. Shri Y.C. Shivakumar, SO/H, FRD, NRG, BARC
17. Dr. Raghumani Singh N.,SO/E, Chemistry Division, CG, BARC
18. Shri Rajvir Singh, SO/G, RSSD, HSEG, BARC.
19. Dr. Surendra Singh, SO/F, SSPD, PG, BARC
20. Dr. Dattatray D. Thorat, SO/F, PMD, MG, BARC.

D. Young Applied Scientist / Technologist Award carries a Cash award of Rs 50,000/-, a Citation and a Medal. There were nine award winners: seven from BARC and two from IGCAR. Following were the award winners from BARC:

1. Shri Vinay Bhardwaj, SO/E, CDM, DMAG, BARC
2. Shri Arup Biswas, SO/E, ASpD, PG, BARC.
3. Dr. Rachna N. Dave, SO/D, WSCD, CG, BARC.
4. Dr. Raghwendra Kumar, SO/F, ThPD, MRG, BARC.
5. Shri Alok Kumar Saxena, SO/E, APD, MRG, BARC.
6. Shri Shivaji R. Shendge, SO/C, TDD, NRG, BARC.
7. Shri Vikas Teotia, SO/D, CnID, E&IG, BARC.

E. 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 1 from VECC. Following were the award winners from BARC

1. Dr. Arunasis Bhattacharyya ,SO/F, RCD , RC&IG, BARC
2. Dr. Kaustava Bhatacharyya,SO/E, Ch. Divn., CG, BARC
3. Dr. Balaji Prasad Mandal,SO/E , Ch. Divn., CG, BARC
4. Dr. Deepak Sharma, SO/E, RB&HSD, BMG, BARC.
5. Dr. Sandeep Verma, SO/E, RPCD, CG, BARC.

F. Young Engineer Award carries a Cash award of Rs 50,000/-, Citation and a Medal. There were eighteen award winners: eleven from BARC, 1 each from NFC and VECC, 2 from RRCAT and 3 from IGCAR. Following were the award winners from BARC:

1. Shri Atul Anand Dhas , SO/D, LWRD, RPG, BARC
2. Shri Vikas Dube, SO/D, LWRD, RPG, BARC.
3. Shri Ajit K. John, SO/E, RCnD, E&IG, BARC.
4. Shri Samrat Kar, SO/E, FRD, NRG, BARC.
5. Shri Parimal Pramod Kulkarni, SO/E, RED, RDDG, BARC.
6. Shri Praveen Kumar Mishra, SO/E, RTD, RDDG, BARC.
7. Shri Sabyasachi Mitra , SO/E, APPD, BTDG, BARC

8. Shri Palash Kumar Mollick, SO/D, PMD, MG, BARC.
9. Shri Bhaskar Paul, SO/E, MPD, MG, BARC.
10. Shri Surender Kumar Sharma, SO/E, E&ED, BARC(Vizag)
11. Shri Inbanathan Thangamani, SO/E, RSD, RDDG, BARC.

G. Special Contributions Award carries a Cash award of Rs 50,000/-, Citation and a Medal.

There were no Award winners in this category.

H. Meritorious Technical Service Award carries a Cash award of Rs 20,000/-, Citation and a Medal. There were twenty nine award winners; 20 from BARC, 5 from IGCAR and 2 each from RRCAT and GSO, Kalpakkam.

1. Shri D.R. Belwalkar, F/B, WMD, NRG, BARC.
2. Shri S.M. Bhatkar, F/A, NABTD, BMG, BARC.
3. Shri Krishna Chandra Boipai, F/B, DRHR, DMAG, BARC.
4. Shri Jayavant S. Dhumal, F/B, L&PTD, BTDG, BARC.
5. Shri M. Ekambaram, T/G, NPD, PG, BARC.
6. Shri Prakash Shankar Gawde, SA/E, MSD, MG, BARC.
7. Shri S.S. Haralkar, F/A, PMD, MG, BARC.
8. Shri D. Jayaprakash, SO/D, APPD, BTDG, BARC.
9. Shri V.S. Joshi, F/D, FRD, NRG, BARC.
10. Shri Dipankar Mitra, F/D, FRD, NRG, BARC.
11. Shri K. Muralidharan, F/B, RMP, BARC.
12. Shri B. Narayana, F/A, RMP, BARC.
13. Shri S.T. Nagre, Sr.Tech./H, CDM, DMAG, BARC.
14. Shri C. Ramakrishnan, Sr.Tech./J, AFD, NFG, BARC.
15. Shri Chandiranjan Sarkar, F/C, TSD, ESG, BARC.
16. Shri S.M. Sawant, SO/D, FRD, NRG, BARC.
17. Shri V.D. Sharma, F/C, RRSD, RG, BARC.
18. Shri K. Thankarajan, F/C, ApSD, PG, BARC.
19. Shri E. Unnikrishnan, SA/D, Seismology Dn., E&IG, BARC.
20. Shri V. Velandi, Sr.Tech./J, RMD, NFG, BARC.

I. Group Achievement Award winners received a medal, a Citation and suitable cash awards for each group commensurate with the group size and its overall achievement. A total number of fifty five Groups received these awards. Out of these, 29 were from BARC, 8 from IGCAR, 5 from RRCAT, 5 from NFC, 2 from BRIT, 3 from VECC and 1 from AMDER, 2 from HWB.

Following were the Group Leaders from BARC, who received the awards for their groups:

1. Dr. K.C. Mittal, Head, A&PPD & Project Manager, EBC, BTDG, BARC.
2. Shri Suresh B. Narwaria, SO/G, HWD/ChEG, BARC & Shri S.G. Belokar, GM (SHE), HWB.
3. Shri A.S. Patil, SO/H, ChTG & Shri T. Anto Kurian, SO/G, CTD/ChTG, BARC.
4. Shri S.B. Jawale, Head, CDM, DM&AG, BARC.
5. Shri C.K. Pithawa, DS & Dir., E&IG, BARC.
6. Shri D.A. Roy, SO/H, RCnD, E&IG, BARC.
7. Dr. A.P. Tiwari, SO/H, RCnD, BARC.
8. Dr. G.J. Prasad, Former Director, NFG, BARC.
9. Dr. A.R. Joshi, SO/H, Head, PDD, RC&IG, BARC.
10. Shri R.S. Yadav, Director, RPG, BARC.
11. Smt. Parvathy H.K. CAO, BARC F, Kalpakkam. (former DEO, TC/TSC)
12. Shri R.K. Rajawat, SO/H+, APPD, BTDG, BARC (Vizag).
13. Dr. S.K. Apte, DS, Associate Director (B), BMG and Head, MBD, BARC.
14. Dr. (Smt) Sulekha Mukhopadhyay, SO/G, ChED/ChEG, BARC.
15. Shri A. Sanyal, Head, CTD, ChTG, & Shri S. Sarkar, DS, PM, RMP, BARC
16. Shri K. Jayarajan, SO/H+, DRHR, DM&AG, BARC.

17. Shri Ram Kishan, Assoc. Director, ESG & Head, TSD, BARC.
18. Dr. S.S. Taliyan, SO/H+, RCnD, E&IG, BARC
19. Dr. A. Vinod Kumar , SO(G), RSSD, HS&EG, BARC.
20. Dr. R.R. Puri, Ex-Head, HRDD, BARC.
21. Shri N. Sakthivel, SO/F, CAD, MRG, BARC
22. Shri S. Bhattacharya, SO/H+, UED, MG, BARC.
23. Dr. K.B. Khan, SO/H, RMD, NFG, BARC.
24. Shri K. Kumaraguru, SO/F & OIC, FRD, NRG, BARC.
25. Shri Manoj Kumar, SO/F, Mech. Section, Tarapur based Reprocessing Plant, NRB, BARC.
26. Shri Rajendra Kumar, Superintendent (PC & PR), NRB
27. Shri C.K. Pithawa, DS & Director, E&IG, BARC.
28. Dr. S.M. Sharma, DS & A.Dir. , PG, BARC.
29. Dr. Naresh K. Maheshwari, Head, PS&SS, RED, RD&DG, BARC

J. Special Contributions Award carries a cash award of upto Rs. 50,000/-, a Citation and a Medal. There were 77 award winners; seventy six were from BARC and one from DAE. Following were the award winners from BARC:

1. Dr. P.D. Krishnani, Head, RPDD, RD&DG
2. Shri K.C. Guha , SO/H, RMP
3. Shri B.G. Chandresh , SO/H, RMP
4. Shri S. K. Kaul, SO/H,TSD, ESG
5. Shri Rajiv Narasimhan, Head, A&SED, ESG
6. Shri S.K. Jaiswal, SO/H, TSD, ESG
7. Shri P. V. L. Narasimha Rao, SO/G, PRPD, RG
8. Shri A.K. Mishra, SO/G, AFFF, NFG
9. Dr. N. Kumar, SO/G, FCD, RC&IG
10. Shri Devesh Kumar, SO/G, RPD, RPG
11. Shri S.K. Patnaik, SO/G, CDM, DM&AG
12. Shri Salil Varma, SO/F, Chem.Dn, CG
13. Shri A . K. Sharma, SO/F, PRPD, RG
14. Shri Roshan Lal Uniyal, SO/F, PRPD, RG
15. Shri Ashok Kumar, SO/F, FCD, RC&IG
16. Shri R. Govindan, SO/F, PDD, RC&IG
17. Shri S.P. Pandarkar, SO/F, CDM, DM&AG
18. Shri S. Sridharan, SO/F, KNRPC, NRB
19. Shri J.K. Bose, SO/F, ED&CD, NRG
20. Dr. Rishi Verma, SO/E, E&ED, BARC(V)
21. Shri U.V. Deokar, SO/E, HPD, HS&EG
22. Shri R.K. Mishra, SO/E, WMD, NRG
23. Shri Ashish Thakur , SO/E, RCnD, E&IG
24. Shri R. K. Kaushik, SO/E, CnID, E&IG
25. Shri N. Vijayakumar, SO/E, RMP
26. Shri N. Sadanandan, SO/E, RMP
27. Shri V. K. Koul, SO/E, RMP
28. Shri R. P. Sharma, SO/E, TRP, NRB
29. Shri S.G. Mishra , SO/D , RSSD, HS&EG
30. Shri S. D. Raut, SO/D, RMD, NFG
31. Shri Tanmoy Das, SO/D, RSSD, HS&EG
32. Shri Rajesh Sankhla, SO/D, RSSD, HS&EG
33. Shri Prabha Mathew, SO/D, HPD, HS&EG
34. Shri R.K. Shivade, SO/D, RSSD, HS&EG
35. Shri Sunil Bhalke, SO/D, Dir's Off.
36. Shri S. M. Tripathi, SO/D, RP&AD, HS&EG
37. Shri P. Srinivasan, SO/D, RSSD, HS&EG
38. Shri A. K. Ranade, SO/D, Dir's Off.
39. Shri Manish Chopra, SO/D, RSSD, HS&EG
40. Shri Sukanta Maity, SO/D, EMAS, HS&EG
41. Shri J. N. Dubey, SO/D, RMD, NFG
42. Shri K. Ravi, SO/D, RMD, NFG
43. Shri. U Shiva Kumar, SO/C, MFD, NFG
44. Shri Amit Kumar Verma, TO/C, RSSD, HS&EG
45. Shri S.S. Bhoir, TO/C, PDD, RC&IG
46. Shri M. R. Shaikh, FMAN B, IF3, NFG
47. Shri P.S. Sreekumaran, FMAN C, AFD, NFG
48. Shri S.S. Patil, SA/E, RSSD, HS&EG
49. Shri S.K. Saroj, SA/E, RSSD, HS&EG

50. Shri P.B. Salvi, SA/E , ED&DD , MRG
51. Shri J.D. Sathe, SA/E, ED&DD, MRG
52. Shri K.T.Gode, SA/D, HPD, HS&EG
53. Shri N. K. Meena, SA/D, HPD, HS&EG
54. Shri Laxmidar Sahoo, SA/C, RSSD, HS&EG
55. Shri D.P. Kokare, SA/C, AFD, NFG
56. Shri Ramesh Raju, SA/B, PDD, RC&IG
57. Shri Hiralal Balkishan, Sr.Tech. H, CDM,DM&AG
58. Shri L. N. Achegaonkar, Sr. Tech.H, PDD, RC&IG
59. Shri K.U. Johnson, Sr. Tech H, FMS, RMP
60. Shri T. M. Patil, Sr. Tech H, CDM, DM&AG
61. Shri S.S. Prasad, Sr.Tech.J, MFD, NFG
62. Shri G.M. Gadkari , Tech. J, PDD, RC&IG
63. Shri J.P. Lokhande, Tech. G, NRB
64. Shri E.D. Sunny, Tech. G, AFD, NFG
65. Shri G.Y. Waingankar, Tech. F, PDD, RC&IG
66. Shri R.K. Chaudhari , Tech. D, ED&DD, MRG
67. Shri V.J. Dhiwar, Tech. D, ED&DD, MRG
68. Shri V. Ramesh Ramanujam, Sr. PS, PRPD,RG
69. Smt. R. Sudha, Sr. PS, RC&IG
70. Shri R. Ravindra Kumar, Sr.PS, RMP
71. Shri P.S. Kalikhan, Dr. SG, PD/Trans
72. Shri S.A.Naik, Driver Gr.I, PD/Trans, Dir's Off
73. Shri N.D. Kharade, Driver Gr.I, PD/Trans Dir's Off
74. Shri S.S. Udmale, Driver Gr.II, PD/Trans, Transport
75. Shri P.B. Hande, Driver Gr.II, RMD, PD/NFG
76. Shri A.S. Parab , Work Asst.B, PDD, RC&IG

K. Meritorious Service Award carries a cash prize of Rs. 20,000/-, a citation and a medal.

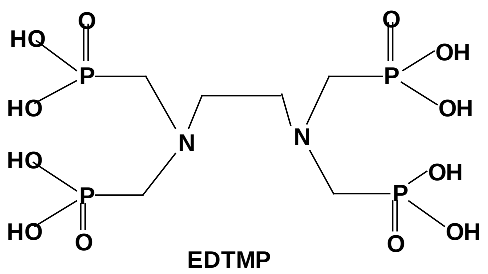
There were 23 Award winners. Eighteen were from BARC, 2 from DAE, 1 each from RRCAT, GSO Kalpakkam and IGCAR Following were the award winners from BARC:

1. Smt. Meera Ananthan, Sr.PS, PD, Adm.Group, BARC.
2. Shri Murichira Bhaskaran, Sr.PS, CDM, DM&AG, BARC.
3. Shri Anand S. Bhere, Dr.Gr.I, & Shri Shankar R. Kurhade, Dr.Gr.I, HRDD, KMG, BARC.
4. Shri K.C. Mohandas, Sr.Accounts Officer, RMP, Mysore.
5. Smt. Sathi Sreekumar Nair, AAO, AD, Adm. Group, BARC
6. Shri Raphel John Palamattam, PPS, Controller's Office, BARC.
7. Shri R.K. Pai, SO/D, TSH, PD, Adm. Group, BARC.
8. Shri C.J. Peter, Asstt. Foreman, 8th Fl. Dept. Canteen, PD, Adm.Group, BARC.
9. Smt. Shashikala Prasad, Asstt., RMP, Mysore.
10. Smt. Geetha Purushothaman, Sr.PS, HS&EG, BARC
11. Shri D. Ramasubramanian, DCA, BARC(F) Kalpakkam
12. Shri Roshanlal, LVD Gr.I, L&PTD, BTDG, BARC.
13. Shri Balakrishna S. Salian, Asstt., MD, BMG, BARC.
14. Smt. Sheela Sivakumar, Asstt. PD, Adm.Group, BARC.
15. Shri S.V. Solankurkar, PS (NS), Comp.Div., E&IG, BARC
16. Shri K. Venkat Subramanian, APO, PD, Adm. Group, BARC.
17. Shri P. Subramanian, Supervisor D(CM), CED, ESG, GSO(K)
18. Smt. Sujata Viswanathan, Asstt., PD, Adm. Group, BARC.

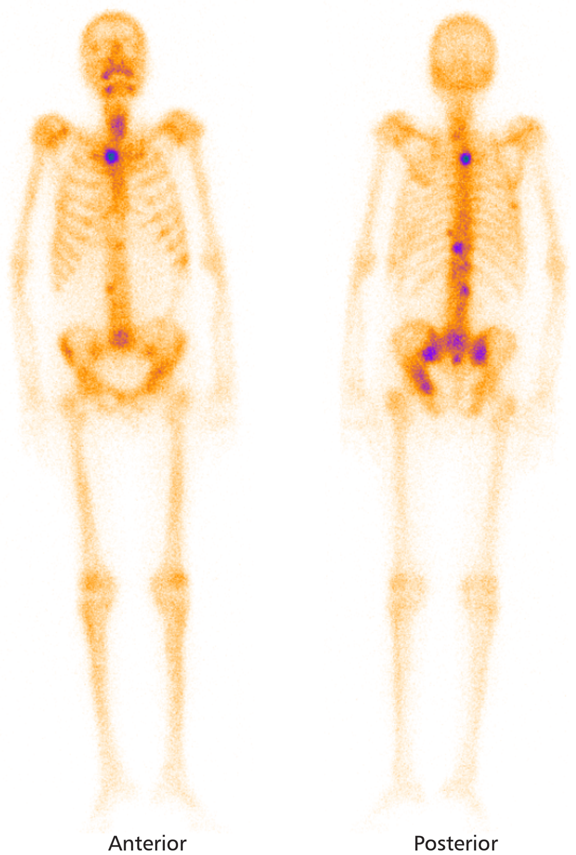
Development and Deployment of Freeze-dried EDTMP Kit for the Formulation of 177Lu-EDTMP for Administration in Human Cancer Patients

(Radiochemistry & Isotope Group)

Disseminated skeletal metastasis is one of the most common features observed in cancer patients at the advanced stage of their diseases. These metastatic lesions in skeleton often lead to excruciating pain and other related symptoms such as, lack of mobility, depression, neurological deficits and those associated with hypercalcemia, which adversely affect the quality of life. The quality of life of these patients can be improved by metastatic bone pain palliation (MBPP). The major objective of this modality is alleviating the pain using the particulate emission of appropriate therapeutic radioisotope present in a suitable radiopharmaceutical. Thus radionuclidic therapy is one of the most effective methods for providing palliative care to the patients suffering from metastatic bone pain. In the last decade 177Lu-labeled ethylenediaminetetramethylene phosphonic acid (177Lu-EDTMP) has emerged as a potential radiopharmaceutical for MBPP for which Radiopharmaceuticals Division (presently known as Isotope Applications and Radiopharmaceuticals Division, IA & RPhD) had played a pioneering role. Recently we have developed a freeze-dried EDTMP kit, which enables the preparation of the agent at the hospital radiopharmacy in a simple and convenient manner through a single-step process. Each kit vial contains a lyophilized mixture of 35 mg EDTMP, 14.1 mg NaOH and 5.8 mg of CaCO3 and capable of producing upto 3.7 GBq (100 mCi) patient dose of 177Lu-EDTMP within 15 minutes at room temperature. The radionuclide (177Lu) is regularly produced in IA & RPhD and regularly supplied to nuclear medicine centers across our country. The biological behavior of the agent was studied in different animal models and subsequently in limited number of human cancer patients in collaboration with All India Institute of Medical Sciences (AIIMS, New Delhi). Based on these



Ethylenediaminetetramethylene phosphonic acid (EDTMP)



Whole-body scintigraphic images of a cancer patient (with skeletal metastases) treated with 2.59 GBq (70 mci) of 177Lu-EDTMP prepared using the freeze-dried EDTMP kit

results, Radiopharmaceutical Committee (RPC) has approved the manufacture and commercial supply of EDTMP kits for the formulation of 177Lu-EDTMP in 2012. Presently these kits are being used in Kovai Medical Center and Hospital (KMCH, Coimbatore), Radiation Medicine Centre (RMC, Mumbai) and Post Graduate Institute of Medical Education and Research (PGIMER, Chandigarh) for treating the cancer patients. The patients showed excellent pain relief and long pain free survival period which demonstrated the potential of the developed kit. The procedure for transferring the technology of formulation of freeze-dried EDTMP kits to Board of Radiation and Isotope Technology (BRIT) for facilitating large-scale commercial supply has been initiated and expected to be completed by December, 2013.

Innovative technique of glass beads preparation in microwave oven

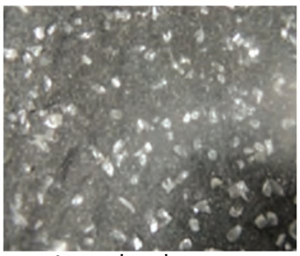
Nuclear Recycle Group

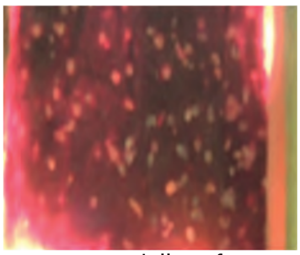
Glass beads of different size, shape, composition and having specific physical properties are needed for various applications in industry,research and development laboratories. Conventionally glass beads are prepared by melt quench technique, where the molten glass droplets are formed andquenched on rotating or vibrating surface to get smooth spherical glass beads. Alternatively, glass beads are commercially prepared from glass cullets. The cullets are coated with carbon prior to heating to avoid fusing, fed in inclined rotating tube furnace, heated near glasssoftening temperature, shaped in spherical form and quenched in water. Both theseprocessesrequire elaborate heating arrangement and are laborious and time consuming. In addition, it is difficult to get the beads of specific composition and properties in small quantities from glass bead manufacturer.

An innovative technique for preparation of glass beads in domestic microwave oven was developed for preparation of spherical glass beads of uniform size for various applications in our laboratory. A graphite bed of three to five mm thick was prepared from fine graphite powder on alumina fiber insulating board. Glass pieces of required size and composition were spread on the bed uniformly taking care that they do not touch each other and placed in microwave oven. Microwave oven was put on for ~20 minutes at full power.Graphite being very good microwave absorber efficiently couples with the microwave radiation and gets heated up to 800^0-900^0 C. The glass cullet when heated near its melting temperature, acquire spherical shape due to surface tension.The graphite bed was allowed to cool and the glass beads were sieved, cleaned and segregated. The temperature of the bed was controlled by heating time of microwave oven and adjusted depending upon the melting temperature of glass.

Scandium containing borosilicate glass beads were prepared by this technique and supplied to IAD, BARC for radioactive particle tracking experiment and flow visualization studies. By similar technique, charcoal coated glass beads were successfully prepared. These coated beads find application in treatment of High Level Waste containing Ru and Mo.

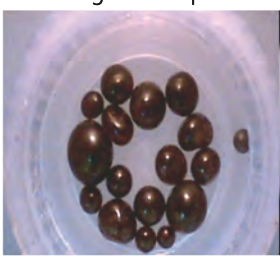
Stages of formation of glass beads in microwave oven


Irregular shape


Partially soft


Moltenstate


Cooled to ambient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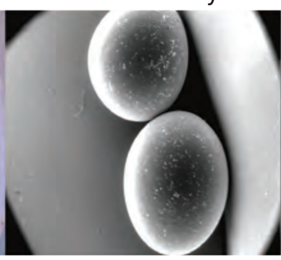
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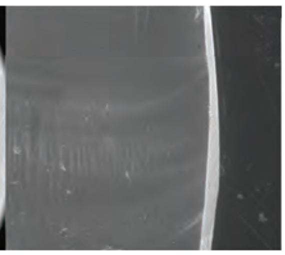
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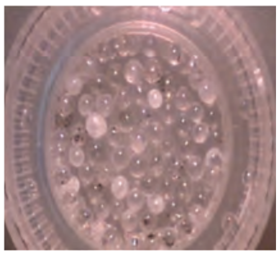
Charcoal Coated glass beads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Scandium glass beads

Novel Features of Multiferroic Materials: $BiFeO_3$ – A Case Study

Dimple P. Dutta and A. K. Tyagi
Chemistry Division

Abstract

Research on multiferroics has been enlarged significantly due to the advent of a novel class of oxides exhibiting interesting multiferroic and magnetoelectric properties arising from magnetically induced ferroelectricity. In this respect, $BiFeO_3$ which is one of the most promising room temperature multiferroic material, exhibit low spontaneous polarization and saturation magnetization values in the bulk state. The article gives an account of the research carried out on $BiFeO_3$ in our lab which resulted in enhanced room temperature multiferroicity in the material.

Introduction

The last decade has seen an upsurge in the research on multiferroic materials. By definition, a single phase multiferroic is a material that simultaneously possesses two or more of the 'ferroic' order parameters—ferroelectricity, ferromagnetism, and ferroelasticity. However, these contrasting order parameters are actually mutually exclusive. The electric and magnetic ordering in solids are most often considered separately since it is the electric charges of electrons and ions which are responsible for the charge effects, whereas it is electron spins that governs the magnetic properties. The exchange interaction between uncompensated spins of different ions, giving rise to long range magnetic ordering, also results from the virtual hopping of electrons between the ions. In this respect the two mechanisms are not so dissimilar, but the difference in filling of the d shells required for ferroelectricity (which are generally transition metal oxides with empty d-shells) and magnetism (requires partially filled d shells) makes these two ordered states mutually exclusive. In multiferroic materials, two types of ordering for spins and electric dipoles should coexist in the same material and, in principle, this opens the possibility to make four state memories if the magnetization (electric polarization) can be tuned by an external electric (magnetic) field. Thus, the search for these materials is driven by the prospect of controlling charges by applied magnetic fields and spins by applied voltages, and using this for new forms of multifunctional applications. The scarcity of magnetoelectric multiferroics can be understood by investigating a number of factors including symmetry, electronic properties, and chemistry. There are only 13 point groups that give rise to multiferroic behavior.

Multiferroics can be classified in two categories, Type I and Type II. The first one corresponds to the compounds with spontaneous polarization (T_C ferroelectric) appearing above the magnetic ordering temperature (T_C or T_N ferro(antiferro) magnetic), such as $BiFeO_3$. In contrast, for the second category (also called "improper" ferroelectrics), the polarization starts to develop below or at the magnetic ordering temperature. Although these Type II multiferroics exhibit smaller polarization (P) values than Type I ferroelectrics, the magnetoelectric coupling between the magnetization (M) and P is much higher. The most studied materials in this category include orthomanganites $RMnO_3$ (with R = Tb and Dy) and orthoferrites $GdFeO_3$.

Among all the multiferroic materials studied so far, $BiFeO_3$ that exhibits the coexistence of ferroelectric and antiferromagnetic (AFM) orders has received great attention as it has the potential to be one of the prime candidates for room temperature magnetoelectric applications due to its high ferroelectric Curie point (T_C ~1103 K) and the antiferromagnetic (AFM) Néel point (TN ~ 647 K). Here, it is the Bi ion with two electrons on the 6s orbital (lone pair) that moves away from the centrosymmetric position in its oxygen surrounding and gives rise to ferroelectricity. The ferroelectric and magnetic orders in these materials are associated with different ions and hence the coupling between them is weak. Also, both its spontaneous polarization and saturation magnetization are disappointingly low when compared to many standard ferroelectrics and ferromagnets. In bulk BFO the Dzyaloshinsky−Moriya (DM) interaction results in a canted AFM ordering of Fe^{3+} spins in the system, which induce a lattice strain increasing the free energy of the crystal.[1] To minimize the free energy, a spiral spin structure is superimposed on the AFM ordering resulting in rotation of the antiferromagnetic axis through the crystal with an incommensurate long wavelength period of 62 nm. This cancels the macroscopic magnetization and inhibits the observation of the linear magnetoelectric effect in bulk BFO. Apart from this, in bulk BFO, measurement of ferroelectric and transport properties are also hindered by leakage problems, which arise as a result of defects, nonstoichiometry, and low resistivity. Thus, for practical applications of this material, it is essential to improve its multiferroic properties. This can be achieved to some extent by decreasing the size of BFO to less than 62 nm and also by introducing suitable dopant ions in the material. The decrease in particle size below the periodicity of helical ordering gives rise to the suppression of modulated spin structure which improves the magnetization in nanoscale particles. A or B site substitution in the ABO_3 type perovskite $BiFeO_3$ can lead to reduction in leakage current and increase in resistivity by eliminating secondary impurities and oxygen vacancies, thereby improving its ferroelectric properties. Hence it was of interest to synthesize doped $BiFeO_3$ nanoparticles and study the effect of the dopant ions on its magnetic and electric properties at room temperature. In this article, we present a brief review of this work.

It has always been a challenge to synthesize pure $BiFeO_3$ as the product is mostly contaminated with secondary phases such as $Bi2O_3$ and $Bi_2Fe_4O_9$.[2] We have successfully synthesized phase pure undoped and doped $BiFeO_3$ nanoparticles through sonochemical route. Sonochemical synthesis is based on acoustic cavitation resulting from the continuous formation, growth and implosive collapse of the bubbles in a liquid.3,4 The materials have been characterized using X-ray diffraction (XRD), X-ray photoelectron spectroscopy (XPS), transmission electron microscopy (TEM), and selected area electron diffraction (SAED) techniques. The magnetic properties, such as magnetization dependence on temperature (M−T) and on field (M−H), have been investigated. P-E measurements and magnetoelectric coupling experiments have also been done.

Materials and methods

All the reactions were carried out at room temperature under ambient conditions. In a typical procedure, an aqueous solution of 1:1 stoichiometric amounts of $Bi(NO_3)_3 \cdot 6H_2O$ and $Fe(NO_3)_3 \cdot 9H_2O$ were sonicated for 20 min. The pH of the solution was made basic by adding ammonia solution, and the resultant mixture was irradiated with a high-intensity (100 W cm^{-2}) ultrasonic radiation operating at 20 kHz, under air at room temperature for 100 min. The subsequently formed white precipitate was centrifuged and washed with distilled water and finally with acetone. The product was heated under air in furnace at 525 °C for 1 h.

For the doped $BiFeO_3$ nanostructures, the method is similar to that reported for undoped $BiFeO_3$ but here a stoichiometric amount of the salt of the dopant ion was also added to the reaction mixture.

Results and Discussion

Ba^{2+}/Ca^{2+} and Cr^{3+}/Mn^{3+} codoped $BiFeO_3$

Phase pure undoped $BiFeO_3$ and co-doped $Bi_{0.9}Ba_{0.1}Fe_{0.9}Mn_{0.1}O_3$ and $Bi_{0.9}Ca_{0.1}Fe_{0.9}Cr_{0.1}O_3$ nanostructures were synthesized sonochemically. The choice of the dopant ions was based on the fact that replacing Fe^{3+} ions in $BiFeO_3$, with other transition metal ions such as Cr^{3+} and Mn^{3+} that has better electronic stability is expected to increase the resistance by reducing valence fluctuations in Fe^{3+}. Also, weak ferromagnetism has been observed[5] at room temperature for single doped $BiFeO_3$ nanoparticles where divalent cations viz. Ba^{2+} and Ca^{2+}, substitute trivalent cations of Bi^{3+}. The XRD patterns of the undoped $BiFeO_3$ as well as that of $Bi_{0.9}Ba_{0.1}Fe_{0.9}Mn_{0.1}O_3$ and $Bi_{0.9}Ca_{0.1}Fe_{0.9}Cr_{0.1}O_3$ are shown in Fig. 1(a-c), respectively. The peaks in all

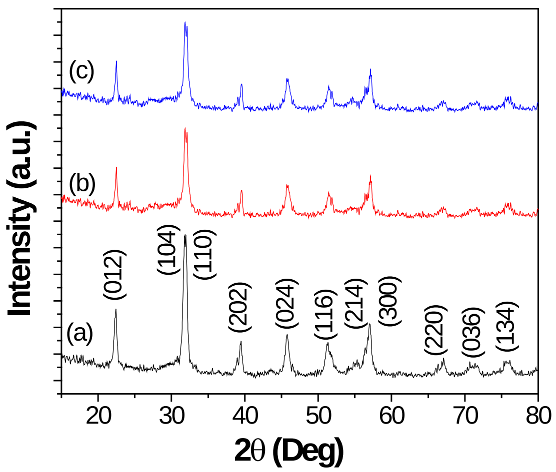

Fig. 1: XRD patterns of (a) undoped $BiFeO_3$, (b) $Bi_{0.9}Ba_{0.1}Fe_{0.9}Mn_{0.1}O_3$ and (c) $Bi_{0.9}Ca_{0.1}Fe_{0.9}Cr_{0.1}O_3$

the XRD pattern corresponded to the rhombohedral structure of $BiFeO_3$ with R3c space group (JCPDS no: 71-2494). The observed broadening of the peaks in the XRD patterns of all the above samples, compared to that normally seen for bulk $BiFeO_3$ obtained via solid state synthesis is typical for nanoparticles. No additional peaks were observed in any of the XRD patterns, confirming the formation of phase pure $BiFeO_3$. TEM images of undoped $BiFeO_3$, showed formation of nanocubes with dimensions of the order of 25–30 nm (Fig. 2a). However, the TEM images of the doped $Bi_{0.9}Ca_{0.1}Fe_{0.9}Cr_{0.1}O_3$ sample (Fig. 2b) showed interesting observations. Though there was not much change in the size of the nanoparticles, in all the cases, very few nanocubes were seen. The majority of the particles have a faceted morphology. This clearly indicates that the nanocube shape of the $BiFeO_3$ particles is destabilized under the influence of the dopant ions. Changes in morphology of parent compound with introduction of dopants have been reported earlier in the case of Mg-doped ZnO and lanthanide-doped CeO_2 nanomaterials.

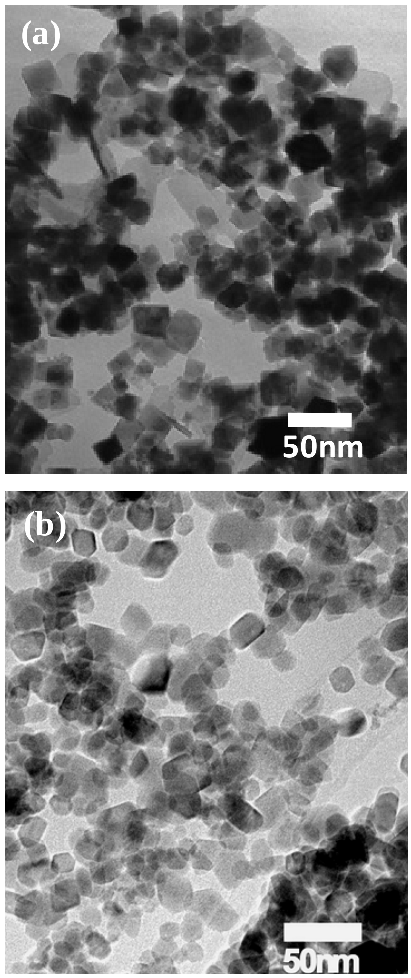

Fig. 2: TEM of (a) undoped $BiFeO_3$, (b) $Bi_{0.9}Ca_{0.1}Fe_{0.9}Cr_{0.1}O_3$.

To investigate the magnetic order at room temperature of our undoped bismuth ferrite nanorods, magnetic measurements were done using vibrating sample magnetometer (VSM). For all the samples we can observe sizable hysteresis with a finite value of the coercive field, remanent magnetization and saturation magnetization that are tabulated in Table 1. A DC magnetization loop of the BiFeO3 nanocubes, recorded at 300 K, is shown in Fig. 3. BiFeO3 nanocubes show a weak ferromagnetic order at room temperature, which

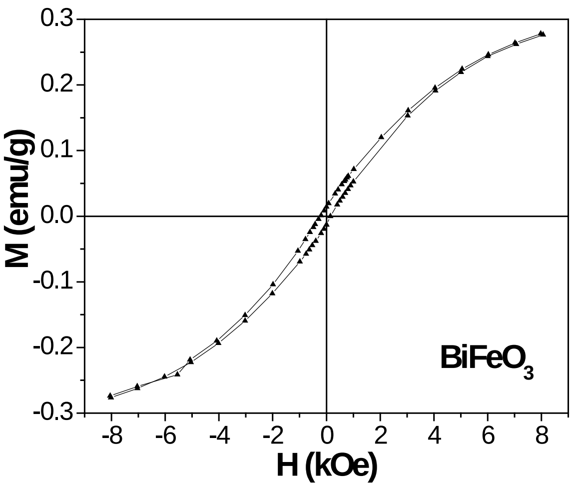

Fig. 3: M-H curve of BiFeO3 nanocubes

is quite different from the linear M–H relationship reported for bulk BiFeO3.The BFO nanostructures with typical dimensions below 62nm can possess favorable magnetic properties due to their grain size confinement, an effect that has been found to partially destroy the long-range spiral spin structure of bulk BFO. The diameters of our BiFeO3 nanocubes are in the range of 20–30 nm, which is less than the wavelength of the incommensurate spiral spin structure of the bulk material. This would lead to partial destruction of the spiral spin structure in the BiFeO3 nanocubes and hence the incomplete spin compensation becomes measurable, resulting in weak FM behaviors. From Table 1 it can be seen that the highest value of MS (1.35 emu g-1), MR (0.25 emu g-1) and coercive field Hc (1.94 kOe) occurs in the double doped Bi0.9Ba0.1Fe0.9Mn0.1O3 nanostructures.

Fig. 4a and 4b show the ferroelectric properties of the undoped $BiFeO_3$ nanorods and double doped $Bi_{0.9}Ba_{0.1}Fe_{0.9}Mn_{0.1}O_3$ and $Bi_{0.9}Ca_{0.1}Fe_{0.9}Cr_{0.1}O_3$nanostructures, investigated by the P–E loop

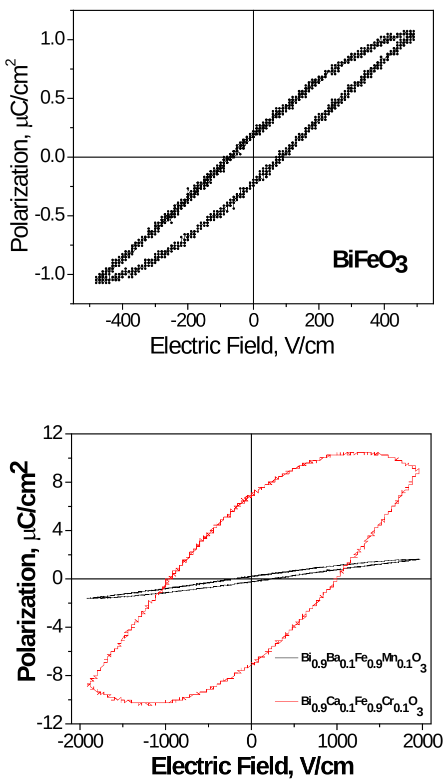

Fig. 4: P-E loops of undoped $BiFeO_3$, $Bi_{0.9}Ba_{0.1}Fe_{0.9}Mn_{0.1}O_3$ and $Bi_{0.9}Ca_{0.1}Fe_{0.9}Cr_{0.1}O_3$.

Table 1: Magnetic Parameters at room temperature

Sample	Coercive field (Oe)	Remanant magnetization (emu/g)	Maximum magnetization (at 8 kOe) (emu/g)
$BiFeO_3$	382	0.01	0.28
$Bi_{0.9}Ba_{0.1}Fe_{0.9}Mn_{0.1}O_3$	1942	0.25	1.35
$Bi_{0.9}Ca_{0.1}Fe_{0.9}Cr_{0.1}O_3$	1142	0.13	1.06

measurements. Saturation of polarization is not observed in case of the $BiFeO_3$ nanorods as well as $Bi_{0.9}Ba_{0.1}Fe_{0.9}Mn_{0.1}O_3$ nanostructures at a maximum applied electric field of ±500 V cm-1 and ±2000 V cm-1, respectively. However, a high saturation polarization (Ps) of 10.5 mC cm-2, Pr of 7 mC cm-2 and Ec of 1957 V cm-1 is observed in case of the $Bi_{0.9}Ca_{0.1}Fe_{0.9}Cr_{0.1}O_3$ nanostructures.

To understand this behavior, we have to first note that in $BiFeO_3$, small amounts of Fe^{2+} ions and oxygen vacancies exist.6 When Ca^{2+}/Ba^{2+} and Cr^{3+}/Mn^{2+} are incorporated in BiFeO3, Ca^{2+}/Ba^{2+} is supposed to substitute Bi3+ because of the close ionic radii of Ca^{2+}/Ba^{2+} and Bi^{3+}. Such acceptor doping of Bi^{3+} by Ca^{2+}/Ba^{2+} is expected to generate oxygen vacancies without the liberation of electrons. Normally, the oxygen partial pressure in the ambience is sufficient to incorporate oxygen into the structure to nullify the oxygen vacancies and show p-type conductivity. The hole generated can be consumed by Fe^{2+} in B site position resulting in lower acceptor doping of Fe^{3+} by Fe^{2+} in BiFeO3 with consequent decrease in conductivity. When Cr^{3+} substitutes Fe^{3+}, the acceptor doping of Fe^{3+} by Fe^{2+} is further reduced since Cr^{3+} is very stable electronically and this further causes a decrease in the conductivity. Hence, Ca^{2+} and Cr^{3+} co-doped $BiFeO_3$ show comparatively non-lossy ferroelectric hysteresis loops compared to undoped $BiFeO_3$ and $Bi_{0.9}Ba_{0.1}Fe_{0.9}Mn_{0.1}O_3$ nanostructures.

Sc^{3+} doped $BiFeO_3$

We had seen that with Cr^{3+} substitution, the acceptor doping of Fe^{3+} by Fe^{2+} was reduced since Cr^{3+} is very stable electronically, and this led to the decreased conductivity. This led to the idea that Sc^{3+} ions could act as a better dopant since it has a stable electronic configuration, which is expected to improve ferroelectric properties and minimize the leakage current in BFO. We have prepared $BiFe_{0.98}Sc_{0.02}O_3$, $BiFe_{0.95}Sc_{0.05}O_3$, and $BiFe_{0.9}Sc_{0.1}O_3$ nanostructures using the sonochemical technique. The products obtained were subjected to thermal treatment, and resultant residues were characterized by XRD. All the XRD diffraction peaks are well matched with the rhombohedral structure (R3c space group) of pure $BiFeO_3$ (JCPDS file no. 71-2494). 7 The survey spectra of $BiFe_{0.95}Sc_{0.05}O_3$ nanoparticles shows that the binding energies of Fe^{3+} 2p3/2 and 2p1/2 spin orbit doublets and Bi 4f7/2 and Bi 4f5/2 are at 711.3, 723.8 eV and 158 and 164 eV, respectively. No additional peak corresponding to Fe^{2+} oxidation has been observed in any XPS data, which indicates the dominant role of Fe^{3+} ion for the observed ferromagnetism in pure and Sc-doped $BiFeO_3$ nanoparticles in magnetic study. 7

Fig. 5a shows the room temperature magnetization (M-H) loop of pure and Sc-doped $BiFeO_3$ nanoparticles. It clearly indicates weak ferromagnetism for undoped $BiFeO_3$, which is visibly enhanced by doping Sc at the Fe-site of the compound. This may arise due to the non-exact compensation of spins with decrease in the particle size. There is also a possibility of the modification of the cycloidal spin structure of $BiFeO_3$ since the sizes of the nanocubes are less than 62nm and this must result in an enhanced ferromagnetism. The hysteresis loops of undoped $BiFeO_3$ nanocubes exhibit very small remnant magnetization and a lack of proper saturation. This can be attributed to the presence of exchange and dipolar interparticle interactions in our system. The M-H curves show an enhancement of the magnetic properties of $BiFeO_3$ on Sc doping and also show that there is a shift in the hysteresis loop toward negative axis, indicating exchange coupling between the antiferromagnetic core and ferromagnetic surface (Fig. 5b). With increase in Sc doping, the magnetization value increases initially and then decreases, exhibiting a maximum for the $BiFe_{0.95}Sc_{0.05}$O3 sample. In our $BiFeO_3$ samples, the XPS data indicates that Fe^{2+} ions and in turn oxygen vacancies were not present either in the undoped or the doped form. Thus, the increased magnetization in the $BiFeO_3$ ceramics might result from the

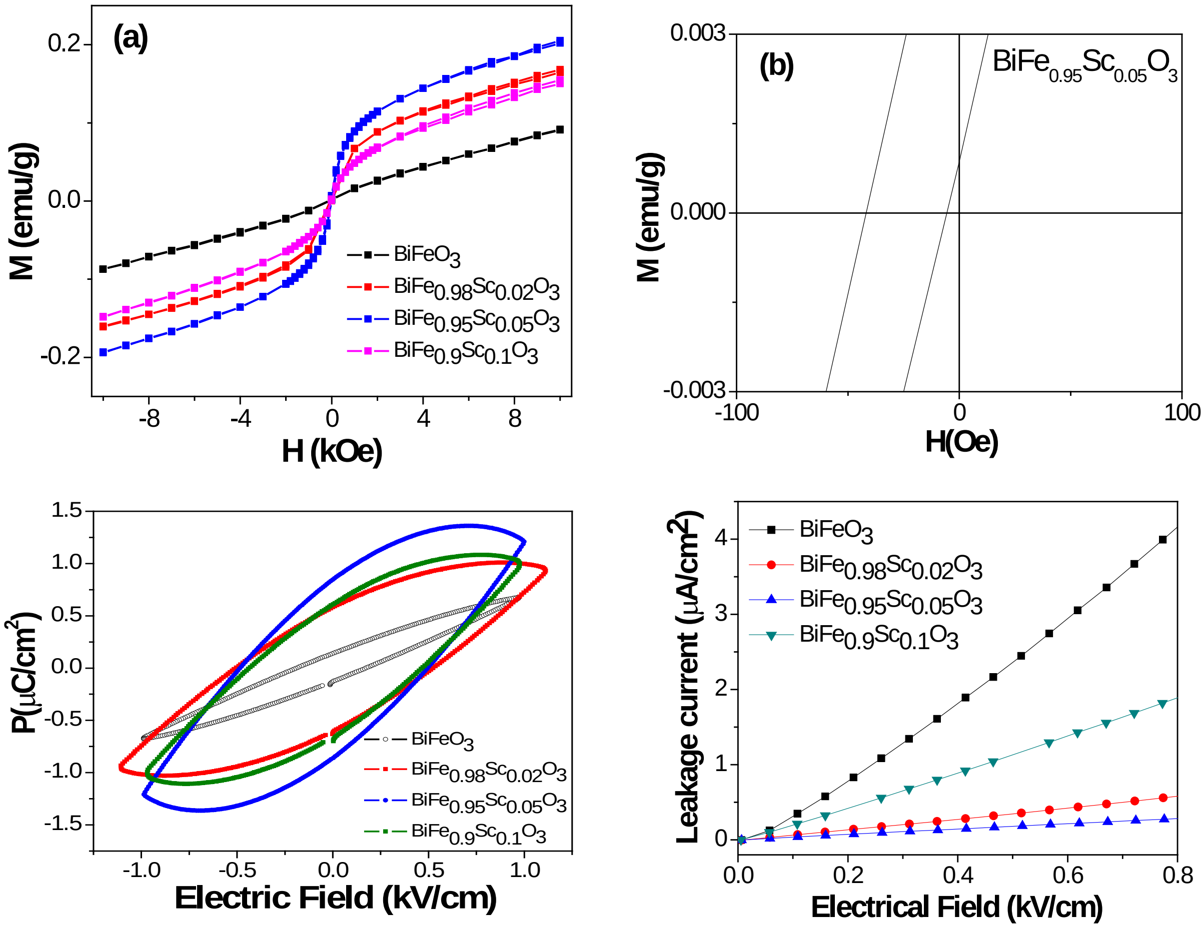

Fig. 5: (a) M-H curves, (b) exchange interaction, (c) P-E loops and (d) leakage current of undoped and Sc^{3+} doped $BiFeO_3$ nanoparticles.

canting of the antiferromagnetic spin structure due to structural distortion and/or disturbance of anti-parallel magnetic ordering by partial substitution at Fe sites with Sc ions which has a larger size and a nonmagnetic nature.

The P-E hysteresis loops of undoped $BiFeO_3$ indicate its ferroelectric nature but with severe lossy characteristics. However, all the Sc^{3+} doped nanostructures exhibited better polarization saturation. The highest saturation polarization (Ps) of 1.4μCcm^{-2}, Pr of 0.9 μCcm^{-2} and Ec of 486 V cm^{-1} is observed in case of the $BiFe_{0.95}Sc_{0.05}O_3$ nanostructures. The leakage current is large for the undoped $BiFeO_3$ nanoparticles. In case of all the Sc^{3+} doped $BiFeO_3$ nanoparticles, the leakage current is reduced. The best results are seen in case of the $BiFe_{0.95}Sc_{0.05}O_3$ and $BiFe_{0.98}Sc_{0.02}O_3$ samples. To understand this behavior, we have to first note that in case of our sonochemically synthesized $BiFeO_3$, the B sites are all occupied by Fe^{3+} ions as Fe^{2+} ions are absent. Hence, when Sc^{3+} substitutes Fe^{3+}, there is no acceptor doping of Fe^{3+} by Fe^{2+} and hence this cannot cause a decrease in the conductivity. Here, structural distortion plays a role in improving the ferroelectricity in Sc^{3+}doped $BiFeO_3$. Sc^{3+} ions occupy the B site and lies in the oxygen octahedron to form Sc 3d-O 2p hybridization. This leads to improved ferroelectric properties due to enhanced stabilization of the ferroelectric distortion.

The Sc^{3+}-doped $BiFeO_3$ nanoparticles synthesized by us behave like a “geometric” ferroelectric, and hence there is a probability of observing magnetocapacitive coupling in this material. The $BiFe_{0.95}Sc_{0.05}O_3$ sample does exhibit magnetocapacitive coupling, which can be attributed to the magnetic signal observed in this sample. The magnetic field induced magnetocapacitive shift is ~0.04% in an applied field of 5 T. This is much higher than that observed for the undoped BiFeO3 nanoparticle which is ~0.007%.

Sc^{3+} and Ti^{4+} co-doped $BiFeO_3$

Further enhancement in the multiferroic properties of $BiFeO_3$ has been observed in sonochemically prepared nanocrystalline $BiFe_{0.95}$-$xSc_{0.05}TixO_3$(where x = 0.025, 0.05) by virtue of the beneficial effect of codoping. XRD and EDX results ruled out the existence of any impurity in the samples. The improved multiferroic properties has been attributed to the modification of the cycloidal spin structure of $BiFeO_3$ since the sizes of the nanoparticles are less than 62 nm and also due to the structural distortion brought about by the codoping. The better shape of P-E hysteresis loop of $BiFe_{0.92}5Sc_{0.05}Ti_{0.025}O_3$ with a comparatively high Ps of 2.63 μC cm^{-2} and coercive field (Ec) of 425 V cm^{-1}, makes it a superior ferroelectric material compared to $BiFe_{0.9}Sc_{0.05}Ti_{0.05}O_3$.

Conclusion

Phase pure $BiFeO_3$ nanocubes have been successfully synthesized using a facile sonochemical technique followed by heat treatment. These nanoparticles show a weak ferromagnetic order at room temperature, which is quite different from the linear M–H relationship reported for bulk BiFeO3. Addition of Ba^{2+}/Ca^{2+}, Cr^{3+}/Mn^{3+}, Sc^{3+} and Sc^{3+}/Ti^{4+} dopant in varying concentrations in these $BiFeO_3$ nanoparticles alters their magnetic as well as ferroelectric properties to different extents. M-T and M-H curves revealed that the as-synthesized nanoparticles showed frustrated magnetic behavior, attributed to the coexistence of canted AFM interaction of Fe-O-Fe. The highest value of magnetization was observed for $BiFe_{0.95}Sc_{0.05}O_3$ and $BiFe_{0.925}Sc_{0.05}Ti_{0.025}O_3$ nanoparticles. These materials also showed enhanced ferroelectric properties with considerably less lossy characteristics compared to the bulk $BiFeO_3$. These studies establish that among all the dopants tried in this study, Sc^{3+} and Ti^{4+} codoping in sonochemically synthesized $BiFeO_3$ nanoparticles, exhibits maximum improvement in its multiferroic properties. A weak coupling behavior has been found which is attributed to the ferromagnetism present in the samples. Thus, fine tuning of the concentration of Sc^{3+} and Ti^{4+} dopants in $BiFeO_3$ nanostructures lead to better materials for different potential applications.

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Understanding The Biological Effects of Thorium and Developing Efficient Strategies for Its Decorporation and Mitigation

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Abstract

In view of DAE's three-stage nuclear programme, which is aimed at the optimal utilization of thorium for nation's energy requirement, it is very important to understand the biological effects of thorium. This paper presents a brief overview of research activities in our laboratory on the effects of thorium in human cells and animal models. Studies have also been undertaken to develop efficient strategies to counter-measure thorium toxicity using animal models. Present study also emphasizes the importance of multidisciplinary interactions to further understand the cellular and molecular basis of radiobiological effects of thorium in mammalian systems.

Introduction

Due to limited sources of natural uranium, Department of Atomic Energy (DAE) has sought thorium (Th) as an alternative source of nuclear fuel. India has one of the largest deposits of natural Th in the form of monazite in Kerala. The currently known Indian Th reserves amount to 155,000 GWe-yr of electrical energy and can meet the energy requirements during the next century and beyond. Thorium-232 (^{232}Th) is the major isotope and constitutes ~9% of monazite. Development of advanced heavy water reactor (AHWR) and fast breeder reactor (FBR) technologies in combination with pressurized heavy water reactor (PHWR) would enable the use of non-fissile ^{232}Th for the generation of fissile element, uranium-233 (U-233). This three stage-Indian nuclear program would meet the goal of self-sustainable energy security in India. In views of increasing realization of ^{232}Th in India, research activities were undertaken to achieve all round capability in the development of safe and eco-friendly thorium fuel cycle (Table 1).

Considering long term ^{232}Th-based nuclear research program, it is anticipated that the activities like mining, reprocessing and deploying of ^{232}Th would significantly increase in coming years. Therefore, it was conceived to understand the health effects of ^{232}Th and related actinides using relevant cell and animal models. Understanding the biological interaction of ^{232}Th at cellular and molecular level would help in developing measures for efficient handling of ^{232}Th at various stages of fuel cycle with adequate health and environmental protection. This would lead to the development of potential biological strategies for decorporation of ^{232}Th and other actinides.

Biological Routes of Exposure

Human intoxication with Th may happen through accidental/occupational inhalation, ingestion and open wounds/skin absorption. Irrespective of the routes of internalization, Th gets absorbed and transported by blood to the major sites of accumulation like liver and bones. If it enters through inhalation, it accumulates in lungs as one of the major retention sites.

Inhalation

Inhalation is one of the major routes of entry for

Th or other actinides in case of general, occupational or accidental exposures. Toxicity of Th to the lungs and distal organs varies when exposed by inhalation route. In general, the more soluble compounds are less toxic to the lungs but more toxic systemically due to easier absorption from the lungs into the blood stream and mobilization to distant organs. In contrary, the more common insoluble salts/oxides (nitrate, hydroxide or dioxide) are more toxic to the lungs through inhalation exposure because of the longer retention time in lungs.

Ingestion

Contaminated food and water could be another route of exposure of Th like any other radionuclides for humans. The differences in gastrointestinal absorption are attributable to different solubilities of the various chemical forms. Human gastrointestinal absorption for Th was estimated in the range of 0.1 to 1%. Thorium-nitrate has ~4 times greater absorption rate than Thorium dioxide, and the absorption rate of Thorium chloride was 10 or 20 times higher than Thorium dioxide, depending on concentration.

Dermal / Wound absorption

Absorption through skin breaks or open wounds is another route of Th entry into the body, especially when person is involved in Th dust operation. Thorium toxicity studies following dermal/wound exposure has not been investigated well.

Biochemical Basis of Thorium Biodistribution

After absorption of Th in blood, it gets deposited in the target organs like liver and bones, which are the major sites of iron storage and utilization in human body. The major property of thorium, which is responsible for getting deposited in these organs, is its iron-like behaviour in blood. This is so because, charge/size ratio of Th(IV) is close to iron(III). Therefore, it suitably binds to an iron-transporting protein in blood, transferrin (Tf), which delivers bound-thorium to the liver. Currently it is unclear whether Th-Tf complex internalizes into liver cell through Tf receptor-mediated endocytosis. Further insight about the recognition of Th-Tf complex by Tf-receptor and mechanism of endocytosis by liver cell would enable us to understand the intracellular distribution of thorium and cellular defence mechanisms against Th.

Table 1 :Thorium-232 Fact Sheet : A Biological View

- Thorium-232 (^{232}Th), a naturally-occurring actinide is an alpha-emitter with specific activity of 4 Bq/mg and radiological half-life of ~14 billion years.
- Heath effects of ^{232}Th mainly depend on solubility/chemical form, route of exposure, particle size and the amount of internalized isotope.
- Annual limits of intake (ALI) for ^{232}Th is 170 mg. ALI is the amount of radionuclide which delivers radiation dose equivalent to annual effective dose of 20 mSv.
- Internal contamination with ^{232}Th may not cause immediate radiation injury. However, early observable biological effects, depending on the dose, could be possible due to its chemical reactions on body function. Due to its low and long-lived alpha-emission activity, late health effects may occur after many years of exposure.

It is relevant to mention that the charge/size ratio of uranium VI (U) is significantly different from Th (IV) and it mainly exists in the form of a Uranyl carbonate ion, a soluble form in blood. As a result, it does not make a stable complex with transferrin thus gets circulated in blood stream and excreted out with the biological half-life of ~4 days. Because of its soluble nature, Uranyl ions reach kidney and affects renal (kidney) functions. Hence U is known for its nephrotoxicity. Since plutonium behaves similar to thorium in blood and other biological fluids, its organ distribution profile is similar to thorium.

Radiological and Heavy Metal Effects of Thorium

Thorium (or other actinides) may exert their toxicity due to both radiological and heavy metal properties depending on the type of isotope. Natural thorium is essentially ~99% of ^{232}Th and has very low gamma activity (4 nCi/mg) suggesting an insignificant concern due to its gamma radiation. ^{232}Th is an alpha-emitter with radiological half-life of ~14 billion years. However, the biological half-life of thorium (i.e. the time that body requires to reduce half of its concentration through physiological mechanisms) in human is ~2 y in liver, ~5 y in lungs and ~20 y in skeleton. Therefore, ^{232}Th is expected to induce late health effects due to alpha emissions and chemical interaction at the targeted tissues/organs. Other isotopes of thorium: Th-228, Th-230 and Th-234 decay much faster than Th-232, thus cause early biological effects due to alpha- and beta- emissions at the site of entry in human body.

Therefore, it is predictable that the biological response of any organs/tissues to ^{232}Th and other alpha-emitting actinides would depend on the net outcome of chemical and radiological impact at cellular and molecular level.

Biological Effects

Thorium toxicity research program at Radiation Biology & Health Sciences Division was initiated few years back. Since, then our research activities are focused to understand the effect of ^{232}Th-nitrate in human cells and animal models.

Cellular level

After internal contamination of Th through various routes, blood becomes a common compartment for its transport and distribution in the body. Therefore, studies revealing the interaction of thorium with blood cells and plasma proteins would provide a rationale clue for designing the novel agents for effective decorporation of thorium from blood. Since at cellular level, membrane forms the first facing target for the action of a heavy metal radionuclide including thorium. Experiments were performed to investigate the effect of ^{232}Th-nitrate in human erythrocytes (employed as cell membrane model), under physiologically isotonic

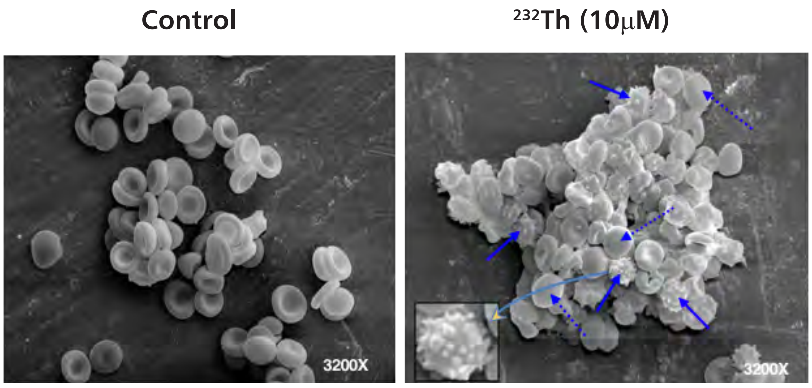

Fig. 1: Morphology of human erythrocytes as observed by scanning electron microscopy. Control showed normal biconcave shape while ^{232}Th treatment induced shape alterations and aggregation of erythrocytes suspended in isotonic-buffered condition (150mM, NaCl, 5mM Hepes, pH~7.4). Source: Kumar et al., Biochimie 92(2010): 869-79.

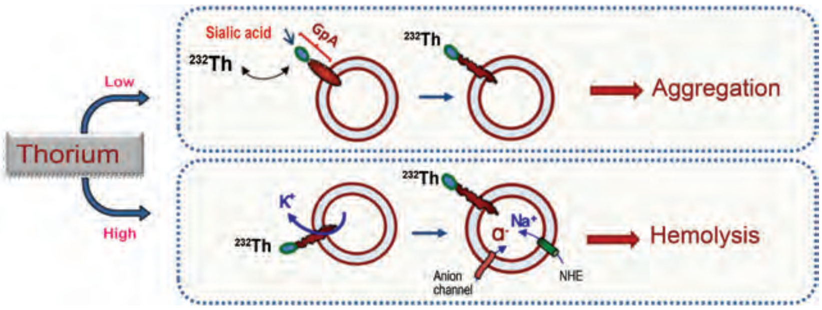

Fig. 2: Schematic representation of ^{232}Th -induced aggregation and hemolysis. ^{232}Th:erythrocytes ratio determines aggregation or hemolytic effect of ^{232}Th. At low ^{232}Th:cell, ^{232}Th bind to negatively-charged membrane sialic acid of GpA resulting surface charge reduction and GpA alterations, which consequently induces erythrocytes aggregation. At high ^{232}Th:cell ratio, ^{232}Th binding to GpA induces its alterations and membrane pore formation so effectively through which significant electrolyte imbalance (due to excessive K^+ loss and Na^+ and Cl^- entry) occurs followed by hemolysis.

buffered conditions. This study revealed that erythrocytes underwent aggregation or lysis, depending on the ratio of ^{232}Th to cells. Results obtained with the application of biophysical techniques like scanning electron microscopy (SEM), atomic force microscopy (AFM) and confocal laser scan microscopy (CLSM) suggested that ^{232}Th induced aggregation and alteration in erythrocyte shape from normal discoid to equinocytic (Fig.1) with increased surface roughness. Biochemical investigation suggested a significant role of membrane sialic acid and glycophorin A protein in aggregation or hemolytic effects of ^{232}Th (Fig. 2). Experiments using specific ion-channel inhibitors and osmoprotection approach indicated that ^{232}Th caused hemolysis by colloid osmotic mechanism. These findings provide a significant insight about the structural, biochemical and ionic-imbalance effects of ^{232}Th in human erythrocytes.

Further studies on human liver and lung cell models are ongoing. Recent results suggest that the low concentration of ^{232}Th (0.1-10 μM) induced proliferation of human liver cell, HepG2 under in-vitro conditions. A detailed mechanism of observed phenomenon and its relevance are under investigation.

Animal level

To identify the target organs of ^{232}Th and associated health effects, experimental animals (mice or rat) were injected intraperitoneally (i.p.) or intramuscularly with ^{232}Th-nitrate. Studies on mice administered with ^{232}Th-nitrate i.p. at 10 mg/Kg of body weight for 30 days (1/40th dose of $LD_{50/30}$) showed liver, spleen and skeleton as the major sites of thorium accumulation. Despite being weakly radioactive and non-redox in nature, ^{232}Th administration was found to induce oxidative stress in these target organs as evidenced by increased lipid peroxidation and decreased activities of antioxidant enzymes such as superoxide dismutase and catalase. In these animals, approximately 3% of total injected ^{232}Th was found to get localize in the brain suggesting the ability of ^{232}Th to cross blood-brain barrier. Further experimental results suggest that ^{232}Th affects cholinergic function associated with neurobehavioral changes.

Biomolecular level

As mentioned above that ^{232}Th accumulates in iron-storage (liver) and iron-utilization (bones) sites in body. Our studies explored the interaction of ^{232}Th with iron-binding or iron-containing protein e.g. haemoglobin, catalase (heam proteins). Our preliminary studies using UV-visible absorbance spectroscopy suggest that ^{232}Th interaction with haemoglobin and hematoporphyrin XI is different from lanthanides and uranium. A detailed study in collaboration with Chemistry Division is under progress to understand the molecular interactions of ^{232}Th with heme-group proteins/biomolecules. This study would guide us in designing efficient decorporating agents which can remove thorium from such binding sites under in-vivo conditions.

Development of Decorporation Strategies

In case of accidental release of radionuclides from a nuclear facility or in other scenario, internal contamination with actinides may pose a severe health risk to human beings. It is therefore important to provide effective decorporation therapy to reduce acute radiation damage, chemical toxicity, and late radiation effects. Diethylenetriammine pentaacetate (DTPA) is a FDA-approved agent for decorporation of Pu and Th. However, it has two major limitations: (i) its limited ability to cross cellular membrane and (ii) insufficient retention time in blood (>90% excreted via urine within a day). Due to these limitations, DTPA does not get access to intracellularly-deposited Th or Pu, and needs multiple injections to maintain its effective concentration in blood. To overcome these limitations, we designed DTPA formulation by encapsulating it into the lipid vesicles (known as liposomes) with the aim of decorporating intracellular fractions of thorium (Fig. 3). Various types of liposomes with different surface charges

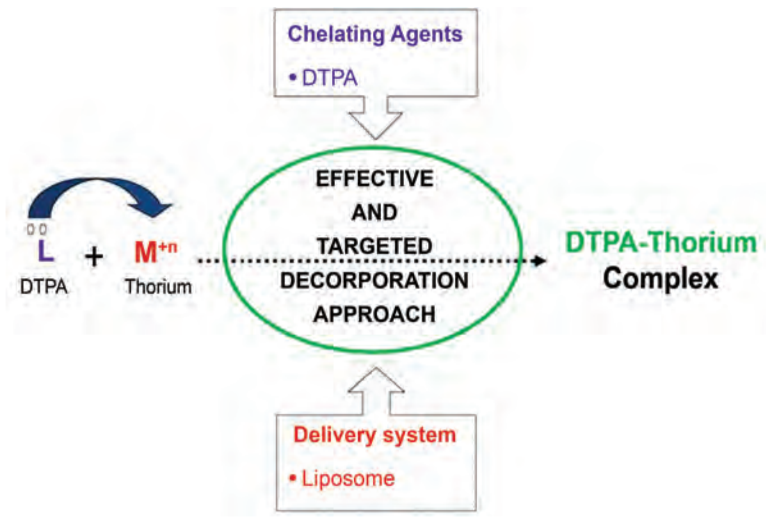

Fig. 3: Schematic diagram of liposomal decorporation approach. Encapsulation of DTPA, a chelating agent, into the liposomes resulted in a significant improvement of ^{232}Th decorporation from liver of rat-administered with ^{232}Th-nitrate compared to free-DTPA.

were prepared and encapsulated with DTPA to match the body distribution of DTPA with thorium-targeted organs. For this, rat as animal model was used to evaluate the decorporation and therapeutic potential of liposomal-DTPA against thorium toxicity.

Biodistribution studies suggest that the neutral- and positively-charged liposomes showed significantly higher delivery of DTPA to liver and kidney, respectively, than the non-encapsulated or free form of DTPA. Retention time of DTPA in blood was found to be improved (~5 folds at 1h) after its encapsulation into the liposomes. Further studies were performed using neutral liposomal-DTPA to test its decorporation efficacy for ^{232}Th from liver which was compared with free-DTPA. Th determination by inductively coupled plasma-atomic emission spectroscopy (ICP-AES) in liver of animals-injected with ^{232}Th-nitrate followed by therapy with liposomal-DTPA suggested a significant increase in ^{232}Th decorporation than the free DTPA. These animals showed improved liver functions than the animals treated with free DTPA. Further studies are required to evaluate the potential of liposomal approach with other novel chelating agents.

Conclusions

Studies on the effects of ^{232}Th in cells and animal models suggested that the ^{232}Th altered cellular structure and biochemical functions depending on the concentration and experimental conditions, which could be different in the real exposure situation. However in-depth studies on interaction,

Table 2 : Thorium Toxicity Research: Future Direction

- To delineate the molecular events of thorium internalization in a cell system.
- Development of techniques for mapping, speciation, and quantification of thorium in sub-cellular compartments.
- Investigating the effect of thorium-232 in combination with alpha-radiation in relevant cell models using in-house developed alpha irradiator 'BARC BIOALPHA'.
- Identification and development of suitable biomarker of thorium toxicity for human application.
- Development of novel formulations of chelating agents including DTPA for thorium decorporation.
- To know the observable adverse effect level (OAEL) and no observable adverse effect level (NOAEL) of thorium through various routes of exposure especially inhalation and ingestion.

transport, metabolism and mechanism of ^{232}Th-induced biological responses would provide rationale clue(s) to develop effective precautionary measures for health protection from ^{232}Th and other fuel cycle related actinides. Finally, it is important to mention that the interdisciplinary approach to address various key questions in thorium toxicity research could play a significant role in improving our knowledge about ^{232}Th interaction with various biological systems relevant for the development of better decorporation and mitigation strategies.

Acknowledgement

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Pulsed Quasi-monochromatic x-ray source for radiography and x-ray absorption spectroscopy

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Abstract

Monochromatic and quasi-monochromatic x-ray backlighting is a proven diagnostic technique with many important applications in Inertial Confinement Fusion and related research work. The quasi-monochromatic x-ray source can also be used in the x-ray absorption spectroscopy. A quasi-monochromatic x-ray backlighting system in the spectral range of 7.9 – 9.4 Å (1.32 - 1.57 keV) range has been developed using Thallium Acid phthalate (TAP) crystal. This diagnostics is tunable in the wavelength range of 7 - 10 Å. In one setting it can cover a spectral range of 1.5 Å (ΔE = 0.25 keV). The x-ray radiograph spectral parameters were optimized using copper plasma. The temporal pulse duration was measured as 1.0 ns using indigenously developed fast x-ray vacuum bi-planar photodiodes (□ 150 ps). The spatial resolution calculated was 50 μm which depends on the plasma source size.

Introduction:

During the last 20 years, x-ray radiography techniques have been successfully used as a dense plasma diagnostics tool in experiments such as Inertial confinement fusion (ICF), high current pinch discharge and high energy density physics [1]. The process of inertial confinement fusion takes place in a nanosecond time scale. The ICF related dynamic experiments require high energy, high resolution microscopy to probe the time dependent symmetry in the compression in Hohlraums [2]. Pulsed radiography with short duration (sub-ns to sub-ps) is required for such an application. Shorter the x-ray pulse duration, better will be the temporal resolution and hence the spatial resolution (minimizing the hydrodynamic smearing) of the radiograph. Pulsed radiograph produces more accurate measurements. Modeling of the implosion and the stability of the spherical shell are being done using the x-ray radiography of thin foil acceleration considering the thin foil as a small section of the spherical target [3]. In an opaque high/ mid Z material, it is not possible to get information about the shock characteristics inside the sample and then to directly measure the fluid (particle) velocities. The x-ray probing /backlighting also can be used to deduce information of other shock parameter such as density [4]. The shock velocity and fluid velocity can be measured simultaneously by using x-ray radiography along with x-ray streak camera [5].

The laser produced plasma can generate an intense monochromatic /quasi-monochromatic x-ray source using a curved / flat crystal spectrometer with a pulse duration of the order of hundreds of femtosecond to nanoseconds (K_α photons of low to mid Z targets depending on the laser pulse duration). Spherically bent crystals are used to select the probe wavelength and create the monochromatic image [6] and flat crystals are used for the quasi-monochromatic x-ray source [7]. Both radiographs are having merits and demerits. For example the bent crystals have the following advantages:

1. X-rays of particular wavelength (monochromatic), which satisfy the Bragg's condition will be reflected and focused on a point on the circle.
2. High luminosity due to the focusing feature of the spherical surface.

3. Better spectral resolution can be obtained in the scheme when the radiation angle of incidence on the crystal surface is close to the crystal normal on the Rowland circle.

   On the other hand, it has various disadvantages over the flat crystal spectrometer such as

1. The bending of the crystals is done with the mechanical arrangement which restrict the clear aperture of the crystal.
2. As mentioned above, high resolution can be achieved by choosing the angle of incidence close to normal, which limits the spectral range.
3. In bent crystal, the angle of incidence is close to the normal where maximum debris fluxes of the laser produced plasma are present which puts the crystal at the risk of maximum damage.
4. Alignment of the spherically bent crystal is more complicated than that of the flat crystal spectrometer and bending of the crystal by putting stress is also very critical. A mismatch in the strain can cause damage of the crystal.

Quasi-monochromatic x-ray backlighter can also be used in absorption spectroscopy. In the absorption spectroscopy, warm plasma is irradiated from behind, typically by broad band photon flux. The warm plasma absorbs radiation from the backlight at frequencies corresponding to the particular transitions. Thus, the absorption feature appear in the spectrum. Analysis of the absorption profile yields the number of ground state ions [8].

Experimental set up:

The experiment was devided into two parts. In the first part, a quasi-monochromatic x-ray backlighter system was developed using our existing 30 J/300 - 800 ps Nd: Glass laser system for the x-ray pulse generation. The laser system was operated at 15 J, and focussed onto the copper target for the generation of the characteric lines in the spectral range of 7.9 – 9.4 Å. Its various parameters were caliberated using the charecterics values of the x-rays from the NIST data base library. After caliberation, the copper target was replaced with gold target.

A single crystal Thallium Acid Pthalate (TAP) (size of 50 x10 mm^2 with a thickness of 2 mm) with cleavage plane parallel to (001) plane and 2d=25.75 Å, was used to select quasi-monochromatic x-ray beam in the spectral range 7.9 – 9.4 Å (1.32 - 1.57 keV) of the gold plasma for the x-ray probing. After reflection from the crystal plane, the probe beam is incident on the detector (x-ray CCD camera of M/s Rigaku). The pixel size of the CCD camera is 13.5 μm x 13.5 μm. It can also accommodate Phosphor screen, MCPs and x-ray film based detection systems. Details of the spatial, spectral and temporal parameter measurement of the spectrometer are described below:

Optimized Crystal spectrometer parameters

The geometrical requirement to ensure maximum spatial resolution and spectral purity within the resolution element in the object can be achieved using schematic shown in Fig 1. The spatial resolution of the backlighter in the x and y direction are dependent on the source size Δx_s and Δy_s in the x and y direction neglecting the contribution of the refraction, diffraction and the hydrodynamic smearing. For ideal case $\Delta x_s \approx \Delta y_s \approx 10$ μm. Diffraction is negligible if $\lambda/\Delta x_s < \delta\theta$, $\delta\theta$ where is crystal rocking angle. A typical value of $\delta\theta$ for TAP crystal is 0.45 - 1 mrad. Therefore, for diffraction to be negligible, λ should be less than 10 Å [9]. Hydrodynamic smearing depends on the compression velocity v of the target during radiograph frame time, Δt, and limits the effective spatial resolution on $\approx$ v.Δt. For a typical value of the particle velocity 5 x 10^6 cm/s and Δt of the x-ray flash of about 500 ps, it put upper limit of 25 μm. In our case, we have laser focal spot of 80 – 100 μm. In our earlier publication, it has been shown that the focal spot can go down as low as to 40 μm due to self focusing of laser beam caused by non-linear processes involved in the plasma [10].

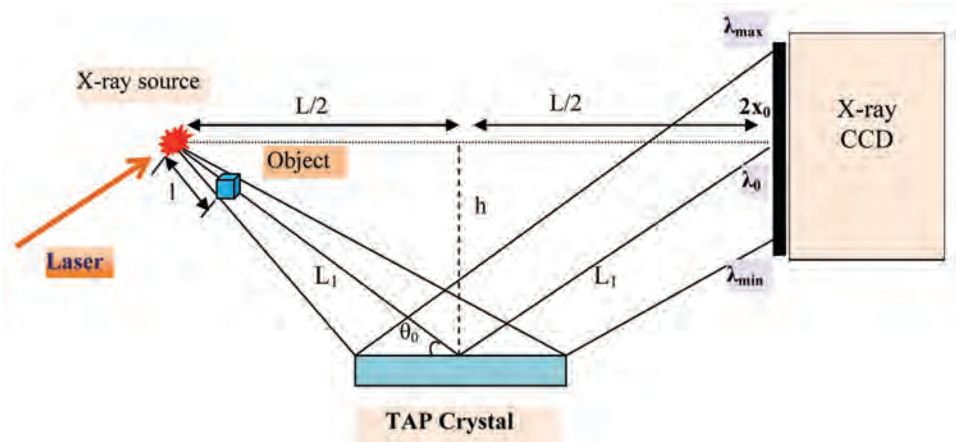

Fig. 1: Schematic diagram of the set up for the x-ray radiography and absorption spectroscopy studies. Thallium Acid Phthalate (TAP) crystal and gold M Band spectrum were used for the quasi-monochromatic x-ray source generation. In our detection system, the x-ray CCD camera size is 27 mm x 27 mm.

Spectral characteristics measurement

The spectral range and spectral resolution depend upon the crystal used (2d as well as size), the distance between the source and the detector (via crystal) and the orientation of the detector with respect to the x-rays incident on it. The spectral range i.e. λ_{min} and λ_{max} using Bragg's condition as shown in Fig. 1 can be written as.

$$\lambda_{max} = 2d\,(2h + x_0) / [\,(2h + x_0)^2 + L^2\,]^{1/2} \qquad \ldots (1)$$

$$\lambda_{min} = 2d\,(2h - x_0) / [\,(2h - x_0)^2 + L^2]^{1/2} \qquad \ldots (2)$$

From equation (1) and (2), it is obvious that the spectral range of the spectrometer depends on the geometrical parameters of the arrangement as shown in Fig. 1. For a given d and fixed L, the spectral range can be changed by changing the distance *h*. Also, for a given d, spectral range (λ_{max} $-\lambda_{min}$) can be increased by reducing the source to detector distance. However, as described above this distance cannot be reduced arbitrarily as the plasma debris could damage the crystal. For a complete shadow of the entire object a source spectrum with a bandwidth $\Delta\lambda_s \geq 2\lambda_0 t(1-\varepsilon^2)^{1/2}/(l\varepsilon)$, where $\varepsilon = \lambda_0/2d$, and t = the target thickness, is required and typically $\Delta\lambda_s/\lambda_0 \approx 0.025$. Quasi-continuous M band emission observed in high Z laser irradiated targets such as gold (used by us) are possible candidates for such sources.

Spectral resolution is determined by the size of the emitting region, and by the rocking angle of the crystal. If we consider ideally monochromatic x-rays from a source, they will, after Bragg reflection from a crystal, fall on a detector and appear as a broad spectral line of certain wavelength interval $\Delta\lambda$. This interval $\Delta\lambda$ can be expressed as

$$\Delta\lambda = \frac{2\,d}{[1 + (2\,h / L)^2]^{1/2}}\,[\delta\theta + \delta x / L[1 + (2h/L)^2] \qquad \ldots (3)$$

The first term in the square bracket in the above equation is a crystal dependent term and the second term is governed by the characteristics of the source and the detector. Further, it can be seen from equation (3) that the resolution $\Delta\lambda$ is small for large values of L and h / L. In our set up the spectral range is 7.9 – 9.4 Å (1.32 - 1.57 keV) with the spectral resolution of $\Delta\lambda \approx 30$ mÅ.

Above calculations, derived from the geometrical arrangement were measured by focusing the laser pulse on the copper target. Strong emission lines from Cu XX and Cu XXI ions are reflected from the Bragg›s crystal and recorded on the x-ray CCD camera and corresponding spectral plot is shown in figure 2 in the spectral range 7.9 - 9.4 Å. For the caliberation, we used wavelength λ = 8. 7 Å ($2p^5$ – $2p^4$4d), 9.106 Å ($2s^2\,2p^6 - 2s^2\,2p^5$ 4d, ^1S - 1/2, 3/2), and 9.24 Å ($2s^2\,2p^6 - 2s^2\,2p^5$ 4d, ^1S – 3/2, 5/2).

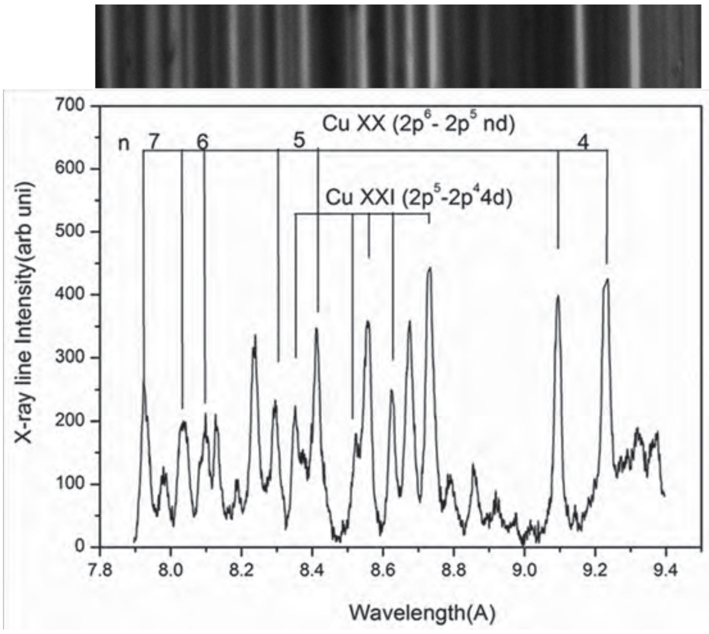

Fig. 2: Spectrum of copper line emission in the spectral range of 7.9 to 9.4 Å range using TAP crystal spectrometer.

Temporal resolution for the x-ray backlighter is dependent on the pulse duration of the laser system used for x-ray generation. The temporal profile of the soft x-ray pulse generated in the spectral range of (0.8 – 1.56 keV) and (> 0.9 keV) using 5 μm Al and B10 filter respectively have been measured using x-ray vacuum bi-planar photodiode (VBPD) and 500 MHz scope (2.5 GS /s) as shown in Fig. 3. The delay between the two pulses is due to the difference in the length of the BNC cable. The x-ray pulse duration measured was approximately 1.0 ns for the laser pulse of duration 500 ps. The multiple peaks observed were due to electrical noise in the circuit. More accurate measurement can be made by coupling the x-ray streak camera with the crystal spectrometer. Earlier published data on the measurement of the x-ray pulse duration of M band spectrum using x-ray streak camera shows the pulse duration close to the laser pulse duration. The x-ray pulse duration can further go down to a few picosecond using ultra-short laser system.

In the seond part, copper target was replaced with gold target. The gold plasma emits continuous M band spectrum in this spectral range. Laser energy of the single beam now increased to 20 J per laser pulse and then was converted into a two arm laser system with 10 J energy in each arm. One beam with 10 J/300 - 800 ps was focused in 80-100 μm diameter (focussed intensity ~ 10^{14} W/cm^2) on a gold target to generate gold x-rays. Other laser beam interacts with the target under investigation for the dynamic studies. We have introduced various objects to be radiographed and also Al foil for the x-ray imaging and absorption spectroscopy. The time integrated absolute x-ray photon flux from the gold plasma on the CCD detector was calculated by taking account of filter transmission (in our case 3 numbers of B 10 filter, transmission > 95% for x-ray radiation > 1 keV) and the crystal reflection (20 -30 % for the alkalimetal bi-pthalate crystal @ λ = 8.3 Å) [11]. The x-ray flux from the

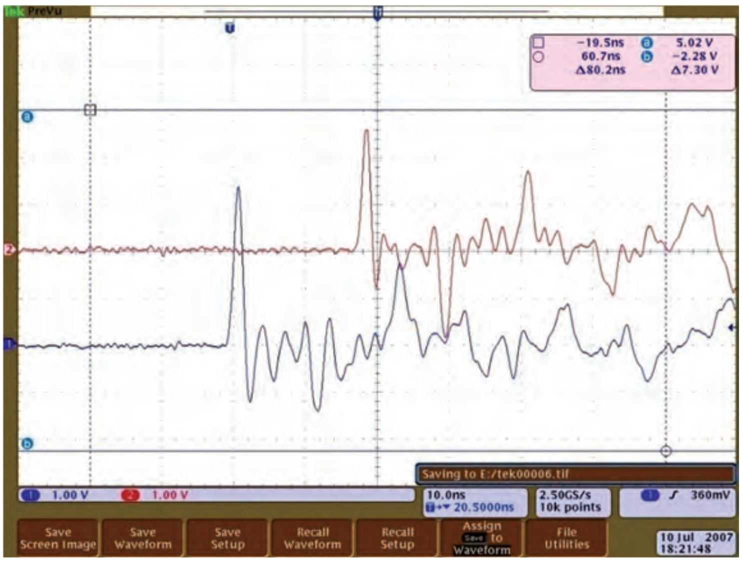

Fig. 3: X-ray probe pulse measured using x-ray bi-planar photodiode with 150 ps rise time and 500 MHz (2.5 GS /s) oscilloscope. The pulse duration measured was 1.0 ns x-ray pulse generated with laser of pulse duration 500 ps in the spectral range (0.7 – 1.56 keV) and (> 0.9 keV) using 5 μm Al and B 10 filter respectively. The oscilloscope was set to 10 ns time scale.

gold plasma measured at the detector was 2 μJ/Sr and total x-ray flux estimated was approximately 8.44 μJ/Sr.

The object to be radiographed was inserted in between source and manochromator crystal as shown in figure 1. The radiography of various targets of different thicknesses (t) were done. Depending on the target thickness, the magnification of the backlighter was fixed by chaniging the distance between x-ray source to object and object to detector. The object thickness t sets a restriction on the source to object distance (l) is for the maximum useful detector diameter ($2x_0$) given as $l \geq t(L_1)/x_0$ to record the whole object with a suitable source size. Thicker the object size, larger will be the source to object distance and hence lower the magnification. The minimum source to object distance is a few mm.

The magnification of the diagnostics could be adjusted from 4 to 60 by changing the distances between x-ray source to target and target to detector (which is required to record an event (laser shocked target) of size approximately 150 to 200 μm). The x-ray radiograph of S. S. wire, S. S. mesh and 20 μm Al foil have been recorded. Figure 4a shows the optical microscope image of the 400 μm thick S S wire whose x-ray radiography record is shown in figure 4b. The magnification of the system in this case was approximately x16. The intensity plot of the x-ray radiation along the X-axis is shown in figure 4c. From figure 4c, it can be seen that the radiograph has very high signal to noise ratio. The signal to noise ratio of thie spectrograph is 240 : 1. Such a pulse x-ray radiograph will provide very high resolution during the dynamic imaging of a fast moving object. A high resolution optical microscope image and x-ray radiograph of mesh with wire diameter about 86 – 90 μm and spacing between two wire of about 340 – 350 μm as measured is shown in figure 5 a & b. The x-ray intensity plot of the x-ray radiation along the X-axis and Y-axis are shown in figure 5c and d. The magnification of the radigraph was approximately 33X. Figure 6a shows the photograph of the target holder mounted with Al foil. Also in this figure the direction of laser pulse and the x-ray pulse are shown by arrows in white and red colours respectively. Figure 6b shows the x-ray radiograph of the 20 μm thick Al foil mounted on step holder marked in yellow circle. Figure 6c shows trhe intensity plot of the x-ray radiograph of 20 μm thick Al foil. The magnification of the system was set approximately x60 due to smaller size of the foil.

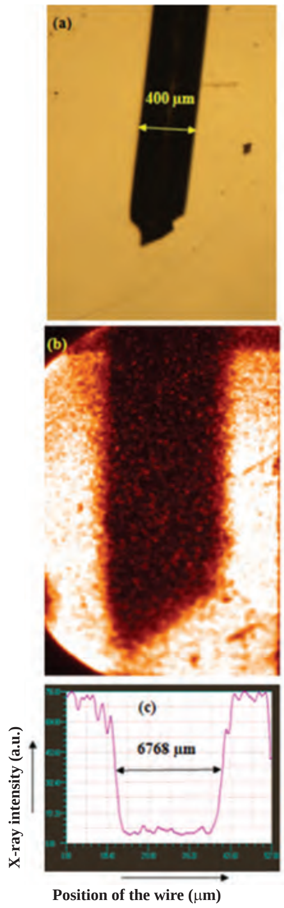

Fig. 4. (a) Photograph of 400 μm diameter Stainless Steel wire measured with high resolution optical microscope. (b) Pulsed X-ray radiography of wire using gold plasma as x-rays source in the spectral range 7.9 – 9.4 Å. (c) Transmitted intensity plot of the radiographed image of the S. S. wire. The intensity plot shows that the wire thickness from the radiographed image is 6769 μm indicating the magnification of the system is approximately 16 X.

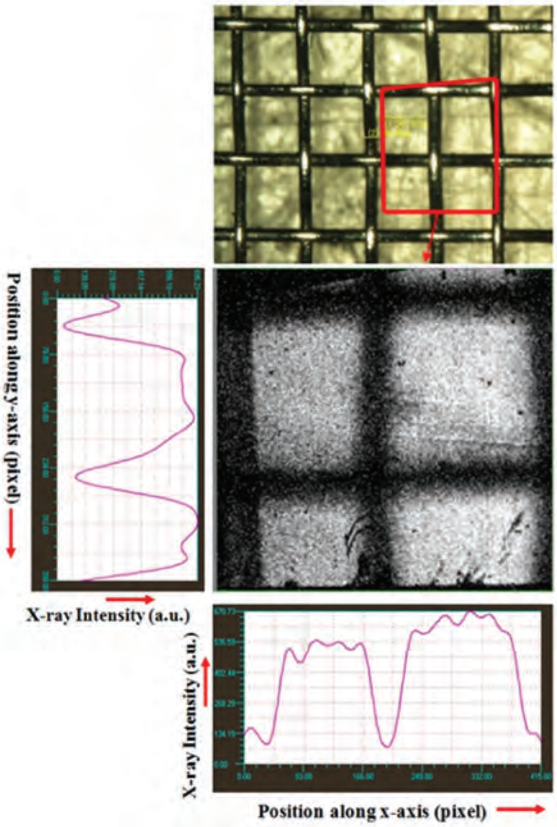

Fig. 5: (a) Image of S. S Mesh of diameter 80 μm and spacing approx 400 μm recorded with high resolution microscope . (b) Pulsed X-ray radiograph of the S. S. Mesh using laser plasma produced x-ray source in the spectral range 7.9 – 9.4 Å and pulse duration approximately ~1.0 ns. Plot (c) & (d) show the intensity distributions of x-ray radiation along the x-axis and y-axis with respect to the spatial position. The magnification of radiograph is approximately 33X. The detection system used in this measurement is x-ray CCD camera.

Absorption spectroscopy:

The online point projeection radiography / point projection absorption technique was developed to characterize the number of different backlighters covering the spectral range of interest to study the basic hydrodynamic behaviour of the package (multilayered targets) and identify the heated material absorption features seen in the radiograph. Absoprtion spectroscopy can be used to obtain important information of atomic structure, such as photoionization cross section and double excited states. In the research of x-ray laser produced

Fig. 6: (a) Photograph of the Al foil mounted on target holder. (b) X-ray radiograph of the circled portion of the Al foil with target holder and (c) intensity plot of x-ray imaged 20 μm thick Aluminum foil of width 2 mm with respect to position. The magnification of the system was approximately 60.

parameter which can't be directly measured by emission spectroscopy but can be measured by absorption spectroscopy.

The opacity of the discrete transition can be written as [12]

$$\mu(\lambda) = \frac{\pi e^2}{mc^2} f_{ik} \lambda^2 N_i L \phi(\lambda) \quad ...(4)$$

where m is the mass of electron,c is the velocity of light, e is the charge of electron, f_{ik} is the absorption oscillator strength, $\phi(\lambda)$ is the normilised line profile, N_i is the ion density on the ith level of transition and the integral is taken along the equivalent absorbing plasma coloumn L. Opacity of the plasma at a particular wavelength can be measured by measuring the transmitted intensity [I(λ)] and incident intensity [$I_0(\lambda)$] using point projection set up and the relation $\mu(\lambda) = \ln[I_0(\lambda)/I(\lambda)]$. Here, in [I(λ)] the contribution of stray light and self emission from the absorbing plasma were subtracted. Once the value of $\mu(\lambda)$ is known one can estimate density (N_i) of the expanded plasma using equation (4) at a particular time and space.

In the absorption spectroscopy set up, first we replaced the gold target with the Alunimium (Al) target. The emission spectroscopy of the Al plasma was recorded and lebelled as shown in figure 7a. The x-ray lines such as the He_a line (resonance line 1S2P $^1P_1$ – $1S^2$ $^1S_0$), the inter-combination line (IC) (1S2P $^3P_1$ – $1S^2$ $^1S_0$), the di-electronic satellite (DS) ($1S2P^2$ ^2D – $1S^22P$ ^2P) lines and the K_a lines from cold atoms of the Al at the wavelength λ = 7.7575 Å, 7.8069 Å, 7.8471 Å and 8.3476 Å are present in the set spectral range 7.9 to 9.4 Å. Then the gold target was used to generate continuous x-ray spectrum in the same spectral range. A 20 μm thick Al foil was mounted in the path of the x-ray radiation and radiographes as shown in the figure 7b. To record the absorption spectroscopy of the Al plasma, the Al target was irradiated with the second laser beam. The delay between the x-ray probe pulse and main pulse on the object (Al) was achieved by providing an optical delay between two laser beams. The delay between the x-ray probe pulse and main laser pulse on target could be varried from 1 ns to 10 ns with temporal resolution of a few tens of pico second. In this case, the delay between the the x-ray probe pulse and main laser pulse on target was set to 3 ns. In figure 7c dark lines are shown as the absorption of continuous x-ray source at the wavelength close to the He_α, IC and DS lines. The low intensity of the absorption lines and the distance from the Al target to the absorption lines can be explained as follows. The plasma expands opposite to the laser beam direction. After 3 ns, the ions with the energy levels $1S^2$ $^1S_{0,}$ $1S^2$ $^1S_{0,}$ $1S^22P$ ^2P may have expanded to a certain distance from the Al target initial position and rarified before being exposed to the x-ray source. From the emission spectroscopy it can be seen that transition probability (oscillator strength) for the transition 1S2P $^1P_1$ – $1S^2$ $^1S_0$, 1S2P $^3P_1$ – $1S^2$ $^1S_0$, and $1S2P^2$ ^2D – $1S^22P$ ^2P are high and hence in the case of abosrption we can see absorption lines correcsponding to these line i.e., $1S^2$ $^1S_0$ - 1S2P $^1P_{1,}$ $1S^2$ $^1S_0$ - 1S2P $^3P_1$, and $1S^22P$ ^2P-$1S2P^2$ ^2D. This is the first observation made in our set up. Further work will be done with higher energy and better resolution.

Conclusion

A pulsed quasi-monochromatic x-ray radiograph of M- band spectrum of gold plasma has been developed. The x-ray spectral range of the radiograph is set to 7.9 – 9.4 Å (1.32 - 1.57 keV) . The spectral width of the quasi monochromatic source was set to 1.5 Å (ΔE = 0.25 keV). The spectral resolution of the system measured using copper plasma was 30 mÅ. The x-ray pulse duration was measured using fast x-ray bi-planar photodiodes and 500 MHz scope as 1.0 ns for the laser pulse duration of 500 ps which is higher than earlier reported pulse duration measured with x-ray streak camera. The spatial resolution of the backlighter is approximately 50 μm depending on the laser focal spot size. The magnification could be varied from

4 to 60. The x-ray radiography of the following have been presented in this paper: (1) S. S. mesh of wire diameter of 86-90 μm and separated by a distance of 342 μm, (2) S. S. wire of diameter of 400 μm and (3) 20 μm thick, 2 μm wide Aluminium foil. Absorption spectroscopy of the Al plasma has been measured using gold quasi-monochromatic x-ray pulse. Absorption lines corresponding to $1S^2\ ^1S_0$ - $1S2P\ ^1P_1$, $1S^2\ ^1S_0$ - $1S2P\ ^3P_1$, and $1S^22P\ ^2P$-$1S2P^2\ ^2D$ transitions have been recorded.

Acknowledgement

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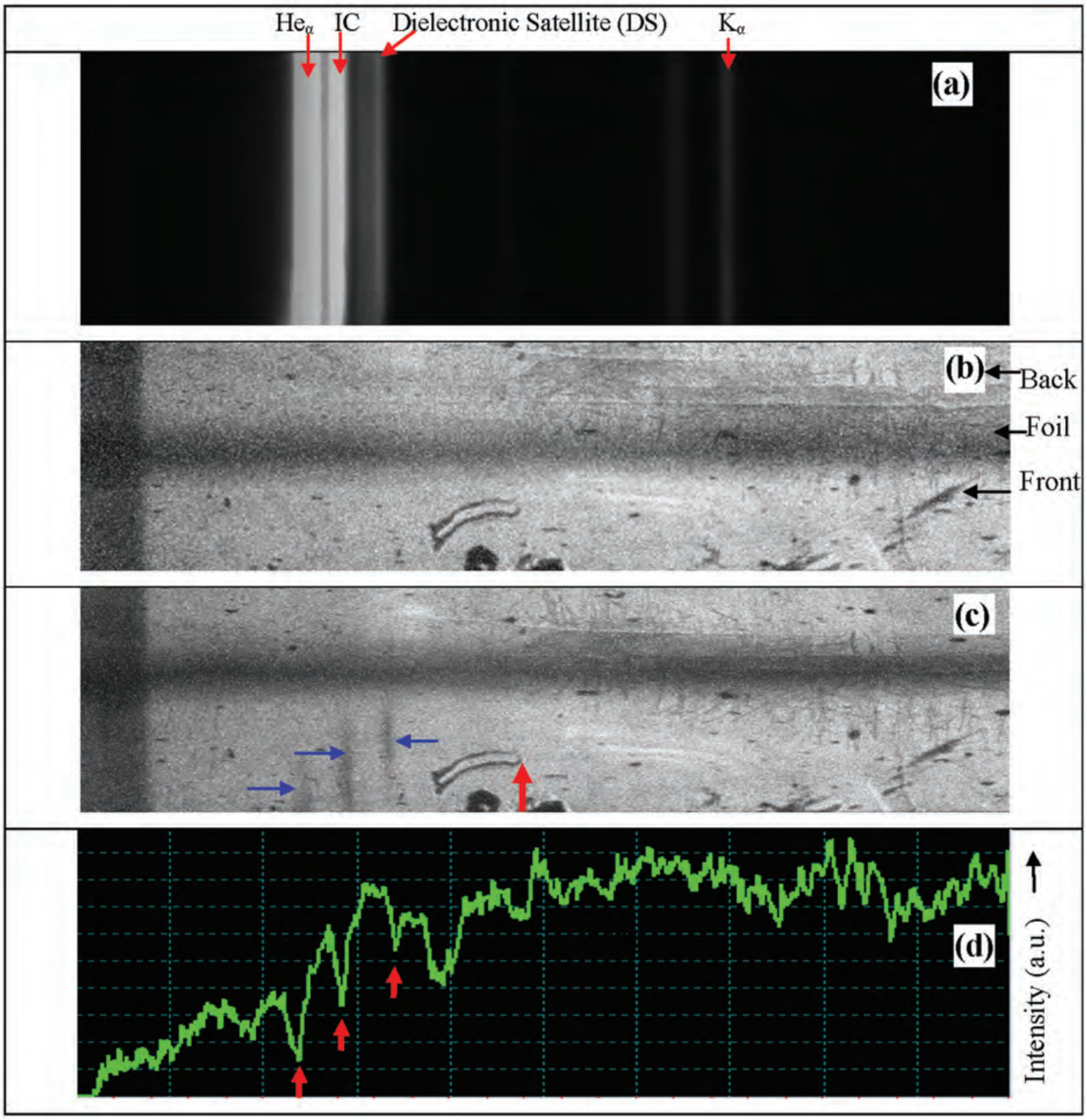

Figure7 (a). Emission spectrum of Al plasma recorded with TAP crystal spectrometer. (b) Radiography of the 20 μm Al foil using M band spectrum of gold plasma in the spectral range 7.6 to 9.4 Å with the blocked laser beam on target (c) absorption spectrum of the Al plasma exposed to the x-rays of the M band spectrum of gold plasma and (d) Intensity plot of the x-rays transmitted through Al plasma. Emission line of Heα, IC and DS are closely matched with the absorption spectrum shown with blue arrows. Al plasma was irradiated 3 ns prior to the generation of x-ray pulse from the gold plasma.

the smooth operation of the laser system and for the electronics support.

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Management of Intermediate Level Radioactive Liquid Waste (ILW) at WIP, Trombay

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Abstract

Intermediate Level Radioactive Liquid Waste (ILW) generated during reprocessing of spent fuel is a legacy waste and is being stored in underground tanks. The ILW is alkaline in nature and more than 99% of radioactivity is contributed by ^{137}Cs. This ILW is treated based on Cs-selective ion exchange process employing indigenously developed Resorcinol Formaldehyde (RF) Resin. A facility has been established at Trombay for treatment of this legacy ILW. The process partitions the ILW into two streams, viz., a high-level cesium-rich eluate stream, from resin regeneration process, and low level effluent stream. The eluate is immobilized in glass matrix. The low level effluent is pumped to Effluent Treatment Plant (ETP). Substantial decontamination and volume reduction factors are obtained by this process. A permanent facility is now commissioned at Trombay and a campaign for treatment of legacy ILW of about 750 m^3 has been successfully completed.

Introduction

In our closed nuclear fuel cycle, spent fuel rods are reprocessed to recover valuable materials. The reprocessing plant generates various kinds of radioactive liquid wastes. These wastes are conventionally termed as High Level Waste (HLW), Intermediate Level Waste (ILW), Low Level Waste (LLW) and Organic Liquid Waste (OLW). At Trombay, the management of HLW and ILW is undertaken by Waste Immobilization Plant (WIP). The Intermediate Level Waste, stored at reprocessing plant, originates from two sources, viz., chemical decladding of spent fuel and from Waste Evaporation Cycle (Fig 1).

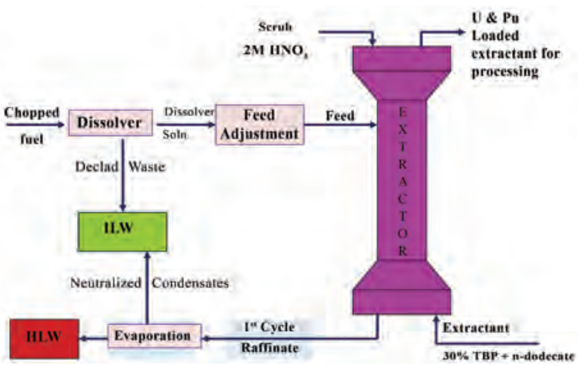

Fig. 1 : Sources of ILW

This waste is primarily alkaline in nature with high total dissolved solids content. More than 99% of radioactivity is contributed by ^{137}Cs. The remaining 1% comprises mainly of ^{106}Ru, ^{125}Sb, ^{90}Sr and traces of ^{144}Ce and ^{99}Tc. Table 1 gives the waste characteristics of ILW stored in Tk4.

Table 1 : Feed and Effluent Characteristics

Param-eter	ILW	Effluent
pH	11-12	8-10
Specific Activity in mCi/l		
Gross β	3.4 - 4.5	$1 \times 10^{-2} - 3 \times 10^{-2}$
137Cs	2.98 - 3.95	$1 \times 10^{-3} - 4 \times 10^{-3}$
90Sr	$1.3 \times 10^{-2} - 1.5 \times 10^{-2}$	$6 \times 10^{-3} - 7 \times 10^{-3}$
125Sb	$1.6 \times 10^{-3} - 9.89 \times 10^{-3}$	$2 \times 10^{-3} - 5 \times 10^{-3}$
106Ru	$1.5 \times 10^{-3} - 9.89 \times 10^{-3}$	$2 \times 10^{-3} - 7 \times 10^{-3}$

The earlier processes considered for ILW treatment were bituminization and cementation. This would have led to unacceptable consumption of limited Near Surface Disposal Facility (NSDF) space considering the huge inventory of legacy waste. In contrast, the ion exchange process offers a simple way for treating this ILW primarily with high decontamination factor (DF) and volume reduction factor (VRF). Resorcinol Formaldehyde (RF) resin is known to be selective to Cs under these conditions, even in presence of high concentration of Na ions. In this process, ILW is partitioned into two streams, a Cs-rich eluate stream which is high level in nature and a low level ion exchange effluent which qualifies for transfer to Effluent Treatment Plant (ETP). The process was deployed at plant-scale initially at WIP, Tarapur and later during Campaign TRIX (Tank Remediation by Ion exchange) at Trombay. It is presently employed at WIP Trombay and WIP Kalpakkam for ILW treatment. The process flowsheet followed for campaign of ILW treatment is shown in Fig. 3.

Process and technology development

The RF resin was synthesized indigenously at BARC[1] (Tarapur and Trombay) in early 80s. The resin was investigated and tested at laboratory scale. These studies led to development of a resin with k_d in excess of 7000 ml/g and an optimum column flow rate of 3-4 bed volumes/h. After extensive testing[2], it was deployed for ILW treatment at IL cell in WIP, Tarapur. The process was scaled up to 50 l column at Campaign TRIX in late 90s. Fig. 2 shows image of the TRIX system. The unit was provided with self-shielded columns, secondary containment, ventilation and remote handling system. Based on successful experience with 50 l column, the unit was upgraded to handle 100 l column in second phase of Campaign TRIX (2005-2006) at Trombay[3]. The performance of the system is given in Table 2. The unit was refurbished in 2008 and is presently deployed at WIP, Tarapur.

Fig. 2 : TRIX Unit

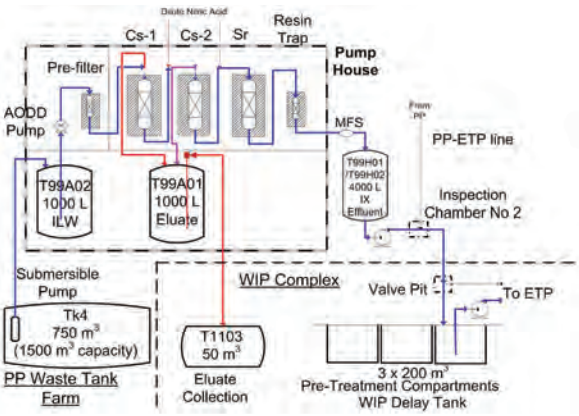

Fig. 3 : Process Flowsheet for ILW treatment by ion exchange

Table 2 : Campaign TRIX performance

Phase	I	II
Year	2000-2001	2005-2006
Cs DF	> 10,000	5,000 – 30,000
VRF	12	26
Column life (cycles)	12	11

Based on the above operational experience, Pump House Ion Exchange (PHIX) facility was designed for column of 100 l. As an improvement over previous generation, the facility was extensively automated for remote process and column handling operations. Through a PLC-based system, the facility is controlled from a centralized control room. The reliability of the process and technology is vouched for by the fact that the same flowsheet is adopted at all the three BARC sites.

Pump House Ion Exchange (PHIX) Facility at Trombay

The Pump House building of WIP, Trombay was originally designed for transfer of HLW and ILW to WIP. The facility has three hot cells and is provided with ventilation and offgas systems. The ion exchange system was retrofitted in these cells to optimally utilize the available infrastructure thus significantly cutting down the construction costs.

The facility is established at Pump House of WIP, Trombay with an objective to serve as a dedicated treatment facility for Intermediate Level Waste. The columns and the resin trap are located inside a MS shielded cubicle with material handling arrangements. Fig. 4 shows the image of the MS cubicle with self-shielded columns. A camera is also provided within this cubicle to visually confirm the status of flanges during operations. Air operated valves (AOVs) and air operated double diaphragm pump (AODDP) are housed in SS-lined cell with leak detection facility. The use of AOVs and AODDP facilitates remote operations of the system. Fig. 5 shows the pump, AOVs and associated piping.

Fig. 4 : Self-shielded ion exchange columns in MS cubicle

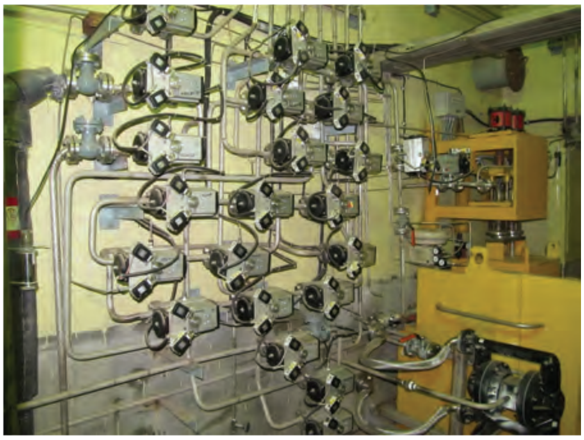

Fig. 5 : AODD pump, AOVs and associated piping in a hot cell.

The control of the operation and monitoring of the parameters is carried out, as mentioned, from a centralized control room through a PLC based control panel. There are closed/open loop controls with interlocks for process parameter control. The PLC also provides graphics with static and dynamic display of process parameters for operation status of control elements. The treated effluent is stored in tanks outside Pump House building and is connected to Delay Tank of WIP. After repeated loading-regeneration cycles, the column performance degrades and is transferred to NSDF for disposal. Prior to its disposal, exhaustive elution is carried out to remove sorbed Cs. Remote material handling is facilitated by use of pneumatically operated flange actuation mechanism, use of trolley-conveyors and motorized hoist.

Operating Experience

After the installation and testing of the ion exchange system, the resin was made functional by converting it to Na-form. The facility was put into service on 3rd July 2012. ILW was pumped from Tk4 using a submersible pump to the Feed Tank at Pump House at a rate of 17-20 lpm. The ILW was metered through the ion exchange columns at a rate of 3-4 bed volumes/hr. An air operated double diaphragm pump (AODDP) was used for this purpose. The AODDP gave inherent advantages of being remotely operable, self-priming and safe under closed-discharge conditions. The effluent from the columns was regularly sampled. Average gross beta activity of the effluent during this campaign was 1.5×10^{-2} mCi/l of which ^{137}Cs contributed $1\text{-}3 \times 10^{-3}$ mCi/l. The major component of radioactivity of the effluent was ^{106}Ru and ^{125}Sb. The effluents were pumped to ETP via WIP Delay Tank. This waste was treated as a regular waste stream at ETP. Regular samples were taken to assess the identify breakthrough of the columns. A gamma monitor on effluent line also provided additional indication for assessing column breakthrough. A typical loading curve is shown in Fig. 6. After completion

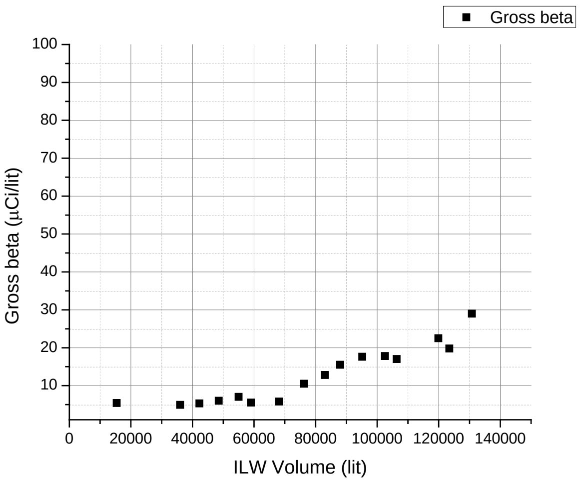

Fig. 6 : Typical Loading Curve

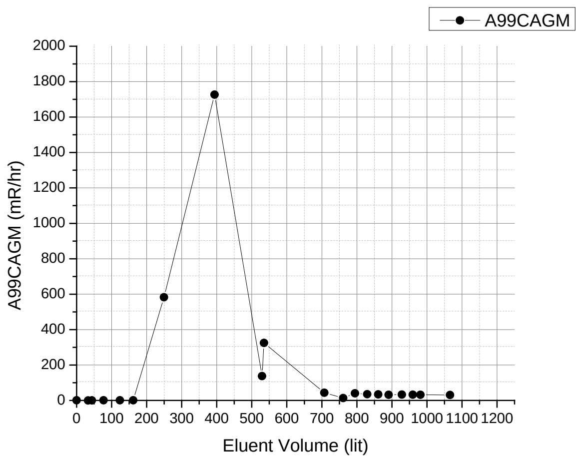

Fig. 7 : Typical Elution Curve

of loading cycle, the columns were subjected to elution with dilute nitric acid. Acid concentration was maintained between 0.5-0.75 M. The extent of elution was ascertained by mean of a gamma monitor stationed on the eluate line. The typical elution curve is shown in figure 7. Approximately 7,67,500 l of ILW was processed in nine loading-regeneration cycles over a period of 7 months. The volume of eluate generated is 12,000 l. The same was pumped to WIP for vitrification. After 6-7 loading-regeneration cycles the resin performance degraded rapidly necessitating change of resin. During the operations, one RF column was replaced. The spent columns were thoroughly eluted before their transport to RSMS for disposal.

An average processing rate of 100-120 m^3 per month is thus achieved by the facility. The major maintenance work in the campaign involved replacement of flexible SS hose, primarily due to pulsating action of the pump. Fining of the resins was also observed in the campaign. Overall volume reduction factor of 64 was obtained with respect to eluate volume. This would further be enhanced if only vitrified waste product volume is taken into account. Cs decontamination factor was in the range of 1000-3000 and gross beta DF was about 266.

Future Works:

Based on the operational feedback during Tk4 operations, detailing of additional improvements is being done. During the operations, it has been observed that the residual beta activity in effluent is primarily due to ^{106}Ru and ^{125}Sb. To address these issues, two new processes are being evaluated viz a Sb removal process based on adsorption on HZO-impregnated on PUF and separation of Ru by ozone oxidation process. It is planned to take up another campaign to treat declad waste stored in Tk3.

Conclusion:

An permanent facility has been established at Pump House building of WIP Trombay for treatment of legacy ILW stored at reprocessing plant. The robustness and reliability of the process and its systems has been demonstrated. A high plant throughput, more than 100 m^3 per month, is achievable in this facility. The entire inventory of ILW at Trombay can now be processed. New processes are also under development for effective management of effluents.

Acknowledgements

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Development of Secondary Sensor System based on Eddy Current Technology for In-line Inspection Tool

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Atomic Fuels Division

Abstract

BARC through MoU's with Indian Oil Corporation Limited (IOCL), have developed several in-line-inspection (ILI) tools for non-destructive evaluation (NDE) of cross country petroleum pipelines. These tools, called 'Instrumented pipeline inspection gauge' (IPIG) have the ability to detect, characterize and geographically localize metal loss (corrosion or gauging) defects on or within the buried pipelines as-well-as major pipe features (welds, flange, support, valve etc). Pipeline operators are required to periodically get their pipelines inspected by IPIGs, thereby ensuring its heath through corrective measures in case possibilities of pipe leak arise. To keep pace with the ever advancing ILI technology available globally to cater for the stringent inspection specifications laid down by apex agencies like Pipeline Operator Forum (POF), there is an urgent need for undertaking new indigenous technology developments in the areas of sensing and inspection capability of ILI tools. Existing technology developed and delivered by BARC has limited ability to distinguish a metal loss defect on the exterior pipe-wall to that on the interior, particularly if it the defect is shallow and small in surface extent. This distinction is of paramount importance as regard to the preventive measures to be taken up by the pipeline operators to circumvent corrosion growth within or on the pipe surface. With this in mind, secondary sensors based on eddy current technology is developed by BARC to replace the earlier, less efficient sensors based on remnant magnetism. The sensor carriage has also been re-engineered to a novel parallelogram mechanism to ensure minimum effects of sensor lift-offs. The technologies reported in the paper have been integrated with the existing ILI tools (IPIGs) with enhanced inspection capability for different sizes of oil and gas pipelines.

Introduction

Over the years, BARC has developed and delivered several Instrumented pipeline inspection gauges (IPIGs) for inspection of pipelines of various sizes (12", 14", 18" and 24" NB) while constantly upgrading and modifying its design to meet the latest standards and advancements in in-line inspection (ILI) technology. The tools were built from the basics and designs were validated through analysis and in-house experimentation. Performance of the instrument with respect to its repeatability, functioning and accuracy in detection and characterization of defects was established through several field trials in actual pipelines and subsequent dig site verifications. Tools have already been used for inspection of 2500 km length of pipelines and preventive maintenance measures were taken by pipeline operators based on the report indicating severe defects and trend of corrosion growth. Apart from metal losses, the tools have detected major pilferages on several occasions. The 12" pigging technology has been transferred to ECIL, Hyderabad for manufacturing commercial version of the tools based on BARC design **(Bhattacharya S et al, 1999, Mukhopadhyay S. et al, 2012)**.

An IPIG has two different sets of sensors for metal loss detection and characterization, viz. primary and secondary (refer **Fig. 1**). These sensors are made to touch the pipe surface from inside by specially designed spring loaded sensor carriages. Signal recorded by the primary sensors (Hall-effect sensors) is used for detection and characterization (i.e. length, width and percentage wall-loss (%WL)) of corrosion defects **(Saha S. et al, 2010)** without distinguishing if it is on the internal or external surface of the pipe. The secondary sensors play the crucial role of the arbitrator as they detect only internal defects. Pipeline operators monitor the IPIG data to examine the growth of corrosion either on or within the pipelines for employing appropriate corrective measures. For example if corrosion growth is on the external surface of the pipe they may use better coating material or strengthen Cathodic Protection. On the other hand if the growth is on the internal surface they may employ necessary additives to the petroleum product to restrain biological corrosion.

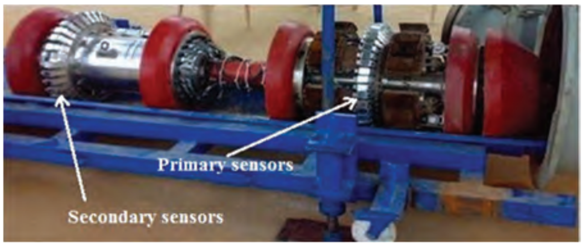


Fig. 1: Sensor layout in IPIG

The secondary sensors based on eddy current technology works on the principle of electromagnetic induction. Eddy current based sensors for non-destructive evaluation (NDE) find application in various critical material inspections, from aviation sector to nuclear power plants **(Palanisamy R. et al, 1983)**. Its efficiency in detecting near wall cracks and material deformity has been established over time. From an electrical point of view, eddy current based sensors for pigging application are required to be in contact with the material surface at all times for proper inspection. To ensure minimal lift off and orientation of the sensors parallel to the axis of the pipe at all working conditions, the sensor carriages are re-engineered to have a novel parallelogram design. This ensures that at all conditions, the top of the sensor carriage remains parallel to the pipe axis thus minimizing lift-off and vibration induced noise due to IPIG movement. As eddy current strength reduces exponentially within metal, the conventional wear plates (thin metal plates covering the sensors) were also re-designed to reduce signal loss.

The paper is organized as follows. Section 2 gives a theoretical overview of eddy current technology. Section 3 discusses the development of eddy current sensors along with its associated electronics and mechanical technologies, wear/endurance evaluation of sensor carriages on indigenously developed in-house test facilities. Section 4 shows the results obtained from a trial IPIG run at test facility, IOCL R&D, Faridabad. Section 5 concludes the work highlighting the achievements and future scope of sensor development in pigging technology.

Eddy current technology

Eddy current testing is based on the use of a wire coil probe (sensor), for inducing electrical current into the metallic surface under inspection. The coil is energized with an alternating current at a particular frequency. When placed in proximity to a metallic surface, a voltage is induced in it due to inductive coupling leading to current (eddy) flow. This current is strongest at the surface and penetrates to a very short distance in the material, as indicated in equation (1).

$$J_x = J_o e^{-\frac{x}{\Delta}} \quad (1)$$

Where J_x is the eddy current density at depth x from the surface, J_o is the eddy current density at the surface, and is the standard depth of penetration. This current generates its own magnetic field opposing the one provided by the probe (Lenz's law). As carbon steel (pipe material) is ferromagnetic, its magnetic permeability concentrates the coil's magnetic field. As a result there is a change in overall magnetic field induced by the coil thereby altering the inductance of the probe. This translates to a change in current flow through it.

Also, as the eddy current dissipates energy, resistance of the probe increases. Thus, the equivalent impedance of the eddy current probe changes when it is brought close to a conducting surface. In presence of cracks and surface defects on the conducting surface, the eddy currents will face sufficient resistance in their path which will be reflected in the opposing magnetic field, thereby in the equivalent impedance of the probe coil. Thus, change in impedance of the probe coil indicates the presence of irregularities on regular metal surface.

The equivalent impedance of the probe is also affected by the way in which the probe is coupled to the test piece. A major factor that influences this coupling is the spacing between the coil and test piece surface. When the coil is close to the test piece, the coupling is strong and as the coil is moved farther away, the coupling is reduced. Thus, there is a significant effect of this spacing (or probe liftoff) on the equivalent probe impedance and in turn on the response of the probe. For corrosion depth measurement, it is this liftoff or displacement mode that is of interest. Because the corrosion areas to be measured are generally large compared to the probe size, the corrosion pits appear more as a change in liftoff rather than a localized change in conductivity. **(Crouch A. E. et al, 2002).** In either case, there is a significant change in the equivalent impedance of the sensor that can be monitored to ascertain the presence of a defect.

Sensor development

Eddy current sensor and electronics development

The sensor coil, made of SS wires wound on ferrite E cores was designed at QAD, BARC and tested for detection of flaws in 6.25 mm thick carbon steel plates. Ferrite core was used to enhance the sensitivity of the test coil. Number of turns and gauge of the wire used for winding the coil were optimized to get the best Q-factor at 5 kHz frequency. Each sensor module (prototype sensor) contains two such coils placed one behind the other along the direction of PIG movement, with differential electrical connections (**Fig. 2**). The sensor was tested on two defects (with length, width, %WL of 24mm, 18 mm, 66% & 36 mm, 24 mm, 35%), made on two separate carbon steel plates. In both the plates, strong signals were observed when the sensor was moved over the defects. When the sensor was moved on the opposite surfaces, which do not contain any defect, showed no significant rise of the signal value. This experiment was necessary to ascertain the ability of the sensor to distinguish between near-wall and far-wall defects. These experiments were also carried out by placing 5 mm thick folded paper between the probe and the plate to simulate the gap between probe and pipe in actual condition. The gap between the plate and the probe reduced the amplitude of the signal but still the defects were detected.

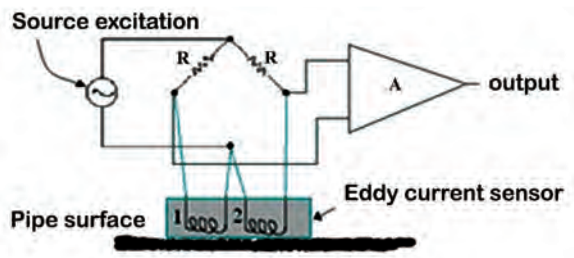


Fig. 2: Prototype circuit for eddy current based sensors

Electrically, the two coils in the sensor module form two arms of a 4 limb 'bridge' in which the other arms comprise of two equal value resistors. In the absence of metal loss defects/ cracks, both the coils in the sensor would perceive the pipe surface identically, thereby altering each coil's impedance by an equal factor. Under this condition, the bridge remains balanced. However, in presence of an anomaly in the pipe surface, each coil passing over it will independently change its impedance with a magnitude different from that of the other coil, leading to an unbalanced bridge. The imbalance in the bridge indicates presence of a near-wall defect.

The bridge output is amplified, rectified and passed through an envelope detector. The resultant output shows a steady dc signal over a normal pipe surface and an ac signal superimposed over it in presence of a metal loss defect. The test setup comprising of prototype sensor and its associated signal conditioning electronics is shown in **Fig. 3**.

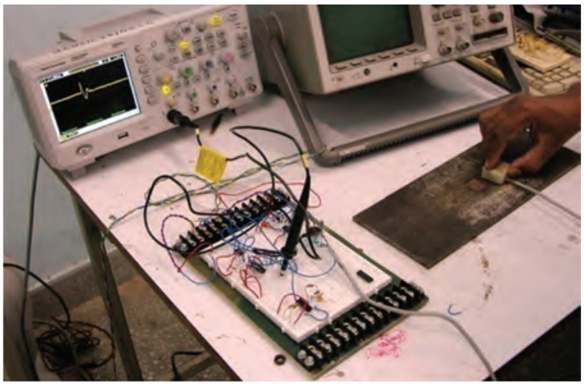


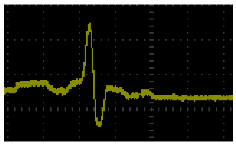
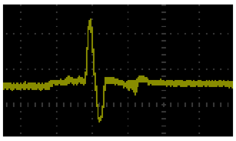
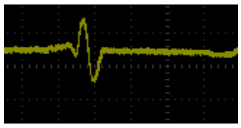
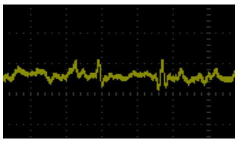
Fig. 3: Test setup of prototype eddy current based sensor and its associated electronics

The setup was thereafter tested for metal loss defects of various %WL. This is done by carving out defects on plates of standard carbon-steel metal, the same used for pipeline manufacture. In each test case, the reverse of the plate is also scanned with the prototype sensor. This is done to ensure that external defects show no signal pickup by the sensor.

The following table (Table 1) gives a graphical comparison of the signals obtained by the prototype sensor on defects of varying percentage WL. The signals are shown in a scale of 200mV/div and 1 sec/div along y and x axis respectively.

No sensor pick up for external defects up to 69%WL and significant sensor signal for internal defects of 15%WL have been observed. With the prototype sensor providing successful detection, the signal conditioning circuit is re-engineered to fit to an existing 12" IPIG for trial runs. A signal conditioning card dedicated for 20 different eddy current based sensors is designed, and added to the existing PIG module. Each sensor output signal is sampled by an ADC at 400Hz and stored in the data acquisition system.

Table 1: Signals obtained by prototype sensors

Signal snapshot	%age WL	Peak to peak signal (mV)
	58.83	700
	42.85	700
	15	400
	69 (external to the metal plate)	150 (noisy)

Sensor carriage

Sensor performance largely depends on the design of mechanical carriage on which it is mounted. A new parallelogram design of sensor carriage has been made as shown in **Fig. 4** such that sensors remain parallel to the pipe surface.

The design ensures that sensor capsule should remain in contact with pipe wall and should be parallel to the tool/pipe axis at all time during the entire inspection run. Criticality in the design includes the integrity of the module for a travel of approximately 250 km of run in a rough terrain of pipeline with bends, variation in pipe bore, inner wall irregularities like corrosion patches, gouges etc. Prevention of wear and abrasion of the sensor top surface is very critical as considerable wear will change not only the sensor lift off but will also impair the integrity of the entire module.

Design helps the sensor module to maintain a near constant lift-off. This improves the signal quality, repeatability, and reliability of the sensor system.

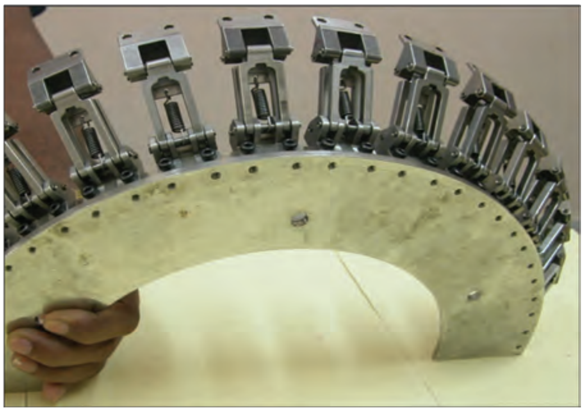


Fig. 4: Sensor Carriage

Wear/endurance test of sensor carriage

The complete sensor module, i.e. the eddy current sensor, embedded in sensor capsule mounted on the sensor carriage was tested in a rotary test rig (**Fig. 5**). The rig (a 28" diameter pipe section of about 0.5 m length) is continuously rotated to create an equivalent 220 km of IPIG run with a speed of 5km/hr, a typical tool speed in the actual pipeline (rig rotation speed: 40rpm). The sensors are kept stationary, firmly mounted on a base plate. Defects are made on the rig surface to test the change in eddy-current signal strength at various stages of this test. Two of the sensors had the hard chrome plated stainless steel wear plates with a rectangular window at the center to let eddy current field pass through. Two other dummy sensors with sensor capsule made of PEEK are tested as an alternate option for stainless steel wear plate.

Fig. 5: Eddy current sensors in rotary test rig setup

The findings of the test are shown in **Fig. 6**. The wear of PEEK sensor capsule is observed to be more than that that of SS. The signal strength didn't change in the entire duration of the test.

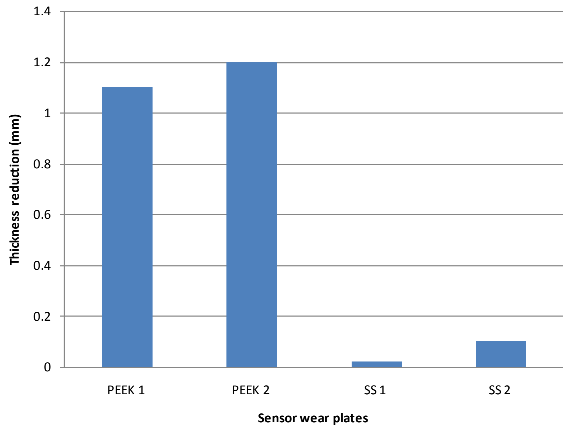


Fig. 6: Performance of wear plates in rotary test rig

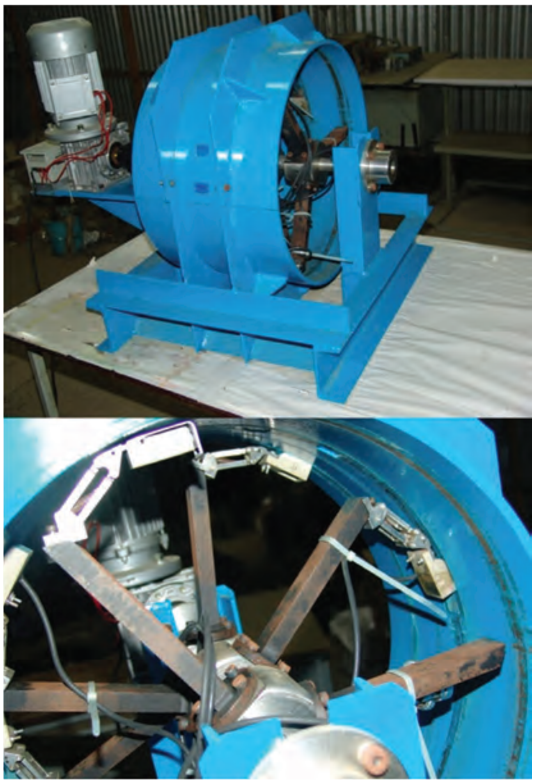


Fig. 7: Dynamic test setup for wear and endurance verification

A new Dynamic test setup (**Fig. 7**) has been commissioned for more realistic wear and endurance verification. Here the sensors rotate inside a stationary pipe section, thereby simulating the movement of sensors with increased surface contact. The setup can at a time test 9 different sensors with parametric variations (friction, speed, sensor wear plate material, sensor lift-off), and is currently being used for wear testing of different wear plates of sensor holding capsules for actual run.

Similar experiments were carried out on the dynamic test setup for wear/endurance evaluation of sensor wear plate made of PEEK and stainless steel. The sensors were rotated to emulate a run of 400 kms. The results obtained showed that hard chrome plated stainless steel wear plate and rollers have undergone negligible amount of wear. Although wearing of PEEK sensor capsule for 400km travel is more compared to stainless steel, it is quite low and acceptable (**Fig. 8**).

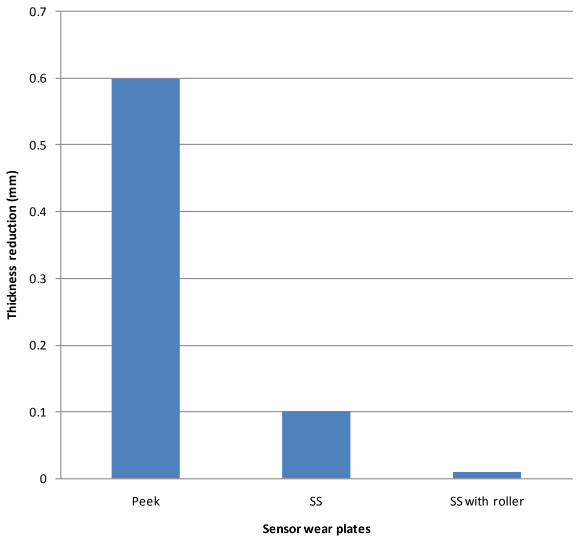


Fig. 8: Performance of wear plates in new Dynamic test setup for wear and endurance verification

Pipeline result

An 18" IPIG fitted with 30 eddy current based secondary sensors was tested in linear pull through rig (LPTR) at IOCL R&D, Faridabad (**Fig. 9**). The pipeline had 10 machine made internal defects with depth varying from 10% wall-loss to 90% wall-loss.

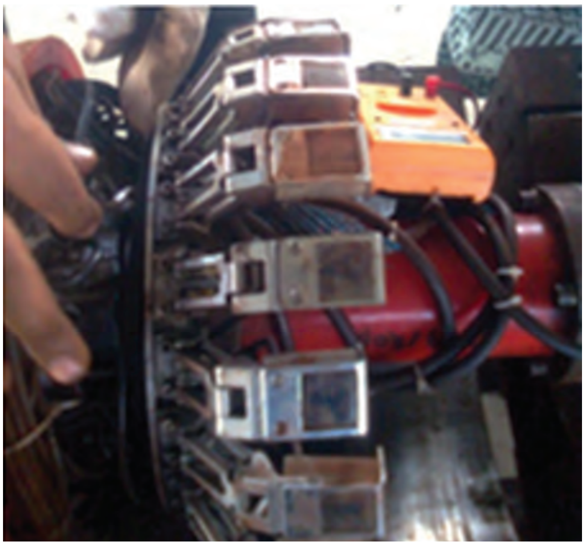


Fig. 9: EC based Sensor Module mounted on IPIG tool

The IPIG is pulled at a speed of 4 km/hr. The sensors distinctly pick 9 defects, along with some pipe features, like weld and flanges. The only defect it had failed to detect had dimensions less than the detection threshold as specified in Pipeline Operator Forum (POF) document. The signals obtained, along with its 2D gray-scale image are shown in **Fig. 10**. The sensors didn't pick up any signal for external

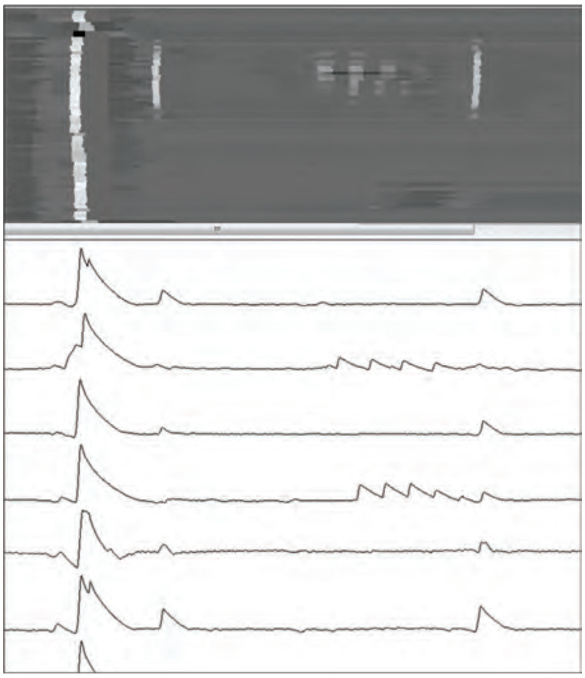


Fig. 10: Eddy current signals in field trial

defects up to 80% wall-loss, thereby successfully distinguishing them from the internal defects.

After successful trials at LPTR, these sensors were tested in commercial pipelines (Mughalsarai-Allahabad, 12" pipe section) and (Jaipur-Rewari, 18" pipe section). The sensors module maintained its mechanical integrity in the entire length of the run (about 194 kms). The signals obtained were found to be satisfactory.

Conclusion

The secondary sensor system with eddy current sensors, its mechanical carriage, cables and associated electronics performed satisfactorily in laboratory, LPTR and thereafter in actual field run. It successfully detected and distinguished all internal defects from the external ones within the specifications stated by POF. Field worthy secondary senor system shall be deployed in all other sizes of IPIG tools.

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DAE BRNS Symposium on Current Trends in Theoretical Chemistry (CTTC-2013): A Report

The DAE BRNS Symposium on Current Trends in Theoretical Chemistry (CTTC-2013) was held at Training School Hostel, Anushaktinagar, BARC, Mumbai, during September 26-28, 2013. This symposium was organized by TheoreticalChemistry Section (TCS), Chemistry Group and was sponsored by the Board of Research in Nuclear Sciences (BRNS). The main objective of this symposium was to discuss the latest advances and future trends on theoretical chemistry and its application to diverse areas of science and engineering. About 450 scientists and students from both India and abroad participated in the symposium.

The Inauguration function started with the welcome of the delegates by Dr. S.K. Ghosh, Chairman, Local Organizing Committee (LOC) and Head, TCS, BARC. Dr. B.N. Jagatap, Chairman, Symposium Organizing Committee and Director, Chemistry Group, in his introductory remarks, spoke about the vibrant field of research in theoretical chemistry encompassing issues that are basic as well as applied. The chief Guest, Dr. R.B. Grover, Director, HBNI and member, AEC, in his address spoke about the importance of theoretical chemistry in the DAE programme and the challenges thrown by the technological regimes to Indiaand the formation of HBNI to sustain the Research and development in Nuclear energy related fields. He also released the Symposium proceedings. The Symposium was inaugurated by Dr. J.P. Mittal, M.N. Saha Distinguished Fellow and former Director, Chemistry Group, BARC. He gave a detailed description about the journey of Theoretical Chemistry in India and its continued uptrendin BARC.He also released two special issues of ISRAPS and SMC bulletin, brought out in this occasion.Dr. A.K. Samanta, Convener, CTTC-2013 proposed vote of thanks.

The current status and new developments as well as frontier applicationsoftheoretical chemistry research were discussed in the scientific programme of the symposium including invited talks and contributed papers in the form of poster

Welcome address by Dr. S.K. Ghosh, Chairman, LOC & Head, TCS, BARC

presentations. A total of fifty five invited talks in eleven sessions by speakers from India as well as abroad and 156 posters in six poster sessions for the contributed papers from the young researcherswere presented. Four foreign nationals (USA, Canada, Sweden, Singapore) attended the Conference anddelivered invited lectures. A special evening lectureon 'Chemistry, Crystallography, and Materials Science' byDr. R. Chidambaram, Principal Scientific Advisor to Government of India and former Chairman, Atomic Energy Commission, was highly stimulating and scientifically enriching.

A special evening lecture by Dr. R. Chidambaram, Principal Scientific Advisor, Government of India and former Chairman, Atomic Energy Commission.

The symposium covered the latest advances and future trends in theoretical chemistry dealing with different topics, which include (i) Recent Advances in the Theoretical Formalisms and Simulation Strategies, (ii) Modeling, Theory, and Simulation Related to New Ligands in Waste Management Research, (iii) Electronic Structure and spectroscopy of Atoms, Molecules, Clusters, Nanomaterials, and Solids, (iv) Theoretical Design of Molecules and Materials Pertaining to Energy Related Research, (v) Theory of Chemical Dynamics, Reactivity, and Catalysis, (vi) Experiment Driven Theoretical Investigations.

An exhibition of various hardwares and softwares for the cutting edge theoretical and computational chemistry research was arranged at the symposium venue. Two talks by the exhibitors (Netweb Technologies and Microoint Computers) on recent technological developments were very useful for scientists working in the field of theoretical chemistry. Eighteen students including two undergraduates below the age of 32 were awarded the 'Best Poster Presentation' awards.

In the concluding session, Dr. M. K. Harbola of IIT, Kanpur presented a brief summary of the symposium. Dr. S.K. Ghosh, chairman, LOC, expressed satisfaction over the growth and quality of theoretical chemistry research and the participation from all over India cutting across disciplines. This was followed by feedback comments from the invited speakers as well as from young student participants. Dr. C.N. Patra, Secretary, CTTC-2013 gave special thanks to all the members of LOC for successfully conducting the Symposium.

Report on DAE-BRNS 2nd National Workshop on Materials Chemistry focused on Catalytic Materials (NWMC-2013: CAT-MAT)

A two-day thematic workshop on catalytic materials was jointly organized by the Chemistry Division, BARC and the Society for Materials Chemistry (SMC), India, at Multipurpose Hall, Training School Hostel, Anushaktinagar, during November 22-23, 2013. It was attended by 150 young researchers working in the areas of chemistry, physics and materials science from BARC as well as other units of DAE, National laboratories and Institutes / Universities. Dr. B.N. Jagatap, Director, Chemistry Group, BARC, welcomed the delegates and wished them stimulating interactions during scientific deliberations. Dr. S.K. Sarkar, President, SMC, briefed about the activities of SMC and highlighted the efforts undergone in organizing the workshop. The workshop was inaugurated by Dr. S. Banerjee, DAE Homi Bhabha Chair and Former Chairman, AEC & Secretary, DAE, Govt. of India. He in his presidential address emphasized the importance of molecular level understanding of catalytic process to develop new catalysts with desired properties to meet the challenges of energy security and clean environment. Prof. M.M. Sharma, Eminent Professor of Eminence, ICT, Mumbai, in his key note address on "An Overview of Catalytic Processes" brought out the important role catalysts have played in shaping up of chemical and pharmaceutical industry globally through green chemistry approach.

NWMC-2013 covered both fundamental and applied aspects of catalysis including heterogeneous, homogeneous, electro and enzyme catalysis related to energy, environment, synthesis, etc. In addition to mechanistic aspects of catalytic process speakers dealt with the novel synthesis strategies to develop new catalysts / photocatalysts for

Release of Proceedings and SMC Bulletin during NWMC-2013: CAT-MAT (L to R) : Dr (Mrs.) S.R. Bharadwaj, Dr. S.K. Sarkar, Prof. M.M. Sharma, Dr. S. Banerjee & Dr. B.N. Jagatap

(a) C-C coupling reactions, (b) pollution abatement, and (c) hydrogen generation via photocatalytic / photoelectrochemical and thermochemical splitting of water. Hydrogen storage potential of modified / functionalized metal organic framework materials was deliberated in detail. In his address while chairing the technical session on "Hydrogen Production and Storage", Prof. J.B. Joshi, DAE Homi Bhabha Chair, projected the economic aspects of hydrogen energy especially from India's perspective. In-house efforts to develop catalysts for DAE's need like hydrogen mitigation, sulfur-iodine thermochemical cycle, uranium (IV) production and denitration at backend of Nuclear Fuel Cycle were systematically brought out during the workshop. Twenty eminent scientists from academic institutions (DAE, National laboratories and Institutes / Universities) and also industry (Monarch Catalysts & Tata Chemicals) shared their experiences with the young participants during seven technical sessions of the workshop. Interactive sessions scheduled after the end of every technical session were effectively utilized by the young researchers for clarification about the subject matter with the speakers. The workshop was concluded by taking the overall impressions from various participants and feedback for improving the future workshop.

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BARC Scientists Honoured

Name of the Scientists	:	Kumud Singh, Javin Itteera, Priti Ukarde, Vikas Teotia, Prashant Kumar, Sanjay Malhotra and Y.K. Taly
Affiliation	:	Control Instrumentation Division, BARC
Name of Award	:	Best Poster Award
Presented at	:	6th DAE-BRNS Indian Particle Accelerator Conference-2013 held at VECC, Kolkata during 19-22 November 2013

Name of the Scientist	:	Dr. Dipak K. Palit
Affiliation	:	Outstanding Scientist & Head, Radiation & Photochemistry Division
Name of Award	:	Elected 'Fellow of the Indian National Science Academy' (FNA)
Presented by	:	Indian National Science Academy (INSA).

Name of the Scientist	:	Dr. Hirendra N. Ghosh
Affiliation	:	Radiation & Photochemistry Division
Name of Award	:	"C.N.R. Rao National Prize for Chemistry Research"
Awarded by	:	Chemical Research Society of India, Bengaluru. Award will be conferred on 7th February, 2014 in 16th CRSI National Symposium in Chemistry (NSC-16) at IIT Mumbai

Name of the Scientist	:	Dr. (Mrs.) Jyotirmayee Mohanty
Affiliation	:	RPCD, BARC
Award	:	"Samanta Chandra Sekhar Award-2011" by the Odisha Bigyan Academy Odisha in recognition of her outstanding contribution towards Science & Technology. The award carries a cash prize of Rs. 50,000/-, a citation, a momento and a medal.
Presented by	:	Chief Minister of Odisha on 19th July 2013 at Bhubaneswar, Odisha.

Name of the Scientist	:	Dr. A.C. Bhasikuttan
Affiliation	:	RPCD, BARC
Award	:	CRSI Bronze Medal for Contributions to Research in Chemistry from Chemical Research Society of India, Bengaluru.
Presented at	:	16th National Symposium in Chemistry (NSC-16) to be held at the Indian Institute of Technology (IIT) Mumbai, during February 6-9, 2014.

Name of the Scientist	:	Dr. Sharmistha Dutta Choudhury
Affiliation	:	RPCD, BARC
Award	:	"SERB Women Excellence Award" in recongnition of her selection as NASI Young Women Scientist of National Academy of Sciences, Allahabad. This award comprises of a research grant of Rs. 5 lakhs per annum and overhead of Rs. 1 lakh per annum, for 3 years.
Awarded by	:	Science & Engineering Research Board (SERB), Department of Science & Technology (DST), India.

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