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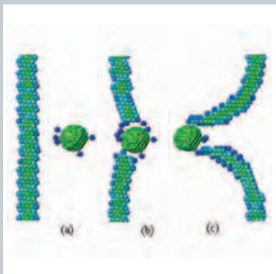

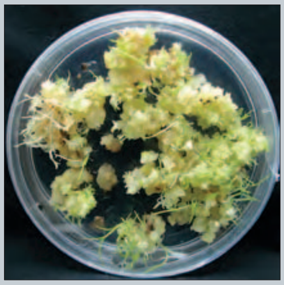

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संस्थापक दिवस - 2010

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

"प्रिय साथियों,

अपने परमप्रिय संस्थापक डॉ. होमी जहांगीर भाभा के 101वें जन्म-दिवस के अवसर पर मैं आप सबको शुभकामनाएं तथा बधाई देता हूँ। जैसीकि परम्परा है, इस दिन हम बीते हुए वर्ष की उपलब्धियों का अवलोकन करते हैं और अपने कार्यकलापों के विभिन्न पहलुओं के माध्यम से राष्ट्र को मजबूती प्रदान करने हेतु अपने आप को पुनःसमर्पित करते हैं। पिछला साल व्यापक क्षेत्र में महत्वपूर्ण उपलब्धियों, कार्यक्रमों में प्रभावशाली प्रगति वाला साल रहा है जिसमें अनेक बड़ी पहलें की गईं। मैं अगले कुछ मिनटों में इन उपलब्धियों का एक संक्षिप्त विवरण प्रस्तुत करना चाहता हूँ।

डॉ. श्रीकुमार बॅनर्जी द्वारा संबोधन

जब हम पिछले वर्ष मिले थे तब से, दो नए नाभिकीय विद्युत रिएक्टरों अर्थात् राजस्थान परमाणु विद्युत परियोजना-इकाई 5 तथा 6 का निर्माण पूरा किया गया और उनका वाणिज्यिक प्रचालन प्रारंभ हुआ। इसके साथ ही देश में प्रचालनरत परमाणु विद्युत रिएक्टरों की कुल संख्या 19 हो गई है जिनकी कुल स्थापित क्षमता 4560 मेगावाट-ई है। फीडरों को एक साथ बदलने के बाद राजस्थान परमाणु बिजलीघर की इकाई 2 को ग्रिड के साथ फिर से सिंक्रोनाइज किया गया। नरोरा परमाणु बिजलीघर की इकाई 2 के शीतलक चैनलों को एक साथ बदलने (ईएमसीसीआर) और उसके उन्नयन (अपग्रेडेशन) का काम पूरा किया गया और उसे पिछले महीने ग्रिड के साथ फिर से सिंक्रोनाइज किया गया। ककरापार परमाणु बिजलीघर की यूनिट 1 के ईएमसीसीआर और ईएमएफआर के साथ-साथ उसका उन्नयन भी लगभग पूरा होने वाला है।

आशा है कि कैगा की इकाई 4, का प्रचालन अगले दो माह में शुरू हो जायेगा। कुडनकुलम में रूसी परिसंघ के तकनीकी सहयोग से 1000 मेगावाट-ई क्षमता वाले दो साधारण जल रिएक्टरों के निर्माण का काम पूरा होने वाला है।

काकरापार परमाणु विद्युत परियोजना-3 एवं 4 तथा राजस्थान परमाणु विद्युत परियोजना-7 एवं 8 की परियोजनाओं के कार्य प्रारंभ किए जा चुके हैं। स्वदेशी रूप से डिजाइन किए गए इन चार दाबित भारी पानी रिएक्टरों में से प्रत्येक की क्षमता 700 मेगावाट-ई है। कुडनकुलम परमाणु विद्युत परियोजना 3 एवं 4

में परियोजना-पूर्व गतिविधियां शुरू कर दी गई हैं। जैतापुर नाभिकीय विद्युत परियोजना-1 एवं 2 के संबंध में वास्तविक रूप से भूमि को अपने कब्जे में लेने का कार्य किया जा रहा है।

एनपीसीआईएल ने भारत में नाभिकीय विद्युत संयंत्रों की स्थापना के लिए एनटीपीसी लिमिटेड, इंडियन ऑयल कारपोरेशन लिमिटेड, नेशनल अल्युमिनियम कारपोरेशन लिमिटेड, कोरिया इलैक्ट्रिक पावर कारपोरेशन के साथ मिलकर काम करने के लिए समझौता ज्ञापनों पर हस्ताक्षर किए हैं। विशेष प्रकार के एक्सोटिक इस्पातों तथा बड़े आकार की फोर्जिंगों के विनिर्माण के लिए इसने हजीरा में एकीकृत सुविधा स्थापित करने के लिए मेसर्स लार्सन एंड टूब्रो के साथ मिलकर एक संयुक्त उद्यम कंपनी स्थापित करने के लिए एक समझौता ज्ञापन पर भी हस्ताक्षर किया है। मालशेज घाट में एक 600 मेगावाट क्षमता का पनबिजली संयंत्र स्थापित करने के लिए न्यूक्लियर पावर कारपोरेशन ऑफ इंडिया लिमिटेड और टिहरी हाइड्रो-इलेक्ट्रिक पावर कारपोरेशन के बीच सम्पन्न एक समझौता ज्ञापन के अंतर्गत विस्तृत परियोजना रिपोर्ट प्रस्तुत की गई है।

यूरेनियम अन्वेषण के क्षेत्र में, आंध्र प्रदेश, राजस्थान और मेघालय में लगभग 15,000 मीटरी टन अतिरिक्त यूरेनियम संसाधन की विद्यमानता को प्रमाणित किया गया है। देश के यूरेनियम संसाधनों की कुल क्षमता बढ़कर 1,40,000 टन U_3O_8 से कुछ अधिक हो गई है। उत्तरी दिल्ली फोल्ड बैल्ट और राजस्थान में लाछरी में; उत्तराखंड में टर्शियरी बेसिन में; मध्य प्रदेश में महाकौशल मेटा सेडिमेंटों में और उड़ीसा में आईओजी बेसिन में यूरेनियम की महत्वपूर्ण विसंगतियाँ देखी गई हैं।

झारखंड के सरायकेला-खर्सवान जिले में मोहुलडीह यूरेनियम खनन परियोजना, और आंध्र प्रदेश में तुमल्लापल्ली यूरेनियम खनन तथा पेषण परियोजना, और कर्नाटक में गोगी में अन्वेषणात्मक खनन का काम किया जा रहा है। आंध्र प्रदेश में लाम्बापुर में और मेघालय किलेंग पिंडेंगसोहियांग, मावथाबाह (केपीएम) में यूरेनियम अयस्क की खनन तथा पेषण परियोजनाओं के लिए परियोजना-पूर्व कार्य किए जा रहे हैं।

नाभिकीय ईंधन सम्मिश्र, हैदराबाद में दाबित भारी पानी रिएक्टर ईंधन बंडलों, जर्कोनियम स्पंज, दाबित भारी पानी रिएक्टर ईंधन ट्यूबों, च्ड़ पदार्थ और नायोबियम धातु का अब तक का सर्वाधिक उत्पादन किया गया। तमिलनाडु में पझायकयाल स्थित जर्कोनियम काम्पलेक्स में जर्कोनियम ऑक्साइड का उत्पादन शुरू हो गया है। एनएफसी ने, वैश्विक स्पर्धा में अंतर्राष्ट्रीय परमाणु ऊर्जा एजेंसी से प्राप्त,च तुर्की परमाणु ऊर्जा प्राधिकरण ईंधन तत्व एंड कैप वैल्डिंग यूनिट छ के विनिर्माण, आपूर्ति, स्थापन तथा कमीशनिंग के एक आदेश को सफलतपपूर्वक पूरा किया।

अभी केवल तीन सप्ताह हुए होंगे जबकि इंदिरा गांधी परमाणु अनुसंधान केंद्र के फास्ट ब्रीडर टेस्ट रिएक्टर तथा रेडियो-धातुकर्मिकी प्रयोगशालाओं ने अपनी रजत जयंती मनायी है। इस अवसर पर, लगभग 165 मेगावाट D/T के बर्न-अप वाले नवीन मिश्रित कार्बाइड ईंधन के प्रभावशाली कार्यनिष्पादन की अंतर्राष्ट्रीय विशेषज्ञों ने प्रशंसा की। कल्पाक्कम में बनाए जा रहे 500 मेगावाट-ई क्षमता वाले प्रोटोटाइप फास्ट ब्रीडर रिएक्टर के निर्माण का लगभग 60 प्रतिशत कार्य पूरा हो गया है। प्रोटोटाइप फास्ट ब्रीडर रिएक्टर टेस्ट उप-असेम्बली ने फास्ट ब्रीडर टेस्ट रिएक्टर में करीब 110,000 मेगावाट D/T का बर्नअप दर्ज किया है जबकि इसकी तुलना में अभिकल्पित बर्नअप 100,000 मेगावाट D/T था।

साधना - सोडियम में प्रोटोटाइप फास्ट ब्रीडर रिएक्टर संरक्षा ग्रेड की क्षय ऊष्मा निष्कासन संबंधी परीक्षण के लिए एक सोडियम लूप कमीशन किया गया था और किए गए परीक्षणों से संघटक और प्रणाली की डिजाइन उपयुक्त पायी गयी है। अंतर्राष्ट्रीय परमाणु ऊर्जा एजेंसी की एक अंतर्राष्ट्रीय सहयोगात्मक परियोजना, जिसमें भारत, चीन, यूरोपीय आयोग, कोरिया गणराज्य तथा रूस की भागीदारी है, को इंदिरा गांधी परमाणु अनुसंधान केन्द्र में प्रारम्भ किया गया। इस परियोजना के एक अंग के रूप में, क्षय ऊष्मा निष्कासन प्रणाली का अध्ययन किया गया है और प्राप्त परिणामों से भावी फास्ट ब्रीडर रिएक्टरों की डिजाइन के लिए महत्वपूर्ण जानकारी प्राप्त हुई है।

फास्ट ब्रीडर रिएक्टरों के लिए आवश्यक समृद्ध बोरॉन के औद्योगिक स्तर पर उत्पादन हेतु देश की पहली दो सुविधाएं तालछेर और मणुगुरु में स्थापित की गईं। ये सुविधाएं क्रमशः विनिमय आसवन तथा आयन विनिमय क्रोमेटोग्राफी पर आधारित हैं। समृद्ध KBF4 को विद्युत-अपघटन प्रक्रिया पर आधारित तात्विक बोरॉन में परिवर्तित करने के लिए एक संयंत्र भी भारी पानी संयंत्र, मणुगुरु में स्थापित किया गया। वर्ष के दौरान भारी पानी संयंत्रों की क्षमता का 100% से भी अधिक उपयोग किया गया। मेसर्स KHNP, दक्षिण कोरिया को 11 मीटरी टन भारी

पानी की आपूर्ति हेतु भारी पानी बोर्ड को 16वां निर्यात आदेश प्राप्त हुआ।

लेड सेलों में प्रगत ईंधन हेतु कलपाक्कम स्थित संहत पुनर्संसाधन सुविधा (कोरल) में 155 गीगावाट d/t के बर्नअप वाले फास्ट ब्रीडर टेस्ट रिएक्टर से प्राप्त भुक्त शेष ईंधन उप-असेम्बली का पुनर्संसाधन किया गया और विखंडनीय पदार्थ को पुन: ईंधन के रूप में संविरछित कर उसे वापस रिएक्टर में लोड किया गया। इस प्रकार फास्ट रिएक्टर ईंधन चक्र को सफलतापूर्वक पूरा किया गया।

इस वर्ष अप्रैल में, लगभग चार दशक पहले दिल्ली विश्वविद्यालय द्वारा कनाडा से आयात किया गया एक पुराना गामा सेल दुर्भाग्यवश दिल्ली के कबाड़ी बाजार में पहुंछा गया जिसके परिणामस्वरूप कुछ व्यक्तियों पर विकिरण का प्रभाव पड़ा। इस संकटकालीन घड़ी में, एक बड़ी संख्या में भाभा परमाणु अनुसंधान केन्द्र, नरोरा परमाणु बिजलीघर, परमाणु खनिज निदेशालय, उत्तरी क्षेत्र तथा परमाणु ऊर्जा नियामक बोर्ड के हमारे सहकर्मियों ने, विकिरणसक्रिय सामग्री को पुन: प्राप्त करने और सुरक्षित रूप से उसका निपटान करने, तथा पूरे क्षेत्र को विसंदूषित करने के लिए लगातार काम किया। मैं उन सबके प्रति अपना समादर प्रकट करता हूँ।

परमाणु ऊर्जा विभाग ने डॉ. बी. बरुआ कैंसर संस्थान, गुवाहाटी के पुनर्नवीकरण के लिए, उत्तर-पूर्वी परिषद और असम सरकार के साथ तीसरे त्रि-पक्षीय करार पर हस्ताक्षर किया है। यह अस्पताल उत्तर-पूर्वी क्षेत्र में कैंसर के इलाज और उसके नियंत्रण के लिए एक क्षेत्रीय कैंसर केन्द्र (आरसीसी) है।

अंतर्राष्ट्रीय परमाणु ऊर्जा एजेंसी, भारत गणराज्य और सोशलिस्ट रिपब्लिक ऑफ वियतनाम के बीच हुए करार के अनुसार वियतनाम को कैंसर चिकित्सा के लिए एक भाभाट्रॉन दूर चिकित्सा मशीन दान में दी गई। इस मशीन का उद्घाटन 28 अप्रैल, 2010 को वियतनाम में कैन थो अर्बुद विज्ञान (आन्कोलॉजि) अस्पताल में किया गया। ऐसी ही दो और यूनिटें, एक श्रीलंका को और दूसरी एक अफ्रीकी देश को दान में दी जा रही हैं। विकिरण तथा आइसोटोप प्रौद्योगिकी बोर्ड में इन-हाउस उत्पादित चुंबकीय सेलुलोस कणों पर आधारित ल्यूटिनाइजिंग हार्मोन (एलएच) के लिए सुगमता से उपयोग की जा सकने वाली एक आईआरएमए किट विकसित की गई।

अभिकलनी (कंप्यूटेशनल) आण्विक गतिकी, पदार्थ मॉडलिंग, रिएक्टर क्रोड परिकलन और संरक्षा विश्लेषण, मौसम संबंधी मॉडल तैयार करने और कंप्यूटर सहायता युक्त इंजीनियरिंग अनुप्रयोगों के क्षेत्रों में उपभोक्ताओं की बड़े पैमाने पर संख्यात्मक अभिकलन की आवश्यकताओं को पूरा करने के लिए इंदिरा गांधी परमाणु अनुसंधान केन्द्र द्वारा उछ्छा कार्य-निष्पादन वाले एक सामान्तर अतिछालक क्लस्टर का कमीशन किया गया। फास्ट ब्रीडर रिएक्टरों और संबद्ध ईंधन चक्र सुविधाओं के मॉडलों की परिकल्पना के लिए इंदिरा गांधी परमाणु अनुसंधान केन्द्र में एक प्रगत परिकल्पना केन्द्र, एक विश्वस्तरीय पूर्ण इमर्सिव प्रणाली भी कमीशन की गई।

हाल ही में इस माह के दौरान दो सप्ताहों के लिए पूरे विश्व ने नई दिल्ली में आयोजित कॉमनवेल्थ खेलों का भव्य समारोह देखा। मुझे आपको यह बताते हुए बहुत प्रसन्नता हो रही है कि परमाणु ऊर्जा विभाग ने उस समारोह के सफल आयोजन में भी अपनी भूमिका अदा की। इलेक्ट्रानिक्स कारपोरेशन ऑफ इंडिया लिमिटेड ने इन खेलों के लिए 230 करोड़ के मूल्य से अधिक के उपस्करों की आपूर्ति की। देश की विभिन्न सुरक्षा एजेंसियों के कार्मिकों को विकिरण स्रोतों का पता लगाने और विकिरण से उत्पन्न किसी भी आपातकालीन स्थिति से निपटने के लिए एक बड़ी संख्या में प्रशिक्षित किया गया। इसके अतिरिक्त, इन खेलों के दौरान विकिरण वैज्ञानिकों का एक दल विकिरण की निगरानी के लिए खेल स्थल पर नियुक्त किया गया।

राजा रामन्ना प्रगत प्रौद्योगिकी केन्द्र में सर्न अनुप्रयोग के लिए विकसित एक ठोस अवस्था प्रतिकारित (काम्पन्सेटेड) माडुलेटर ने निर्धारित विनिर्देश प्राप्त किया और उसे सर्न दल द्वारा स्वीकार किया गया। राजा रामन्ना प्रगत प्रौद्योगिकी केन्द्र ने अंतरविश्वविद्यालय त्वरक केन्द्र (आईयूएसी), नई दिल्ली के सहयोग से दो प्रोटोटाइप 1.3 गीगा हर्ट्ज़ एकल प्रकोष्ठ अतिछालक गुहिकाओं (कैविटियों) का संविरछान किया और उनका 22 एमईवी/एम प्रवणता के लिए अमरीका की फर्मी प्रयोगशाला में परीक्षण किया गया।

वर्ष के दौरान भारत ने परमाणु ऊर्जा के शांतिपूर्ण उपयोगों में सहयोग के लिए कई देशों के साथ द्विपक्षीय करारों और समझ ौता ज्ञापनों पर हस्ताक्षर किए हैं। उनमें से कुछ देश नामीबिया, मंगोलिया, रूसी परिसंघ और कनाडा आदि हैं। इसने यूनाइटेड किंग्डम के साथ असैन्य नाभिकीय सहयोग के लिए एक संयुक्त

घोषणा भी की थी। भारत ने संलयन ऊर्जा अनुसंधान के क्षेत्र म सहयोग हेतु यूरोपियन एटॉमिक एनर्जी कम्युनिटी के साथ एक करार पर भी हस्ताक्षर किए हैं।

मैंने अभी-अभी कुछ उन प्रमुख उपलब्धियों का उल्लेख किया है जो विभाग द्वारा पिछले वर्ष के दौरान हासिल की गयी हैं। वस्तुत: हमारा कार्यक्रम बहुत तेज़ी से आगे बढ़ रहा है। मैं इस मोड़ पर, अगले दशक के अंत तक, अपने भावी परिदृश्य की एक तस्वीर आपके सामने रखना चाहता हूँ :

- आज हमारी नाभिकीय विद्युत उत्पादन की स्थापित क्षमता लगभग 4500 मेगावाट की है। आशा है कि हम वर्ष 2020 में 30,000 मेगावाट से अधिक की क्षमता हासिल कर लेंगे।

- आज देश में नाभिकीय विद्युत उत्पादन प्राथमिक रूप से दाबित भारी पानी रिएक्टरों के माध्यम से होता है। एक दशक के बाद, हम लगभग 10,000 मेगावाट तक की क्षमता के दाबित भारी पानी रिएक्टरों का प्रछालन कर रहे होंगे। इसके अतिरिक्त, हमारे पास विभिन्न प्रकार के साधारण जल रिएक्टर, वीवीईआर्ज़, ईपीआर्ज़, बॉयलिंग वाटर रिएक्टर तथा एपी-1000 होंगे। फास्ट ब्रीडर रिएक्टर, उनमें से कम से कम तीन, प्रगत भारी पानी रिएक्टर, दोनों ही प्लूटोनियम तथा कम समृद्ध यूरेनियम से प्रछालित किए जाते हैं। भारतीय डिजाइन के साधारण जल रिएक्टरों का निर्माण कार्य भी शुरु किया जाएगा।

- कैप्टिव नाभिकीय बिजलीघर भारतीय रेलवे को अपनी सेवाएं प्रदान करेंगे, और एक प्रायोगिक उछ्छा तापमान रिएक्टर नाभिकीय ऊर्जा द्वारा हाइड्रोजन के उत्पादन को प्रदर्शित करेगा, और इस प्रकार परिवहन के क्षेत्र में नाभिकीय ऊर्जा की भूमिका को स्थापित करेगा।

- भारतीय उद्योग इस स्थिति में होगा कि वह नाभिकीय दाब पात्रों, बड़े आकार के टर्बो जेनेरेटरों सहित सभी प्रमुख प्रणालियों तथा उपस्करों की आपूर्ति न केवल स्वदेशी जरूरतों को पूरा करने के लिए कर सकेगा बल्कि भारत नाभिकीय आपूर्तिकर्ताओं का एक ऐसा केन्द्र बन सकेगा जो विश्व की जरूरतों को पूरा कर सके।

- देश के अनेक भागों में यूरेनियम खानें तथा मिलें प्रचालित की जाएंगी। इसके अतिरिक्त, हमारे पास विदेशों में यूरेनियम परिसम्पतियाँ होंगी जहाँ से हमें अपने नाभिकीय कार्यक्रम के लिए यूरेनियम की निर्बाध आपूर्ति सुनिश्चित की जाएगी।

- देश में समृद्धिकरण की क्षमता को इस स्तर तक बढ़ाया जाएगा कि समृद्ध ईंधन की आवश्यकता की एक बड़ी मात्रा स्वदेशी रूप से उपलब्ध कराई जा सके।

- हम बड़े पैमाने के एकीकृत पुनर्संसाधन संयंत्रों का प्रचालन कर सकेंगे, जिनमें से दो या तीन संयंत्रों में से प्रत्येक 500 टन से अधिक भारी धातु का प्रहस्तन (हैंडलिंग) कर रहा होगा।

- हमारे सामरिक कार्यक्रम को इतना सशक्त किया जाएगा कि न्यूनतम विश्वसनीय प्रतिरोधक क्षमता (डिटरेंट) सुनिश्छित की जा सके। वैद्युत चुम्बकीय और उछ्छा शक्ति की सूक्ष्मतरंग युक्तियाँ हमारी मिसाइल रक्षा प्रणाली में सन्नध होंगी।

- त्वरकों के क्षेत्र में, एक 2.5 गीगा वोल्ट सिंक्रोट्रॉन इंडस-II, मुक्त इलेक्ट्रॉन लेसर सहित अन्य प्रगत प्रकाश स्रोत अतिचालक साइक्लोट्रॉन, विकिरण सक्रिय आयन किरणपुंज सुविधाएं, चिकित्सीय साइक्लोट्रॉन, एक अतिचालक लाइनेक द्वारा प्रेरित पेलेट्रॉन, और समुत्खंडन (स्पालेशन) न्यूट्रॉन स्रोत और उछ्छा ऊर्जा इलेक्ट्रॉन त्वरकों को, न केवल उच्च ऊर्जा भौतिकविज्ञानियों को, बल्कि पदार्थ वैज्ञानिकों, रसायनज्ञों, जीववैज्ञानिकों तथा अभियंताओं को भी व्यापक स्तर पर कई प्रकार की प्रायोगिक सुविधाएं उपलब्ध कराने के लिए उनके इष्टतम स्तर तक प्रछालित किया जाएगा।

- भारत में स्थापित न्यूट्रीनों वेधशाला (आईएनओ), विश्वभर के वैज्ञानिकों को प्रगत अनुसंधान के लिए सुविधाएं उपलब्ध कराएगी।

- अंतर्राष्ट्रीय वैज्ञानिक समुदाय के साथ हमारे संबंधों को और मजबूत किया जाएगा। हम सर्न, आईएलएल, गेनिल, अन्यत्र सिंक्रोट्रॉन बीम लाइनों, जूल्ज़ होरोविट्ज़ रिएक्टर में किए जाने वाले परीक्षणों में सक्रिय रूप से भाग लेंगे। हम आईटीईआर सुविधाओं के कमीशनन के अंतिम चरण में होंगे।

- कई सौ भाभाट्रॉन तथा दसियों इलेक्ट्रॉन त्वरक हमारे देश को विकिरण अर्बुद (आनकोलॉजी) विज्ञान सुविधाएं उपलब्ध कराएंगे। राष्ट्रीय कैंसर ग्रिड देशभर में उपलब्ध सुविधाओं को एकीकृत करेगा।

- भारतीय किसानों को व्यापक अनुप्रयोगों के लिए विभिन्न किस्म के किरणित उत्परिवर्ती (म्यूटेन्ट) बीज मिलेंगे। इसका विस्तार तिलहनों और दालों से लेकर कई अन्य खाद्यान्नों में किया जाएगा। गामा और इलेक्ट्रॉन किरणन, खाद्य परिरक्षण के लिए बड़े पैमाने पर उपयोग में लाए जाएंगे। कई इलेक्ट्रॉन किरणकों को साइलों, जिनका उपयोग

स्वास्थ्यकर खाद्य पदार्थों के भंडारण के लिए किया जाता है, से संबद्ध किया जाएगा।

- देश के सभी प्रवेश और निकास द्वारों जैसे कि भूमि, समुद्र और हवाई मार्गों को, नाभिकीय सामग्री के अनधिकृत रूप से लाने ले जाने के विरुद्ध सुरक्षा प्रदान करने की दृष्टि से विभिन्न प्रकार के स्कैनरों से सुसज्जित किया जाएगा।

- कई नाभिकीय निर्लवणीकरण संयंत्रों का प्रचालन किया जाएगा।

- हमारे अनुसंधान केन्द्र देश के उन युवा प्रतिभाशाली चात्रों को अत्यधिक चुनौती भरे अनुसंधान के अवसर प्रदान करेंगे जिन्हें उन अवसरों के लिए कहीं और नहीं देखना पड़ेगा। हम विभिन्न विधाओं और अंतरापृष्ठ (इन्टरफेस) क्षेत्रों में अनुसंधान को बढ़ावा देने के लिए बीछा के अवरोधों को समाप्त करने में सफल हो पाएंगे। हम न केवल अपनी विभागीय गतिविधियों के लिए, अपितु समूचे देश में प्रगत विज्ञान और प्रौद्योगिकी के लिए भी बड़े पैमाने पर मानव संसाधन तैयार कर रहे हैं।

नए केन्द्र, जैसे कि भाभा परमाणु अनुसंधान केन्द्र का विजाग परिसर, टाटा मूलभूत अनुसंधान केन्द्र, हैदराबाद का परिसर और उसके अन्य केन्द्र जैसेकि अंतर्राष्ट्रीय सैद्धांतिकी अध्ययन केन्द्र और राष्ट्रीय जीव-विज्ञान केन्द्र, बंगलौर वैज्ञानिक अनुसंधान के क्षेत्र में भारत को नेतृत्व की भूमिका के दायरे में लाने में प्रमुख भूमिका निभाएंगे।

मैंने जो कुछ भी कहा है वह वास्तव में उस समय-सीमा के अंदर संभव है जिसका मैंने उल्लेख किया है । जब होमी भाभा ने एक ऐसे नए उदित राष्ट्र, जिसके पास सीमित आधारभूत सुविधाएं थीं और जो अपने अस्तित्व को बनाए रखने के लिए संधर्ष कर रहा था, की पृष्ठभूमि में एक पूर्ण स्वदेशी परमाणु ऊर्जा कार्यक्रम की परिकल्पना की थी तो वह एक सपना मालूम पड़ता था। पिछले छः दशकों में उनके अधिकांश सपनों को साकार किया गया है, वह भी तब जब हमने वस्तुतः एक पूर्णतः एकाकी परिस्थितियों में कार्य किया है। आज, जब हम अपने भविष्य के बारे में सोचते हैं, तो हम उन्हें सपने नहीं कह सकते, क्योंकि हम निश्चित रूप से उन्हें पूरा कर सकते हैं। हमें उन्हें अपना लक्ष्य मानना चाहिए। इन लक्ष्यों को हासिल करने के लिए हमें न केवल कड़ी मेहनत करनी पड़ेगी, बल्कि परस्पर उनमें तालमेल बैठाने के लिए अपने कार्यकलापों में सामंजस्य भी बैठाना पड़ेगा। जैसा कि मैंने पहले भी उल्लेख किया है, प्रत्येक क्षेत्र में हमने उल्लेखनीय प्रगति की है और मैं ऐसा कोई कारण नहीं देखता कि हम अपने सम्मिलित प्रयासों से उन लक्ष्यों को हासिल न कर पाएं। दूसरे शब्दों में मैं यह कह सकता हूँ कि हमने मध्य क्षेत्र में काफी अच्छा प्रदर्शन किया है। अब समय आ गया है कि हम अपने लक्ष्य को प्राप्त करें और मैं अपने सभी साथियों से यह आह्वान करना चाहूँगा कि वे पूरे विश्वास और उत्साह के साथ वे कार्य हाथ में लें जो हमारे देशवासियों के जीवन को स्पर्श करें। समूछा विश्व तथा हमारे देशवासी हमारी ओर बहुत आशा भरी निगाहों से देख रहे हैं। आइए हम अपने देशवासियों की आशाओं को पूरा करने का भरसक प्रयास करें और इस प्रक्रिया में विश्व को हम यह दिखा दें कि भारतीय वैज्ञानिक और प्रौद्योगिकीविद् वास्तव में लाखों-करोड़ों लोगों के जीवन को बदल सकते हैं और देश को एक विकासशील राष्ट्र से एक बड़ी शक्ति के रूप में बदल सकते हैं। वास्तव में यह संस्थापक होमी भाभा के प्रति हमारी बहुत बड़ी श्रद्धांजलि होगी।

जय हिन्द।"

Address by Dr. Srikumar Banerjee

Chairman, Atomic Energy Commission & Secretary to Government of India, Department of Atomic Energy

"Dear Colleagues,

I extend my warm greetings and compliments to all of you on the occasion of the 101st birth anniversary of our beloved founder Dr. Homi Jehangir Bhabha. As is customary on this day, we take stock of the year gone by and rededicate ourselves for the cause of strengthening the Nation through various facets of our activities. The last year witnessed landmark achievements, impressive growth in programmes, and major initiatives, covering a wide spectrum. I intend to present a brief account of some of these achievements in the next few minutes.

Since we met last year, construction of two new nuclear power reactors viz. Rajasthan Atomic Power Project – Unit 5&6 was completed and they commenced commercial operation. With this the total number of nuclear power reactors in operation in the country has become 19 with total installed capacity of 4560 MWe. The Unit 2 of RAPS was resynchronised with the grid after completing its enmasse feeders replacement. Enmasse coolant channel replacement (EMCCR) and upgradation of Unit 2 of Narora Atomic Power Station was completed and it was resynchronised to the grid last month. The upgradation including EMCCR and EMFR of Unit 1 of Kakrapar Atomic Power Station is nearly complete.

Kaiga Unit 4 is expected to become operational within next two months. Two light water reactors of 1000 MWe each being built in technical cooperation with the Russian Federation at Kudankulam are advancing towards completion.

The project works on Kakarapar Atomic Power Project-3&4 and Rajasthan Atomic Power Project-7&8 have been started. These four indigenously designed PHWRs are of 700 MWe each. Pre-project activities on Kudankulam Nuclear Power Project - 3&4 have been initiated. In respect of Jaitapur Nuclear Power Project -1&2, the physical possession of land is in progress.

The Nuclear Power Corporation of India Ltd. has signed MoUs with NTPC Ltd., Indian Oil Corporation Ltd., National Aluminium Corporation Ltd., Korea Electric Power Corporation etc. to work together for setting up nuclear power plants in India. It also signed an MoU with M/s Larsen & Toubro to incorporate a Joint Venture Company to set up an integrated facility at Hazira for the manufacture of special exotic steels and large size forgings. Under an MoU between NPCIL and Tehri Hydro-electric Power Corporation for setting up a 600 MW hydroelectric plant at Malshej Ghat, Detailed Project Report has been submitted.

In the field of uranium exploration, about 15,000 tonnes of additional uranium resources have been established in Andhra Pradesh, Rajasthan and Meghalaya. The country's uranium resources have been updated to a little more than 1,40,000 tonnes of U3O8. Promising uranium anomalies have been located in the North Delhi Fold Belt and Lachhri in Rajasthan; Tertiary basin in Uttarakhand; Mahakoshal

meta sediments in Madhya Pradesh and IOG Basin in Orissa.

Mohuldih Uranium Mining Project in the Saraikela-Kharsawan district of Jharkhand and Tummalapalle Uranium Mining & Milling Project in Andhra Pradesh and Exploratory Mining at Gogi in Karnataka are advancing. Pre-project activities for Uranium ore mining and milling projects at Lambapur in Andhra Pradesh and Kylleng Pyndengsohiong, Mawthabah (KPM) in Meghalaya are on.

Highest ever production of PHWR fuel bundles, Zirconium sponge, PHWR fuel tubes, rod material & Niobium metal was achieved at the Nuclear Fuel Complex, Hyderabad. The Zirconium Complex at Pazhayakayal, Tamil Nadu has started production of Zirconium Oxide. NFC successfully executed an order received from IAEA against global competition for manufacture, supply, erection and commissioning of fuel element end-cap welding unit to Turkish Atomic Energy Authority.

Hardly three weeks back, the Fast Breeder Test Reactor and the Radio-metallurgy Labs of IGCAR celebrated their Silver Jubilee. On the occasion, the spectacular performance of the novel mixed carbide fuel with a burn-up of about 165 MWD/T received applause from international experts. The 500 MWe PFBR being constructed at Kalpakkam has achieved about 60 % physical progress. The PFBR test sub-assembly has logged a burn-up of close to 110, 000 MWD/T in the FBTR against the designed burn-up of 100,000 MWD/T.

SADHANA- a Sodium loop for testing of PFBR Safety Grade Decay Heat Removal in sodium was commissioned and experiments have qualified the component and system design. An IAEA international collaborative project, with participation of India, China, European Commission, Republic of Korea and Russia, has been initiated at IGCAR. As part of this project, study of decay heat removal system has been carried out and the results provide significant inputs for design of future FBRs.

Country's first two industrial scale production facilities for enriched boron, required for the fast breeder reactors, were commissioned at Talcher and Manuguru. These are based on exchange distillation and ion exchange chromatography respectively. A plant for converting the enriched KBF_4 into elemental Boron based on the process of electrolysis was also set up at HWP, Manuguru. The capacity utilization of heavy water plants, during the year exceeded 100%. Heavy Water Board bagged the sixteenth export order for supply of 11 MT heavy water to M/s KHNP, South Korea.

At the Compact Reprocessing facility for Advanced Fuels in Lead cells (CORAL), Kalpakkam, the spent fuel subassembly from FBTR with a burnup of 155 GWd/t was reprocessed and the fissile material was re-fabricated as fuel and loaded back into the reactor. This marked the successful closing of the fast reactor fuel cycle.

This year in April, an old Gamma Cell imported by Delhi University about four decades back from Canada, unfortunately landed in a scrap market in Delhi resulting in radiation exposure of a few persons. At the time of this emergency, a large number of our colleagues from BARC, Narora Atomic Power Station, AMD Northern Region and AERB worked relentlessly for recovery and safe disposal of the radioactive material and decontamination of the whole area. I offer my compliments to all of them.

DAE has signed the Third Tripartite Agreement with the North-Eastern Council and the Government of

Assam, for the revitalization of the Dr. B. Barooah Cancer Institute, Guwahati. This hospital is a Regional Cancer Centre (RCC) for cancer treatment and control in the North-Eastern Region.

A Bhabhatron teletherapy machine for cancer therapy was donated to Vietnam as per an agreement between International Atomic Energy Agency, Republic of India and Socialist Republic of Vietnam. The machine was inaugurated at Can Tho Oncology Hospital in Vietnam on April 28, 2010. Two more such units are being donated – one to Sri Lanka and the other to an African country. At BRIT, a user-friendly IRMA kit for Luteinizing hormone (LH) based on in-house produced magnetizable cellulose particles was developed.

A parallel high-performance supercomputing cluster has been commissioned by IGCAR to cater to the large-scale numerical computational requirements of users in the areas of computational molecular dynamics, material modelling, reactor core calculations & safety analysis, weather modelling and computer aided engineering applications. An advanced visualization centre, a world-class fully immersive system has also been commissioned at IGCAR to visualize the models of fast breeder reactors and associated fuel cycle facilities.

Recently for two weeks during this month, the whole world saw the spectacular Common Wealth Games held at New Delhi. I am particularly glad to share with you that DAE had its own share in the success of this event. ECIL supplied equipments worth over Rs. 230 Crores for the games. A large number of personnel from various security agencies in the country were trained on detection of any radiation sources and mitigation of any radiation emergency. In addition, during the games, a team of radiation scientists was deputed at the venue for radiation surveillance.

An all solid state bouncer compensated modulator developed at RRCAT for a CERN experiment achieved rated specifications and was accepted by the CERN team. RRCAT fabricated two prototype 1.3 GHz single cell superconducting cavities in collaboration with the Inter University Accelerator Centre (IUAC), New Delhi and they were tested at Fermi Lab, USA for 22 MeV/m gradiant.

During the year India has entered into bilateral agreements and MoUs with many countries for cooperation in peaceful uses of atomic energy. Some of these countries are Namibia, Mongolia, the Russian Federation and Canada etc. It also had a joint declaration with the United Kingdom on Civil Nuclear Cooperation. India also signed an agreement with the European Atomic Energy Community for cooperation in the field of Fusion Energy Research.

I have just highlighted some of the major achievements that have been accomplished by the Department during the last year. We are infact going through a period of very rapid growth of our programme. At this turning point, let me paint a scenario for our future, at the end of next decade :

Today we are having an installed nuclear power production capacity at a level of about 4500 MWe. In 2020, we hope to reach a level exceeding 30000 Mwe.

Today nuclear power generation in the country is primarily through PHWRs. After a decade we will be operating PHWRs to a capacity of about 10000 MWe. In addition we will have Light Water Reactors of different kinds, VVERs, EPRs, BWRs and AP-1000. Fast Breeder Reactors, atleast three of them, Advanced Heavy Water Reactors, both plutonium and low enriched uranium driven. Construction of Light Water Reactors of Indian design will also begin.

Captive nuclear power stations will serve Indian Railways and an experimental High Temperature Reactor will demonstrate generation of hydrogen by nuclear energy, thus establishing the role of nuclear energy in Transport Sector.

Indian industry will be in a position to supply all major systems and equipment including nuclear pressure vessels, large sized turbo generators not only to meet the domestic needs but also for making India a hub for nuclear suppliers for global requirements.

Uranium mines and mills will operate in several parts of the country. On top of it, we will have uranium assets abroad from where unhindered flow of uranium will be assured for our nuclear programme.

The enrichment capacity in the country will be enhanced to a level that a substantial quantity of enriched fuel requirement will be met indigenously.

We will be operating large scale integrated reprocessing plants, 2 or 3 of them each handling over 500 tons of heavy metal.

Our strategic programme will be further strengthened to assure minimum credible detterents – our triad of the delivery system will be fully functional. Electromagnetic and high power microwave devices will be deployed in our missile defence system.

In the area of accelerators, a 2.5 Gev synchrotron Indus-II, other advanced light source including free electron laser, superconducting cyclotrons, Radioactive Ion Beam Facilities, medical cyclotrons, pelletron boosted by a super conducting LINAC, Spallation Neutron source and high energy electron accelerators will be operational at their optimum level to provide a wide variety of experimental facilities to not only high energy physicists but also to material scientists, chemists, biologists and engineers.

India based Nutrineu Observatory (INO) will be providing scientists world over facilities for advanced research.

Our association with the international scientific community will be further strengthened. We will be actively participating in experiments in CERN, ILL, GANIL synchrotron beam lines elsewhere, Jules Horowitz reactor. We will be in the final stages of commissioning ITER facilities.

Several hundred Bhabhatrons alongwith several tens of electron accelerators will provide radiation oncology services to our country. The national cancer grid will integrate the facilities available all over the country.

Indian farmers will get a variety of radiation mutated seeds for widescale applications. The scope will expand beyond oil seeds and pulses to many other foodgrains. Gamma and electron irradiation will be deployed on a large scale for food preservation. Several Electron irradiators will be attached to silos meant for hygienic food storage.

All the entry and exit points to the country – land, sea and air – will be equipped with scanners of different kinds to provide security against any unauthorised movement of nuclear materials.

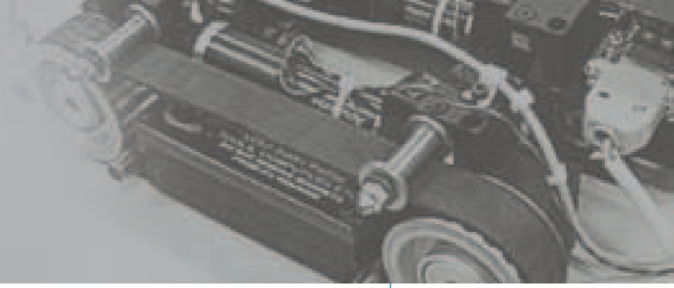
Several nuclear desalination plants will become operational.

Our research centres will be offering most challenging research opportunities to fresh talents in the country who do not have to look for opportunities elsewhere. We will be successful in breaking the barriers between the disciplines and promoting research in several interface areas. We are building up a large human resource not only for our own departmental activities, but also for advanced science and technology in the country as a whole.

The new centres such as BARC Vizag Campus, TIFR Hyderabad campus and its other centres such as International Centre for Theoretical Studies and National Centre for Biological Sciences in Bangalore will play a major role in bringing India in a leadership role in scientific research.

All that I have mentioned are indeed possible in the timeframe that I have indicated. When Homi Bhabha thought of a completely indigenous atomic energy programme in the backdrop of a new-born nation with limited infrastructure, striving for survival, it was a dream. In the last six decades most of his dreams have been realised, that too when we operated essentially in complete isolation. Today, when we think of our future, we cannot call them as dreams because they are definitely realisable. We should consider them to be our targets. To achieve these targets, not only we have to work very hard, but also we have to harmonise our activities to bring synergy. In each of the areas I mentioned earlier, we have made substantial advances and I do not see any reason why by concerted efforts of all of us we will not be able to achieve them. In a lighter vein I can say that we have played in the mid field quite well. A time has come when we should score goals and I call upon all my colleagues to have the determination and the zeal to take up the work which will touch the lives of all our countrymen. The whole world as well as our own countrymen are looking at us with great expectations. Let us try our best to fulfill the aspirations of our countrymen and in the process show the world that Indian scientists and technologists can indeed change the life of millions and bring about a transition of a country from developing state to a major power. This will indeed be the most fitting tribute to our founder Homi Bhabha.

- Jai Hind -"



डॉ. आर.के. सिन्हा
निदेशक, भाभा परमाणु अनुसंधान केंद्र
द्वारा
संस्थापक दिवस संबोधन
शुक्रवार 29 अक्तूबर, 2010

डॉ. बॅनर्जी, अध्यक्ष, परमाणु ऊर्जा आयोग, परमाणु ऊर्जा परिवार के यहाँ उपस्थित वरिष्ठ सदस्यगण एवं प्रिय साथियों,

मेरे लिए वास्तव में यह बड़ी प्रसन्नता एवं गर्व का विषय है कि मैं इस महान संस्थान, भाभा परमाणु अनुसंधान केंद्र के संस्थापक डॉ. होमी जे. भाभा के 101 वें जन्मदिवस पर आप सभी का गर्मजोशी से स्वागत कर रहा हूं।

हम प्रति वर्ष 30 अक्तूबर को होमी भाभा के जन्म दिवस समारोह मनाते हैं तथा पिछले वर्ष के दौरान प्राप्त उपलब्धियों का लेखा-जोखा लेते हैं और नाभिकीय विज्ञान एवं प्रौद्योगिकी के विकास से संबंधित लक्ष्य केंद्रित कार्यों के प्रति अपने आप को पुनःसमर्पित करते हैं ।

डॉ. आर.के. सिन्हा द्वारा संबोधन

परंपरा के साथ चलते हुए, इस वर्ष, हम इस समारोह को 30 अक्तूबर के पूर्व अंतिम कार्य दिवस अर्थात एक दिन पहले मना रहे हैं क्योंकि उस दिन सप्ताहांत की छुट्टी है ।

पिछले एक वर्ष के दौरान, भा.प.अ. केन्द्र की अनेक महत्वपूर्ण उपलब्धियां रही हैं । उन्हें पूर्णतः न दोहराते हुए मैं पूरा प्रयत्न करूंगा कि दिए गए समय में आपको हमारी सतत प्रगति का दर्शन करवा सकूं यहां मैं केवल हाल ही में प्राप्त कुछ उपलब्धियों की चर्छा करूंगा।मैं आपको, उदाहरणतः चंद शब्दों में एक संक्षिप्त परिप्रेक्ष्य देना चाहूंगा।

अनुसंधान रिएक्टर

दिनांक 10 जुलाई, 2010 को साइरस के 50 वर्ष का प्रालन और दिनांक 8 अगस्त, 2010 को ध्रुवा के 25 वर्ष का प्रछालन पूरा होना भापअकेंद्र के इतिहास में दो अतिविशिष्ट एवं महत्वपूर्ण मील के पत्थर हैं। मुझे विश्वास है कि आप भी मुझसे सहमत होंगे, कि वर्ष 2010 में ये दो अवसर हमारे संस्थापक डॉ. होमी भाभा के प्रति सर्वोत्तम श्रद्धांजलि है। इन दोनों रिएक्टरों ने हमारे आइसोटोप उत्पादन, मूलभूत अनुसंधान, पदार्थ परीक्षण एवं मानव संसाधन विकास की गतिविधियों में महत्वपूर्ण योगदान दिया है ।

अप्सरा रिएक्टर को 52 वर्ष की सफल सेवा के पश्चात जून, 2009 में शट डाउन किया गया एवं रिएक्टर क्रोड को 2MW तक उन्नयन करने के लिए उसकी विकमीशनन गतिविधियाँ लगभग पूरी हो चुकी हैं। अप्सरा क्रोड ईंधन का ट्रांबे के बाहर परिवहन का कार्य प्रारंभ हो चुका है। अप्सरा की नई डिज़ाइन में अनेक प्रगत सुविधाएं होंगी जिसमें प्रगत परिक्षेपण प्रकार का सिलिकाइड ईंधन होगा। नए सिलिकाइड ईंधन के उत्पादन हेतु प्रक्रिया का पूर्णतः विकास एवं स्थापन किया जा चुका है ।

आधुनिक भूकम्पीय मानदंडो को पूरा करने के लिए रिएक्टर की पुरानी संरचना का मूल्यांकन किया गया। यह पाया गया कि बाहरी संरचना को बदल कर उच्चतर भूकम्प प्रतिरोधक आधुनिक संरछना तैयार की जाए। अप्सरा के पुराने भवन को गिराने के बाद नए भवन का निर्माण किया जाएगा और इसमें यह ध्यान रखा जाएगा कि नया भवन बनाते समय पुराने भवन की सभी वास्तुरेखीय विशेषताएं बरकरार रहें।

प्रगत भारी पानी रिएक्टर (AHWR) एवं 540 MWe PHWR हेतु क्रांतिक सुविधा (CF) को विभिन्न प्रयोगों के लिए 74 अवसरों पर प्रचालित किया गया। ग्रैफाइट रिफ्लेक्टर रीजन में 13 नाभिकीय संसूछाकों का परीक्षण किया गया। थोरिया तथा यूरेनियम पिन युक्त ईंधन गुछ्छ के भरण के पश्चात, अनेक मापन कार्य संतोषजनक रूप से किए गए। इस सुविधा का प्रयोग न्यूट्रॉन सक्रियण विश्लेषण हेतु (NAA) बृहत् आयतन नमूनों के विकिरण के लिए भी किया गया।

AHWR कार्यक्रम

एएचडब्ल्यूआर हेतु स्वगृहे विकसित एक अतिरिक्त 3 MW यंत्रीकृत ईंधन छड़ गुच्छ अनुकारक के साथ पूर्ण स्तरीय समग्र परीक्षण लूप का संवर्धन किया गया। यह संवर्धित सुविधा चैनल शक्ति मापन एवं अस्थिरता के संसूचन जैसी अनेक नई तकनीकों के मान्यकरण हेतु एक जांच केंद्र के रूप में कार्य करेगी ।

पैसिव पॉइजन इंजेक्शन सिस्टम (PPIS), AHWR में उपलब्ध कराई गई एक विशिष्ट प्रणाली है जो वायर्ड शटडाउन सिस्टमों के विफल होने की स्थिति में शटडाउन कार्य को पूरा करेगी। AHWR के PPIS में प्रयोग किए जाने वाले घ्यॉइजन इंजेक्शन पैसिव वाल्व (PPIV)ङ के प्रोटोटाइप का डिज़ाईन तथा विकास करके अनुकारित स्थितियों में उसका परीक्षण किया गया । यह वाल्व मुख्य ऊष्मा वहन (MHT) सिस्टम उछ्छा दाब पर प्रवर्तित होता है एवं रिएक्टर को निष्क्रिय पद्धति से शट डाउन कर देता है। AHWR की विभिन्न संरक्षा प्रणालियों हेतु विकसित यह लगातार तीसरा निष्क्रिय वाल्व है, जिससे निष्क्रिय वाल्व डिज़ाइन एवं विकास के क्षेत्र में प्रौद्योगिक परिपक्वता सिद्ध होती है।

AHWR के प्रमुख घटकों में कुछ अभिनव विशेषताओं के विकास हेतु हम भारतीय उद्योगों के साथ संपर्क कर रहे हैं। प्रगत भारी पानी रिएक्टर (AHWR) के वाष्प ड्रम में एकीकृत नोज़लों, इनलेट हेडर तथा एंड फिटिंग्ज के लिए पुल आउट प्रौद्योगिकी के विकास के लिए नाभिकीय घटकों के अग्रणी निर्माता के साथ एक समझौता ज्ञापन पर हस्ताक्षर किए गए ।

उच्च तापीय रिएक्टर कार्यक्रम

उच्च तापीय रिएक्टर का भौतिकी अभिकल्पन कार्य और आगे बढ़ा है। रिएक्टर स्टार्ट अप और नियमन के प्रयोजन हेतु क्रोड एवं रिएक्टर पात्र के बाहर संसूचक स्थानों पर न्यूट्रॉन फ्लक्स का अनुमान लगाने के लिए मॉन्टे कॉर्लो अनुकारण किए गए ।

PHWR कार्यक्रम

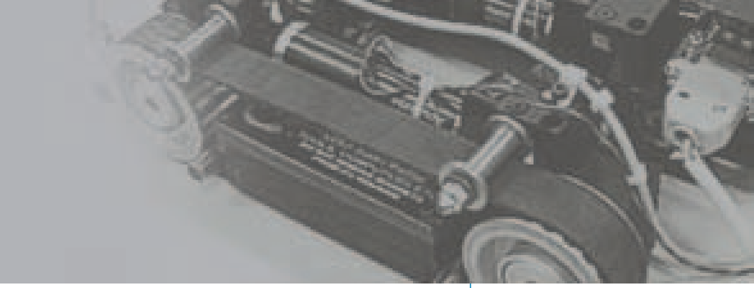
NPCIL को कालप्रभावन प्रबंधन गतिविधियों के लिए तकनीकी एवं विश्लेषणात्मक सहायता प्रदान की गई।*नलियों की अवशिष्ट आयु के पूर्वानुमान हेतु हाइड्रोजन/ड्यूटिरियम निर्धारण के लिए RAPS-3 एवं KAPS -2 रिएक्टरों की दाब नलियों की खुरछान युक्त नमूने प्राप्त करने के लिए सफलतापूर्वक आर्द्र खुरचन किया गया* ।

नाभिकीय ईंधन कार्यक्रम

कलपाक्कम स्थित FBTR एवं PFBR (निर्माणाधीन) सहित द्रुत रिएक्टर कार्यक्रम के लिए भापअ केंद्र द्वारा प्लूटोनियम युक्त ईंधन की आपूर्ति की जाती है ।

भापअ केंद्र द्वारा पहले निर्मित एवं आपूर्ति किए गए प्रयोगात्मक PFBR MOX ईंधन को FBTR में किरणित किया जा रहा है। यह ईंधन 100,000 MWd/T के डिज़ाइन टार्गेट बर्न अप से आगे बढ़कर अब 107,000 MWd/T की बर्न अप क्षमता तक पहुंच गया है।

उच्च प्रजनन अनुपात वाले प्रगत द्रुत प्रजनक रिएक्टरों हेतु धात्विक ईंधनों पर हमारे अनुसंधान एवं विकास के अंतर्गत भापअ केंद्र में एक नवीन ताप भौतिक गुणधर्म मूल्यांकन प्रयोगशाला की स्थापना की गई है। इस प्रयोगशाला में



U-15% ईंधन हेतु विभिन्न ताप भौतिक गुणधर्मों का निरूपण किया गया है। तापभौतिकी गुणधर्मों पर विखण्डन उत्पादों का प्रभाव यथा ताप चालकता, ताप प्रसारण इत्यादि पर अध्ययन किए गए हैं।

ईंधन पुनर्संसाधन एवं अपशिष्ट प्रबंधन

विद्युत रिएक्टर ईंधन के पुनर्संसाधन हेतु तारापुर में ROP (Revamping of PREFRE) नामक एक नए पुनर्संसाधन संयंत्र का निर्माण किया गया। इस संयंत्र को डिजाइन करते समय देश के अन्य पुनर्संसाधन संयंत्रों के निर्माण एवं प्रचालन के अनुभव को ध्यान में रखा गया। संयंत्र का निर्माण कार्य संपन्न हो चुका है एवं इसका कमीशनन कार्य प्रगत स्तर पर है। मुझे यह घोषणा करते हुए हर्ष हो रहा है कि आज सुबह 6.45 बजे कमीशनन प्रक्रिया के अंतर्गत भुक्तशेष ईंधन के स्थान पर निष्क्रिय प्राकृतिक यूरेनियम आधारित ईंधन का प्रयोग करते हुए संयंत्र का कोल्ड ट्रायल रन प्रारंभ किया गया। 30 ईंधन गुच्छों के सफलतापूर्वक चापिंग के पश्छात विलयनन प्रक्रिया जारी है।

अनुसंधान रिएक्टरों से भुक्तशेष ईंधन को पुनर्संसाधित करने के लिए प्लूटोनियम संयंत्र का प्रचालन जारी रहा।

एमएपीएस से प्राप्त भुक्त शेष ईंधन का भुक्तशेष ईंधन सुविधा (SFSF), कलपाक्कम में भंडारण किया गया और इसका कार्प सुविधा में संसाधन जारी रहा।

नाभिकीय अपशिष्ट प्रबंधन के क्षेत्र में हमारी उल्लेखनीय उपलब्धियों में अतिरिक्त अपशिष्ट टंकी फार्म (AWTF) का कमीशनन एवं भुक्त शेष ईंधन भंडारण सुविधा (SFSF) में 90% भंडारण सुविधा का उपयोग के साथ साथ ईंधन के ढेर युक्त रैंक के भूकंपीय मान्यकरण पर विस्तृत कार्य शामिल है।

अपशिष्ट निश्चलीकरण संयंत्र, कलपाक्कम में द्वितीय सिरेमिक गलक पर प्रयोग आरंभ हो गए हैं और कल प्रेरण तापन रन की शुरुआत हुई है।

कोल्ड क्रूसिबल इंडक्शन मेल्टर को नियमित रूप से प्रचालित किया गया ताकि प्रचालन डाटा तैयार किया जा सके। दो कॉइल इंडक्टर सिस्टम का प्रयोग करते हुए गालक के पचालन को सफलतापूर्वक निर्दर्शित किया गया।

अम्लीय उच्च स्तर अपशिष्ट से रेडियो सीज़ियम की प्राप्ति हेतु प्रक्रम-चित्र तथा रक्त किरणक हेतु विकिरण स्रोत के रूप में प्राप्त सीज़ियम के रूपातंरण का सफलतापूर्वक निरूपण अनुकारित अपशिष्ट सहित कर लिया गया है।

विकिरण भेषजीय अनुप्रयोगों में उपयोग हेतु उच्च स्तरीय अपशिष्ट में उपस्थित ^{90}Sr एवं ^{160}Ru को पुन:प्राप्त किया गया।

स्वास्थ्य, संरक्षा एवं पर्यावरण

मायापुरी, दिल्ली में घटित विकिरणकीय घटना पर आपातकालीन अनुक्रिया केंद्र (ईआरसी), भापअ केंद्र द्वारा तुरन्त प्रतिक्रिया (कार्यवाही) की गई। Co-60 स्रोतों को पहचानने व खोजने और सुरक्षित रूप से उन्हें फ्लास्कों में परिरक्षित करके नरोरा पहुंचाने में ईआरसी दिल्ली, नरोरा, राष्ट्रीय आपदा अनुक्रिया बल एवं एईआरबी ने अनुक्रिया दल को सहायता प्रदान की। प्रभावित दुकानों को विसंदूषित किया गया तथा चट्टों को उछित प्रकार से कंक्रीट की मोटी परत में पुन: दबा दिया गया, ताकि प्रभावित क्षेत्रों में पृष्ठभूमिक विकिरण को घटना-पूर्व सामान्य स्तर पर लाया जा सके।

भाभा परमाणु अनुसंधान केंद्र में कार्बन लेपित एल्यूमीनियम ऑक्साइड आधारित प्रकाश उद्दीपित संदीप्ति (OSL) फॉस्फ़ोरस का विकास किया गया। एक नया चार एलीमेन्ट वाला OSL मात्रामापी बैज और प्रोटोटाइप OSL मात्रामापी बैज रीडर का विकास किया गया है। प्रयोग के तौर पर विभिन्न सुविधाओं को OSLD बैज प्रदान किया गया ।

लीथियम मैग्नीशियम फॉस्फेट नामक एक और फॉस्फर ($LiMgPO_4$: Tb) का संश्लेषण किया गया है । इसकी OSL संवेदनशीलताओं, मन्द और रैखिकता अभिलक्षणों से लगातार उत्साहवर्धक परिणाम प्राप्त हुए हैं। किसी भी घटक का आयात किए बिना ही इस फॉस्फ़ोरस का बड़े पैमाने पर उत्पादन किया जा सकता है।

3 गीगर मुलर (GM) ट्यूबों वाले (विकिरण स्तर संसूछान की निम्न रेंज हेतु 2 और उच्च रेंज हेतु एक) पर्यावरणीय विकिरण मॉनीटरों के नवीन मॉडल का सफलतापूर्वक विकास किया गया है। ये अपने आप में निराले, सौर शक्ति से परिपूर्ण प्रणालियां GSM एवं LAN आधारित संचार युक्तियाँ हैं और सुदूर

क्षेत्रों में स्थापन हेतु बनी हैं एवं स्वयं प्रचालित हैं । देश के विभिन्न भागों में इसी प्रकार के पच्चास मॉनीटरों को स्थापित किया जा चुका है।

हाल ही में 07 अगस्त, 2010 को मुंबई खाड़ी में घटित तेल रिसाव की घटना के प्रभाव के आकलन पर अध्ययन किए गए हैं । सायरस जेट्टी के आगत बिन्दुओं से समुद्र जल के नमूने लेकर उसमें तेल व ग्रीस की मात्रा का लगातार विश्लेषण किया गया तथा इसका डाटा महाराष्ट्र प्रदूषण नियंत्रण बोर्ड को भेजा गया।

विद्युत अपघटन संग्रह एवं प्रस्फुरण सेल सिद्धांतों पर आधारित बेंच-टॉप पोर्टेबल सतत रेडॉन मॉनीटरों का विकास किया गया है । स्वदेश में विकसित इन यंत्रों में उच्चतर संवेदनशीलता, आवेशित क्षय उत्पादों पर आर्द्रता प्रभावों हेतु क्षतिपूर्ति, नेटवर्किंग क्षमताएं हैं तथा ये व्यापारिक रूप से उपलब्ध मॉनीटरों की तुलना में सस्ते हैं।

सुदूर हस्तन एवं रोबोटिकी

कांपैक्ट लैप्रोस्कोपिक मैनिपुलेटर (CoLaM) नामक एक रोबोटिक यंत्र का विकास लैप्रोस्कोपिक सर्जरी के दौरान एंडोस्कोप (दर्शी उपकरण) को नियंत्रित करने के लिए किया गया है जिसे जॉयस्टिक और स्विचों के प्रयोग द्वारा पैरों से चलाया जा सकता है। इसके द्वारा शल्य चिकित्सा दोनों हाथों में शल्यक्रिया के औज़ार होने के बावजूद सीधे तौर पर शल्य क्रिया वाले स्थान को देखकर नियंत्रित व समायोजित कर सकता है। इस प्रकार का पहला प्रोटोटाइप यंत्र इस वर्ष 22 सितंबर को स्थानीय प्रयोगों के लिए क्रिस्टियन मेडिकल कॉलेज (CMC) वेल्लोर को सौंपा गया ।

इलेक्ट्रॉनिकी तथा यंत्रीकरण

नैशनल नॉलेज नेटवर्क (NKN) के माध्यम से फ्रांस के ग्रेनोबल में स्थित सिंक्रोट्रान FIP बीमलाइन तक अभिगमन तथा उसके सुदूर नियंत्रण हेतु भापअ केंद्र में एक सुविधा स्थापित की गई है।

भापअ केंद्र में औद्योगिक सहभागी के साथ मिलकर एक स्कैनिंग इलेक्ट्रॉन सूक्ष्मदर्शी का विकास किया गया है। इसमें 30 KV पर 4 नैनोमीटर का विभेदन और अधिकतम 1,50,000 तक का आवर्धन किया जा सकता है ।

PIN सूचना उपलब्ध करवाने हेतु RFID कार्ड रीडर का प्रयोग करते हुए कार्मिकों की पहचान के सत्यापन के लिए भापअ केंद्र में एक अभिनव एवं संहत हैंड स्कैन बायोमैट्रिक सिस्टम (HSBS) का विकास किया गया है। नेटवर्कड मोड पर कार्यरत HSBS की चार इकाइयों को उनके मूल्यांकन के लिए भापअ केंद्र में स्थापित किया गया है।

Co-60, Cs- 137 आदि रेडियोसक्रिय न्यूक्लाइडों के संसूचन हेतु एक संहत एवं पोर्टेबल प्रणाली (हेंडहेल्ड टेली रेडियो न्यूक्लाईड डिटेक्शन सिस्टम फॉर कवर्ट ऑपरेशन) का विकास किया गया है। निश्चित सीमा से अधिक सक्रियता संसूचित होने पर प्रणाली द्वारा मोबाइल फोन पर एलार्म भेजा जाता है और रिमोट सर्वर पर भी देशान्तर रेखांश व अक्षांश सूचना सहित एक अलार्म भेजा जाता है ।

पदार्थ एवं धातुकी

नाभिकीय श्रेणी बेरिलिया का उत्पादन करने के लिए एक पाइलट सुविधा की स्थापना की गई जो CHTR एवं पुनर्सज्जित अप्सरा रिएक्टर के लिए मंदक-सह-परावर्तक है ।

CHTR हेतु प्रयोग में आने वाले कणिक ईंधन के एकल अभियान में सभी परतों के लेपन को ऑनलाइन नियंत्रित करने के लिए कणों के TRISO लेपन पर अध्ययन किए गए हैं।

उच्चताप रिएक्टरों तथा द्रुत रिएक्टरों में न्यूट्रॉन अवचूषकों के अतिरिक्त हाईपरसोनिक रीएन्ट्री वेहिकल की तापीय संरक्षा जैसी उछ्छा तापमान संरचानाओं के लिए बोरॉन कार्बाइड एवं दुर्गलनीय/विरल मृदा धातु बोराइड कैंडिडेट पदार्थ होते हैं। तप्त दाबन की तुलना में काफी निम्न तापमान पर समृद्ध बोरॉन कार्बाइड, हैफनियम डाइबोराइड, ज़र्कोनियम डाइबोराइड एवं टाइटेनियम डाइबोराइडों के सन्निकट सैद्धांतिक सघन पिंडों को स्पार्क प्लाज़्मा सुविधा का प्रयोग करते हुए समेकित किया गया।

लेसर प्लाज्मा एवं त्वरक प्रौद्योगिकी

द्रव यूरेनियम हेतु अभिनव सिरेमिक संरक्षणात्मक लेपनों के विकास की खोज में टैन्टेलम क्रूसिबल पर जमे हुए प्लाज्मा स्प्रेड यीट्रिया लेपनों का परीक्षण किया गया ताकि विशेष रूप से अभिकल्पित सुविधा में मोल्टेन यूरेनियम का आक्रमण होने पर

प्रतिरोध किया जा सके। ये लेपन लगातार 120 घंटों के टैस्ट रन के दौरान तथा 400 घंटों से अधिक संचयी टैस्ट रन के दौरान स्थिर रहे और रासायनिक आक्रमण सहन कर गए।

3MevDC त्वरक को नियमित रूप से 1.0 MeV बीम एनर्जी एवं 4.6mAबीम करन्ट पर प्रचालित किया गया। एक स्थानीय निर्माता से डोसीमीटर फिल्मों (B3) एवं 2.5 mm मोटे रबर के नमूनों को उक्त रेटिंग पर 2.2m प्रति मिनट की गति पर 80 पासों के लिए किरणित किया गया और उनका विश्लेषण किया गया।

LEHIPA एक चड्रिफ्ट ट्यूब लाइनेकछ है जिसमें स्थायी चुंबक, जल शीतित ड्रिफ्ट नलियों (DTड्ड) को डीटी टंकी के अक्ष के साथ लगाया जाता है। भापअ केंद्र द्वारा दो प्रोटोटाइप ड्रिफ्ट ट्यूबों का डिजाइन एवं संविरचन किया गया। इन नलियों की चुंबकीय फ्लक्स मापन एवं शीतलन जांच (अनुकारित ऊष्मा भार सहित) सफलता पूर्वक की गई।

आइसोटोप अनुप्रयोग

177 Lu-DOTATATE, नामक एक पेप्टाइड आधारित रेडियोभेषज सफलतापूर्वक तैयार किया गया है और इसे भारत के 5 अस्पतालों के सहयोग से रोगलाक्षणिक (क्लिनिकल) योजना में प्रयोग हेतु और तंत्रिका अंत:स्रावी (न्यूरोएन्डोक्रीन) ट्यूमरों से ग्रसित रोगियों के उपचार में इसके प्रयोग हेतु प्रदर्शित किया गया है। अब तक, 100 से भी अधिक रोगियों के लिए 177Lu-DOTATATE का प्रयोग करके हमारी विधि से और हमारे केंद्र में उत्पादित उच्च कोटि के Lu177 से खुराकें तैयार की गई हैं ।

राष्ट्रीय संस्थानों जैसे डीआरडीओ, इसरो, आईजीकार को उनके अनुसंधान हेतु ^{55}Fe, ^{57}Co एवं ^{63}Ni की आपूर्ति की गई है। इनमें से अनेक स्रोत आयात किए गए स्रोतों से काफी सस्ते हैं और कुछ खरीद के लिए उपलब्ध ही नहीं है।

हमारे विकिरण औषध केंद्र में कैंसर हेतु उपचारात्मक कर्मक वाले दो फ्लोरीन-18 (F-18), कैंसर में इमेजिंग सेल प्रोलिफिरेशन हेतु फ्लूरोथाइमिडाइन एवं ट्यूमर में हाइपॉक्सिक कारणों के इमेजिंग हेतु [18-F] फ्लूरोमिसोनिडाजोल ([F-18] FMISO) के लिए संश्लेषण नयाचार, विकिरण रसायन मूल्यांकन एवं व्यावसायिक उत्पादनों का विकास किया गया।

रसायन इंजीनियरी

इलेक्ट्रॉनिक श्रेणी (प्रकार E-III/प्रकार E-IV) वाले अति-शुद्ध जल के उत्पादन हेतु एक इलेक्ट्रो-वि-आयनीकरण (EDI) यूनिट को निम्न तापमान वाष्पीकरण (LTE) समुद्र जल निर्लवणीकरण संयंत्र के साथ समाकलित किया गया है जिसमें चालकता 0.1 माइक्रोसीमेनस/cm और सिलिका तत्व 50 ppb से कम हैं तथा जिसके सुपर-कंप्यूटर के समान उच्च सीमा तक अनुप्रयोग हैं।

एक ऐसे द्विचरणीय स्पन्द ट्यूब क्रायोकूलर का विकास किया गया जिसमें हीलियम प्रशीतन के रूप में कार्य करती है। इसमें 2.8 केलविन के निम्नतम तापमान तक पहुंछाने की क्षमता है । क्रायोकूलर का उपयोग क्रायोजेनिक अनुप्रयोगों हेतु तापमान संवेदक के अशांकन के लिए किया जाएगा।

नाभिकीय यंत्रीकरण कार्यक्रम के अंतर्गत प्लव संस्तर तकनीक के माध्यम से एकल सिलिकॉन क्रिसटल को खींछाने के लिए प्रचालन प्राचल की स्थापन की गई। एकल क्रिस्टलों के मुख्य प्रचलों के अभिलक्षणन किए गए और उन्हें अंतरर्राष्ट्रीय मानकों पर संतोषजनक पाया गया।

भौतिक विज्ञान

कला विपर्यास प्रतिबिम्बन सुविधा [(फेज कंट्रास्ट इमेजिंग फैसिलिटी) (जो भारी तत्वों के एक आव्यूह में हल्के तत्व प्रोफाइल का उद्घाटन करने में समर्थ है)] और न्यूट्रॉन प्रेरित इलेक्ट्रॉन रेडियोग्राफी सुविधा (जो दस्तावेजों, पेंटिंग तथा जैविक नमूनों की जांच करने में लाभदायक है) का हाल ही में साइरस में कमीशनन किया गया।

गामा-रे संसूचन में अनुप्रयोगों हेतु उच्च गुणवत्ता वाले थैलियम मादित सीजियम आयोडीन एकल क्रिस्टलों की वृद्धि की गई।

परमाणु खनिज अन्वेषण एवं अनुसंधान निदेशालय (AMDER) के भू-कालानुक्रमीय अनुप्रयोगों में उपयोग के लिए उच्च परिशुद्धता के साथ आइसोटोप अनुपात मापन हेतु एक नए सप्त संग्राहक घ्तापीय आयनन द्रव्यमान स्पेक्ट्रममापीछ का अभिकल्पन तथा विकास किया गया।

रासायनिक विज्ञान

ऑनलाइन संक्षारण/निघर्षण (वेअर) दर मापन के लिए तनु स्तर सक्रियण (थिन लेयर एक्टिवेशन) विधि का प्रयोग करके एक क्रियाविधि स्थापित की गई है। PHWR फीडरों में प्रवाह त्वरित संक्षारण (FAC) मॉनिटरिंग में इस क्रियाविधि का सीधा उपयोग किया जा सकता है।

एक ऐसी पॉलीमर प्रणाली का विकास किया गया है जिसमें क्लोरीन आक्साइड को निरन्तर स्वस्थाने उत्पादित करने की क्षमता है और जिसे हाल ही में जैव-परिदूषण नियंत्रण कर्मक के रूप में उच्चकोटि का जीवनाशी स्वीकार किया जाने लगा है।

नाभिकीय कृषि

मूंगफली और तूर दोनो की एक-एक अर्थात् दो और नई किस्में, क्रमशः आंध्रप्रदेश तथा महाराष्ट्र राज्यों की वेरायटी रिलीज समितियों द्वारा जारी की गई हैं और इनकी केंद्रीय अधिसूचना की प्रतीक्षा की जा रही है। इससे इस केंद्र में विकसित उत्परिवर्ती प्रजनक बीज किस्मों की कुल संख्या उनतालीस हो जाती है।

नाभिकीय कृषि एवं जैव प्रौद्योगिकी प्रभाग, भापअ केंद्र के मार्गदर्शन में देश के विभिन्न स्थानों में 50 निसर्गऋण ठोस अपशिष्ट उपछार संयंत्रों की स्थापना की गई।

खाद्य प्रौद्योगिकी

विभिन्न प्राकृतिक जैव बहुलकों का प्रयोग करके जैव-निम्नीय (बायोडिग्रेडेबल) तथा रोगाणुरोधी पैकेजिंग पदार्थ तैयार किया गया। ग्लिसरॉल का उपयोग प्लास्टिसाइज़र के रूप में तथा आवश्यक वाष्पशील तेलों का उपयोग रोगाणुरोधी एजेंटों के रूप में किया गया।

माइक्रोबियल प्रणाली पर किए गए इन-विट्रो प्रयोगों से पता चला है कि शहद में प्रतिपरिवर्तजनिक एवं विकिरण-संरक्षा गुणधर्म होते हैं।

मानव संसाधन विकास

भापअ केंद प्रशिक्षण विद्यालय ने अपने आधारभूत ढांछो के उन्नयन के लिए तथा अपने लगातार चलने वाले शिक्षण कार्यक्रम के एक अंग के रूप में वैज्ञानिकों एवं इंजीनियरों के फायदे के लिए सायंकालीन व्याख्यान शुरू करने के लिए कई उपाय किए।

चिकित्सीय सुविधाएं

हाल ही में भापअ केंद्र अस्पताल की अवसंरचना में विस्तार किया गया है ताकि परमाणु ऊर्जा विभाग के अंशदायी स्वास्थ्य सेवा योजना के हितग्राहियों को विस्तृत चिकित्सा सेवाएं प्राप्त हो सकें।

प्रिय साथियों,

सामरिक परिदृश्य में किए गए विशाल योगदान के अलावा हमारे केंद्र के 15000 से अधिक लोगों द्वारा विभिन्न वैज्ञानिक एवं तकनीकी विषय में किए गए अभिनव कार्यों का वर्णन इतने कम समय में कर पाना असंभव है। अपने भाषण में उन सब का ज़िक्र न कर पाने पर भी उन सब कार्यों का महत्व कम नहीं हो जाता।

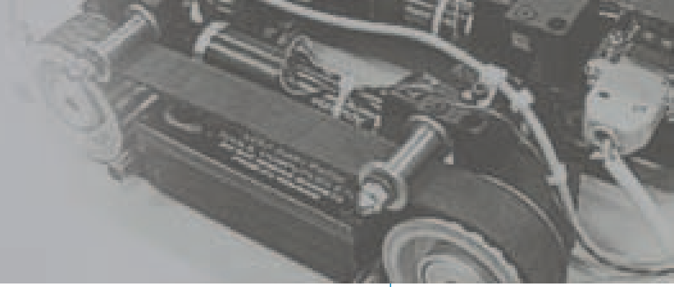
मैंने पिछले एक वर्ष के दौरान भाभा परमाणु अनुसंधान केंद्र की उपलब्धियों का सार प्रस्तुत करने की हर संभव कोशिश की है। राष्ट्रीय सुरक्षा से संबंधित क्षेत्र में हमारे विस्तृत योगदान को मैंने यहां शामिल नहीं किया है। मेरे भाषण में यदि कुछ बातें छूट गई हों तो इसका अर्थ यह नहीं है कि उनका महत्व कम है।

अपना संबोधन समाप्त करते हुए, मैं इस बात पर जोर देना चाहूंगा कि हमारे आगे बहुत सी चुनौतियां हैं। मुझे पूर्ण विश्वास है कि भाभा परमाणु अनुसंधान केंद्र के वैज्ञानिकों, इंजीनियरों तथा प्रशासकों के सहयोगात्मक प्रयास से, हम भाभा परमाणु अनुसंधान केंद्र की परंपरा के अनुरूप भविष्य की चुनौतियों का सामना करने में सफल होंगे।

साथियों, अंत में इस विशेष दिवस पर आइए हम दृढ़तापूर्वक संकल्प लें कि हम अपने देश की जनता की उन्नति के लिए नाभिकीय विज्ञान एवं प्रौद्योगिकी के अग्रणी क्षेत्रों में सतत श्रेष्ठता के लिए अपने-आपको समर्पित बनाए रखेंगे।

धन्यवाद

जय हिंद।"



Address by Dr. R.K. Sinha

Director, BARC

Dr. Banerjee, Chairman, Atomic Energy Commission, senior members of DAE family present here and dear colleagues.

It is indeed a matter of great pleasure and proud privilege for me to extend a warm welcome to you all to celebrate the 101st birth anniversary of Dr. Homi Jahangir Bhabha – the founder of this great institution, Bhabha Atomic Research Centre.

We celebrate Homi Bhabha's birthday every year on the 30th October by taking stock of our achievements during the previous year and rededicating ourselves towards our mission oriented tasks related to the development of nuclear science and technology.

This year, In keeping with the tradition, we are having this function today, the last working day before the 30th, which happens to fall on a week-end.

During the last one year, there have been numerous noteworthy achievements of BARC. In the given time my effort will be directed to give you a broad over-view of our continued progress, taking only a few of the recent achievements, as examples.

Research Reactors

The completion of 50 years of operation of CIRUS on July 10, 2010 and 25 years of operation of Dhruva on August 8, 2010 are two very unique and significant milestones in the history of BARC. I am sure, you all will agree with me, that these two events in the year 2010 are fitting tributes to the memory of our founder Dr. Homi Bhabha. Both these reactors have served extremely well in our activities of isotope production, basic research, material testing and human resource development.

The APSARA reactor was shut down in June 2009 after 52 years of useful service and thereafter its decommissioning activities have been nearly completed. Transport of APSARA core fuel out of Trombay has commenced. The new design of APSARA will have several advanced features that include advanced dispersion type uranium silicide fuel. The process for production of the new silicide fuel has already been fully developed and established. The core will have a capability to deliver 2 MWth power at a neutron flux, which will be as high as that existing in the CIRUS reactor.

The old reactor structure has been evaluated for the fulfillment of modern seismic criteria. It was found that the external building structure would need to be replaced with a modern structure of higher seismic resistance. The new building of APSARA will be built after demolishing the old building and all care has been taken to retain the major architectural features of the old building in the new building.

The Critical Facility (CF) for Advanced Heavy Water Reactor (AHWR) and 540 MWe PHWR was operated on 74 occasions for various experiments. Thirteen nuclear detectors were tested in graphite reflector region. After loading of a fuel cluster containing Thoria and Uranium pins, several measurements have been carried out satisfactorily. This facility was also utilised for large volume sample irradiations for Neutron Activation Analysis (NAA).

AHWR Programme

The full scale Integral Test loop for AHWR has been augmented with an additional 3 MW, instrumented fuel rod cluster simulator developed in-house. The augmented facility will serve as a test bed for validation of many new techniques, such as that for channel power measurement and detection of instability.

The Passive Poison Injection System (PPIS) is a unique system provided in AHWR to fulfill the shutdown function in the event of failure of wired shutdown systems. A prototype 'Poison Injection Passive Valve (PIPV)' to be used in PPIS of AHWR has been designed, developed and tested under simulated conditions. This is the third passive valve in succession, developed for various safety systems of AHWR, proving the technological maturity in the area of passive valve design and development.

We are interacting with the Indian industries for the development of some unique features in the major components of AHWR. An MOU for development of Pull-out technology for integrated nozzles in steam drum, inlet header and end fittings of Advanced Heavy Water Reactor (AHWR) was signed with a leading manufacturer of nuclear components.

High Temperature Reactor Programme

The physics design of the Compact High Temperature Reactor progressed further. Monte Carlo simulations have been performed to estimate the neutron flux in the core and at detector locations outside the reactor vessel for the purpose of reactor start-up and regulation.

PHWR programme

Technical and analytical support to NPCIL was provided for the ageing management activities. Wet scraping was successfully used to obtain scraped material samples from pressure tubes of RAPS-3 and KAPS-2 reactors, to determine hydrogen/deuterium contents for predicting residual service life of the tubes.

Nuclear Fuels Programme

BARC supplies Plutonium bearing fuels for the Fast Reactor Programme, including FBTR and PFBR (under construction) at Kalpakkam.

The experimental PFBR MOX fuel earlier manufactured and supplied by BARC has been undergoing irradiation at FBTR. The fuel has now reached a burn-up of 107,000 MWd/T, exceeding the design target burn-up of 100,000 MWd/T.

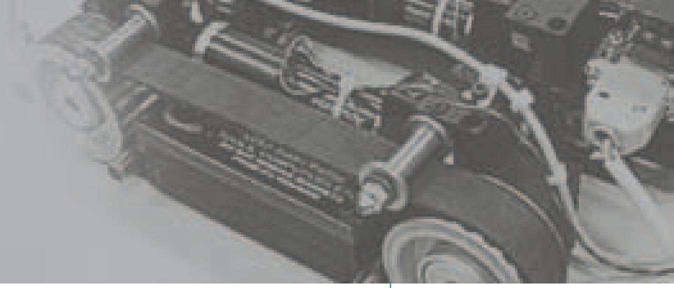
As a part of our R&D on metallic fuel for the advanced fast breeder reactors with high breeding ratio, a new thermophysical property evaluation laboratory has been set up in BARC. In this laboratory, various thermophysical properties for U-15%Pu fuel have been determined. Effect of fission products on thermophysical properties like thermal conductivity, thermal expansion etc. have been studied.

Fuel Reprocessing and Waste Management

A new reprocessing plant called ROP (Revamping of PREFRE) has been constructed at Tarapur for carrying out the reprocessing of power reactor fuel. The design of this plant takes into account the experience of construction and operation of other reprocessing plants in the country. I am glad to announce that this morning at 6.45 AM as a part of the commissioning process, the cold trial run of the plant has been started with the use of inactive natural uranium based fuel, in place of spent fuel, which will follow later. After the successful chopping of 30 fuel bundles the dissolution process is currently in progress.

Operation of Plutonium Plant, Trombay was continued to reprocess spent fuel from research reactors.

Storage of spent fuel received from MAPS in Spent Fuel Storage Facility (SFSF) at Kalpakkam and its



processing at KARP facility were continued.

In the area of nuclear waste management our noteworthy achievements include Additional Waste Tank Farm (AWTF) commissioning and 90% storage capacity utilisation in Spent Fuel Storage Facility (SFSF), following extensive work on seismic validation of stacked fuel racks.

The trials on second ceramic melter at Waste Immobilisation Plant, Kalpakkam have started with the initiation of the induction heating run yesterday.

The Cold Crucible Induction Melter was operated on regular basis to generate the operational data. Starting of the melter using a two coil inductor system was successfully demonstrated.

Flow sheets for recovery of radio-caesium from acidic high level waste and conversion of recovered caesium as a radiation source for blood irradiator have been successfully demonstrated with simulated waste.

^{90}Sr and ^{106}Ru present in high level waste were recovered for use in radio pharmaceutical applications.

Health, Safety & Environment

The nodal Emergency Response Centre (ERC) at BARC responded quickly to the radiological incident that occurred at Mayapuri, Delhi. The response team was also assisted by ERC Delhi, Narora, National Disaster Response Force and AERB in identifying and locating the Co-60 source and safely securing and transporting them in the shielded flasks to Narora. The affected shops were decontaminated and the roads suitably resurfaced with thick concrete, so as to bring down the background radiation in the affected area to normal pre- incident level.

The carbon doped aluminium oxide based Optically Stimulated Luminescence (OSL) phosphor has been developed in BARC. A new four element OSL dosimeter badge and a prototype OSL dosimeter badge reader have been developed. OSLD badges have been given to various facilities on trial basis.

Another phosphor, namely Lithium Magnesium Phosphate ($LiMgPO_4$:Tb) has been synthesised. Its OSL sensitivities, fading and linearity characteristics have yielded consistently promising results. This phosphor can be readily produced on a mass scale without imported components.

New model of environmental radiation monitors (IERMON) having 3 Geiger Muller (GM) tubes (two for lower range and one for higher range of radiation level detection) has been developed successfully. These are stand alone, solar powered systems with GSM and LAN based communication devices and are meant for installation at remote location and unattended operation. Fifty such monitors have already been installed at different places in the country.

Studies have been carried out to assess the impact of recent oil spill incident occurred on 7th Aug., 2010 on Mumbai bay. Continuous analysis of oil & grease in sea water samples collected at intake point of CIRUS Jetty was carried out and the data submitted to Maharashtra Pollution Control Board.

Bench-top and portable continuous radon monitors have been developed, based on electrostatic collection and scintillation cell principles. These indigenous instruments have higher sensitivity, compensation for humidity effects on charged decay products, networking capabilities and are lower in cost, compared to commercially available ones

Remote Handling and Robotics

A robotic device named Compact Laparascope Manipulator (CoLaM) for control of endoscope (viewing apparatus) during a laparoscopic surgery using foot-operated joystick and switches has been developed. This allows the surgeon to directly control and adjust the view of the operating area, inspite of the fact that both his hands are engaged with surgical tools. The first prototype of this device has been delivered to Christian Medical College (CMC), Vellore, on 22nd September this year for field trials.

Electronics & Instrumentation

A facility has been setup at BARC for remote control and accessing the synchrotron FIP beamline located at Grenoble, France, through the National Knowledge Network (NKN).

A Scanning Electron Microscope (SEM) has been developed in BARC in association with an industry partner. It features a resolution of 4 nanometers at 30 KV and a maximum magnification of 1,50,000.

BARC has developed a prototype of a unique and compact Hand Scan Biometric System (HSBS) for verification of identity of personnel using an RFID card reader to provide PIN information. Four units of the HSBS, working in networked mode have been installed in BARC for evaluation.

A compact and portable system (Handheld Tele Radio Nuclide Detection System for covert operation) has been developed for detection of radioactive nuclides like Co-60, Cs-137 etc. On detection of activity above a set limit, the system sends alarm to a mobile phone and to a remote server along with longitude and latitude information.

Materials and Metallurgy

A pilot facility has been setup for producing nuclear grade beryllia, which is moderator cum reflector for CHTR and for refurbished APSARA reactor.

Studies have been carried on TRISO coating of particle type fuel to be used for CHTR, for online control of the coating of all layers in single campaign.

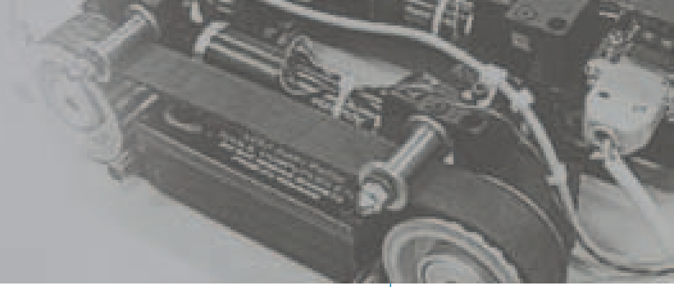
Boron carbide and refractory / rare earth metal borides are candidate materials for high temperature structures such as thermal protection of hypersonic re-entry vehicles, in addition to neutron absorbers in high temperature reactors and fast reactors. Near theoretical dense bodies of enriched boron carbide, hafnium diboride, zirconium diboride and titanium diborides were consolidated using spark plasma facility at relatively lower temperature, as compared to hot pressing.

Laser, Plasma and Accelerator Technology

In the search for development of novel ceramic protective coatings for liquid uranium, the plasma sprayed yittria coatings deposited on tantalum crucible were tested for resistance to attack by molten uranium in a specially designed facility. These coatings were stable and withstood chemical attack during continuous test run for 120 hours and a cumulative test run for over 400 hours,

The 3 MeV DC accelerator was regularly operated at 1.0 MeV beam energy and 4.6 mA beam current. Dosimeter films (B3) and 2.5 mm thick rubber samples from a local manufacturer have been irradiated for 80 passes at 2.2 m/min speed at the above ratings and analysed.

LEHIPA is a "Drift Tube Linac" in which permanent magnet, water cooled drift tubes (DT's) are lined up along the axis of the DT tank. Two prototype DT's were designed and fabricated by BARC. Magnetic flux measurements and cooling tests (with simulated heat loads) of these tubes were also successfully carried out.



Isotope Aplications

177Lu-DOTATATE, a peptide based radiopharmaceutical has been successfully prepared for use in clinical setting and demonstrated for its use in treatment of patients suffering from neuroendocrine tumors, by collaborating with 5 hospitals in India. Till date, more than 100 patient doses have been prepared using the 177Lu-DOTATATE prepared using our method and the high grade Lu177 produced at our Centre.

National Institutions like DRDO, ISRO, IGCAR have been supplied ^{55}Fe , ^{57}Co and ^{63}Ni sources for their research work. Many of these sources are far less expensive than the imported sources and some are not even available for buying.

In our Radiation Medicine Centre, the development of synthesis protocols, radiochemical evaluation and commercial production was carried out for two Flourine-18 (F-18) containing diagnostic agents for cancer viz; $[^{18}F]$ Fluorothymidine ($[^{18}F]$ FLT) for imaging cell-proliferation in cancers and [18-F] Fluoromisonidazole ([F-18] FMISO) for imaging of hypoxic regions in tumours.

Chemical Engineering

An Electro-De-Ionisation (EDI) unit has been integrated to Low Temperature Evaporation (LTE) sea water desalination plant for producing electronic grade (Type E-III/ Type E-IV) ultra-pure water with conductivity less than 0.1 micro-siemens/cm and silica content less than 50 ppb for high end applications such as super-computers.

A two stage pulse tube cryocooler with Helium as refrigerant was developed. It is capable of reaching a lowest temperature of 2.8 Kelvin. The cryocooler will be utilised for calibration of temperature sensors for cryogenic applications.

Under nuclear instrumentation programme, operating parameters for pulling single silicon crystal through float zone technique were established. Characterisation of major parameters of single crystal have been carried out and are satisfactory with respect to international standard.

Physical Sciences

Phase contrast imaging facility (capable of revealing light element profile in a matrix of heavy elements) and Neutron induced electron radiography facility (useful for inspecting documents, painting and biological samples) have been recently commissioned at CIRUS.

High quality thallium doped caesium iodide single crystals for applications in gamma-ray detection have been grown.

A new seven collector 'Thermal Ionization Mass Spectrometer' has been designed and developed for Atomic Minerals Directorate for Exploration and Research (AMDER) for high precision isotope ratio measurements in its geo-chronological applications.

Chemical Sciences

A procedure has been established for online corrosion/wear rate measurement using Thin Layer Activation method. This work has direct application in Flow Accelerated Corrosion (FAC) monitoring in PHWR feeders

A polymer system has been developed, with a capability of continuous in-situ production of chlorine dioxide, a superior biocide currently gaining acceptance as a bio-fouling control agent. The biocide-releasing polymer will have application in biomedical fields and in industrial settings.
Nuclear Agriculture

Two more new varieties of mutant breeder seed varieties developed in BARC, one each of groundnut and tur (pigeonpea) are released by State Variety Release Committee, Andhra Pradesh and Maharashtra respectively, and are awaiting Central notification. This brings the total number of mutant breeder seed varieties developed in this Centre to thirtynine.

Fifty Nisargaruna solid waste treatment plants were established in various places in the country under the guidance of Nuclear Agriculture & Bio-Technology Division, BARC.

Food Technology

Biodegradable and antimicrobial packaging material was prepared using different natural biopolymers. Glycerol was used as a plasticizer and essential oils as antimicrobial agents.

In-vitro experiments on a microbial system have shown that honey has anti-mutagenic and radio-protective properties.

Human Resource Development

The BARC Training School took several steps to upgrade its infrastructure and start evening lectures for the benefit of scientists and engineers as part of its continuing education programme.

Medical Facilities

The infrastructure available at our BARC Hospital has been recently expanded to provide further enhanced medi-care services to beneficiaries under the DAE's Contributory Health Service Scheme.

Dear Colleagues,

Even without a mention of our voluminous contributions in the strategic domain, a coverage of all the highlights of recent work done by our organisation of more than 15,000 persons, spanning practically all scientific and technological disciplines, is impossible in a short time. Any omissions in my speech do not undermine the importance of the value of all such work.

While concluding my address, I would like to emphasise that with the envisaged massive growth in the nuclear sector in the country, we have plenty of challenges ahead. With the synergetic effort of all of us in BARC, I am sure, we will be able to rise to the occasion to meet these challenges in a manner consistent with the tradition of BARC.

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

Thank you

-Jai Hind-

DAE (Excellence in Science, Engineering & Technology) Awards – 2009

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 2009 were given on the eve of Founder's Day (October 30th) which was celebrated this year on October 29th, 2010 in BARC. These were presented to the winners by Honourable Mr. Prithvi Raj Chauhan, Minister of State in the Prime Minister's Office, GOI.

These Awards were in the following categories:

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

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

1. Dr. S. Chattopadhyay, Head, BOD, CG, BARC
2. Dr. P. K. Mohapatra, SO/G, RCD, RC&IG, BARC
3. Dr. (Smt) Sadhana Mohan, Head, HWD, ChEG, BARC
4. Dr. B. K. Nayak, SO/H, NPD, PG, BARC
5. Mr. P. Sreenivas, SO/H, RPD, RPG, BARC
6. Dr. Dinesh Srivastava, SO/H, MSD, MG, BARC.

Dr. S. Chattopadhyay was awarded for his innovative contributions in green chemistry/ biochemistry (biocatalysts, ionic liquids, metallo-organics and herbal drugs), redox biology and supramolecular chemistry to develop nuclear solvents, radiopharmaceuticals, drugs, laserdyes and functional materials for use in nuclear sciences.

Mr. Prithvi Raj Chauhan presenting the Homi Bhabha Science & Technology Award 2009 to Dr. S. Chattopadhyay

Dr. P.K. Mohapatra was awarded for his excellent contributions in the development of selective separation processes that will help in radioactive waste remediation and mitigate their long term hazards to the environment.

These include flow sheet development for actinide partitioning and lanthanide-actinide separations using novel hollow fibre supported liquid membrane technique, and development of crown ether and calix-crown-6 based solvent systems for Sr & Cs recovery from high level wastes.

Mr. Prithvi Raj Chauhan presenting the Homi Bhabha Science & Technology Award 2009 to Dr. P.K. Mohapatra

Dr. Sadhana Mohan was awarded for her excellent contributions from 'Concept' to 'Commissioning' in the indigenous detector grade silicon technology development programme. Detector grade single

Mr. Prithvi Raj Chauhan presenting the Homi Bhabha Science & Technology Award 2009 to Dr. Sadhana Mohan

crystal production technology is a highly challenging and demanding technology due to its stringent requirements of purity. She has been instrumental in achieving this task and this has made India one of the few countries in the world to pull successfully a single crystal of silicon by using the Float Zone method.

Dr. B.K. Nayak was awarded for his outstanding research contributions in heavy ion reaction studies utilizing the Pelletron accelerator. He has taken a lead role to develop a gamma ray multiplicity set up at Pelletron facility, which is being extensively used by experimentalists.

Mr. Prithvi Raj Chauhan presenting the Homi Bhabha Science & Technology Award 2009 to Dr. B.K. Nayak

He has recently developed a new experimental technique now known as 'Hybrid surrogate ration method' in literature to measure reaction cross sections involving unstable target nuclei.

Dr. Nayak has co-authored more than 25 publications in reputed international journals in the last five years.

Mr. P. Sreenivas was awarded for his excellent contribution in conceptualization, design and

Mr. Prithvi Raj Chauhan presenting the Homi Bhabha Science & Technology Award 2009 to Mr. P. Sreenivas

development of special heavy structural reactor equipment and high pressure – high temperature special valves for nuclear steam generating plants for various projects of national importance. These were the first of their kind to be made in the country.

Dr. D. Srivastava was awarded for his excellent contributions in the field of understanding of the physical metallurgy aspects of all major diffusional and diffusionless phase transformations of Zr base alloys mainly of Zr-2.5Nb, Zr-1Nb, Zircaloy-2 and Zircaloy-4.

Mr. Prithvi Raj Chauhan presenting the Homi Bhabha Science & Technology Award 2009 to Dr. D. Srivastava

The resulting modifications in the process and microstructure have also resulted in superior mechanical and corrosion properties, better yield and enhanced quality of the components.

2. Scientific & Technical Excellence Award carries a Cash award of Rs 1 Lakh, a Citation and a Medal. There were thirty eight award winners: twenty nine from BARC and five from IGCAR, two from VECC and one each from RRCAT and NFC.

1. Dr. Raghunath Acharya, SO/F, RCD, RC&IG, BARC
2. Mr. Kailash Agarwal, SO/H, NRB, BARC
3. Dr. Sharmila Banerjee, SO/G RPhD, RC&IG, BARC
4. Dr. A.C. Bhasikuttan, SO/G, RPCD, CG, BARC
5. Dr. Dibyendu Bhattacharya, SO/F, ApSD, PG, BARC
6. Dr. R.C. Bindal, SO/H, DD, ChEG, BARC
7. Dr. Jayanta Chattopadhyay, SO/G, RSD, RD&DG, BARC
8. Mr. Santanu Das, SO/F, UED, MG, BARC &
9. Mr. Raj Kumar, SO/D, UED, MG, BARC
10. Dr. Ashutosh Dash, SO/G, RPhD, RC&IG, BARC
11. Mr. R. Dinesh Babu, SO/G, LWRD, RPG, BARC
12. Dr. Anurag Gupta, SO/F, RPDD, RDDG, BARC
13. Dr. D.C. Kar, SO/G, DRHR, DMAG, BARC
14. Mr. Arbind Kumar, SO/F, QAD, NFG, BARC
15. Mr. K. Madhusoodanan,SO/H, RED, RD&DG, BARC
16. Ms. Smitha Manohar, SO/G, PDD, NRG, BARC
17. Dr. Hari Sharan Misra, SO/F, MBD, BMG, BARC
18. Dr. S.C. Parida, SO/F, PDD, RC&IG, BARC
19. Dr. Chandra Nath Patra, SO/G, TCS, CG, BARC
20. Mr. H.R. Pimparkar, SO/G, NRB, BARC
21. Dr. S. Pradhan, SO/G, RPD, RPG, BARC
22. Mr. Shyamal Roy, SO/G, RTD, RD&DG, BARC
23. Dr. Alok Samanta, SO/G, TCS, CG, BARC
24. Mr. Sanjay Sethi, SO/F, L&PTD, BTDG, BARC
25. Dr. Jung Bahadur Singh, SO/G, MMS, MG, BARC

25\. Mr. J.L. Singh, SO/H, PIED, NFG, BARC

27\. Ms. Padmini Sridharan, SO/G, ED, E&I Group, BARC

28\. Mr. M. Srinivasa Rao, SO/G, RPD, RPG, BARC

29\. Dr. Dinesh Venkatesh Udupa, SO/G, ApSD, PG, BARC.

3. Young Applied Scientist / Technologist Award carries a Cash award of Rs 50,000/-, a Citation and a Medal. There were ten award winners: eight from BARC and one each from IGCAR and VECC.

1. Mr. Kamlesh Chandra, SO/E, MSD, MG, BARC
2. Dr. Shivanand Chaurasia, SO/E, LNPD, PG, BARC
3. Mr. B. K. Sahoo, SO/D & Mr. Jitendra J. Gaware, SA/E, RPAD, HS&EG, BARC
4. Mr. Shaji Karunakaran, SO/E, TDD, NRG, BARC

5. Mr. Ramakrishna. P, SO/E, RTD, RD&DG, BARC
6. Mr. P. S. Sarkar, SO/E, LNPD, PG, BARC
7. Mr. Vivek Shrivastav, SO/E, LWRD, RPG, BARC
8. Mr. Ved Prakash Sinha, SO/E, MFD, NFG, BARC.

4. Young Scientist Award carries a Cash award of Rs 50,000/-, a Citation and a Medal. There were six award winners: five from BARC and one from RRCAT.

1. Dr. Amit Kumar, SO/D, RB&HSD, BMG, BARC
2. Dr. Atanu Barik, SO/E, RPCD, CG, BARC
3. Dr. (Ms.) Vinita Grover Gupta, SO/E ,Chem.Div., CG, BARC
4. Dr. Sanjay Kumar Mishra, SO/D, SSPD, PG, BARC
5. Dr. Pramod Sharma, SO/E, Chemistry Division, CG, BARC.

5. Young Engineer Award carries a Cash award of Rs 50,000/-, Citation and a Medal. There were twelve award winners: ten from BARC and two from NFC.

1. Mr. Indranil Banerjee, SO/E, RMP, BARC
2. Mr. Radhelal Bharadwaj, SO/F, L&PTD, BTDG, BARC
3. Mr. Bhuvaneshwar Gera, SO/D, RSD, HS&EG, BARC
4. Mr. Mukesh Goyal, SO/E, CrTD, ChEG, BARC
5. Mr. M.K. Mishra, SO/E, DRHR, DM&AG, BARC
6. Mr. S.B. Patil, SO/E, TDD, NRG, BARC
7. Mr. Bibhu Narayan Rath, SO/E, PIED, NFG, BARC
8. Mr. J. Sreejith, SO/E, LWRD, RPG, BARC
9. Ms. Menka Sukhwani, SO/D, ED, E&IG, BARC
10. Mr. Anil Kumar Tiwari, SO/E, CTD, CTG, BARC.

6. Group Achievement Award winners received cash awards a medal and a Citation. A total number of forty six Groups received these awards. Out of these, twenty eight groups were from BARC, six from IGCAR, four from NFC, three from RRCAT, two from VECC and one each from DCSEM, BRIT and HWB. Following were the Group Leaders from BARC, who received the awards.

1. Mr. H.S. Kamath, Director, NFG, BARC
2. Dr. P.K. Tewari, Head, DD, BARC & Shri A.Y. Dangore, Plant Supdt., NDDP(Kalpakkam)
3. Mr. P.K. Dey, OS, Head, FRD,BARC& Shri S.K. Munshi, OS, Chief Supdt., RF, NRG
4. Mr. Arun Kumar, Head, RMD, BARC
5. Mr. R.L. Suthar, Head, CDM, BARC & Shri D. Saha, A.Director, RD&DG, BARC
6. Dr. S. L. Chaplot, DS, Head, SSPD, BARC
7. Mr. Manjit Singh, Director, DM&AG,BARC
8. Dr. Inderjit Singh, Head, ET&MDS, BARC
9. Dr. A.M. Patankar, Head, TT&CD, BARC
10. Dr. K.C. Mittal, OS, Project Manager, EBC, BARC
11. Dr. S.M. Sharma, OS, Head, HP&SR Physics Div., BARC & Dr. N.K. Sahoo, Head, ASD, BARC
12. Mr. Arup Kumar Pal, SO(G), RED, BARC
13. Mr. V.K. Mehra, Director, RPG, BARC
14. Mr. V.K. Mehra, Director, RPG, BARC
15. Mr. K. Agarwal, SO/H, NRG, BARC
16. Dr. G.P. Kothiyal, OS, TPD, BARC
17. Dr. D. Sathiyamoorthy, OS, Head, PMD, MG, BARC
18. Dr. V.K. Jain, SO (H+), CD, BARC
19. Dr. Pradeep Kumar K.S., RSSD, BARC
20. Mr. Kalyan Banerjee, SO(H), SWPS, NRG, BARC
21. Mr. R.J. Patel, OS, RTD, BARC
22. Mr. A. Nandkumar, SO(H+), RMP,Mysore
23. Mr. S. Sarkar, PM(Process), RMP/BARC/Mysore
24. Mr. J.K. Mukherjee, SO(H), E&IG,BARC
25. Mr. C Ajayanandan, Head, PSS, RMP, BARC
26. Dr.Sharmila Banerjee, SO(G), RPhD, BARC
27. Mr. A. Rama Rao, SO(H), RED, BARC
28. Mr. Rakesh Kumar Gupta, SO(G), MDD, BARC.

7. Special Contributions Award carries a cash award of Rs. 50,000/-, a Citation and a Medal. There were sixty two award winners; sixty one from BARC and one from DAE.

1. Mr. Gaurav Pandey, BARC
2. Mr. Amit Rav, BARC
3. Mr. Trilok Singh, BARC
4. Mr. S.B. Menon, BARC

5. Mr. P. Ramakrishnan, BARC
6. Dr. M.S. Kale, BARC
7. Mr. P.B. Chaudhary, BARC
8. Mr. S.B. Khune, BARC
9. Mr. T.G. Unni, BARC
10. Mr. R. Mallick, BARC
11. Mr. A.T. Sushibine, BARC
12. Mr. Y.T. Kumbhar, BARC
13. Mr. Jose Joseph, BARC
14. Mr. S.K. Sahoo, BARC
15. Mr. M.B. Kamble, BARC
16. Mr. K.K. Singh, BARC
17. Mr. A.R. Khot, BARC
18. Mr. S.H. Shinde, BARC
19. Mr. S. Mondal, BARC
20. Mr. C. Subramanian, BARC
21. Mr. N.E. Mawal, BARC
22. Mr. D. Selvaraj, BARC
23. Mr. B.T. Nair, BARC
24. Mr. Mohd. Afzal, BARC
25. Mr. N.K. Karnani, BARC
26. Mr. S.T. Pawar, BARC
27. Mr. V.D. Patil, BARC
28. Mr. V.K. Keni, BARC
29. Mr. N. Purushothaman, BARC
30. Mr. B.C. Jamsandekar, BARC
31. Mr. S.K. Pal, BARC
32. Mr. G.P. Mishra, BARC
33. Mr. R.S. Mahadik, BARC
34. Mr. M.N.B. Pillai, BARC
35. Mr. S.N. Pillai, BARC
36. Mr. N. Malviya, BARC
37. Mr. P.F. Pereira, BARC
38. Mr. R.R. Singh, BARC
39. Mr. Suman Lal, BARC
40. Dr. S.K. Sali, BARC
41. Dr. N.K. Kulkarni, BARC
42. Mr. A. K. Pradhan, BARC
43. Dr. D.R. Ghadse, BARC
44. Dr. (Smt.) K. Jayanthi, BARC
45. Mr. B.D. Thakur, BARC
46. Mr. D.D. Patil, BARC
47. Mr. A.K. Ghoderao, BARC
48. Mr.A.K. Singh, BARC
49. Mr. T.P. Chaturvedi, BARC
50. Dr. S.V. Godbole, BARC
51. Mr. C.P. Paul, BARC
52. Mr. D.B. Sutar, BARC
53. Mr. P.C. Lad, BARC
54. Mr. K. Venkataramana, BARC
55. Mr. Rajit Kumar, BARC
56. Mr. Ajay Kumar, BARC
57. Mr. M.H. Rao, BARC
58. Mr. T.B. Walunj, BARC
59. Mr. A.M. Chalke, BARC
60. Mr. D.N. Salunke, BARC
61. Mr. C.G. Vhatkar, BARC.

8. Meritorious Service Awards winners received Cash award of Rs 20,000/-, a Citation and a Medal. There were twenty five award winners; nineteen from BARC, one each from DAE and VECC and four from IGCAR.

1. Mr.Hiraman Chand Ahire, Sr. Technician/H, RED, BARC
2. Ms. Kakali Banerjee, APO, PD, BARC
3. Mr. S. N. Bodele, T/H, RSD, HSEG, BARC
4. Mr. N. Chatterjee, Foreman-B, RRMD, BARC
5. Mr. P. S. Ghadge, T'man/H, DRHR, BARC
6. Mr. Sadanand S. Jadhav, Sr. Tech.(J), L&PTD, BTDG, BARC
7. Mr. N. J. Jagtap, T/E, (Traffic Supervisor), BARC
8. Mr. Mahendra Arjun Kadave, Technician/D, DM/PD/BARC
9. Mr. Muthathian Krishnan, SA/F, WMD, NRG, BARC
10. Mr. Mallappa Majjagi, T/G, Assembly Facility, RMP, BARC
11. Mr. Sharad D. Nalavade, Assistant, PD, BARC
12. Mr. Yagya Narayan Prasad, F/C, AFD, BARC
13. Ms. Mohini P. Raval, SO/F, SIRD, KMG, BARC
14. Mr. Ankush Nagu Sarangule, T/G, ECMS, MG, BARC
15. Mr.S. S. Sharma, Foreman/C, AFFF, BARC, Tarapur
16. Mr. Vishnu J. Shinde, Foreman/B, RRMD, Reactor Group, BARC
17. Mr. R. B. Shinde, T/G, RMD, NFG, BARC
18. Ms. Malini Suresh, AO, Accounts Division, BARC
19. Mr. H.S. Tamore, Mali D, L & CMS, AG, BARC.

22nd DAE All India Essay Writing Contest

The 22nd DAE All India Essay Contest on Nuclear Science and Technology for students at the undergraduate level was held in 2010. A total of 169 essays were received on the following three topics. The essays were written in English and Hindi.

Topic 1: Bridging the Energy Gap – Role of Nuclear Energy in India

Topic 2: Recent Developments in Application of Radiation and Radioisotopes for Societal Benefits.

Topic 3: Recent Uses of Power Beams (Plasma, Laser and Electrons) in Nuclear Energy and Environment Management.

Out of the 169 essays received for the contest, 26 were shortlisted. 12 in the merit list for Topic 1, 8 in the merit list for Topic 2 and 6 in the merit list for Topic 3. The contestants of these essays were invited to Mumbai, to visit the various facilities of the Department of Atomic Energy (BARC, BRIT, ACTREC, Electron Beam Centre at Kharghar, Tarapur Atomic power Station 1-4) and to make an oral presentation of their essays before a panel of judges. The oral presentation was held on October 28, 2010 at the DAE Headquarters at OYC and 23 contestants made their presentations.

The Chairman AEC, gave away the prizes to the winners on the Founder's Day, celebrated on Friday, October 29, 2010.

The First, Second and Third Prize winners in each topic were:

Topic 1: Bridging the Energy Gap – Role of Nuclear Energy in India	
I Prize Winner Ms. Sonia Sharma	Final Year, BVsc & AH Bikaner; Hindi
II Prize Winner Mr. Paul Benjamin S	B.Tech.II Coimbatore; English
III Prize winner Mr. Debmalya Nandy	B.Sc. III Kolkata; English

Topic 2: Recent Developments in Application of Radiation and Radio Isotopes for Societal Benefits	
I Prize winner Mr. Manpreet Singh Giru	B. Tech.II Coimbatore; English
II Prize winner Mr. Kiran Sankar Chatterjee	B.Sc.II Birbhum; English
III Prize winner Ms Dimpee Lahkar	MBBS 7th Sem Dibrugarh; English

Topic 3: Recent Uses of Power Beams (Plasma, Laser and Electrons) in Nuclear Energy and Environment Management	
I Prize winner Mr. Fasaluraham Parakkal	B.Sc.III Calicut; English
II Prize winner Mr. Amit Shastri K.	B.Sc.II Mangalore; English
III Prize winner Mr. Dattatreya Jana	B.Sc.II Kolkata; English

The remaining 14 students were awarded consolation prizes.

Participants of 22nd DAE All India Essay Contest on Nuclear Science and Technology

Industrial Safety Awards at BARC

The Industrial Safety Awards Scheme was introduced by the Industrial Hygiene and Safety Section, RSSD in the year 2004. These awards in the form of Industrial Safety Shields are given exclusively to BARC Units annually based on their safety performance. The entries from the various Divisions/ Sections/ Units of BARC for the year 2009 were invited from three different categories of units/ facilities, namely: Category A: Operating Plants, Category B: R&D Labs and Industrial Units and Category C: Engineering, Projects and Support Units.

A thorough scrutiny of the entries were 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. During the Founder's Day programme on October 29, 2010, Shri N.D. Sharma, Chairman, Industrial Safety Award Scheme Committee and Chairman, Conventional and Fire Safety Review Committee announced the winning units for the year 2009, which were as follows:

A: Operating Plants - Reactor Operations Division(ROD)-CIRUS Reactor

B: R&D Labs and Industrial Units - Radiometallurgy Division (RMD),

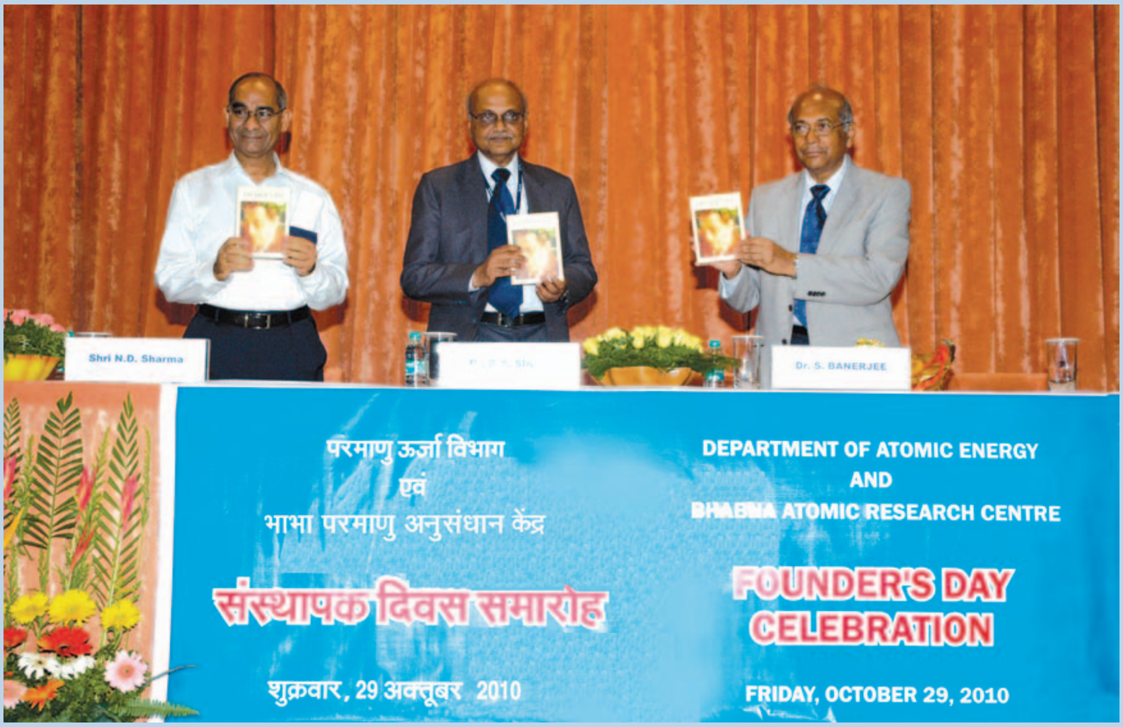
C: Engineering, Projects and Support Units - N R G Projects, Kalpakkam.

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

On behalf of Reactor Operations Division-CIRUS Reactor, Mr. S Duraisamy, Head, ROD, N. Ramesh, Reactor Superintendent, CIRUS Reactor and S.Mahato, Safety coordinator, CIRUS Reactor received the shield. Dr T.R.G. Kutty, RMD and Mr. P.V.Hegde, Safety Coordinator, RMD received the shield on behalf of Radiometallurgy Division. Lastly, Mr. Amitava Roy, Project Director and Mr. A.K.Jha, NRG Projects received the shield on behalf of NRG Projects, Kalpakkam.

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

Every year, the special issue of the BARC Newsletter is released on the occasion of the Founder's Day. It features the R&D work of BARC Scientists and Engineers for which they received national and international awards in the preceding year. A record number of 67 papers were published in the Founder's Day Special Issue of the BARC Newsletter this year. For the first time, it was printed entirely in the CD format. The issue was released by Dr. Srikumar Banerjee, Chairman, DAE.



(from R to L): Dr. S. Banerjee, Chairman, AEC, Dr. R.K. Sinha, Director, BARC, Mr. N.D. Sharma, Controller, BARC, releasing the Special Issue of BARC Newsletter, on the occassion of Founder's Day.

Founder's Day Lecture (a brief outline) by Honourable Mr. Prithvi Raj Chauhan,

Minister of State, Prime Minister's Office, GOI

Mr. Prithvi Raj Chauhan, Minister of State, Prime Minister's Office, GOI delivering the Founder's Day Lecture at the Central Complex auditorium

Mr. Prithvi Raj Chauhan began his talk by remembering Dr. Homi Jehangir Bhabha on the occasion of Founder's Day. It was his farsightedness which had put India in a position of strength in the area of Nuclear Science and Technology. He spoke about the beginning and the subsequent development of Atomic Energy programme in India and the contributions of Dr. Bhabha, other Senior Scientists and Engineers and the unstinting support of Pandit Jawaharlal Nehru. According to him, India needed to be more self reliant in all the core strategic areas as well as the non strategic areas of national development. Innovation would be the key to further progress in R&D. He then spoke about the future energy requirements of India and the need for innovation and R&D in bio-fuels and other fuels of the future. Honourable Mr. Chauhan emphasized the need to reduce the cost of innovation, which would make any technology feasible. For this purpose, fusion and deep commitment between R&D and industry would be necessary, which would facilitate the transition from research/innovation to the international market. Apart from strategic applications of energy and defence, R&D/Industry cooperation, in other non strategic applications in Nuclear Science and Technology such as in Health, Agriculture, Food and Water also needed to be increased. He summed up his talk by reiterating that Science, Technology and Innovation were the three cornerstones of national development and a New India.

Technology Developments with Robots

Manjit Singh
Design, Manufacturing & Automation Group

The Division of Remote Handling & Robotics (DRHR) is engaged in developmental activities in a range of areas relating to reactivity control and in-service inspection of nuclear reactors at one end, to master-slave manipulators, industrial robots and mobile robots on the other. While master slave manipulators form the core of remote handling operations all over DAE, and are closely related to Robotics, they have been described at length earlier issues. In this article, we focus instead on the range of technologies under development using robot manipulators, mobile robots and other customized robotic devices for applications in automated material transfer, automated radiation survey, vision guided and force controlled manipulation, telepresence and surgery. We describe ongoing activities, occasionally hinting at future programmes that we wish to pursue in some of these areas.

Automated Material Transfer System (AMTS)

An Automated Guided Vehicle (AGV) based material transfer system has been developed, for automated transfer of materials between supply station, machining, and assembly units of a typical manufacturing setup. The same concept can also be used for automated transfer of radioactive materials from one point to another of a nuclear establishment (e.g., NFC, BRIT). Automated loading and unloading operations are performed by programmed motion of powered roller conveyors onboard the AGV, and on corresponding stationary units. Apart from the design and fabrication of the AGV (Fig.1), the system includes development of various software modules for AGV motion control, position sensing (using laser navigator), and trajectory tracking (following pure pursuit algorithm). The possible routes for the AGV along with nominal speeds and stoppages can be specified in advance with a trajectory editor. A supervisory control program allows the operator to monitor status of AGV and conveyors, and intervene if necessary. He may also issue fresh commands for material transfers.

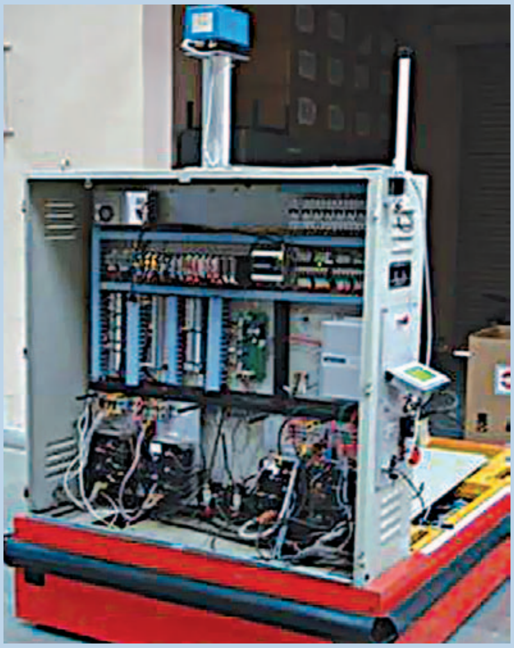


Fig. 1: Automated Guided Vehicle

Outdoor Mobile Robot with Onboard Slave Arm

A Mobile robot with onboard slave arm, suitable for inspection and manipulation of a remote hazardous site is being developed (Fig. 2). It has four large wheels, each of which can be driven and steered independently. By suitably coordinating the speeds and angles of these wheels, the mobile robot can move along a straight line, turn on an arc, turn-in-place, and crab. The mobile robot will be teleoperated from a console equipped with a steering wheel and paddles for acceleration and brake. It has an onboard panoramic camera and display software to enhance situational awareness of the operator. The vehicle has an Attitude and Heading Reference System (AHRS) that consists of MEMS based Inertial Measurement Unit (IMU), integrated GPS and 3-axis digital compass to make it suitable for autonomous navigation in a pre-surveyed outdoor environment. This mobile robot can drive at a speed of 1m/s on terrains such as pavement, grass, tar roads etc., and can negotiate a slope of 20% grade. A slave manipulator will be mounted on the vehicle. It will be teleoperated with a miniature master arm located at the control console.

In the near future, we wish to build wheeled and tracked platforms capable of negotiating stairs, curbs, ditches and rubbles. With an onboard foldable manipulator, this kind of robot can be compact and robust against shocks. Such robots may be gainfully deployed in anti-insurgency operations.

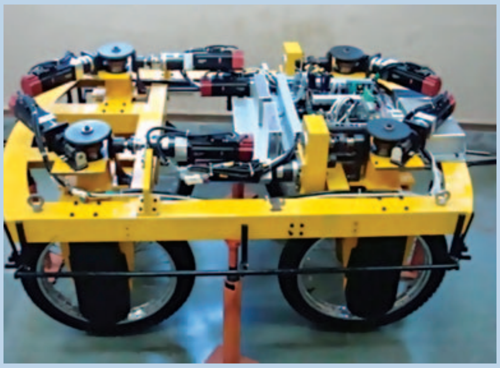


Fig. 2: Outdoor Mobile Robot

Automated Radiation Monitoring using Mobile Robot

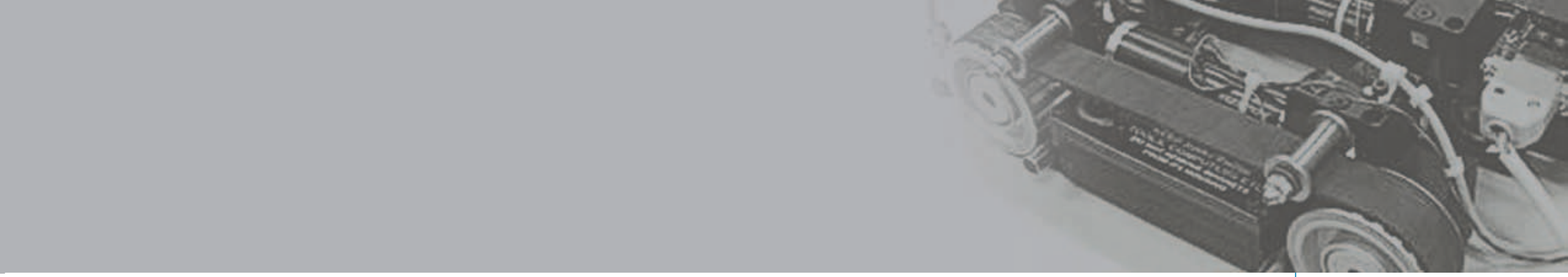
Monitoring and mapping of radiation level, as well as locating sources of radiation are routine requirements in many areas of a nuclear installation. In order to reduce radioactivity exposure to the human operators, a small mobile robot equipped with onboard radiation detectors (1 ìR/hr to 2000 R/hr) has been developed, in collaboration with the Radiation Safety Systems Division (RSSD) of BARC (Fig. 3). This battery powered robot is equipped with a camera for driving remotely using radio communication from a Graphical User Interface (GUI) on a host computer. The GUI allows a user to build a radiation map of a contaminated area. It also helps in identifying the direction of source of radiation.

A variant of this robot is being constructed for monitoring from control room the gamma and neutron dose in vault areas during operation of superconducting cyclotron at VECC, Kolkata. In the future, we have plans to build an array of mobile robots for radiation survey in indoor as well as outdoor environments. For building radiation map over a wide area, coordination of multiple robots will also be necessary.

Fig. 3: Robot for radiation survey in indoor environment

Magnetic Climbing Robot

Developed under an MoU with NTPC during July 2007 for inspection of boiler tubes, this robot comprises two sets of pulley-belt arrangement individually driven by two high-torque DC geared



motors, and uses Nd-Fe-B permanent magnets for adhesion while climbing onto the tubes (Fig.4a). The robot is designed for various payloads by proper selection of size, numbers and arrangement of these magnets. The robot can be moved Up, Down, Left or Right by changing direction of the two motors used as above.

We have built a robot with a payload capacity of 9 kg and maximum linear speed of 120 mm/s. An ElectroMagnetic Acoustic Transducer (EMAT) sensor module, being non-coupliant inspection, is ideally suited for boiler tube inspection. The sensor module was integrated with the robot (Fig.4b) and the system was field tested for tube thickness mapping at NTPC's upcoming 500 MWe plant at Dadri during June 2009.

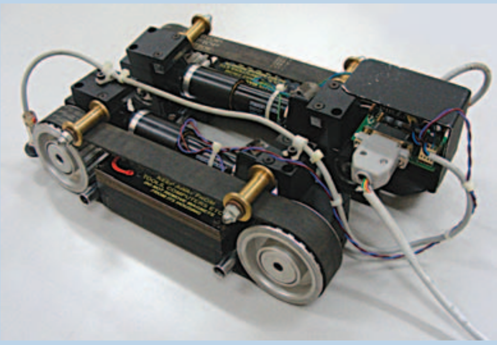


Fig. 4(a): Magnetic Climbing Robot-Prototype-I

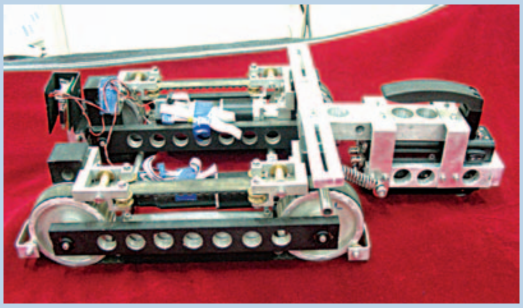


Fig. 4(b): Magnetic Climbing Robot-Prototype-II integrated with EMAT

In future, we wish to install on-board, a camera for on-line visual inspection. Such magnetic climbing robots may find application in nuclear reactors as well. We intend to extend its application for dry/under-water cleaning of large size vessels having active fluid (e.g., Surge tank at Tarapur-1 &2; Active fluid built-up in nuclear waste reprocessing plants).

Vision Guided Robot Manipulation

In an unstructured environment, a robot can use vision to locate the object it is expected to handle. We have programmed a vision sensor interfaced to a KUKA KR-6 robot to identify, locate, pick and arrange randomly oriented PHWR fuel pellets from a table (Fig. 5). To achieve high accuracy in pick and place, the camera and robot were calibrated using customized grids. This will form part of a robot based automated fuel pellet inspection system being developed at DRHR in collaboration with RRCAT, Indore.

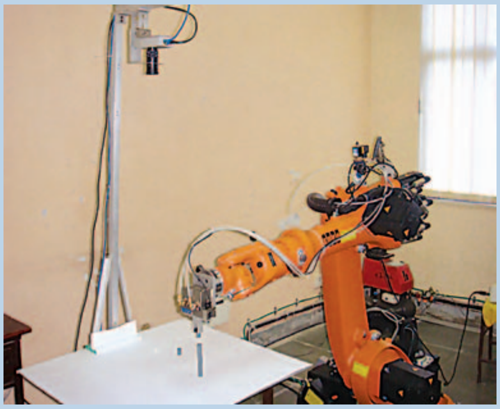


Fig.5: Robot picking up pellets from the table to form a stack

Remote Immersive Viewing

This project aims to develop a system for immersive viewing of a remote location. When deployed at the slave station of a Servo Manipulator, this enhances the master operator's ability to manipulate remotely. The system consists of a pair of cameras mounted parallel on a pan-Tilt-unit (PTU) and stationed at the remote (slave) site, and a Head Mounted Display (HMD) and a head-tracker installed on the master operator's head. With signals from the head-tracker, the camera unit is made to follow the pitch and yaw motion of the operator's head. Head mounted system displays videos from left and right cameras of the slave environment in front of respective eyes of the operator. This creates the desired immersive experience - the operator feels as if he is present in the slave environment. Subsequently, parallel cameras were replaced with toed-in type camera arrangement to achieve better fusion of left and right eye images of objects close to the cameras. Other capturing and visualization techniques such as encoded video streams displayed on various types of stereoscopic and auto-stereoscopic display systems are also being designed and integrated under this project. A typical arrangement of remote immersive viewing system is indicated in Fig. 6.

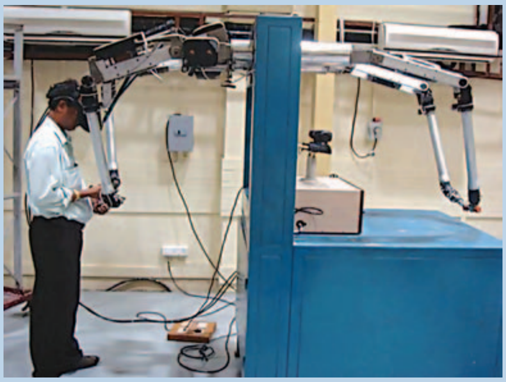


Fig.6: Immersive viewing system deployed on Mini MSM

In future, we wish to build a telepresence station for the master operator as an immersive interface to the remote slave environment. In addition to visual immersion, it will include stereo audio interface, as well as haptic interface through wearable exoskeleton as master, with cyberglove /cybergrasp to manipulate a robotic hand on the slave manipulator.

Force Sensing and Control in Robot Manipulation

For tasks in which a robot has to operate being in contact with external objects, it is necessary to sense the forces of interaction, so it can control its motion in a way that the task objective is achieved while keeping forces within their safety limits. A Schunk Force/Torque (F/T) sensor has been installed at the wrist of a KUKA KR-6 robot arm, and the robot programmed for some simple contour following operations (Fig.7). Here the robot is asked to follow a certain trajectory exerting a constant force on the surface of the object. Otherwise, for following complex shapes in the absence of an F/T sensor, the programmer has to teach numerous intermediate points. Even then, if the path does not coincide exactly with the surface and dimensions of the part, it may damage the object or tooling. With the help of an F/T sensor, the robot can easily adapt its path over the complex contour of the object. This type of control has applications in robotic machining, finishing, deburring and polishing operations with axial or radial tools.

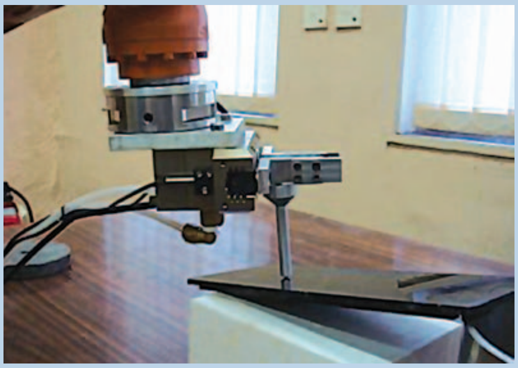


Fig. 7: KUKA robot with F/T sensor tracing a slope

We have also programmed the robot for 'lead by hand', in which the robot is guided to a desired position, by applying a gentle pressure with hand. This makes it possible to move heavy loads with the help of a robot, without having to program it.

Parallel Manipulators

Parallel manipulators are a class of robots; their architecture and mechanisms give them very high rigidity and accuracy within a limited workspace. Various types of Parallel manipulators have been designed and developed. They can perform high precision manoeuvres and can handle payloads higher than their self-weight. Fig. 8 shows a three-degrees-of-freedom parallel manipulator developed in the division.

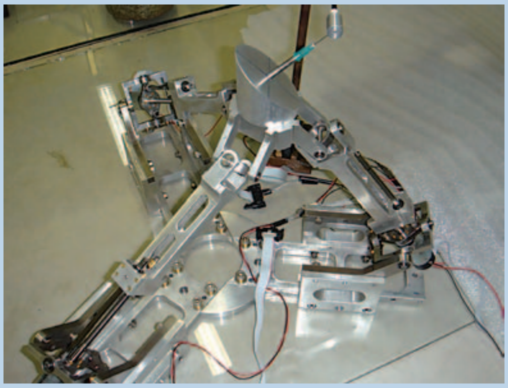


Fig.8: A Three-Degrees-of-Freedom Parallel Manipulator

Force-Torque Sensor (F-T Sensor)

A jointless parallel mechanism based six-axis Force-Torque sensor has been developed, along with a DSP based signal conditioning, processing and communication system. It is designed to measure very small forces (1.5N) and moments (50N mm). Fig. 9 shows the F-T sensor acting as a working table while performing a robotic operation in association with a parallel robot.

Fig.9: F-T sensor acting as a sensing support table during robotic operation

Snake-Arm Robot

Quite often, inspection needs to be carried out in inaccessible locations, such as the rear side of a cluster of pipes. No fixed-size manipulator can access all bends in such a constricted space. Only a Snake-arm robot may be able to access such a location. A Snake-arm robot is made up of a large number of independently controlled segments, so it can assume various shapes to suit the application. It can carry a payload ranging from 2kg to 20kg depending on the number of bends and the distance it has to cover. We have developed a prototype snake-arm robot having a total length of 1m (Fig. 10). A second version with a different mounting configuration is currently under development.

The snake-arm robot can be considered as a human spine comprising a number of vertebrae. Each segment is controlled by a set of wire ropes terminating at various points along the length of the snake. This permits control of each segment and thus the curvature and plane of curvature. Using a servo motor, the length of each wire rope is controlled independently. The control software calculates necessary lengths of all the wires to produce the desired shape. There are sixteen servo motors controlled simultaneously using a bus protocol. The software has many modes of operation. The user can use a joystick to drive the tip. This enables the snake arm to avoid obstacles and follow its tip into complex environments. Alternatively, the operator may specify the co-ordinates of the desired destination, and the tip of the snake will find its way or move on a programmed path to the desired point. For this, special servo drives and a front end GUI based application program have been developed. In an application, the snake-arm robot may typically carry a camera or a probe for inspection, a gripper for manipulation, or application specific tools for operation.

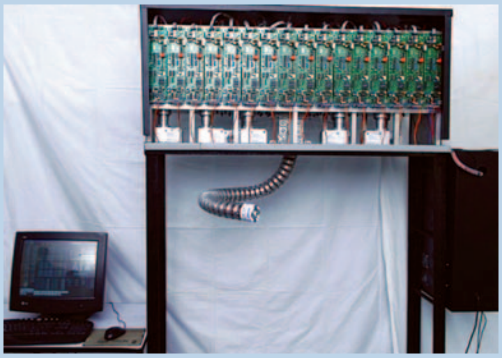


Fig. 10: Prototype 1m long hanging snake-arm robot

Robotic Assistant for Laparoscopic Surgery

Laparoscopy or Minimally Invasive Surgery (MIS) allows surgeons to perform the same procedures as in traditional open surgery, using small incisions instead of large abdominal cuts. In such procedure, the surgeon monitors the surgical procedure by special video camera system (laparoscope) instead of looking directly at the organ being operated. There are significant benefits to the patient in terms of reduced post operative pain, reduced hospital stay and quicker return to normal physical activities. During MIS, both hands of the primary surgeon remain engaged in manipulating the surgical tools, while another surgeon (assistant) assists by holding the laparoscope focusing on the region of interest as commanded by the primary surgeon.

In a revised approach, a robotic arm performs the job of the assistant surgeon by positioning the laparoscope at the surgical site and holding it steady. The primary surgeon now manipulates the laparoscope using a foot-operated console. When the primary surgeon controls the laparoscope, it is more likely that it will be positioned to provide the best exposure for the job to be performed. Additionally, steadier camera positioning, fewer inadvertent movements will improve the performance significantly. The system is demonstrated successfully using an industrial robot available at DRHR. For convenience in clinical use, the robot is mounted on a small trolley as shown in Fig. 11.

Fig. 11: Robot for endoscope control

As an alternative and cost-effective solution, another system is also being developed. It has three degrees of freedom, and all the motions are decoupled. It can be mounted on the surgical table and can be powered from a small rechargeable battery. The basic operations were successfully demonstrated using the prototype shown in Fig. 12. Both the systems are planned to be thoroughly tested on animals at the Christian Medical College (CMC), Vellore, before using on humans.

Fig. 12: Alternative robot configuration for endoscope control

Robotic System for Minimally Invasive Surgery

Although laparoscopic surgery has been a boon in many surgical procedures, the laparoscopic tools have limited dexterity, restricting the procedure to relatively simple operations. Also, these operations are quite demanding for the surgeons. As an alternative, a Surgeon can perform operations using miniature robotic arms in master-slave mode, sitting comfortably at a remote location. Robots are not to replace the surgeon, but to extend human skills. Improved 3D view of the surgical site, force reflection, tremor-filtration etc., can drastically improve the surgical performance. Similar devices are successfully being used in DAE for nuclear (hot-cell) applications. Miniaturization and some more improvements can make it suitable for medical applications.

The robotic system under development consists of three miniature (slave) arms - two for holding interchangeable modular surgical tools; the third one for manipulating the camera. The surgeon will sit comfortably at a remote console holding two master arms.

Programme in Autonomous Robotics at IIT Delhi

A programme, as a collection of projects in Autonomous Robotics, has been initiated at IIT Delhi, with support from the Board of Research in Nuclear Sciences (BRNS). The purpose is to involve the academia in technology developments in Robotics. The initial pool of projects relate to force controlled and vision-guided manipulation with robots, exploring alternative configurations for master slave manipulation with an industrial robot, developing telepresence solutions for immersive interface to a remote environment, as well as developing solutions for coordinated operation of multiple mobile robots. As we already have ongoing activities in these areas, we expect the programme to supplement our efforts through development of technically sound and refined approaches. Some of these solutions are aimed at meeting two basic challenges of inserting fuel pellets into clad – under program control, as well as through teleoperation using a telepresence interface.

RESEARCH ARTICLE

Material Modelling to Assess Properties of Irradiated Material

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Abstract

Development programs for materials for future fusion power reactors are being carried out all over the world. Possible structural materials for the reactor chamber first wall and blanket structure are limited, because these materials are expected to operate above 500 °C and see a damage of upto 150-200 dpa. Ferritic/martensitic steels are candidate structural materials to operate at such extreme conditions. Mechanical behaviour of these materials under irradiation conditions are studied, using both numerical and experimental techniques. Recent progress in computational materials science, allows us to understand the behaviour of irradiated materials through numerical simulations. Multi-scale material modelling is such one computational tool, that helps in the determination of macroscopic material deformation (MD) behaviour in a hierarchical way. It helps in understanding the role of nano, micro and meso level defects (voids, dislocations, micro cracks, grain boundaries, dislocation interactions etc.) in plasticity of materials, so as to support laboratory experiments.

In the present article, we describe BARC in-house work in the area of atomistic modelling of mechanical behaviour of irradiated materials, with focus on ferritic/martensitic steels. This work also forms part of ongoing research, on use of multi-scale material modelling methodology, in the determination of mechanical properties of irradiated structural materials.

1. MULTI-SCALE MATERIAL MODELLING (MMM)

The candidate materials to be used in fusion reactor applications are low activation or reduced activation ferritic/martensitic steels (with 9-10% chromium) due to their high resistance to radiation embrittlement. The mechanical behaviour of these materials is not fully understood under the conditions of fusion environment. The irradiation of metals by energetic particles, causes significant degradation of the mechanical properties, most notably an increased yield stress and decreased ductility. Although these phenomena have been known for many years, the underlying fundamental mechanisms and their relation to the irradiation field have not been clearly demonstrated.

The microstructure of irradiated materials evolves a wide range of length and time scales, making radiation damage an inherently multi-scale phenomenon. At the shortest scales (nano meters, and pico seconds), recoil-induced cascades of energetic atomic displacements give rise to highly non equilibrium concentration of point defects and point defects clusters. Over micro- macroscopic

length and time scales, these defects can migrate/diffuse and alter the chemistry and microstructure, often inducing significant degradation of mechanical and other properties at continuum scale. It is also found, that the high energy neutrons produced in fusion reactions are capable of inducing (n, α) transmutation reactions in the structural materials resulting in the production of helium and hydrogen gas. It has been estimated that the blanket material in its service life of 5 years receives a dose of 150-200 dpa (Najmabadi et al 2006, Janeschitz et al 2006) and a helium production of 10-15 appm/dpa (Juslin et al 2009). These gases, in particular helium have detrimental effects on the mechanical behaviour of the materials (Juslin et al 2009, Wirth et al 2004),

There is ongoing research all over the world on the use of MMM methodology in the determination of irradiated material properties. A diagram showing the use of hierarchical materials modelling is shown in Fig. 1. The different numerical models at each scale in MMM are well developed and current research in MMM is largely devoted to finding suitable linking mechanisms from one-scale to another. In the present article, we describe BARC in-house efforts in MMM for irradiated materials with focus on MD simulations of dislocation-defect interactions in Fe, Fe-Cr and Fe-Cr-He systems.

2. ATOMISTIC MODELLING

The present section describes the MD setup to run dislocation-defect interactions, the methodology of applying strain to the simulation cell and the inter-atomic potentials used. The MD simulations are carried out using public domain molecular dynamics code LAMMPS (Plimpton et al (1995)).

2.1 Inter-atomic potential for Fe, Fe-Cr and Fe-Cr-He crystals

The potentials available in published literature are used for the simulation purpose. The inter-atomic

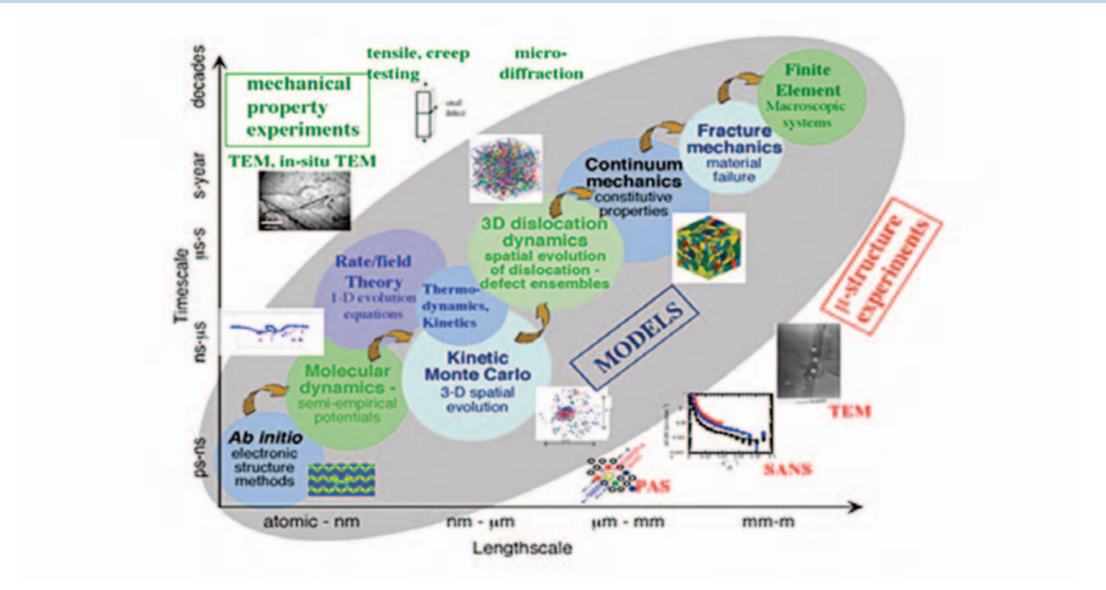

Fig. 1: Schematic diagram showing multiscale material modeling stages.
(Source http://iron.nuc.berkeley.edu/~bdwirth/Public/WRG/wrg.html)

potentials are an important part of MD simulations. The Fe-Fe potential by Mendelev et al (2003) is used in various simulations reported in the present paper. The concentration dependent two elements Fe-Cr potential (Stukowski et al (2009)) is used for Fe-Cr interactions. The Fe-He (Seletskaia et al 2007), Cr-He (Terentyev et al 2009) and He-He (Aziz et al 1995) potentials are employed from various published literature to analyze Fe-Cr-He crystal.

2.2 Simulation of shear deformation by applying the strain increment

All the molecular dynamics simulations have been carried out at 10 K to determine the Peierls stress for pure Fe, Fe-10%Cr and Fe-10%Cr-1%He. The simulation domain has a size of 20×9×10 nm^3 and contained approximately 150,000 atoms. Periodic boundary conditions are applied along the dislocation line direction and burgers vector direction.

In addition to the above studies, required CRSS for an edge dislocation to overcome the void/bubble is also determined for various cases. The spherical void/bubble is introduced at a distance of 5 nm from the dislocation core. The void is introduced by eliminating the atoms falling within a region of specified diameter. However, in case of bubble, the Fe atoms within the same region are replaced by He atoms.

2.3 Determination of Flow stress for edge dislocation in pure Fe, Fe-10%Cr and Fe-10%Cr-1%He.

The Peierls/flow stress is determined by MD simulation of edge dislocation motion in pure Fe. The boundary conditions and crystal dimensions used are as described in section 2.2. The potential given by Mendelev et al (2003) is employed. The maximum stress, i.e. Peierls stress, required to move the dislocation in its slip plane is 81 MPa. Similarly, the flow stress for edge dislocation to move in Fe-10%Cr alloy and alloy with1% He in the matrix is also determined. The chromium and helium atoms are randomly placed in the crystal using a random number generator. The peaks in stress-strain plot are amplified due to the presence of Cr atoms and are less regular in comparison to pure Fe. In the presence of 1% He, the peak stress values are more amplified and the stress required to move the dislocation increases significantly. This is due to the pinning and releasing of the dislocation, by a cluster of two or more chromium atoms. This analysis shows hardening effect due to the presence of Cr atoms in pure Fe. The analyses are repeated for various random distributions of chromium and helium atoms. The stress-strain curves for different random distributions are shown in Fig. 2 for Fe-10%Cr and in fig. 3 for Fe-10%Cr-1%He. The linear part shows the elastic behaviour. This is followed by plastic deformation of the crystal, where the dislocation becomes mobile. The average of maximal flow stress (i.e. average of group of peak values) is 130 MPa for Fe-10%Cr and 230MPa for Fe-10%Cr-1%He as shown by dotted lines in the respective figures.

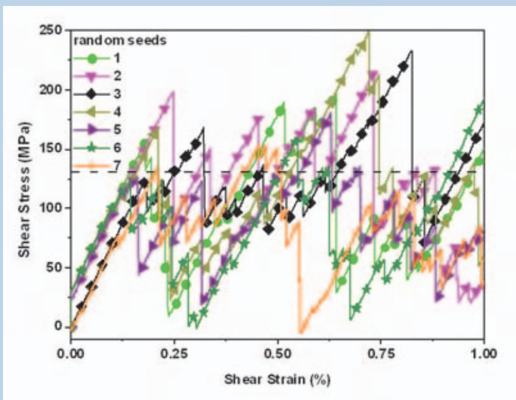

Fig. 2: Stress-strain plot for Fe-10%Cr with different random number seeds.

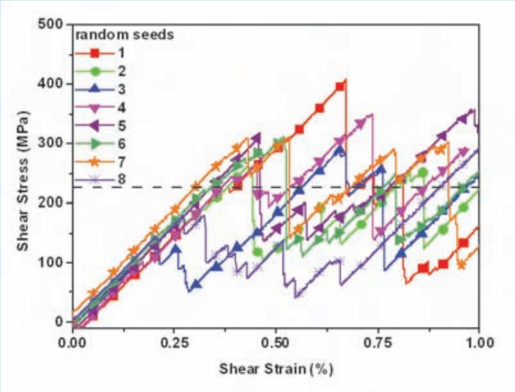

Fig. 3: Stress-strain plot for Fe-10%Cr-1%He with different random number seeds.

2.4 Determination of CRSS for edge dislocation interacting with voids and bubbles.

2.4.1 Interaction of edge dislocation with voids in Pure Fe, Fe-10%Cr and Fe-10%Cr-1%He.

The MD simulations of interaction of edge dislocation with voids/bubbles are carried out, to determine the CRSS. These can be used as inputs, in the higher length scale models, such as Discrete Dislocation Dynamics (DDD). It has been found experimentally that the vacancies produced in radiation cascade, accumulate to form vacancy clusters. These clusters subsequently grow to form nano-metric voids. The dislocation motion shows the general behaviour described as follows:

i. Free movement of dislocation in initial stage at low stress values.
ii. Attraction of edge dislocation by void, resulting in bending of dislocation and drop in applied stress.
iii. Pinning and subsequent bowing of dislocation leading to increase in applied stress with more and more strain increment.
iv. Release of dislocation by void, resulting in sharp drop in flow stress, with the formation of step on the void surface.

A step is formed on the spherical void surface on slip plane, due to shearing of the void by dislocation. The dislocation bends due to pinning action of void with strain increment. In the following section, interaction of edge dislocation with void in Fe, Fe-10%Cr and Fe-10%Cr-1%He is discussed. The boundary conditions and crystal dimensions used are as described in section 2.2.

The MD simulation of interaction of edge dislocation with voids in pure Fe is carried out. The void diameter is varied from 0.8 to 1.6 nm. Fig. 4 shows stress-strain plot for interaction of edge dislocation with voids of different diameter. The initial drop in stress values due to dislocation attraction by void increases with void size as shown in figure. It is also observed that the CRSS increases approximately linearly with void diameter up to 1.6 nm. Similarly, the interaction of edge dislocation with a void of diameter 1.6nm is considered for Fe-10%Cr. The 10% Cr atoms are randomly distributed in Fe matrix with two random number seeds. The stress-strain behavior is found to be similar as that of pure Fe with slightly higher CRSS i.e. an increase of 38 MPa in CRSS is observed due to addition of 10%Cr in Fe matrix.

The MD simulation of edge dislocation interaction with voids is carried out for Fe-10%Cr alloy with 1%He. The 10% Cr atoms and 1% He atoms are distributed randomly in Fe matrix with three different random number seeds. The stress-strain plot for interaction of edge dislocation with a void of diameter 1.6 nm is shown in Fig. 5. The CRSS value for 1.6 nm voids is 992 MPa. In comparison to pure Fe, an increase of 190 MPa for 1.6 nm diameter void is observed. An increase of 150 MPa for 1.6 nm void diameter is observed in comparison to Fe-10% Cr. There is a significant increase in CRSS due to the presence of 1%He. Fig. 6 shows the two stages of interaction of dislocation with void in Fe-10%Cr-1%He system.

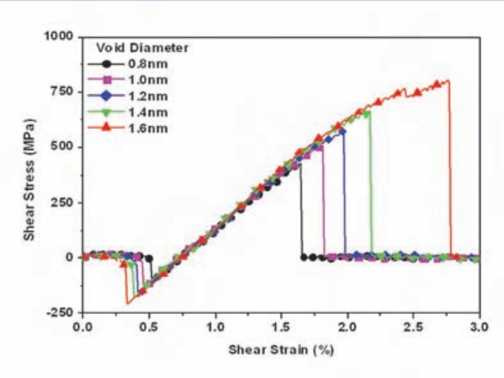

Fig. 4: Stress-strain plot for ED interacting with different sizes of voids.

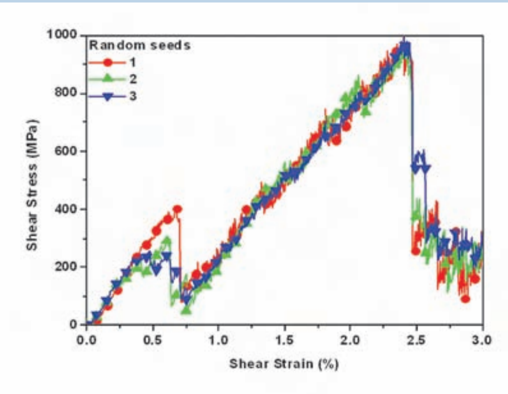

Fig. 5: Stress-strain plot for ED interacting with voids a of 1.6 nm diameter for 3 random distributions of Cr atoms.

2.4.2 Interaction of edge dislocation with He-bubble in Pure Fe and Fe-10%Cr.

The MD simulations of interaction of edge dislocation with helium bubble of different diameters are carried out at 10K temperature. Under irradiation, He gas atoms are produced in the metal matrix due to (n, α) transmutation reaction. These He atoms diffuse towards vacancy clusters, to form various sizes of He bubbles. These bubbles act as barriers for dislocation motion leading to the hardening of metal and loss of ductility. In this section, interaction studies of an edge dislocation with He bubble are reported for pure Fe and Fe-10%Cr matrix at 10K. The boundary conditions and crystal dimensions are the same as described in section 1.2.

The MD Simulations are carried out for interaction of edge dislocation with He bubbles of 0.8nm to 1.6nm in pure Fe and Fe-10% Cr. The chromium atoms are randomly distributed in Fe matrix, using two different random number seeds. The bubble is inserted by replacing Fe lattice atoms with He atoms in a spherical volume of finite radius (i.e. bubbles of type 1He-1V). The stress-strain curves for edge dislocation interacting with helium bubbles of different diameters in the above systems, are shown in Figs. 7(a) and 7(b). It is seen that He bubbles of this type are weaker obstacles in comparison to the

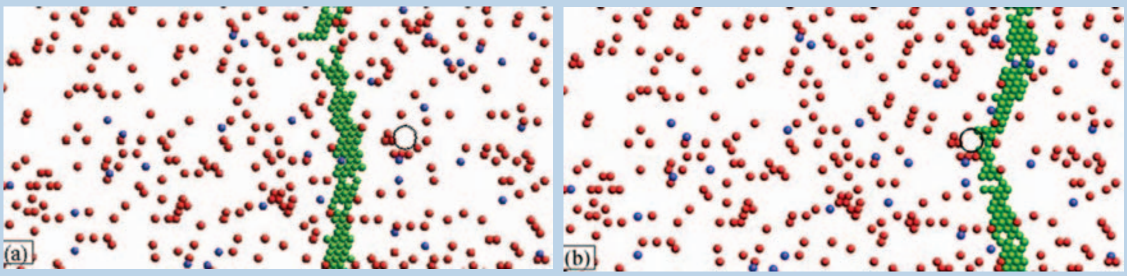

Fig. 6: Interaction of ED with 1nm void in Fe-10%Cr-1%He: (a) dislocation line before pinning (b) dislocation line after pinning (Cr atoms-red color, He atoms-blue color, Fe atoms not shown here).

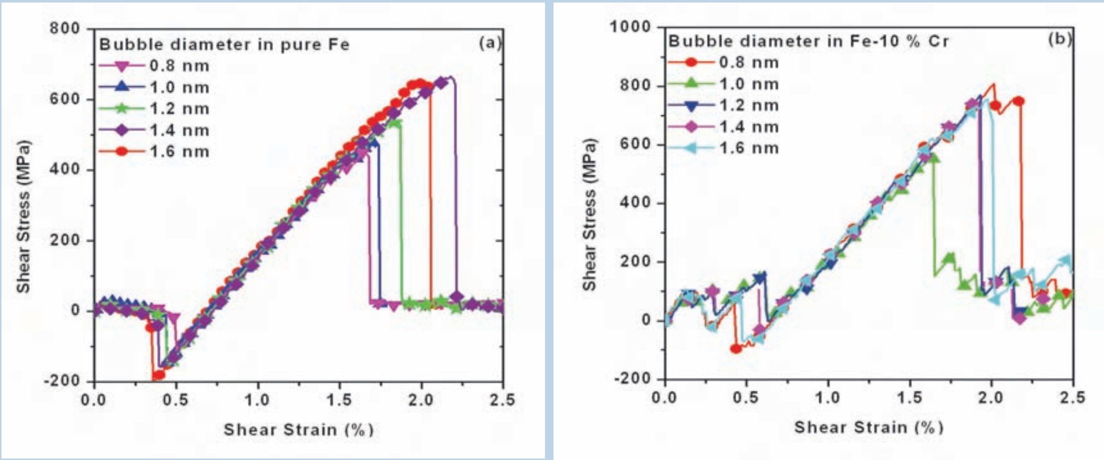

Fig. 7: Stress-strain plot for interaction of ED with He bubbles of diameter 1.0nm to 1.6nm in a) pure Fe and b) Fe-10%Cr.

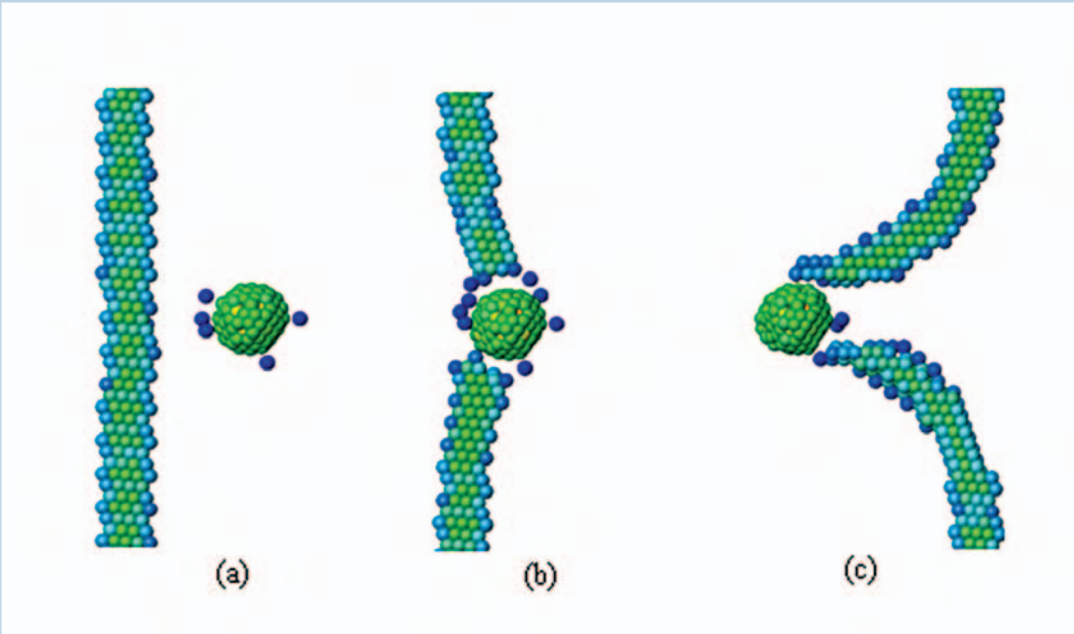

Fig. 8: Different stages of interaction of ED-1.6 nm bubble, (a) initial configuration, (b) dislocation attraction, (c) bowing of dislocation due to pinning by bubble.

voids of same size as highlighted by Schaublin et al (2007). The stages of interaction of dislocation with He bubbles as obtained by present computation are shown in Fig. 8.

3. CONCLUSIONS

The following conclusions may be drawn from the present simulations:

1. The average of maximal stress (i.e. flow stress) for dislocation motion in Fe, Fe-10%Cr, and Fe-10%Cr-1%He are obtained as 80MPa, 130MPa and 230MPa respectively.
2. In dislocation void interaction, it is found that the CRSS increases linearly with increase in void diameter from 0.8 nm to 1.6 nm in pure Fe.
3. The CRSS required for edge dislocation to overcome the void of diameter 1.6 nm in Fe-10%Cr is slightly higher (35-40MPa) than that of pure Fe. However, the same for Fe-10%Cr-1%He is significantly (150-160MPa) higher.
4. The CRSS for interaction of edge dislocation with He bubble (1He-1V) is close to that of the void up to 1.0 nm diameter. The same has been found to be less for the bubbles having diameter more than 1 nm.
5. The results obtained through the present MD simulations will be useful in higher length scale simulations, such as dislocation dynamics studies.

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Biotechnological interventions in sugarcane improvement: Strategies, methods and progress

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Abstract

Sugarcane is one of the most important field crops grown in the tropics and sub-tropics. Conventional and biotechnological research inputs have contributed in solving some of the constraints limiting crop productivity. However, limitations such as complex genome, narrow genetic base, poor fertility, susceptibility to biotic and abiotic stresses and long duration to breed elite cultivars, hinder crop improvement programmes. Sugarcane, thus, is a suitable candidate for application of plant biotechnology and genetic engineering tools. In this direction, we have been working towards employing in vitro culture system combined with radiation induced mutagenesis in the improvement of sugarcane. Several radiation induced mutants with agronomically desirable traits were isolated and evaluated under field conditions, besides studying abiotic stress responses using biochemical, physiological and molecular tools. This article describes the developments in the in vitro culture systems and related biotechnologies that are evolving as novel strategies in the recent years for use in sugarcane improvement.

INTRODUCTION

Sugarcane (*Saccharum* spp.) is an important industrial crop, ranking among the ten most planted crops in the world. Besides being the major sugar contributor with more than 70% of the world's sugar, sugarcane is important as the raw material for sugar producing and allied industries. India is the largest single producer of sugar, including traditional cane sugar sweeteners, khandsari and Gur equivalent to 26 million tonnes raw value followed by Brazil in the second place [1]. The *Saccharum* complex includes the agronomically and industrially important sugarcane genotypes obtained from *S. officinarum, S. spontaneum and S. robustum* crosses. Although conventional breeding has contributed to the development of agronomically improved cultivars, limitations such as narrow gene pool, complex genome, poor fertility and the long breeding/selection cycle make it difficult to undertake further improvement. In addition, modern cultivars have a variable chromosome number (2n=100-120) and rarely flower. Sugarcane is a typical glycophyte and hence exhibits stunted growth or no growth under salinity, with its yield falling to 50% or less than its true potential. To sustain sugarcane production and to improve the productivity, tolerance to biotic and abiotic stresses, nutrient management, improved sugar recovery are some of the concerns. Both the conventional and biotechnological methods have greatly contributed in solving some of these constraints. This article describes the development of *in vitro* culture systems and biotechnological approaches for use in sugarcane improvement.

IN VITRO CULTURE SYSTEMS - SOMATIC EMBRYOGENESIS

Plant regeneration in sugarcane can occur through two main routes, direct and indirect morphogenesis. In direct morphogenesis, plants are regenerated directly from tissues such as immature leaf roll discs and also from shoot tip culture, by which sugarcane is propagated commercially. Indirect morphogenesis involves initial culturing of leaf roll sections or inflorescences on an auxin-containing medium to produce an undifferentiated mass of cells, or callus. Somatic embryogenesis techniques have two main goals: the development of a highly efficient method for propagating large number of uniform plants in less time and possibly at lesser cost than the conventional propagation methods, and a cell culture based regeneration system useful for genetic transformation [2,3]. Embryogenic cultures have also found their place in a wide variety of applications, from obtaining virus resistant plants through somaclonal variation, to mutagenesis and *in vitro* selection and developing transgenic plants.

There have been continuous efforts towards refinement of protocols for efficient morphogenesis *in vitro* [2]. In our laboratory, protocols for direct somatic embryogenesis (DSEM) and indirect somatic embryogenesis (ISEM) have successfully been developed using young leaf rolls and immature inflorescence segments of Indian sugarcane cultivars [4]. Comparison was made of different media combinations of coconut water (CW), kinetin, zeatin and TDZ to optimize callus growth and regeneration. CW and zeatin were more effective over other growth regulators for callus induction while CW alone was found effective for plant regeneration. Different stages in the pathway of indirect and direct somatic embryogenesis are presented in Fig. 1 and 2.

The DSEM system is useful for cost-effective and large-scale clonal propagation besides providing a new target explant source for genetic transformation [5]. For an efficient application, it is also essential to ensure the rapid development of embryos from cultured explants with subsequent regeneration into

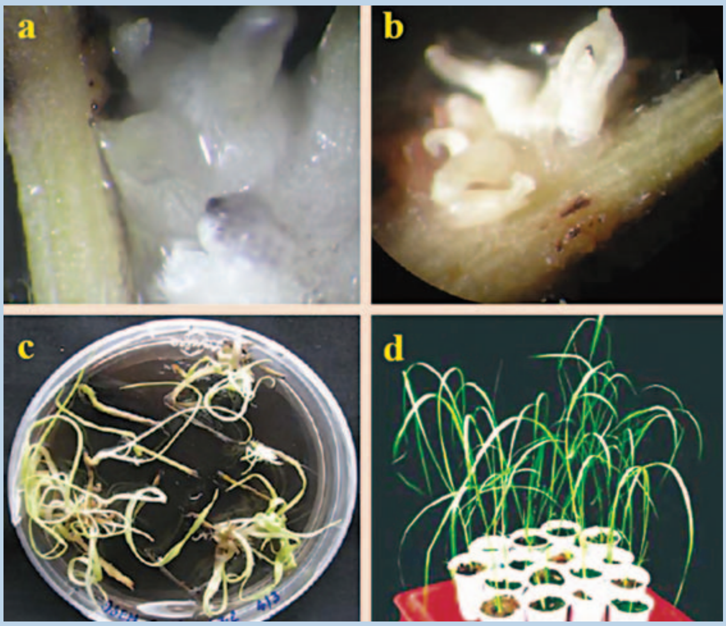

Fig.1. Regeneration through Direct Somatic Embryogenesis (DSEM)) in sugarcane a, b-development of direct somatic embryo from immature inflorescence segments; c- regenerated plantlets; d- Hardened plantletsin the green house

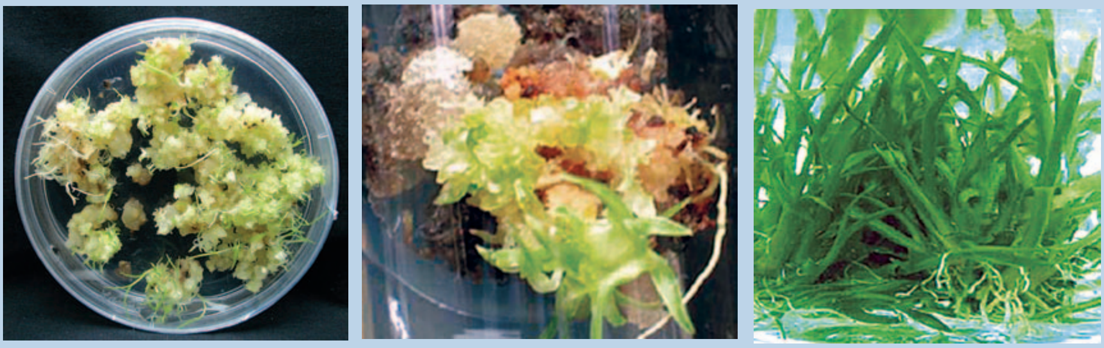

Fig. 2. In vitro selection for salt tolerance in sugarcane : (a) regeneration on control (without salt) medium, (b) 85.6 mM salt medium respectively, (c) rooting of the 85.6 mM salt selected plantlets

complete plants. The plants derived through DSEM have been found to be uniform in growth pattern with more vigour compared to plants derived through indirect somatic embryogenesis pathway. When analyzed at the molecular level using RAPD markers, the plants exhibited no variation [6]. This method also yielded a large number of plants (7-8 per explant) in a short span of seven weeks. Assuming an average of 24 segments per inflorescence, the total number of plants that can be generated could be around 185–200 [5]. Subsequently this technique of direct somatic embryogenesis has been extended to several other sugarcane cultivars suggesting wide adaptability, and plants raised have been field planted for performance evaluation.

The induction and maintenance of highly embryogenic callus is critical for commissioning research efforts aimed at genetic manipulation of sugarcane. To optimize the somatic embryogenesis system, we proposed that analysis of elemental composition would offer valuable information on the specificity of the elements with a stage of development and to provide data that can be used in formulating suitable nutrient medium to favour a developmental pattern. Energy-dispersive X-ray fluorescence technique (EDXRF) was employed to analyze elemental accumulation during somatic embryogenesis [7]. Considerable variation was observed in Mg, K, Ca, Mn, Fe, Cu and Zn with specific elemental accumulation [higher Mg, K and Fe] was seen in the early phase of embryogenesis. The information on the elemental profile could be useful in formulating specific media for induction of high frequency of embryogenesis and provision of modified amounts of elements in culture medium can have greater benefits for modulating pathways of differentiation.

BROADENING GENETIC VARIABILITY THROUGH *IN VITRO* MUTAGENESIS AND SELECTION

Induced mutations have contributed significantly and several mutant varieties have been developed through mutation breeding. We have been working towards employing *in vitro* culture combined with radiation induced mutagenesis in the improvement of sugarcane [8]. Somaclonal variation in combination with *in vitro* mutagenesis can be beneficial for the isolation of salinity and drought tolerant lines in a short duration employing *in vitro* selection. Earlier studies using radiation induced mutagenesis and *in vitro* techniques led to the development of salt tolerant mutants in sugarcane using 5, 20, 40 and 60 Gy gamma-ray irradiated cultures. In our studies, we have used *in vitro* mutagenesis in combination with cellular selection for salt tolerance in popular sugarcane cv. CoC-671 [9]. Embryogenic calli were subjected to gamma irradiation at different doses (0 - 50 Gy) and exposed to NaCl (42.8 to 342.2 mM). Cell viability decreased and higher levels of osmolytes like free proline and glycine betaine were found to accumulate in stressed calli as compared to control. Electrolyte leakage was 2.8 times more under salt stress and leached out Na^+ and K^+ were much more than that of retained in both the adapted and unadapted callus cultures. The results are indicative that physiological and biochemical attributes are critical in alleviating salt stress effects and in improving salt tolerance in sugarcane.

Under the DAE-BRNS collaborative research with Dr. Punjabrao Deshmukh Krishi Vidyapeeth, Akola, field trials of the gamma-ray irradiated plant population were conducted [8]. The field performance of the selections was evaluated and results indicated a broad range of mutations for morphological, quality and yield contributing characters were observed (Fig. 3). Mutation spectrum varied among the cultivars employed for the study: broader mutation spectrum was observed for morphological traits in Co 94012, while for quality and yield traits, Co 86032 showed a wide range of mutations. A total of 44 clones were identified for different desirable agronomic traits. Better performance over respective checks was recorded for average cane weight and H.R. Brix (% sucrose) (AKTS 2, 7, 11 of CoC 671; AKTS 22, 26, 27 of Co 86032; AKTS 36,38,39, 44 of Co 94012). The mutant clones are currently undergoing further evaluation in rod-row trials for stability in performance.

PARTIAL DESICCATION STIMULATES SOMATIC EMBRYO DIFFERENTIATION

In vitro techniques can be employed in various steps of a mutation-breeding programme and in such a process, meristematic cells or tissues and mitotically active cells can be propagated under tissue culture conditions to prepare sufficient amount of material for mutagenic treatments. Intrasomatic competition discriminating mutagen affected cells and

Fig. 3. Mutant with multiple tillering and field view of the irradiated plant population

potentially causing a loss of their cell progenies may be controlled by modifying *in vitro* conditions resulting in a better competitiveness of mutant cells. In sugarcane, we have successfully demonstrated that partial desiccation for 4-6 hr can be used to stimulate and enhance somatic embryo differentiation and regeneration response of gamma-irradiated embryogenic callus cultures [10]. Subsequently this method has successfully been extended to other sugarcane cultivars. Water deficit, directly through partial desiccation, is known to stimulate ethylene evolution that may influence morphogenetic response in vitro. Partial desiccation treatment can offer as a simple and novel approach in stimulating regeneration response of higher dose gamma- irradiated cultures.

PRIMING MEDIATES THE INDUCTION OF STRESS TOLERANCE

Priming methods have been used to accelerate synchronized seed germination, improve seedling establishment, stimulate vegetative growth and crop yield in many field crops, and to perform better under sub-optimal conditions such as salinity stress. Improved stress tolerance of primed plants is thought to arise from the activation of cellular defense responses, better osmotic adjustment and a better antioxidant system in primed plants on exposure to stress. The molecular mechanisms responsible for priming effects are thought to involve accumulation of signaling proteins or transcription factors. Priming is also thought to bring about chromatin remodeling, which possibly facilitates quicker and more potent responses to subsequent stress exposure [11]. In our studies, the effect of halopriming in improving germination and subsequent growth was analyzed in four sugarcane cultivars varying in salt tolerance [12]. Priming during germination of the sets improved both the percent and rate of germination. Improved growth performance of two month-old sugarcane plants in terms of shoot length, shoot and root fresh weight was observed when subjected to 15 days iso-osmotic (-0.7 MPa) NaCl (150mM) or polyethylene glycol (PEG 8000; 20% w/v) stress. The primed plants also exhibited lower salt- and dehydration-induced leaf senescence. Improved osmotic adjustment appeared to be more critical than improved antioxidant capacity in facilitating growth under stress conditions. Steady state transcript expressional analysis of stress responsive genes revealed up regulation of NHX and down regulation of SUT1, P5CS and PDH. The results suggest halopriming can be useful as an efficient strategy for imparting abiotic stress tolerance in sugarcane.

MOLECULAR DETAILING OF STRESS RELATED GENES

The development of genomic technologies that can yield structural and functional information about key genes provides useful information through profiling experiments and/or through the candidate gene approach. The candidate gene approach is facilitated by the large number of sequences and freely available gene information found in plant genetic databases to identify potential candidate genes and pathways involved in stress tolerance. In our studies, we have analyzed the expression of different stress related genes *NHX* and *SUT1, P5CS* and *PDH*, involved in direct protection of plant cells (osmoprotectants, antioxidant enzymes, ion transporters) or regulatory functions (signaling genes and transcription factors). On long-term exposure to salt or PEG stress the steady state levels of both *P5CS*, a gene coding for an important enzyme of the proline biosynthesis pathway and *PDH*, which codes for an enzyme which plays a role in proline catabolism, increased, which also correlated to proline accumulation under these stress conditions.

Plant GSK3/Shaggy-like kinases are involved in hormone signaling, development and stress response. We have used PCR based cDNA suppression subtractive hybridization (SSH) technique to construct sugarcane salt (NaCl) stress specific forward and reverse subtracted cDNA library from salt (NaCl) stressed shoot and root tissues. Sequencing the clones from the forward subtracted cDNA library, identified shaggy like protein kinase (hereafter referred as sugarcane shaggy like protein kinase-*SuSK*; NCBI GenBank EST database Acc: FG804674). The sequence analysis of the *SuSK* revealed homology (inclusive of the catalytic domain) to *Arabidopsis thaliana* shaggy-related protein kinase delta (E value: $1e^{-108}$), dzeta and iota. Spatial and temporal transcript expression profiling of the *SuSK* gene based on Real Time PCR revealed significant induction of transcript expression in response to short-term salt (NaCl 200mM) or polyethylene glycol-8000 (PEG 20% w/v) induced osmotic stress in leaves and shoots of sugarcane plants [13].

TRANSGENIC SUGARCANE

The range of potential applications through the transfer of genes from a wide variety of plant and non-plant sources (i.e. creating transgenics) is increasing rapidly in sugarcane [5]. Some of these genes include, insect resistance and herbicide resistance, altered sucrose content via down-regulation of pyrophosphate-dependent phosphofructokinase and sucrose accumulation with antisense soluble antisense acid invertase gene. Further, genetic engineering of sugarcane varieties that can produce high-value compounds such as pharmaceutically important proteins, functional foods and nutraceuticals, biopolymers and precursors and enzymes and biopigments is paving ways to launch sugarcane as a biofactory in coming years. With the availability of efficient transformation systems, it should be possible to improve commercially important traits in elite germplasm that subsequently can lead to the development of an ideal plant type of sugarcane.

CONCLUSIONS AND FUTURE DIRECTIONS

The availability of cellular and molecular toolbox has opened up a plethora of prospects in sugarcane. Current research is centered on developing innovative *in vitro* culture systems with potential for rapid propagation and generating novel germplasm with desirable traits. The advances in sugarcane biotechnology could become remarkable in the coming years, both in terms of improving plant productivity as well as gaining ground from a commercial viewpoint.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the constant encouragement and support of Dr. S.F. D'Souza, Associate Director (A), BMG, and Head, NABTD, during the course of the sugarcane work. Sincere thanks are also due to all my colleagues, research associates and students who were closely associated and contributed to this program. This article is a tribute to their cooperation and to the belief that 'team work always prospers'.

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I&C Security for Nuclear Power Plants: A Study

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Abstract

Instrumentation & Control (I&C) security, dealing with protection of I&C functions against unauthorized modifications, needs to be managed by a systematic, comprehensive and dynamic methodology. This paper outlines such a methodology based on national and international standards and practices. It also touches upon typical threats and vulnerabilities related to computer-based systems and associated safeguards. The article concludes with a brief description of present work and other complementary approaches and emerging methodologies related to this topic.

1. INTRODUCTION

Computer-based systems are increasingly being used to implement safety functions as part of Instrumentation and Control (I&C) systems in Nuclear Power Plants (NPPs). Any breach of security in these systems can potentially affect the plant safety. Besides, the plant availability depends on smooth operation of I&C systems. I&C security deals with securing functions of these I&C systems against malicious attacks. It is necessary to design, operate and maintain these systems keeping in mind the security objectives. For this purpose, it is necessary to evolve a systematic, comprehensive and dynamic methodology to take care of the current threat scenarios and new threats that could show up in the future.

Unlike physical security and information security, I&C security (see box - *Definitions*) is a more recent branch of study and sufficient awareness and importance of this topic may not be prevalent among all stake holders. This article attempts to elucidate the concept, the issues and the methodology related to managing I&C security, which is causing increasing concern to the NPP regulators and operators all over the world.

2. I&C SECURITY

Computer-based I&C systems are extensively used in NPPs for various purposes: reactor protection,

Definitions

I&C security: Deals with protecting the functions of Instrumentation & Control (I&C) systems – especially those important to NPP safety. This is also termed as computer system security, cyber security or software security in some standards/guides.

Physical security: Deals with protecting installation, equipment, building, etc.

Information security: Deals with protecting information and information systems from unauthorized access, use, etc.

Vulnerability: A feature or weakness that can be exploited to bring out an undesirable consequence.

Threat: Potential to cause an undesirable consequence.

Risk: Perceived consequences of a successful attack: combination of probability of a security related event and its consequences.

Malicious code: Virus, Trojan horse, time-bomb, hidden functions, etc.

power regulation, supervisory controls, control room displays, data acquisition systems, etc. Unauthorised modification of these systems (in software or hardware) or disruption of its functions can significantly affect the plant operation. It may affect the plant safety (if safety functions are affected) or normal operation (if safety related or other control functions are affected) or it can lead to mal-operation by the operator (if control room functions are affected). I&C security is related to developing safeguards to protect the functions of I&C systems from these malicious attacks, which may even be programmed to act at certain time or condition of the plant. The safeguards should be systematic – the security features should be built into the system design and the system development process; the 'security patches' coming as 'after-thought' never give a complete solution. The safeguards should be comprehensive – covering all aspects of the system and its operating environment; the omissions are the ones mostly exploited by potential attackers. The safeguards should be dynamic – they should be assessed and updated on a continuous basis; new vulnerabilities show up with time and new counter-measures are to be put in place.

3. SECURITY REQUIREMENT AND OBJECTIVES

The I&C security requirement can be stated as follows:

"I&C systems of NPPs should be designed, operated and maintained with adequate security measures to protect these systems against (sabotage by insiders or outsiders by) unauthorised modification of system resources or disruption of its services"

There are three security objectives, namely integrity, availability and confidentiality. Integrity refers to correctness of the asset (software/hardware/configuration, etc.); protection against unauthorized modification is essential to preserve integrity. Availability ensures reliable and timely operation/access of the asset; protection against denial/disruption of service is essential for meeting this objective. Confidentiality relates to the restrictions on the access and disclosure of the asset; this is generally not relevant to NPP I&C systems, except in cases where the operational data is confidential.

4. THREATS & VULNERABILITIES

Typical threats to computer-based systems are:

1. Introduce (deliberately/unintentionally) malicious code in software. This may happen during development or Operation & Maintenance (O&M) phase. The malicious code may be introduced via USB, CD-drive, Ethernet etc. Malicious code could be virus, Trojan horse, time-bomb (which is dormant and acts at a particular time or condition of the plant), etc.
2. Unauthorized modification of software or setpoints
3. Alter system configuration (e.g. alter board settings, I/Os)
4. Jam/disrupt network services
5. Tampering of sensors or sending erroneous data through network, to give wrong information about plant status.

Vulnerabilities may exist in the product (e.g. the system or the software) as well as in the process (e.g. development). Listed below are some of the product vulnerabilities:

1. Inadequate safeguard features (e.g. in access control) or bugs in application software. This allows potential attacker to gain control & alter the system resources

2. Unused/unprotected hardware such as USB, CD-drive etc. These are means to introduce malicious codes
3. Security holes in Operating System (OS) or insecure OS. The attacker exploits inherent vulnerabilities of the OS to gain control of the system
4. Unknown security bugs in or 'contaminated' Pre-Developed Software (PDS).

Unlike in-house products, PDS is not subjected to thorough Verification & Validation, making it difficult to understand their inherent security deficiencies. PDS also may contain hidden functions or viruses.

It may be noted that use of standard technologies or products, such as commercial operating systems, Ethernet network, etc. makes a system more vulnerable. Hence, use of such products must be justified for critical systems and adequate care should be taken in selection, acquisition, qualification and deployment of such products.

Some of the process vulnerabilities are listed below:

1. Insecure development, testing or validation environment. This is exploited to mix malicious software with genuine software, making it very difficult to detect & eliminate.
2. Insecure/inadequate configuration management Intermediate or final software products developed or verified are modified before integrating into the system. This is applicable to development phase as well as O&M phase
3. Inadequate verification/validation. Malicious code goes undetected although subjected to V&V.

5. REGULATORY REQUIREMENTS

AERB safety guide D-25[1] (see box – *standards and guides for computer-based I&C systems*) has recently been updated with specific security requirements to be satisfied by I&C systems. This includes protection against unauthorized modification of setpoints and other resources, role based access restrictions, tamper proof event logs, sanitization of pre-developed software, etc. Unfortunately D-25 does not have enough design guidance and does not include global issues related to the complete I&C system and the O&M phase. International standards of IEC (which are referred from D-25) are more comprehensive in this respect. IEC 61513-2001[2] stipulates that an overall security plan should be prepared for overall I&C systems and a system security plan - based on the overall plan and system specific features - should be prepared for individual systems. IEC 60880-2006[3] and IEC 62138-2004[4] spell out security requirements related to software used in class IA and class IB&IC systems respectively. IEC-60880, specifically stipulates security requirements to protect against introduction of malicious code during software development. I&C security has invited adequate attention from other international organizations too.

6. I&C SECURITY FRAMEWORK

Based on AERB and international standards and guides, mentioned above, a typical I&C security framework is illustrated in Fig. 1.

An overall security plan should be prepared addressing the global and common issues related to all I&C systems. Based on this plan and system specific security features - revealed by security analysis of a system – a system security plan should be prepared for each system. Based on the plan document and relevant regulatory and enterprise standards, security policies and procedures are prepared for the overall I&C system and for individual system. The plan documents, policies and

Standards and Guides for Computer-based I&C Systems of NPP

I&C systems of Indian NPP's are governed by AERB safety guides D-10 – for safety class IA systems – and D-20 – for safety class IB and IC systems. For computer-based I&C systems, additional regulatory requirements are specified in D-25[1].

IEC has a series of standards applicable to I&C systems used in NPPs. IEC-61513[2] is applicable the system; IEC-60880[3] and IEC-62138[4] are applicable to software used in class IA and IB&IC systems respectively.

IAEA safety guides: NS-G-1.3 is applicable to NPP I&C systems important to safety; and NS-G-1.1 is applicable to software used in such systems.

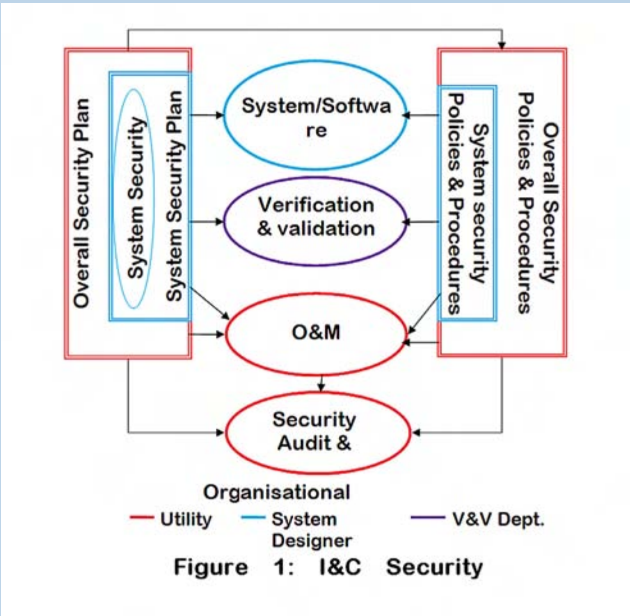

Fig. 1: I&C Security Framework

procedures give rise to specific system/software requirements, which are used in the system/software development. The verification & validation (V&V) activity assesses, a) if the security requirements are adequately translated into system/software requirements; and b) if the system/software design conforms to the specified requirements, policies and procedures. The O&M phase uses the security plans, policies and procedures to securely operate and maintain the I&C systems. A security audit should be conducted periodically to check if the security plans, policies procedures are complied with. Security certification may be obtained from appropriate authorities to determine the extent to which the plans, policies and procedures are implemented correctly, operating as intended, and producing the desired results.

These security plans are described in detail below.

6.1 Overall Security Plan

A preliminary version of this plan may be prepared by the plant I&C designer taking into account the overall I&C architecture. The final version of the plan should be prepared, maintained and updated by the utility.

The plan shall specify the security requirements so as to meet the security objectives of integrity, availability and confidentiality. It shall consider the operating environment of the plant and the I&C architecture. It should describe set security controls, which when implemented would most cost-effectively comply with the stated security requirements and also demonstrate the organization's commitment to security. There are three types of security controls: management, operational and technical. Management controls are techniques and concerns that are normally addressed by management. Operational controls address security methods focusing on mechanisms, primarily implemented and executed by people (as opposed to systems). Technical controls focus on security controls that the computer system executes. Listed below are typical security controls addressed in overall security plan:

1) Management Control
    a) Security Planning
    b) Security Assessments & Certification
    c) Risk Assessment
2) Operational Control
    a) Security awareness & training
    b) Configuration Management
    c) Physical and Environmental Protection
    d) System Integrity Monitoring
3) Technical Control
    a) Access Control
    b) Audit & Accounting
    c) Identification and Authentication
    d) System and Communication Protection.

Additionally, the overall security plan may dictate specific security controls to be exercised during system development.

6.2 System Security Plan

The system security plan is prepared by the system designer.

As a first step, a security analysis should be conducted. The security analysis consists of asset analysis and vulnerability analysis. Asset analysis examines the importance of the assets, to be secured, and impact of their failure on the three security objectives: integrity, availability and confidentiality. Vulnerability analysis studies the threats and vulnerabilities associated with the system. The vulnerability analysis should cover all relevant life-cycle phases of the system. The overall security impact of the assets and vulnerability analysis results, are used to select the right combination of security controls in system security plan.

The system security plan is prepared by selecting (and if required augmenting) the security requirements and security controls from overall I&C security plan that are applicable to the system and based on the results of security analysis.

Listed below are typical security controls addressed in system security plan:

1) Sanitization of PDS, such as operating system
   Examples: Validate/scan PDS before using, execute intrusion tests, use of trusted OS, etc.
2) Configuration management during development
   Examples: Use digital signature to authenticate intermediate software products or the final validated code. Similar technique may also be used online to check tampering of the binary code executing on the target.
3) Access control, Identification and Authentication
4) System and Communication Protection
   Examples: Removal/disabling/blocking of USB ports/Pen drives, on-line checks on unauthorised network access or abnormal network activity etc.
5) Integrity checks & system monitoring
   Examples: Monitor system/network activity to detect deviation from normal behavior.
6) Rigorous V&V and intrusion resistance tests.

6.3 Policies and Procedures

Based on the security plans and other governing standards, policies and procedures are formulated for overall I&C systems and individual systems or a group of systems. Like the security plans, these policies and procedures also should be assessed periodically and be updated when required.

7. CURRENT WORK

The Control Instrumentation Division, E&I Group, BARC has prepared generic documents for system security plan, overall security plan and system security analysis – asset analysis and vulnerability analysis – based on the methodology described above. These documents can be adapted and implemented appropriately to ensure, that the security requirements have been percolated into the software/system requirements and software/system design as well as in the development process. Formulation of these plans, policies and procedures a *priori* to development of a system is expected to make the system more robust against security related attacks.

8. OTHER APPROACHES/METHODOLOGIES

There are many approaches/methodologies that complement the methodology given in this article. Some of these attempt to quantify security attributes and some attempt to manage risks associated with various attack scenarios.

The risk management methodology uses a process by which particular combinations of threat, vulnerability and impact are identified, documented and appropriate protective controls are devised. The process identifies the susceptibility of computer systems to sabotage, evaluates the system's robustness, and provides cost-effective counter measures to 'fix the holes'. An example of risk assessment based approach on a Korean NPP is given in the paper [5].

There are emerging methodologies [6] that attempt to quantify security attributes, such as cost of attack, impact, etc. These models attack scenarios and rely on probabilistic techniques using attack trees and Markov chains to derive these attributes. Use of these techniques in real applications is yet to be established.

9. CONCLUSION

I&C security is a nascent topic, considerable work is to be done to evolve a robust and cost-effective approach to manage I&C security. Besides, there is a need to spread awareness and importance of this topic among the utilities and I&C system designers, as I&C security is going to be one of the key elements for ensuring safe and smooth operation of NPPs in the future. It must be emphasized that I&C security is equally applicable to any plant/installation/device, which uses computer-based control, and for which any of the security attributes – safety, availability or confidentiality - are critical.

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Phase Transformations in U-Zr Alloy System

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Abstract

U-Zr alloy system is a potential candidate for metallic fuels for nuclear reactors. In this context, it is important to understand the phase transformation characteristics of this alloy, as it will govern the in-pile behaviour. The present study is limited to the U-rich part of the U-Zr system, i.e. alloys containing upto 10wt%Zr. However, the U-50wt%Zr composition was also thoroughly investigated to obtain a deeper understanding of the phase transformations involving gamma and delta (UZr_2) phases. The results of the present work provide a new insight into the structural and microstructural changes in U-Zr alloys. The present work also tries to address some of the important aspects of phase transformation reported in literature that were either misinterpreted or inadequately addressed.

Keywords: Uranium, Zirconium, Delta phase, Phase transformation, Characterization

1. INTRODUCTION

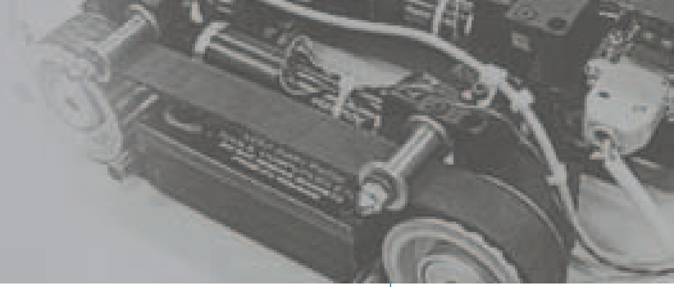
U-rich U-Zr alloys are of interest, because of their potential use in low power or research reactors; since Zr has a low thermal-neutron cross section. Also, the U-Zr binary alloy system is an important subsystem of the U-Pu-Zr ternary system that has been recognized as a promising metallic fuel for fast breeder reactors. Moreover, uranium alloyed with Zr shows excellent corrosion resistance and dimensional stability during thermal cycling. These favorable properties have led to the development of uranium-zirconium fuel for reactor use in several countries. In fact, the U-10wt%Zr alloy was used in EBR-II, USA in early 1985 [1]. The present study details the following aspects of U-rich, U-Zr alloy alloys –

i. Evolution of the as-cast microstructures in U-rich U-Zr alloys.
ii. Formation of UZr_2 phase (δ-phase) in U-rich U-Zr alloy.
iii. Mechanism of the $\gamma \rightarrow \delta$ phase transformation in U-50wt%Zr alloy.

2. PRE-CHARACTERIZATION METHODOLOGIES

U-rich U-Zr alloys (upto 10wt%Zr) were melted in a vacuum induction melting furnace at approximately 100°C above their liquidus temperature. The Zr-rich U-Zr alloy (e.g. 50wt%Zr), on the other hand, was melted in a non-consumable vacuum arc melting furnace. In both melting practices, oxygen impurity in Ar gas was removed, by passing it over hot uranium turnings. In the case of arc melting, the alloy buttons were remelted several times to ensure chemical homogeneity. The alloy buttons were then jacketed in copper tubes and hot rolled at 850°C to 75% reduction in thickness.

Though U-Zr alloys are amenable to the standard metallographic practice, the etching characteristic varies considerably with Zr content. For U-rich U-Zr alloys, water and phosphoric acid mixture (1:1 V/V) was used for both electro-polishing and electro-etching, with a constant open



circuit DC potential of 25V and 2V, respectively. Samples of U-50wt%Zr were etch-polished using water and nitric acid mixture (9:1V/V) with few drops of HF at the final stage of polishing.

The following techniques were used for characterization of the transformations and microstructures in these alloys e.g. Optical Microscopy (OM), Scanning Electron Microscopy (SEM) with Energy Dispersive Spectroscopy (EDS), Transmission Electron Microscopy (TEM), Differential Scanning Calorimetry (DSC) and Dilatometry.

3. MICROSTRUCTURAL EVALUATION OF AS-CAST U-RICH U-ZR ALLOYS

Earlier studies indicated that in as-cast condition U-rich U-Zr alloys consist of orthorhombic α-phase and hexagonal δ-phase at room temperature [2-3]. In fact U-Zr phase diagram also suggests the same. However, no concrete experimental evidence exists to prove this claim. SEM micrographs of the as-cast U-Zr alloys show fine lamellar structure (Fig. 1 (a)). From the phase diagram it can be seen, that for U-10wt%Zr alloy, the equilibrium phase fraction (in w/w) of δ-phase would be about 27% which is well within the detectable limit of the conventional XRD technique. However, the XRD analysis upto 10wt% Zr alloys shows single alpha phase, as shown in Fig. 1 (b). Zr-L_α x-ray mapping from EDS, as shown in Fig. 1 (c-d), indicates that only a small amount of Zr partitioning takes place across these lamellae; on the other hand the Zr concentration should be at least ~37wt% in the δ-phase. Thus, it can be concluded that, the as-cast U-rich U-Zr alloys consist of supersaturated α-phase. Further investigations prove that the lamellar configuration of the α-phase originates from high temperature monotectoid reaction.

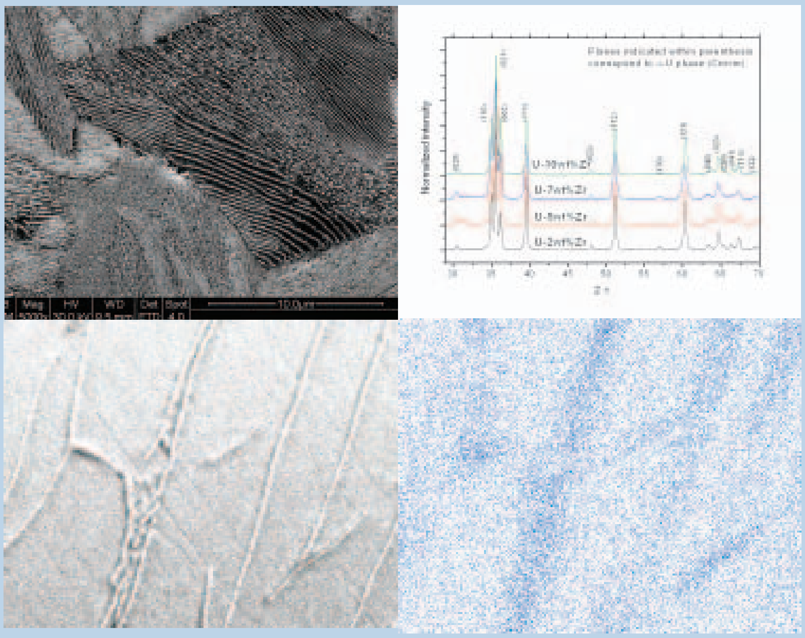


Fig. 1: (a) SEM micrograph of U-7wt%Zr alloy. (b) XRD patterns of as cast U-rich U-Zr alloys. (c-d) SEM image and corresponding Zr-L_α x-ray mapping respectively for as-cast U-2wt%Zr.

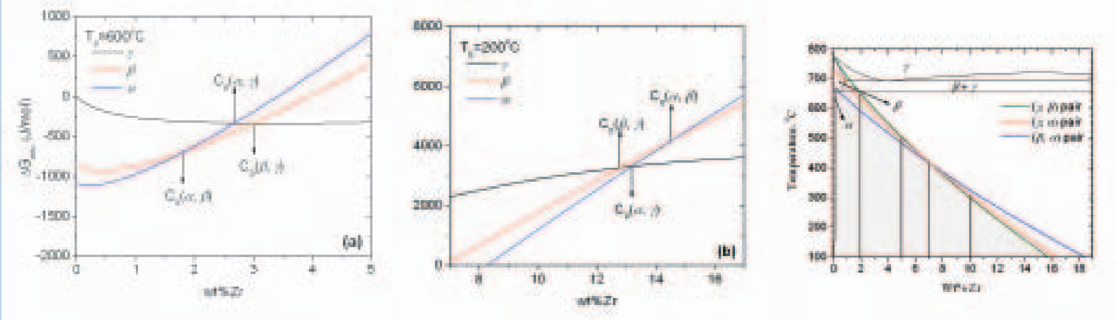


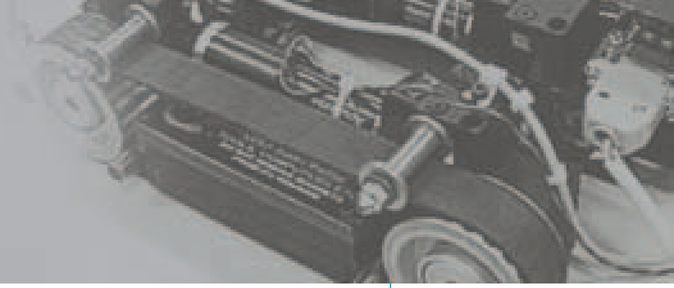
Fig. 2. (a-b) Traces of (C_0, T_0) at 600°C and 200°C respectively and (c) region of supersaturated alpha phase (hatched area) superimposed on the phase diagram.

With the help of free-energy composition diagram and (C_0, T_0) trace it might be possible to see if it is thermodynamically possible to get the supersaturated α-phase at room temperature. Being a substitutional solid solution it could be expected that the diffusivity of Zr in α-U would be low. Though there is no data available on the α-phase, even the high temperature bcc γ-phase in U-Zr system shows one order magnitude of lower inter-diffusion coefficient than that of fcc Au-Ni system [4]. Thus in order to predict the thermodynamic origin of the as-cast structure, the concept of lowest common tangent could no longer be applicable. So, the as-cast structure in U-Zr system cannot be explained by the global thermodynamic equilibrium as predicted by the phase diagram. Comparing the Fig. 2 (a) and (b) it is apparent that as temperature decreases the C_0 value for α-γ pair shifts towards higher Zr content. The (C_0, T_0) trace, superimposed on the phase diagram, is presented in Fig. 2 (c) showing the hatched area where only α-phase is stable under supersaturated condition.

4. FORMATION OF UZr_2 PHASE (δ–PHASE) IN U-RICH U-ZR ALLOY

Naturally the question arises as how the UZr_2 phase forms in U-rich U-Zr alloys. To answer this question a prolonged heat-treatment schedule was designed where, the holding time was increased below the monotectoid and eutectoid isotherms. The heat-treatment schedule consists of 480hrs. of holding at 680°C followed by 1520hrs. of soaking at 650C and a final soaking at 600°C for 500hrs and 2880hrs respectively.

The XRD results confirm the presence of delta phase even in Zr-lean U-2wt%Zr alloy as shown in Fig. 3 (a). In fact using GSAS computer program, the lattice parameter and site occupancy of the α-matrix in different alloys were determined with high precision. After, 2880hrs. of soaking at 600°C it was seen that the lattice parameters of the Zr-lean α-matrix do not vary significantly from one alloy to another. This clearly indicates that the phases in these heat treated alloys have reached the equilibrium state in terms of compositions and structure. The SEM micrograph of U-7wt%Zr alloy is presented in Fig. 3 (b) showing the precipitates of the delta phase in the α-matrix. In fact one can clearly see the striking difference between the as-cast microstructure and the microstructure containing δ-phase comparing Fig. 1(a) to Fig. 3 (b). Also, EDS results (not shown here) clearly indicate the Zr content of these particles is nearly 37% whereas the same in the matrix is below detectable limit. These results clearly show that formation of δ-phase in U-rich U-Zr alloys is kinetically very sluggish in nature. Evidently, in U-rich U-Zr alloys formation of the δ-phase is highly unlikely in as-cast condition.



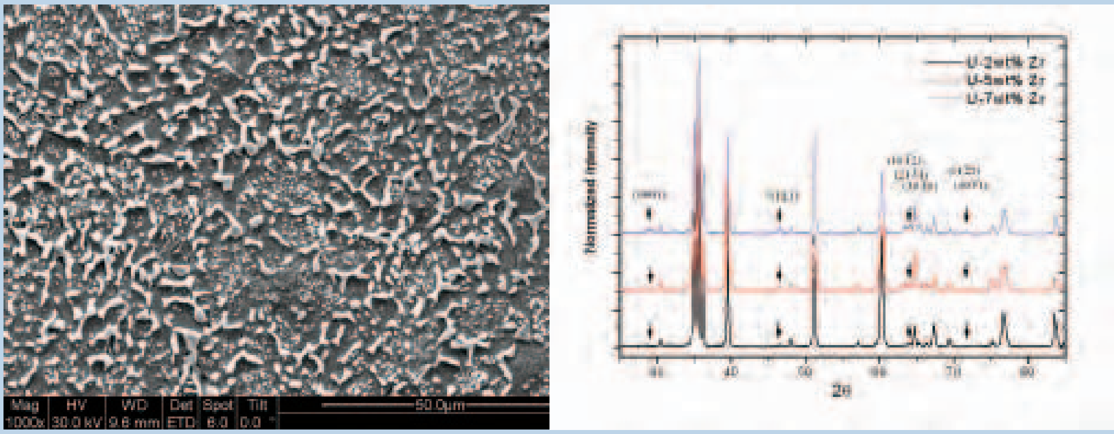


Fig. 3: (a) SEM micrograph of U-7wt%Zr alloy showing delta phase precipitates (after 2880hrs. holding at 600°C) and (b) XRD patterns of the heat-treated U-rich U-Zr alloys showing (arrows) the peaks corresponding to the hexagonal δ-phase.

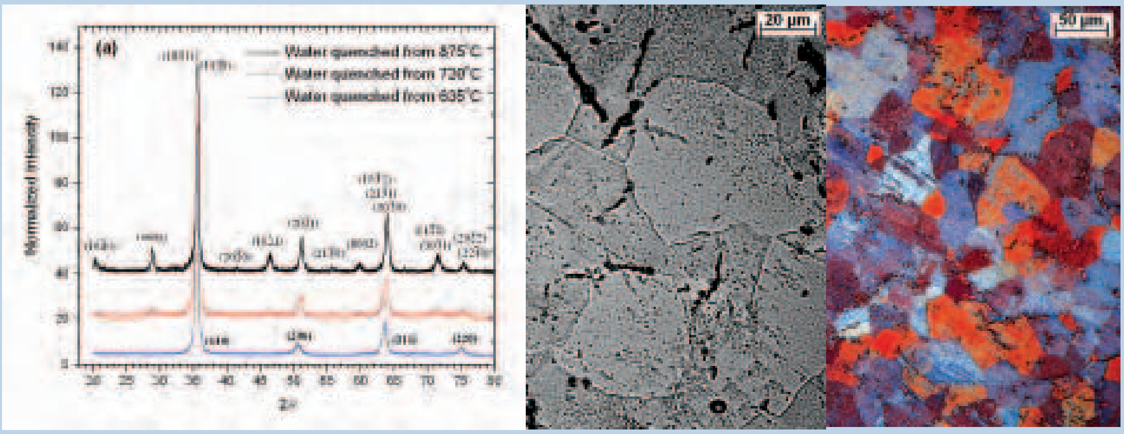


Fig. 4: (a) XRD patterns of U-50wt%Zr alloys under different quenched conditions and (b-c) optical micrograph of bcc gamma (bright field) and hexagonal δ-phase (polarized).

5. PHASE TRANSFORMATION MECHANISM FOR γ→δ IN U-50wt%Zr ALLOY

γ→δ transformation occurs at around 613°C in U-50wt%Zr alloy. Interestingly, U-50wt%Zr alloy manifests peculiar phase transformation behaviour. The high temperature γ-phase remains metastable if quenched from a temperature just above the γ→δ transus; e.g. 635°C. However, annealing or quenching from high temperature (e.g. 700°C and above) tend to form the equilibrium δ-phase at room temperature as confirmed from the XRD patterns, Fig. 4 (a). In fact the bcc gamma phase does not respond under polarized light illumination which is in contrast to the hexagonal d-phase as shown in Fig. 4 (b) and (c).

The space group of the δ-phase is P6/mmm (sp. gr. no. 191) having three nonequivalent lattice positions (0,0,0), (1/3, 2/3, 1/2) and (2/3, 1/3, 1/2) where the first position is occupied by the Zr atoms and the rest two are randomly occupied by U and Zr atoms [5]. Since, the crystal structure of the δ-phase resembles hexagonal AlB_2 type structure and the parent gamma phase is disordered bcc; the investigation was started somewhat intuitively

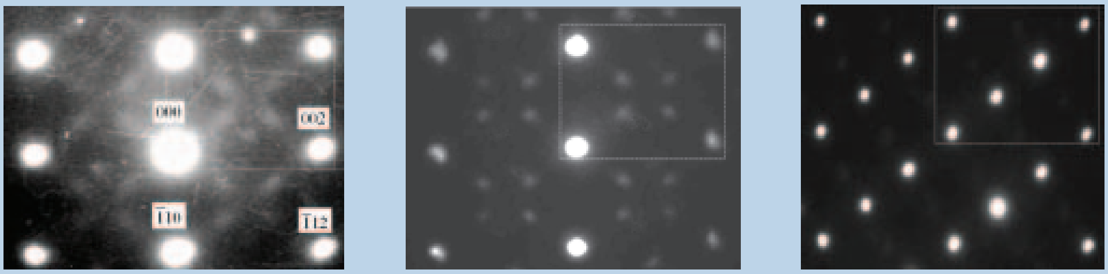


Fig. 5. Selected Area Electron Diffraction (SAED) patterns of U-50wt%Zr alloy along [110] zone axis showing; (a) metastable γ-phase with streaking, (b) multi-variant δ-phase after ageing at 300°C for 4 hrs. and (c) single variant δ-phase after ageing at 300°C for 24 hrs.

towards exploring the omega transformation mechanism.

TEM investigation reveals the presence of a very small amount of δ-phase in the metastable γ-phase, which otherwise could not be detected in XRD. Ageing of this metastable γ-phase shows diffuse streaking in the diffraction patterns. With increasing ageing time, these streaks finally transform into spots and further ageing finally promotes single variant d-phase; as shown in Fig.5 (a-c). These observations clearly indicate that the γ→δ transformation takes place by omega transformation where 2/3 of the (111) planes of bcc gamma phase collapse and give rise to hexagonal UZr_2 δ-phase. Clearly, ageing for longer duration indeed promotes the growth of the different variants of the delta phase.

6. CONCLUSIONS

The present article emphasizes the following points related to the phase transformation behaviour in U-Zr alloy system –

i. In U-rich U-Zr alloys (upto 10wt%Zr), the as-cast structure is lamellar due to the higher thermodynamic driving force below the monotectoid isotherm. Only a small amount of solute (Zr) partitioning takes place across the lamellae. So, the as cast structure of the U-rich U-Zr alloys could be considered as Zr-supersaturated α-phase.

ii. Formation of δ-phase in the U-rich U-Zr alloy could be established beyond doubt by a specially designed heat-treatment schedule. This further emphasizes that δ-phase cannot be formed under as-cast condition.

iii. U-50wt%Zr alloy exhibits metastable γ-phase if it is quenched from a temperature just above the equilibrium transformation temperature (~613°C). This retention is due to the lack of driving force for omega transformation. The metastable γ-phase, upon ageing, eventually transforms into equilibrium δ-phase by plane collapsing omega transformation mechanism.

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Indian High Temperature Reactor Programme: An Overview

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Abstract

High temperature reactors have a large potential to provide necessary high temperature process heat for hydrogen production, through high efficiency hydrogen production processes. BARC is carrying out developmental work related to various aspects of high temperature nuclear reactors. Besides design, R & D work encompasses development of high temperature high burn-up fuel, special materials, joining technologies, coatings, characterization techniques, instrumentation, passive systems for high temperature thermal management, high temperature heat pipes, systems for reactor safety. Studies planned to be carried out include, seismic behaviour, irradiation behaviour of fuel and materials, inter material compatibility, oxidation and corrosion-related studies.

1. INTRODUCTION

In India, high temperature reactor development programme was initiated because of a need to develop alternate energy carrier to substitute fossil fuel based transport fuel [1]. Hydrogen production processes by thermo-chemical splitting of water need either electricity or process heat at high temperature, or both depending upon the process of hydrogen production selected. High temperature nuclear reactors have a large potential for sustainably supplying energy for these hydrogen production processes at required high temperature conditions. BARC is currently developing high temperature nuclear reactors capable of supplying process heat at a temperature around 1000 °C. Presently, technology development for a small power Compact High Temperature Reactor (CHTR) capable of supplying high temperature process heat at 1000 °C is being carried out. In addition, preliminary design of a 600 MWth reactor, capable of supplying heat at 1000 °C for large scale hydrogen production, is in progress.

2. COMPACT HIGH TEMPERATURE REACTOR

The CHTR [2] is being developed as a prototype reactor, for the development and demonstration of technologies associated with high temperature reactors. The reactor is modular in design and is being designed to be compact in weight and size for ease in its deployment in remote locations for its use as a compact power pack. It has a prismatic core configuration consisting of nineteen hexagonal shaped beryllium oxide (BeO) moderator blocks. These blocks contain centrally located fuel tubes. Fuel tubes would be made of high density, isotropic, nuclear grade carbon-carbon composite or graphite. They would be coated with oxidation-resistant coatings. Each fuel tube carries fuel compacts inside longitudinal bores made in its wall. Thorium-^{233}U based fuel compacts are made-up of Tri-Isotropic

(TRISO) coated particle fuel [3], facilitating high burnup and high temperature application. The fuel tube also serves as coolant channel. Molten Lead-Bismuth Eutectic (LBE) alloy has been chosen as coolant. Twelve movable and six fixed reflector blocks of BeO surround the moderator blocks. These are in turn surrounded by graphite reflector blocks. These components are contained in a reactor shell of a material, resistant to corrosion against LBE, and provided for return of the cold coolant to lower plenum. The reactor shell is surrounded by two gas gaps that act as insulators during normal reactor operation and reduce heat loss in the radial direction. These gas gaps help in dissipating neutronically limited power to an external sink, in case of a postulated accident. A passive system has been provided to fill these gas gaps with molten metal in case of abnormal rise in coolant channel outlet

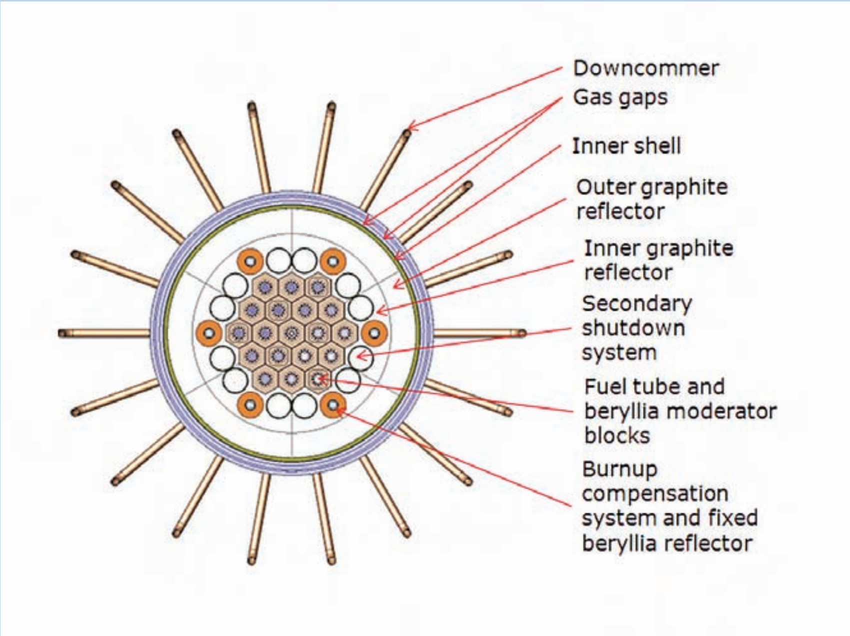

Fig. 1: Cross-sectional view of Compact High Temperature Reactor

suitable for high temperature applications. Cross-sectional layout of the reactor is shown in Fig.1.

Top and bottom closure plates of similar high temperature and corrosion-resistant material, close this reactor shell. Above the top cover plate and below the bottom cover plate, cyclindrical vessels called coolant plenums are provided for coolant exit and entry into the core respectively. Upper plenum has graphite block for guiding coolant flow, between the fuel tube and down comer tube temperature. Nuclear heat from the reactor core is removed passively by natural circulation based flow of coolant between the two plenums, upward through the fuel tubes and returning through the downcomer tubes. On top of the upper plenum, the reactor has heat utilization vessels to provide an interface to systems for high temperature process heat applications. A set of sodium heat pipes passively transfer heat from the coolant to these heat utilization vessels. To shut down the reactor, a set of seven tantalum alloy based shut-off rods has been provided, which fall by gravity in the central seven coolant channels. Twelve control rods of same material have been provided in the balance fuel tubes. Appropriate instrumentation like neutron detectors, fission/ ion chambers, sensors, and auxiliary systems such as cover gas system; purification systems, etc. are being incorporated in the design. CHTR component layout is shown in

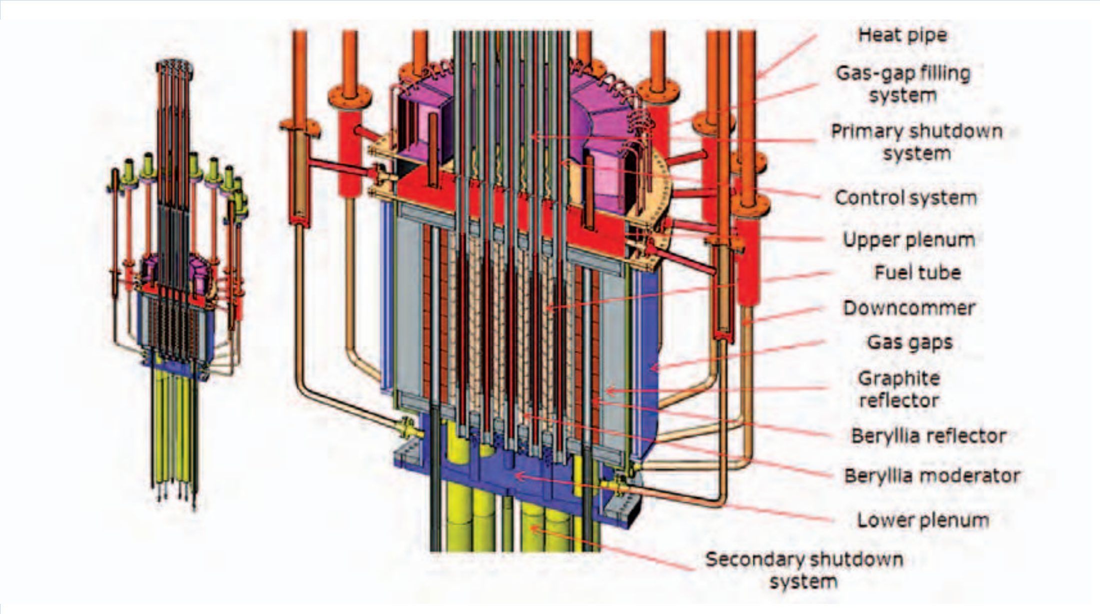

Fig. 2: Layout of CHTR Components

Table 1: Major design and operating characteristics of CHTR

Attributes	Design Parameters
Reactor power	100 kWth
Core configuration	Vertical, prismatic block type
Fuel	^{233}U and Th based TRISO coated fuel particles shaped into fuel compacts with graphite matrix
Fuel enrichment by ^{233}U	33.75%
Refuelling interval	15 effective full power years
Fuel Burnup	≈ 68000 MWd/t of heavy metal
Moderator	BeO
Reflector	Partly BeO and partly graphite
Coolant	Molten Pb-Bi eutectic alloy (44.5% Pb and 55.5% Bi)
Mode of core heat removal	Natural circulation of coolant
Coolant flow rate through core	6.7 kg/s
Coolant inlet temperature	900 °C
Coolant outlet temperature	1000 °C
Loop height	1.4 m (actual length of the fuel tube)
Core diameter	1.27 m
Core height	1.0 m (Height of the fuelled part and axial reflectors)
Primary shutdown system	Mechanical shut-off rods
Secondary shutdown system	Axial movement of movable BeO reflector blocks

Fig. 2 and major design and operating parameters are listed in Table 1.

2.1 Current status of CHTR

CHTR has led to initiation of R & D activities in many areas of nuclear engineering. This includes development of high chemical purity special materials like beryllium oxide, carbon based materials like graphite and carbon-carbon composites, refractory metal alloys with oxidation and corrosion resistant coatings, and TRISO coated particle based fuel. In addition, many passive systems are being developed for heat removal. There is also a need to establish design rules for brittle materials as well as high temperature components, not covered in conventional design codes. A feasible design of the CHTR and associated systems has been established. An experimental facility to carry out studies related to liquid metals is in operation. The manufacturing capabilities for BeO, carbon components and fuel micro-spheres have been demonstrated. Trials for TRISO coatings have started. These activities are being pursued in different divisions of BARC. Demonstration of technologies for CHTR has been planned under on going plan projects in two stages. The first stage is based on demonstration with non-nuclear heating, use of surrogate materials and at temperature around 500 °C. In the next stage, it would be demonstrated as a critical facility operating at 1000 °C.

3. 600 MWTH INNOVATIVE HIGH TEMPERATURE REACTOR (IHTR)

BARC is carrying out design of a 600 MWth reactor for commercial hydrogen production [3]. For this reactor, various design options as regards fuel configurations, such as prismatic bed and pebble bed were considered for thermal hydraulics and temperature distribution analysis. Coolant options such as molten lead, molten salt and gaseous medium like helium were analyzed. Besides these, other criteria such as ease in component handling, irradiation related material and fuel degradation, better fuel utilization and passive options for coolant flow etc. were also considered. Initial studies carried out indicate selection of pebble bed reactor core with molten salt-based coolant. Table 2 shows proposed specifications and Fig. 3 shows schematic of the reactor.

Table 2: Proposed general specifications of the IHTR

Reactor power	600 MWth for following deliverables
	• Hydrogen: 80,000 Nm^3/hr
	• Electricity: 18 MWe
	• Drinking water: 375 m^3/hr
Coolant outlet/ inlet temperature	1000 °C / 600 °C
Moderator and reflector	High density, isotropic, nuclear grade graphite
Coolant and mode of cooling	Molten salt by passive natural circulation of coolant
Fuel in the form of pebbles	$^{233}UO_2$ & ThO_2 based high burn-up TRISO coated particle fuel
Energy transfer systems	Intermediate heat exchangers for heat transfer to system for hydrogen production + High efficiency turbo-machinery for electricity generation + Desalination system for potable water
H_2 production process	High efficiency thermo-chemical processes

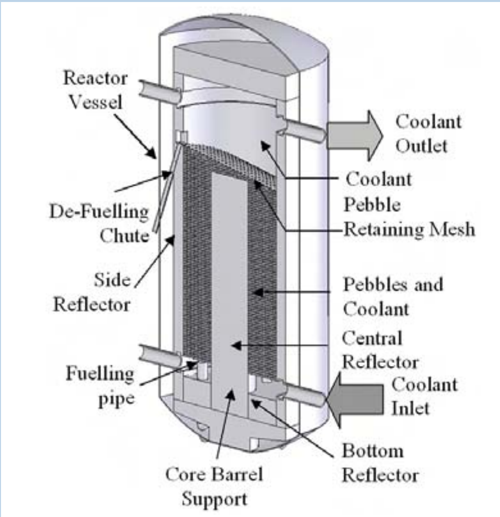

Fig. 3: Schematic of core configuration of 600 MWth IHTR

3.1 Current Status of 600 MWth IHTR

Intial reactor physics and thermal hydraulic designs of the reactor have been carried out and feasibility of the design has been established. Currently reactor physics design is being optimized. Thermal and stress analysis of the core components have been carried out. Based on these, pebble sizes have been decided. A computer code is under development for simulating pebble motion within the core. Studies have been carried out with molten salts to study their properties and their freezing and de-freezing behaviour. Many of the technologies developed for CHTR would be utilized for this reactor. There are plans to setup engineering laboratories for carrying out research and development related to reactor components, coolant technologies, reactor safety, fuel and material development and other aspects related to such high temperature reactors. Development of technologies for this reactor would be carried out under ongoing plan projects.

4. CONCLUDING REMARKS

Development of Indian High Temperature Reactors and their associated systems pose several challenges due to very high temperature and aggressive coolant environment. These have opened many new avenues of research in the department and developmental work has already been initiated in most of these areas. The R & D work encompasses selection and development of materials and their fabrication technologies for actual component manufacture, compatibility studies, oxidation and corrosion resistant coatings, joining technologies, development of high temperature high burn-up fuel, irradiation behaviour of fuel and materials, development of characterisation techniques and development of many passive systems for high temperature thermal management. Considering anticipated demands and deployment of such reactors in large numbers, an emphasis has been put on inclusion of inherently safe design features and development of passive design options so as to ensure increased safety margins.

ACKNOWLEDGEMENTS

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Technology Development for Indigenous Water lubricated bearings

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Abstract

Water Lubricated Bearings (WLB) are used in various mechanisms of fuel handling systems of PHWRs and AHWR. Availability and random failures of these bearings was a major factor in refuelling operations. Indigenous development of these bearings was taken up and 7 types of antifriction bearings in various sizes (totaling 37 variants) for PHWR, AHWR and Dhruva applications were successfully developed. This paper deals with various aspects of WLB development.

1.0 INTRODUCTION

Rolling element bearings are often used under severe environmental conditions such as high contact pressure, high temperatures and absence of lubrication. One such demanding application is in nuclear reactor fuel handling system, where bearings are submerged in water environment of controlled chemistry. In conventional applications, small trace of water infiltration in lubricant and contamination can cause flaking of rolling contact surfaces of the bearings, hence selection of bearings for fuel handling applications poses a major challenge. One of the solutions used is a composite bearing having races made of Martensitic stainless steel AISI 440C and rolling elements of Stellite [1]. 440C offers good corrosion resistance to water environment and provides sufficient surface hardness for rolling element bearing to operate. However performance of these bearings has not always been satisfactory, as 440C contains coarse eutectic carbides which act as crack initiators under Hertzian stress. These coarse carbides are produced during solidification and remain unchanged even after heat treatment. They reduce Cr content in martensitic matrix, leading to reduction in corrosion resistance [2]. While taking up indigenous development of water lubricated bearing a major challenge was to assure quality of AISI 440C. Other aspects of bearing design like cage design, clearances, osculation also plays an important role in the performance of these bearings. These bearings were developed indigenously covering complete aspects of bearing manufacturing technology right from material to endurance testing. Lessons were learnt from continuous testing and were applied to the development cycle.

2.0 PRIOR INVESTIGATIONS OF WATER LUBRICATED BEARINGS

WLB are in use at various NPPs in fuelling machines. Operating experience from various plants indicate random failures of these bearings. Most of the early failures were due to cracking of inner or outer races or crushing of balls. Failures after some service life are related to wear or non fatigue related surface distress. One of the systematic tests carried out by RTD and NPC by G. Murlidhar[1] et al, resulted in failure due to cracked races and cage. Microstructural evaluation and root cause analysis indicated that failures are due to poor microstructure of the 440C and excessive loading. Later RTD

had developed few bearings of 6008 type in various designs and material combinations (for balls and cages) and tested them. There were no catastrophic failures obtained, failures were rather due to wear of the components in service life. It has been observed that bearings can be operated with AISI 440C balls with lower wear life than Stellite balls and polymeric cages provided higher wear life than bronze cages. Use of 440C balls was also found satisfactory in bearings used at DHRUVA fuel handling system. Rolling Contact Fatigue (RCF) testing using four-ball tester was also carried out to generate data on fatigue and wear life of the 440C. Typical data is presented in Fig.1 which compares RCF data of 440C with different microstructure using Weibull chart. Results indicate that early and random failures are due to large primary carbides and excessive segregations or network formation. Similar data also indicates that load carrying capacity under water lubrication is approximately 1/8th as compared to oil lubrication.

3.0 DESIGN FEATURES OF WATER LUBRICATED BEARINGS (WLB)

Design features and technical specification of the bearings are discussed in details by G.Murlidhar[1] et al. To summarize, inner and outer races are manufactured from AISI 440C VIM-VAR (Vacuum Induction Melted- Vacuum Arc Re-melted) grade, balls are made of Stellite (Cobalt-Chromium-Tungsten alloy) and Cages are made of Silicon Iron Bronze (Copper-Nickel-Silicon-Alloy). Since the wear is a dominant process in water lubricated bearing, passage to remove wear debris is achieved by increasing radial internal clearance to Class C3 and increasing Osculation from to 54%. Increase osculation also helps in reducing intensity of Hertzian contact pressure.

4.0 TECHNOLOGICAL CHALLENGES

A successful bearing design is one, in which the predominant failure modes have been predicted or

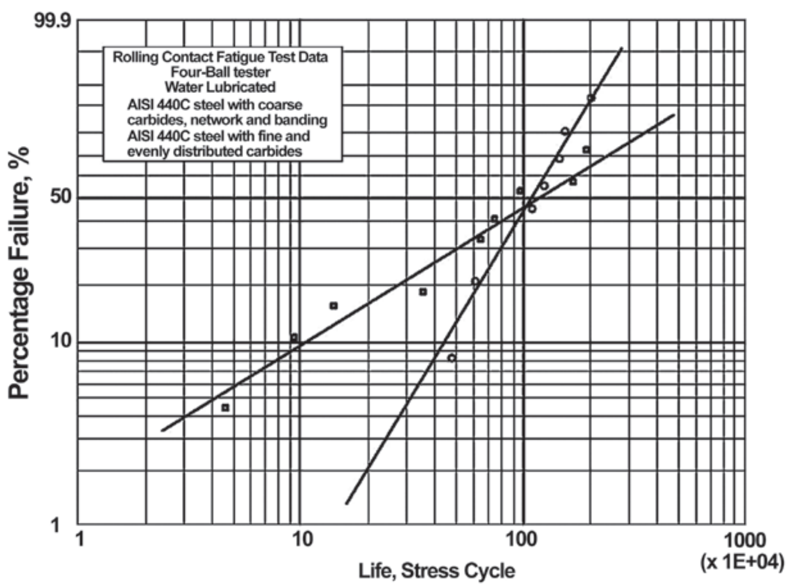

Fig. 1: Water Lubricated RCF data on AISI 440C

identified. Very little design information for WLB could be obtained from literature. So for taking up large scale development of WLB for AHWR, PHWR and Dhruva Fuelling machines, The following challenges were considered for prime focus:

4.1 Material Qualifications

Raw material qualification is one of the most challenging tasks. Chemical and mechanical testing standard has been provided by ASTM. However inclusion rating and microstructure plays a major role in selection of the material. In annealed condition ideal microstructure shall consist of chromium rich spherodized carbide particles in ferrite matrix. These eutectic carbide size shall be 10μm less and they shall be evenly dispersed in the matrix. It has been observed that these carbides are often of larger size. Large size carbide particles not only induce stress concentration during Hertzian contact but also decrease the hardness during tempering. These carbides have a tendency to form networked clusters or bands in the direction of working, thus increasing occurrence of crack generation and propagation.

4.2 Bearing Design and Manufacturing tolerances

Dimensional features of conventional and existing bearings were studied and new designs of the bearings were prepared. Key difference in design is the number of balls used. To prevent RCF and surface fatigue, the Hertzian stress intensity shall be reduced. To achieve this more number of smaller dia balls were provided. This facilitates better load sharing, reducing stress on maximum loaded contact. This also allowed race design to be thicker, providing better control on the grinding process. The cage pocket ball clearances were kept marginally higher to allow wear debris passage. Cages were designed for Inner Ring Land Rider (IRLR) configuration as these have given best results in earlier tests. Emphasis was given on selection of geometrical tolerances.

4.3 Load Carrying Capacity

Formulas suggested by ISO 281 and ISO 76 were used, to calculate dynamic and static load ratings of the bearings respectively, using geometrical features. These formulas give load ratings for conventional bearings, hence the factor discussed above was used to calculate optimum dynamic load carrying capacity.

4.4 Selection of Heat treatment process

Heat treatment is the most important aspect of bearing manufacturing. Various heat treatments cycles were studied and experimented. Bearing rings were stress relieved at 650 °C for 2 Hrs, Preheated to 850 °C for 1 Hr, austinized at 1060 °C for 60min and quenched in a mixture of Air+Nitrogen. Rings were treated to sub zero tempreture in dry ice at -75 °C for 6 Hrs and then double tempered at 200 °C for 2 to 3 Hrs. Heat treatment is carried out in vacuum furnace to avoid any kind of contamination. This treatment has given fine grain martensitic structure of ASTM 8, no retained austenite and well dispersed secondary carbide.

4.5 Manufacturing and Stage wise inspection

Although conventional manufacturing techniques were used for machining and grinding of races, selection of tool and grinding wheel played a crucial role in process optimization. Dimensions and geometrical tolerance were controlled during various stages of grinding by adopting special comparators for each type of bearing. Single piece machined cages were used for all types of bearings, except

deep groove ball bearings. Special jigs were manufactured for machining the cage pockets. In deep groove ball bearings due to higher no. of balls limited space was available for riveting two pieces, hence special SS 304 rivets were manufactured and riveting was done using die.

5.0 TESTING OF BEARINGS

With proper attention to bearing design, manufacture and application, all other modes of rolling bearing failure are avoided with the exception of RCF and wear. In that situation, the life of any one bearing, operating in the application, can differ significantly from that of an apparently identical unit. During testing of conventional bearings, vibration data is used to detect initiation of failure, however in case of water lubricated bearings this method cannot be applied as bearing operates in boundary lubrication mode, and metal to metal contact prevailed. In such case, increase in frictional torque and monitoring of Radial Internal Clearances (RIC), gives better idea of useful life of the bearing. A test setup was designed (shown in Fig. 2) to test various type and sizes of bearings. The setup has a facility to apply radial as well as axial load through hydraulic loading and can test deep groove, angular contact, thrust ball and taper roller bearings of various sizes ranging from 25mm ID to 120mm ID. Online measurement of frictional torque along with other parameters like applied load, RPM etc were incorporated. Out of 37 variants of bearings developed, 8 types of bearing covering range of size and type were selected for endurance testing. Since the lot size was smaller, it was decided to test four bearings of each selected size. No failures were observed during the initial phase of the testing (i.e. 4 bearings of each type for the rated life). To establish failure parameters, it was decided to carry out extended testing by either increasing load or test duration till a failure was noticed. Failures are attributed to cage and race wear, spalling and smearing. Figs. 3 (a & b) show some of the failed components.

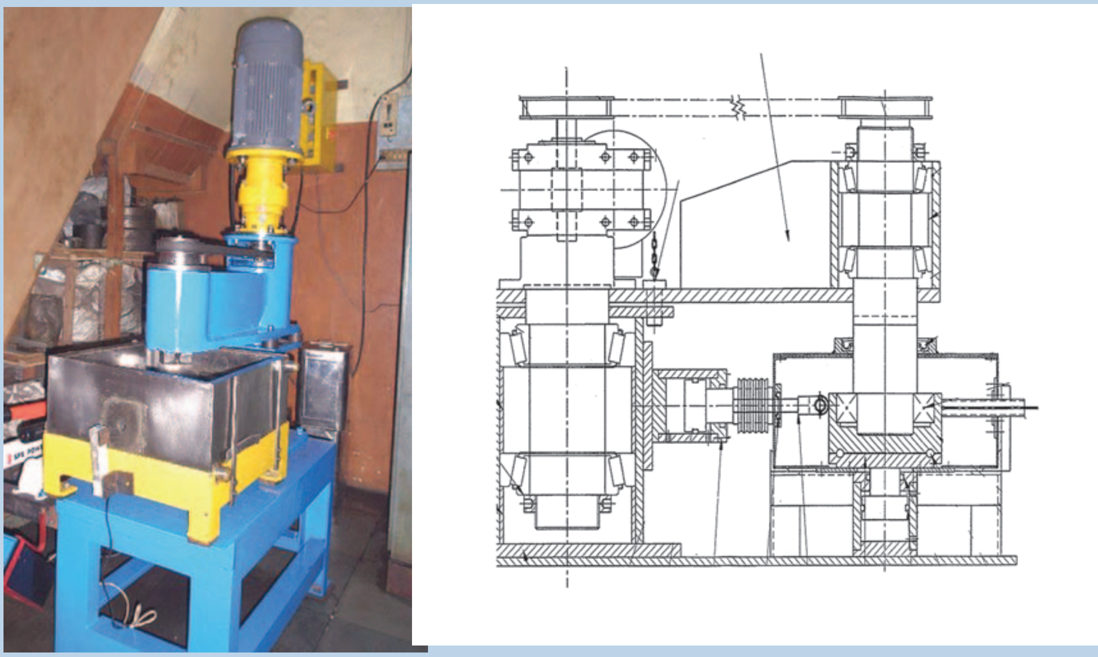

Fig. 2: Water lubricated bearing test setup

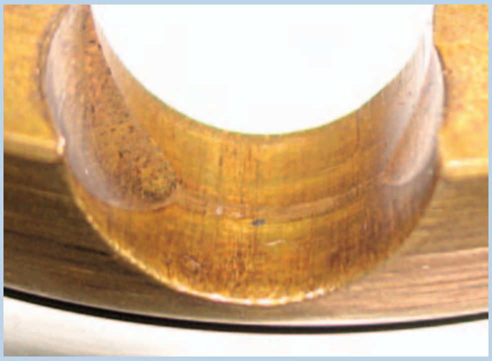

Fig 3 (a) : 6215 Cage pocket wear

Fig 3 (b) : 22210CC Outer race wear out

6.0 CONCLUSION

Indigenous water lubricated bearings in a large variety of types and sizes were manufactured and tested successfully. Technology required for development has been achieved and shared with other users at NPCIL and BARC. Material qualification and heat treatment are the key elements to the development of WLB. Careful selection of sampling location is an essential element in material qualification as 440C shows random distribution of primary carbides.

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Collaborative R&D Activities under BRNS: Past, Present and Future – An Overview

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BRNS, an extra-mural funding agency, born even before independence of India, has undergone significant transformation in its structure, activities and functioning over the past 5 to 6 decades. With the ambitious programmes of the DAE in the next few decades, it has probably a bigger role to play. There are bigger challenges ahead, which would be met by BRNS by way of increased participation of R&D personnel from DAE, adoption of newer tools in information technology and effective project management and administration. This article brings out the role of BRNS in collaborative research activities of the DAE in the past, present and in the time to come.

1.0 INTRODUCTION

The Department of Atomic Energy (DAE) has been pursuing the R&D activities in the diverse areas, not only pertaining to nuclear power technology, but also in the frontier areas of basic sciences and several other allied disciplines related to applications of radiation technology in the fields of agriculture, food preservation, hydrology, water desalination, medicine, industry, etc. which are of societal importance and also in the strategic areas which are important in the context of national security. The Board of Research in Nuclear Sciences (BRNS) under DAE has emerged as a unique institution for strengthening the network of researchers and research institutes in the country and involving them in collaborative R&D activities leading to the various objectives of the departmental programmes. Historically, the Atomic Energy Committee, which was formed in the year 1945 under the aegis of Council of Scientific Research (CSIR), was renamed as Atomic Research Committee in (ARC) in 1947, which subsequently became Board of Research in Atomic Energy (BRAE) under the Atomic Energy Commission which was formed during 1947-48, Following this, in the year 1955, the BRAE was again renamed as Board of Research in Nuclear Sciences (BRNS). In its role of an advisory body to the DAE, one of the prime mandates of BRNS (be it in the form of ARC or BRAE) has been to build strong linkages with the national R&D labs and universities for their active participation in the departmental R&D activities in the collaborative mode and thereby generate a large pool of qualified and skilled human resources to cater to the needs of the department in the time to come.

It would be of interest to everyone who is associated with the DAE's activities, as well as to those who wish to contribute to this cause, to carefully examine as to how far BRNS has succeeded in fulfilling this mandate so far. It would also pave ways to chalk out future strategies towards betterment, particularly in the current scenario of much higher expectations of performance from DAE and the rapid reforms taking place within and outside the country in the areas of technology and knowledge management at global level. Since, BRNS had undergone major restructuring during 1998, it would be logical to understand the role and activities of BRNS, its achievements and impact in two phases, viz., the first four decades prior to 1998 and the current decade (mainly after 1998 till date). In the light of such afore-mentioned observations, it should be possible to refine and refocus the objectives of BRNS and chalk out the strategies to meet challenges in the coming future.

The present article briefly brings out the role of BRNS in collaborative R/D activities of DAE, its methodology of functioning and contributions to the departmental programmes. Based on the experiences gained over the last 4 to 5 decades, ideas for improving its impact as well as its way of functioning have been also proposed.

2. BRNS - THE FIRST FOUR DECADES

BRNS in its earliest form i.e. Atomic Research Committee (ARC), between its formation year (1945) and the year of formation of Atomic Energy Commission (1947), had the following terms of reference:

- To explore the availability of raw materials required for generating atomic energy,
- To suggest ways and means of harnessing the materials for production of atomic energy, and
- To keep in touch with similar organizations functioning in other countries and to make suggestions for coordinating the work of this committee on an international basis.

Obviously, during this period for all purposes, this institution was almost playing the role of Atomic Energy Commission. During the years 1947 to 1954, it started functioning as Board of Research in Atomic Energy (BRAE) under AEC. This was the period when the well conceived three phase nuclear power programme for the country was being put on the firm footing by none other than Dr. Bhabha himself, by way of institution building and starting several core activities with the help of carefully chosen teams of experts within the department. During this period, BRAE was being looked upon as an advisory body with the responsibility to advice about the distribution of research grants to the universities and research institutions.

In 1955-56, when BRAE was renamed as BRNS, it continued functioning, with the help of only three advisory committees, towards the two main mandates, viz. a) enhance collaborative activities between the R&D units of DAE and the national universities, R&D institutions and national research labs and b) contribute to human resource development activities. The initially set up three committees were later increased to eight to encompass many facets of DAE's R&D programmes in science and technology, under the purview of BRNS. Accordingly, the two major activities pursued by BRNS during this period were; a) to sponsor and provide financial grant for the R&D projects to universities and R&D labs and b) to provide support for organizing national /international conferences and seminars. The R&D projects supported by BRNS, during this phase, were generally of "coordinated", rather than "collaborated" type of projects. The method followed those days was to send a circular from BRNS to a large number of universities, R&D institutes and research labs in the country inviting R&D proposals in the specified frontier areas of interest of DAE. In response to this, R&D projects were conceived and formulated by the prospective project investigators (PI) themselves and submitted to BRNS. Based on the peer review, the projects used to get selected for BRNS sponsorship. The progress of these projects was coordinated by the respective appointed project coordinators (PC) from within DAE. With a little peep into the sponsoring activities of BRNS, one may conclude that most of the R&D activities carried out through BRNS projects were of "supplementary" nature to the departmental R&D activities. This being the period, during which the IITs grew as the outstanding centres of higher education in the country, they had probably a larger share of participation in the BRNS activities, next to national universities.

No specific attempt has been made here to throw much light on the impact of BRNS during this period

in respect of major programmes, extent of funding and its distribution pattern, overall impact of the R&D projects in terms of their outcome, etc., due to difficulties in extracting the needed information.

3. BRNS – THE CURRENT DECADE

The BRNS, born in the pre-independence period, can be called as the first extra-mural funding agency of Government of India for sponsored R&D activities in the country. However, this unique position held by BRNS changed soon with the CSIR extramural research funding becoming available, especially with the creation of the Department of Science and Technology (DST). With time, DST had grown into a major funding agency for R&D activities in all branches of science and technology. In the light of these developments, it became more eminent to make BRNS more focused for the DAE's needs.

Accordingly, BRNS was restructured in the year 1998, with an independent BRNS secretariat headed by Scientific Secretary, who is assisted by the Programme Officers (chosen among scientists and engineers from within BARC) and the requisite administrative staff. The advisory committees were reduced to following six advisory committees based on the broader aspects of DAE's programme.

- Advanced Technology Committee (ATC)
- Basic Sciences Committee (BSC)
- Nuclear Reactor and Fuel Cycle Committee (NRFC)
- Radiation Technology and Applications Committee (RTAC)
- Strategic Studies Advisory Committee (SSAC)
- DAE Graduate Fellowship Scheme Committee (DGFS)

Some of the significant reforms introduced to improve the effectiveness and impact of the BRNS in respect of a) sponsored R&D projects, b) sponsoring of conferences, c) human resources development and d) other miscellaneous activities during the current decade are briefed below.

3.1 Sponsored R&D Projects

The nature of sponsored R&D projects has undergone a change from the "supplementary departmental R&D activities" to the "complimentary departmental R&D activities". As a result, one of the major modifications in formulating the new R&D project proposals has been the introduction of process of joint formulation (both by PI and PC together) of the project proposals to ensure that project outcome is of direct use to the PCs departmental activities and the PC actively collaborates (rather than coordinates) to achieve the targeted outcome of the project. Several other new things introduced for the overall improvement in execution and quality of R&D projects is as listed below:

- Stronger outreach programme based on pro-active steps by the advisory committees to interactively formulate R&D project proposals
- Thematic Sub-committees to formulate, generate, scrutinize, review projects and assist the advisory committees
- Technical Programme Discussion Meetings (TPDMs) for review of fresh as well as ongoing projects
- Young Scientist Projects for encouraging younger faculty below the age of 35 years
- Categorization of projects based on total research grant (for speedier processing) in 3 categories; viz. a) below Rs. 25 lakh, b) between Rs. 25 lakh to 35 lakh and c) above Rs. 35 lakh
- Mega projects in the MoU mode and Multiple Projects (on identical theme) in the Coordinated Research Project (CRP) mode
- Prospective Research Projects for DAE employees to encourage taking up challenging R&D activities not covered under the plan project activities of the department
- Special extension of projects for enabling

project research staff complete their doctoral programmes.

With the introduction of these mechanisms, BRNS could indeed expand its activities of sponsoring R&D projects in terms of disbursement of R&D grant in a big and fruitful way. Fig.1 depicts the increasing annual BRNS budget over the past 10 years. Almost more than ten times increase in the financial outlay of BRNS in the past ten years has been phenomenal and unprecedented in the history of BRNS ever since its inception. Fig.2 depicts the research grant disbursed by one of the advisory committees (NR&FC) in the last two years, among universities, national R&D labs and IITs (including IISc). The commonly prevailing misgiving, that most of the research grant of BRNS goes to elite academic institutes (such as IITs and IISc) in the country, can be seen to be incorrect from Fig.2. Since the

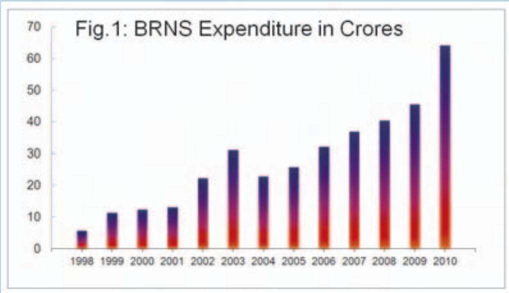

Fig. 1: BRNS Expenditure in Crores

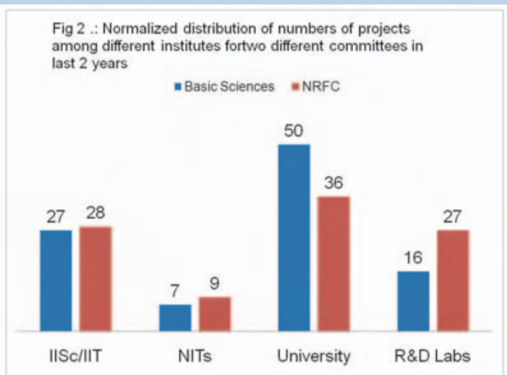

Fig. 2: Normalized distribution of numbers of projects among different institutes for two different committees in last 2 years

inception of NITs in the country, their participation in BRNS activities is also seen to be growing steadily in the past few years.

3.2 Sponsoring of Conferences

Conducting national and international conferences, seminars, and workshops facilitates researchers to exchange ideas on their research findings and to chalk out further research programmes to fill up the gaps or to take up newer thrust activities. BRNS has been providing grants for organizing such events in the country. In order to make this activity more focused, Prof. Joshi's committee appointed by the BRNS board had recommended a list of 17 conferences (Pl. see Box-1) to be fully funded by BRNS which are of direct interest to DAE and which should be periodically organized by DAE. A concept of Thematic Meetings was also introduced to organize meetings among smaller group of experts from within as well as outside the country, including participation of experts from abroad, to conduct brain storming discussions on the issues required to be resolved by DAE on priority and for chalking out the required R&D activities in collaborative mode.

Besides fully funded DAE conferences, BRNS has been providing partial support to several other conferences hosted by non-DAE organizations, provided the topic has relevance to the DAE's programme or it is important in the national / international context. Such events have been the major platforms exploited by the BRNS officials to give a boost to the collaborative R&D activities under BRNS. Fig.3 depicts the year wise BRNS funding for fully funded and partially funded conferences in the country. Again, the four fold increase in the support to BRNS sponsored conferences/symposia in the past 5 years has been highly impressive and indicative of the dent BRNS has made at the national level.

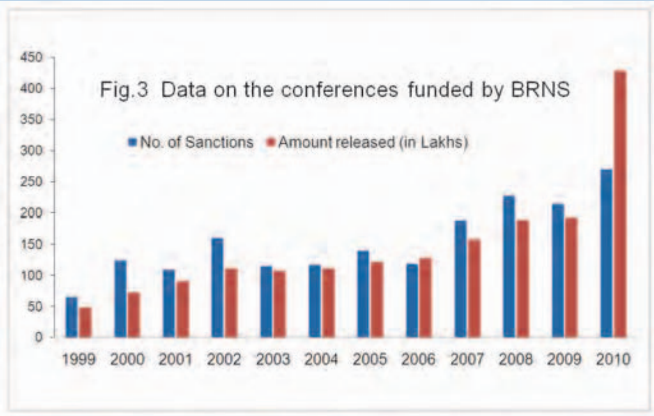

Fig. 3: Data on the conference funded by BRNS

3.3 Human Resource Development

While sponsoring R&D activities in the university setup, development of skilled and qualified human resources for taking up the DAE's R&D programmes was another important mandate of BRNS. The research staff working on the BRNS sponsored R&D projects did contribute to this mandate indirectly by way of simultaneously acquiring higher degrees such as PhD/ME/MTech in the respective institutes and by way of producing quality publications in international/ national journals and conferences of repute. However, the need to directly meet the requirement of human resources in DAE was fulfilled by bringing in, the already existing process of induction of post-graduate engineers directly in DAE, under the new scheme called DAE Graduate Fellowship Scheme (DGFS) under BRNS in the year 2002 and by introducing Dr. K.S. Krishnan Research Associate (KSKRA) scheme for the lateral entry of qualified doctoral/post-doctoral fellows into DAE's main stream from the year 1998.

3.3.1 DAE Graduate Fellowship Scheme

Besides entry of fresh science post-graduates and engineering graduates through the BARC training school, direct recruitment of post graduate engineers through introduction of one semester orientation course was started in 1992. The modified scheme, known as DAE Graduate Fellowship Scheme (DGFS) was introduced and operated through BRNS from the year 2002. The fifth advisory committee, named DGFS advisory committee, was constituted for this purpose under BRNS. As per the new scheme, students who have secured admission for post graduate programme in IITs/IISc and are also selected by BARC Training School are offered the DAE fellowship to complete the ME/MTech degree in the respective IITs, by completing one year of project work on the topic of interest to DAE under a guide from DAE. On completion of the post graduate programme, such fellows are suitably absorbed in DAE after successful completion of the one semester orientation course in BARC training school. Since last year, the scheme has been extended to selected departments of a few NITs in the country.

Under the scheme, it has been possible to recruit from last eight batches 118 DGFS fellows directly in various R&D units of DAE and successful completion of high quality project works of direct relevance to DAE's activities, leading to publications in reputed journals.

3.3.2 KSKRA Scheme

For the lateral entry of doctoral / post-doctoral fellows in DAE, Dr. K.S. Krishnan Research Associate (KSKRA) scheme was introduced in the year 1998. The selected fellows are given fellowship for a maximum period of two years for working in laboratories of R&D units of DAE, after which they are suitably adsorbed at SO/D or SO/E level depending upon their performance. The recruitment process in invoked twice in a year and has provision of selecting a maximum of 20 fellows every year. Over the years, the scheme has earned excellent prestige and has attracted significantly large number of doctoral fellows. Data in respect of recruitment

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of KSKRAs over last 11 years, depicted in Fig. 4, is a testimony to the success of this scheme.

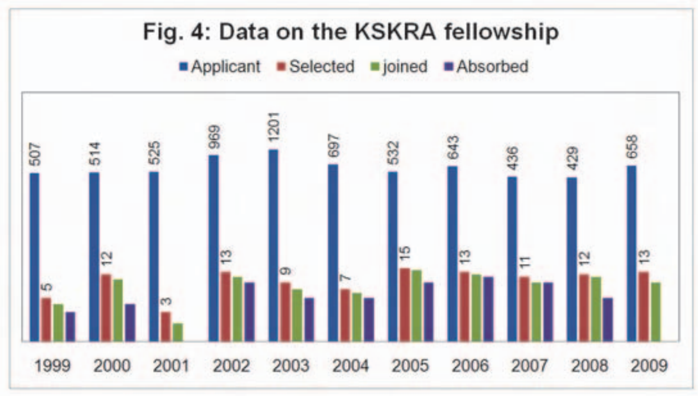


Fig. 4: Data on the KSKRA fellowship

3.4 Other Miscellaneous Activities

Besides the above described activities, several other important schemes of DAE are also operated through BRNS. These are:

- Raja Ramana Fellowship (earlier known as Senior Scientist Scheme)
- DAE Visiting Scientist Scheme
- DAE-Science Research Council Awards (instituted in 2005)
- Support to HBCSE for participating in International Olympiad Programmes
- Foreign Travel Assistance to young researchers through CCSTDS
- Funding for scientific publications such as IANCAS bulletin, Current Science, Resonance, etc.

4. IMPACT OF BRNS ACTIVITIES

During last one decade, the activities of BRNS have been multi-dimensional and have made significant impact all over the country. As regards its activities of sponsored R&D projects, its visibility is obvious through a large number of state-of-the-art facilities built/being built and used/being used extensively for collaborative R&D activities at various institutes in the country. Only a few of the prominent activities, both completed and ongoing are listed below:

4.1 Test Facilities and Research Programmes in Engineering:

1. SITAC facility at IIT Bombay, Mumbai and Advanced Seismic Testing And Research Lab at SERC, Chennai for seismic qualification of nuclear power plant components and equipment
2. Center for design and verification of software (CFDVS) at IIT, Bombay
3. LOCA qualification test facility at ERDA, Vadodara
4. Design, development and supply of high pressure, high temperature two phase gamma ray (3-beam) densitometer for use in FISBE in BARC at Flow Control Research Institute, (FCRI), Palghat, Kerala
5. High pressure, high temperature Test facility at Jadavpur University, Kolkata to study Leak-Before-Break (LBB) phenomena
6. Centre for Non-Destructive Evaluation of Reactor Components at IIT, Madras, Chennai
7. National Facility for Advanced Electron Microscopy (NFAEM) at IISc, Bangalore and at IIT Bombay, Mumbai
8. CRP (8 projects) on Thermal Ecology Studies at MAPS, Kaiga NPS and Kudankulam NPP sites
9. CRP (5 projects) on Baseline studies in a region of 30 km radius around Kudankulam site
10. CRPs (15 projects) on "Uranium mining related issues specific to Jadugoda site" and (10 projects) on "Baseline Studies on

proposed Uranium Mining Sites at KP Mawathabah (Domiasiat) in Meghalaya and 24 projects at Tumalapalle, Lambapur-Pedagattu, Sherepalle (Andhra Pradesh) & Gogi (Karnataka).

11. Ongoing CRPs (17 projects) at NPP sites for; a) evaluation of transfer factors, b) epidemiological and demographic surveys and c) effect of exposures to X-rays in hospitals against natural background radiation fields.
12. Establishment of "Centre for Radio-ecological Studies" at Guru Jambeshwar Univ., Hisar, Harayana
13. Initiation of projects for establishment of "Marine Radio-ecological Centre" at Central Institute of Fishery Education (CIFE), Mumbai
14. Initiation of projects for establishment of "Centre for robotic Studies" at IIT, Delhi

4.2 Major Research Programmes in Advanced Technologies:

1. Production and Supply of Special Nd-doped Phosphate glass Source Cylinder for use in High Power Laser.
2. Establishment of 8 MeV Linear Accelerator , Microtron Centre for R & D in Radiation Physics and Interdisciplinary areas of Science & Technology at Mangalore University
3. Development of indigenous, robust CFD code ANUPRAVAH-KIIT at IIT, Kanpur
4. Establishment of Electron Beam Welding Technology Development at IIT, Kharagpur
5. Establishment of a facility for Development , Production and supply of Microwave Substrates for High Power Micro Wave Amplifiers at C-MET, Thrissur, Kerala
6. Establishment of a Facility for Development and Supply of laser glass rods and slabs at Sri Venkateswara University, Tirupati
7. Setting up of Laser Facility for Medical and Technological Applications at Anna University, Chennai
8. Setting up a Programme in Left Handed Maxwell (LHM) Systems at SAMEER Kolkota Centre , Kolkota.

4.3 Major Research Programmes in Basic Sciences:

1. Establishment of a "National Centre for Free Radical Research (NCFRR)" at University of Pune,
2. CRP (8 projects) on "Spintronic materials and applications."

4.4 Major facilities based on the Applications of Radiation Technology :

1. Establishment of Radiotracer Laboratory at College of Agriculture, Jabalpur and Multilocation Testing of BARC Crop Varieties" at Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKVV), Jabalpur
2. Establishment of Radiotracer Laboratory and Multi-location Testing of BARC Crop Varieties at Rajasthan Agricultural University (RAU), Bikaner:
3. Installation and Commissioning of Gamma Chambers at JNKVV, Jabalpur and TNAU, Coimbatore
4. Facility for Production of Safe and Quality Meat Products using gamma irradiation
5. Establishment of Isotope Hydrology Laboratory for Himalayan Environmental Studies and Conservation Organization (HESCO), Deharadun
6. Initiation of establishment of "Centre for Advanced Applications of Radiation Technologies – CAART" at Mangalore university, Mangalore.

4.5 Some examples of scientific and Technical outcome under BRNS projects:

There are quite a large number of excellent achievements reported every year under the BRNS projects. Just to give a glimpse of the quality of work carried out under the BRNS projects, a few examples are illustrated below.

Fig.5 depicts a 2-stage pulse tube cryocooler along with its components developed under a project at IISc, Bangalore. This cryocooler produces a no load temperature of ~ 2.5 K in the second stage cold head, while the first stage reaches a temperature ~ 60K. The cooling power achieved presently is approximately 300 mW at 4.2 K. With this power, a small NbTi wire wound superconducting magnet of 10 mm internal diameter, 50 mm length, was successfully cooled down from room temperature down to 3.5 K. The magnet was charged with current to obtain a magnetic field of ~0.25 Tesla. The magnet could be operated in persistent mode and system performance was stable for several tens of hours.

Fig. 5 : 2-stage pulse tube cryocooler along with its components developed under aproject at IISc, Bangalore

Filled PTFE substrates are ideal choice for microwave circuit fabrication owing to their exceptional electrical, mechanical and thermal properties. USA is the leading manufacturer of this technologically important class of materials. As a part of indigenization of these strategic materials, C-MET have developed a proprietary processing methodology comprising of Sigma Mixing, Extrusion, Calendering followed by Hot pressing (SMECH) processes to fabricate dimensionally stable, planar, isotropic PTFE/ceramic composite laminates through BRNS funding. Sodium naphthalate based chemical etching methods have been employed to modify the surface of filled PTFE substrates for better adhesion with metal conductor layers. Copper cladding technology has been established through vacuum lamination process to realize fine circuitry over flexible substrates.

A few numbers of Cu-cladded microwave substrates of 5" x 5" size (Fig.6) were handed over to RRCAT, Indore for testing and qualification. RRCAT has used these laminates to develop solid state RF amplifiers (Fig.7) operating at centre frequency of 352 MHz and successfully tested at 700 watts, which is more than twice the full rated power of 270W. The performance of the substrates in terms of output power, gain and efficiency was very good. CMET will start production of the laminates on a pilot plant scale soon.

Experiments performed at RRCAT established that the indigenously developed microwave circuit boards can, not only be utilized for the particle accelerator applications but can also be commercially exploited for variety of microwave circuit applications in the international market. Moreover, such a reliable and novel Indian product and the devices fabricated out of them can forge

Pulse Tube Refrigerator

Vacuum jacket

Typical pulse Tubes

Typical Regenerator

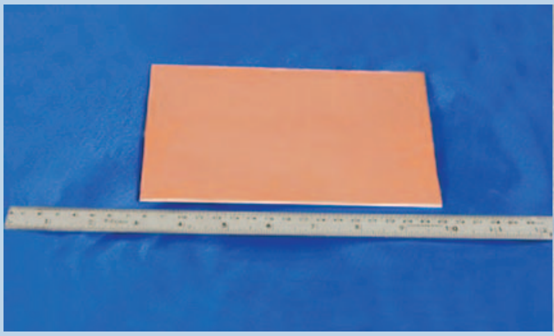


Fig.6: Cu-cladded microwave substate 19 cm (L) x 13 cm (B) x 0.16 cm (T) developed at C-MET

Fig.7 : Prototype high power solid state amplifiers fabricated at RRCAT, Indore

fruitful scientific internal collaborations especially in joint ventures such as ITER, Large Hadron Collider experiment, etc.

As a part of studies on Leak Before Break phenomena, a Leak Test facility was established at Jadavpur University, Kolkata under BRNS project with the objective of measuring critical flow rate through a simulated crack on the pipe surface using circumferential slit geometry (simulating pipe crack) and validating the in-house developed computer code as well as the international code RELAP5 using the test data. The facility (Fig.8) consists of a High Pressure High Temperature (HPHT) loop capable of generating PHWR and AHWR coolant condition (70-90 bar, 220-270°C), a N_2 system required to maintain the slit/crack upstream pressure and a test section where slit/crack pipes can be placed. The facility is getting augmented where bending moment on the crack pipe can be created with servo hydraulic machine.

Seismic qualification of various equipment, components and instruments used in nuclear power plants is an essential safety requirement. A seismic test facility has been established at SERC, Chennai, comprising of 25 ton and 5 ton shake tables (Fig. 9) as well as a pseudo test facility under the Advanced Seismic Test And Research Lab (ASTAR lab), which is operational for the past couple of years. Several users from BARC, IGCAR and NPCIL are being getting benefitted through extensive use of this facility. Fig. 10 shows the test being carried out for seismic qualification of the spent fuel storage pool using 25 ton shake table.

From the detailed reports on each of the above listed activities (which are only indicative), which are available in the BRNS Secretariat, it can be seen that R&D efforts through BRNS sponsored activities have generated a wealth of high quality information in almost every facet of nuclear technology (except probably in the area of back end technology) and in many other advanced technologies as well. While several technologies have been / are being patented, some of them are being explored for commercial exploitation. The development of qualified and skilled human resources through this route has been equally impressive, both in qualitative and quantitative terms.

Thus, with the various reforms introduced during the current decade, BRNS has been overwhelmingly successful in fulfilling the main mandates given by DAE.

5. BRNS - IN THE COMING FUTURE

The implementation of the three stage Indian nuclear power programme, carved out by Dr. Bhabha, has been the mainstay of DAE's activities. While DAE has successfully implemented and achieved excellent

Fig. 8 : Part of HPHT Loop of Leak Test Facility at Jadavapur University, Kolkata

Fig. 9 : Seismic Test Facility at SERC, Chennai

Fig.10: Spent Fuel Storage Pool loaded on the 25 ton shake table

maturity in the first phase by adopting indigenously developed PHWR based nuclear power programme in the country, it is almost ready to implement the second stage by installing the first 500 MWe Prototype Fast Breeder Reactor (PFBR) very soon. In parallel, DAE is already developing the required technologies for the third stage, which is targeted towards exploitation of large resources of thorium in the country for nuclear power generation. The development of technologies for Advanced Heavy Water Reactor (AHWR), Compact High Temperature Reactor (CHTR) and Accelerator Driven Subcritical System (ADSS) are some of the currently important and challenging R&D programmes of the DAE. In its effort to achieve quantum jump in installed nuclear power generation capacity, the department is embracing many new technologies related to Pressurized Water Reactors (PWRs). The same thing should be true in respect of several other advanced technologies in the area of high power accelerators, lasers, and computers, as well as in respect of bigger challenges in basic research in physical, chemical and life sciences. Considering the limited human resources and facilities that the DAE could support in the future, it becomes imperative as well as compulsive to take stronger and active participation of already matured and well groomed academic and other researcher communities from universities, reputed academic institutes and national R&D laboratories in the country.

BRNS is already poised to play a major role towards achieving the afore-mentioned objectives by adopting several new reforms. These reforms are mainly on three accounts, viz., a) Enhanced participation in R&D activities of DAE, b) Improved Management of R&D projects and c) Effective administration. Further elaboration on these reforms, which are already underway and are at different stages of implementation are briefly described below.

5.1 Enhanced Participation in R&D Activities of DAE

The scientific and technical programmes to be executed through BRNS are being made highly complimentary to the DAE's activities by the following means.

a. Detailed lists of thrust areas for BRNS activities were earlier drawn at the inception of XIth plan programme of DAE, through a brain-storming session conducted during the Board meeting held in the year 2007-08. This has yielded several fruitful R&D programmes during the current five year plan. The same

process will be continued to renew the list of thrust areas for every future five year plan. It would not be a too ambitious target to define more than 800 R&D projects under BRNS (per five year plan), by formulating 2 or more BRNS projects from each of the 400 sub-projects under the DAE's 32 Apex Projects. Execution of these BRNS projects by the pre-identified PCs from among the R&D units of DAE and the PI/s from the academic institutes based on available expertise and infrastructure should result in much more significant and fruitful contribution of BRNS to the DAE's activities.

b. Identification and introduction of other important frontier thrust areas of R&D in the national and international context (which may not have immediate direct relevance to the DAE's activities) is currently being carried out by conducting highly focused thematic meetings, in which exerts from within and outside the country are invited to participate. Such activities will be further strengthened based on the advice from academia and by keeping vigil on the current trends of research world over.

c. The existing provision of sponsoring R&D projects to private R&D houses has never been exploited by BRNS till now, probably due to lack of such competent bodies. However, with the fast changing scenario in the country in the field of academics, industrial R&D and larger availability of expertise with private houses, this would be worth giving a trial to start with on a lower scale, followed by its expansion, matching with the likely success in returns.

d. Fully funded DAE-BRNS conferences (Table:1) are proved to be the major platforms of interactions among DAE and non-DAE researchers. Introduction of more number of DAE's fully funded and periodically held conferences / seminars /workshops and theme meetings and improvement in their quality is already being planned to meet the said objectives.

5.2 Improved Management of R&D Projects

The success of sponsored R&D activities lies in good project management on the part of PI and PC and ensuring excellent provisions for periodic review by the peers, timely flow of funds & other administrative help and good incentives to the project investigators for successful completion of the work. High quality research and maximum utility of the research findings to complement the DAE's activities would be possible only through a well conceived project, effective project management and active participation of the PCs in the project activities.

Almost all the afore-mentioned provisions are currently in place in the present BRNS setup, except probably the incentives to the PI and PC. Such incentives need not necessarily be monetary. Probably, incentives by way of instituting awards in different categories, such as; best project award, best thesis award, best publication in high impact national/international journal, patent, etc. could be thought of to make the BRNS activities more competitive. This is all the more important, because a thoroughly professional approach in project management is being adopted by the project reviewers, who are empowered to recommend termination/short-closure the project due to lack of adequate progress, which helps in curbing mediocrity.

5.3 Effective Administration

Effective administration is a must for smoothly running any organization. This would be yet more important in case of BRNS because all the deliverables are proposed to have direct bearing on the progress of the plan projects of DAE. Following provisions are being taken up / introduced for improving the effectiveness of administration in the BRNS secretariat.

a. Expansion of BRNS secretariat both in terms of space and manpower and spreading its wings in other R&D units of DAE

b. Exploitation of tools and facilities under information technology, viz. fully internet based highly interactive office management, record handling and archival creation. This activity is currently underway.

c. Accounts handling is an important activity under the administration, the delays in which are extremely detrimental to the programme. Efforts are being made to make accounts as an integral part of the BRNS secretariat.

BRNS, with the above reforms currently underway, should be able to make a stronger contribution to the departmental programme in the years to come. A larger participation from within the DAE researcher community and pro-activeness to tap excellence in terms of expertise and facilities should help to achieve the goal in terms of reaching annual financial layout of more than Rs 100 crore and meeting its mandate of mission towards implementing collaborative research programmes and nurturing human resources for the DAE.

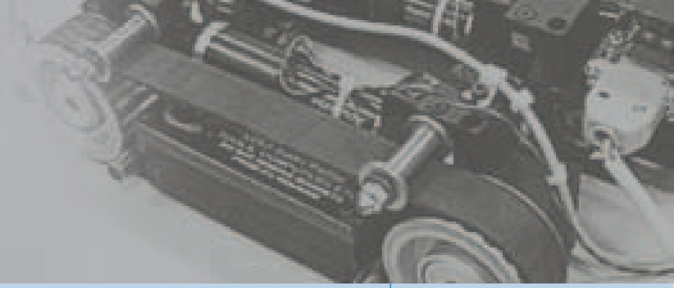
6. CONCLUDING REMARKS

BRNS, an important organ of DAE, has made a significant impact during the past more than 10 years in the national context and is currently poised to further boost these activities, which are complementary to the research activities of DAE. Its effectiveness and quality of contributions are being improved further by way of introducing some of the reforms which are presented in this article. With the successful implementation of these, BRNS should be ready to take up the bigger challenges commensurate with the DAE's ambitious programme for the coming future.

Table 1: List of Fully Funded series of DAE-BRNS Symposia/ Conferences / Workshops*

S. No.	Name of the Symposia	Frequency
1.	DAE-BRNS National Symposium on Nuclear and Radiochemistry (NUCAR)	Biennial
2.	Trombay Symposium on Radiation and Photochemistry (TSRP)	Biennial
3.	DAE Symposium on Nuclear Physics	Annual
4.	DAE Solid State Physics Symposium	Annual
5.	High Energy Physics Symposium/ Workshop (alternate year)	Annual
6.	BRNS Symposium on Environment	Annual/now biennial
7.	Water and Steam Chemistry Symposia	Biennial/ Triennial
8.	Symposium on Intelligent Nuclear Instrumentation	Biennial
9.	National Laser Symposium (NLS)	Annual
10.	National Symposium on Thermal Analysis	Biennial
11.	National Conference on Physics/ Astrophysics of QGP	Biennial
12.	Nuclear Reactor Technology	Biennial
13.	Technology of Nuclear Fuel Cycle	Biennial
14.	National Symposium on Physics and Technology of Accelerators	Biennial
15.	Separation Science & Technology	Biennial
16.	IANCAS workshop on "Radiochemistry and Applications on Radioisotopes"	3 per year
17.	DAE-BRNS Training Programme on IAEA Protocol- TRS-398	2 per year

** BRNS also gives full funding to select conferences in addition to those listed above*



BARC Scientists Honoured

Name of the Scientist	:	**Srikumar Banerjee, Chairman, AEC**
Conferred	:	D.Sc.
Conferred by	:	IIT Kharagpur at its Convocation on 17th July 2010

Name of the Scientist	:	**Zafar Ahmed, Nuclear Physics Division**
Conferred	:	D.Sc.
Conferred by	:	Mumbai University at its Convocation in April 2010

Name of the Scientist	:	**Dr. K.K. Singh, Chemical Engineering Division**
Title of the Paper	:	"Studies on Hydrodynamics of Pump-mix Mixer Settlers at IIT, Bombay"
Award	:	Award for Excellence in Thesis Work (for his PhD, from IIT, Mumbai)
Presented at	:	Annual Convocation at IIT, Mumbai, held on 6th August, 2010

Name of the Scientist	:	**Mr. Joseph Amal Nathan, Reactor Physics Design Division**
Honour	:	Appointed as Deputy Leader of the Indian team that represented India at the International Mathematical Olympiad held at Astana, Kazakhstan from July 5-14, 2010.
Appointed by	:	National Board for Higher Mathematics/DAE.

Name of the Scientist	:	**Dr. A.K. Tyagi, Chemistry Division**
Award	:	Rajib Goyal Prize in Chemical Sciences
Awarded by	:	Kurukshetra University on April 19, 2010.

Name of the Scientist	:	**A. Jain and S.M. Yusuf** **Solid State Physics Division**
Title of the Paper	:	"Magnetism of geometrically frustrated quasi-one-dimensional-spin-chain compounds $Ca_3Co_{2-x}Fe_xO_6$"
Award	:	Best Poster Award
Presented at	:	Conference on Advances in Magnetism: Phenomena and Materials (AMPM 2010) held at Manali, India, during June 3–5, 2010.

Colville's Glory

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