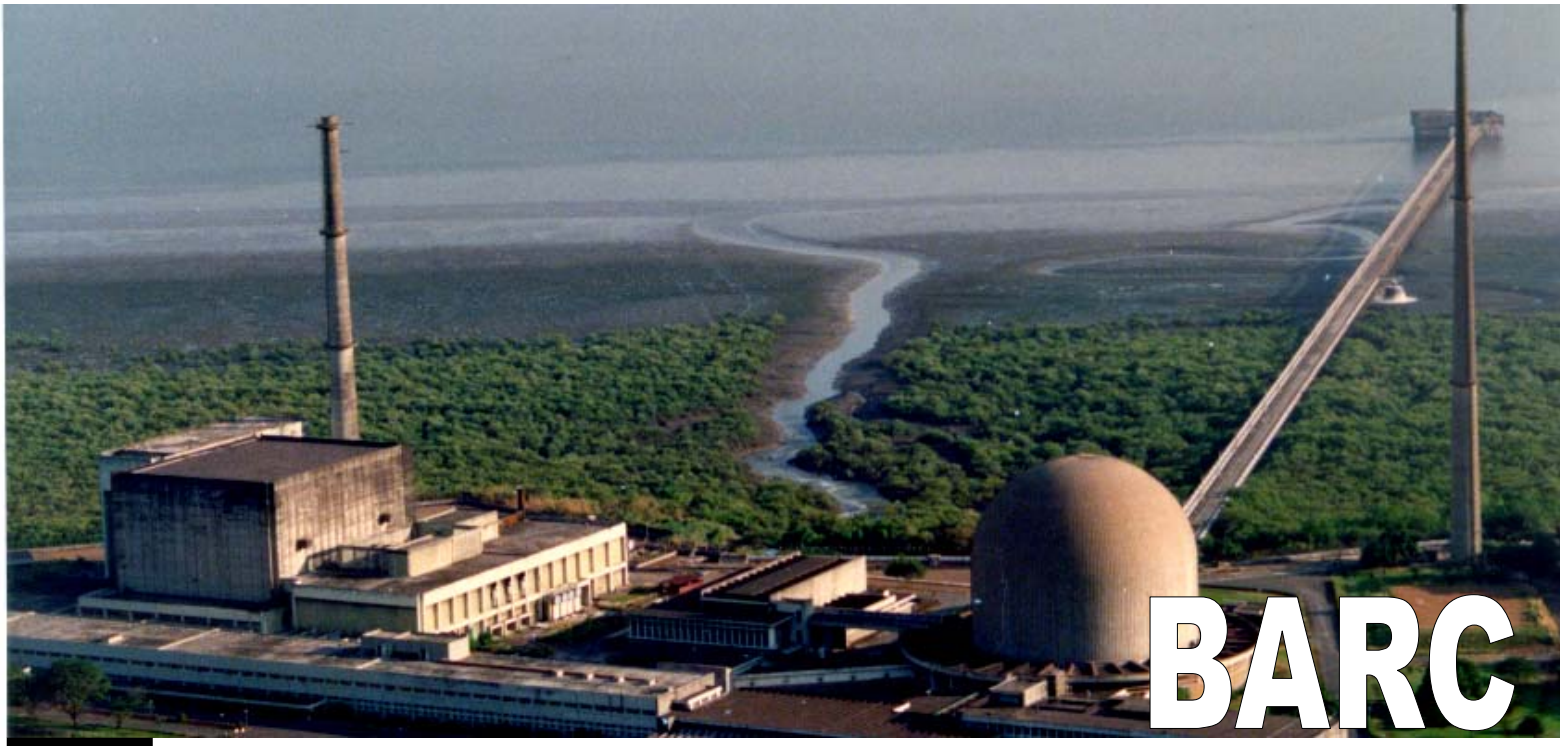

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New Year Message from Director, BARC

Dear colleagues,

At the outset, let me wish you all a happy and prosperous New Year.

Atomic Energy in India has lived through 50 glorious years. We can take pride in the fact that with each passing year, the Department of Atomic Energy has consistently added feathers in its cap. I need not recount the Department's achievements here – it is an open book for every one to see and admire.

Last year ended on a tragic event with a very devastating natural calamity caused by powerful Tsunami tidal waves. The unprecedented calamity snatched away thousands of lives including the lives of some of our colleagues and their family members in the DAE Township at Kalpakkam. All our nuclear installations and systems at Kalpakkam were safe and intact. In keeping with the finest traditions of our Department, the entire DAE fraternity and members of their family rose to the occasion to show their solidarity

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by way of rendering their help towards relief and rehabilitation in the affected areas. I particularly compliment members of BARCOA, medical doctors and other colleagues from BARC for taking the initiative and special efforts towards organizing relief work and for providing medical assistance.

I am extremely happy to state that last year has been yet another successful year in our developmental efforts to exploit nuclear science and technology in various sectors, such as power generation, food production and preservation, health care and industry. Among the various systems and technologies developed during the last year, I would like to mention only a few examples.

BARC has been providing the much needed R&D support to NPCIL. The first fuelling machine of 540 MWe PHWR is being subjected to acceptance testing under simulated conditions in a dedicated experimental facility. Full computerisation of the reactor protection system, installation of programmable digital comparator for process control and software verification and validation are also important developments done by BARC for 540 MWe PHWRs, the first of which at Tarapur will attain criticality very soon.

In the area of operating PHWRs, sliver sampling and analysis for hydrogen content were carried out on a large number of pressure tubes of RAPS-1 reactor and based on the data generated, RAPS-1 was rehabilitated for power generation.

Several activities have been initiated in connection with the development of AHWR. Detailed engineering and design validation of AHWR is progressing well. Several innovative features have been incorporated in the design to further enhance its performance and safety. Preparations are under way for pre-licensing safety appraisal of AHWR by AERB.

The other innovative reactor being developed at BARC is the High Temperature Reactor (HTR), which is being designed to operate at a temperature of about 1000˚C. To study the thermal hydraulics and the corrosion compatibility behaviour of lead and lead bismuth based liquid metal coolant to be used in the HTR, natural circulation driven liquid metal loops of different scales are being set up. With the development of High Temperature Reactor (HTR), we would like to demonstrate nuclear energy as a primary heat source which can be deployed not only for the power production but also for production of hydrogen at low cost.

BARC has specific contributions to make towards the success of the Prototype Fast Breeder Reactor (PFBR) being constructed at Kalpakkam. Our responsibilities include supply of mixed oxide fuel, boron carbide control rod material, fuel handling system and the detector system with the associated electronics. These items are of vital importance which are to be supplied within the stipulated time-frame to make the project successful. BARC is also joining hands with IGCAR for developing spent fuel reprocessing and waste management for closing the fast reactor fuel cycle. This activity is also essential for making the fast reactor programme sustainable in the long run. With the induction of AHWR, we will be

gaining experience in technologies associated with thorium which are so vital for our third-stage of nuclear power programme.

Waste management facilities at Trombay, Tarapur and Kalpakkam were operated safely to provide treatment, discharge and disposal of the waste generated at these sites. The facilities at CWMF, Kalpakkam have been augmented for the disposal/storage of pressure tubes and end fittings from the campaign of En-masse Coolant Channel Replacement at MAPS-1. Joule Heated Ceramic Melter of Advanced Vitrification System has been cold commissioned successfully at Tarapur.

During the last year, one of the major achievements in the technology development area has been the design and development of 1 kW cryo-distillation unit.

BARC continued to take strides in several areas pertaining to development and deployment of high technologies. A mobile robot 'SmartNav' was developed for remote surveying and inspection. The installation of 10 MeV – 10 kW Radio Frequency Electron Linac is nearing completion at the Electron Beam Centre, Kharghar, Navi Mumbai. High power Pulse Electron Accelerator KALI-5000 has been commissioned at an energy of 650 keV and an Electron Beam power of 40 GW. BARC technology for B-10 enrichment based on exchange distillation and ion exchange process was transferred to Heavy Water Board. A fluorine electrolyser of 6000 Amps current rating has been successfully commissioned and integrated with the fluorination plant.

Over 25 MOUs have been signed with various organizations for technology transfer. Ultra-filtration polysulfone membrane technology has been provided to a total of 12 parties for manufacturing of Domestic water purifier. Some of them have already launched their products in the market. A fluoride detection kit for use by the general public for detection of fluoride contamination in ground water is a notable example of spin off technology. Setting up of a demonstration unit of Electron Beam Welding facility for industrial use in the MIDC, Mhape, marks a beginning of a new pattern of technology transfer through user interactions.

A modified surgical gamma probe for sentinel node detection based on CsI detector has been developed as import substitute with improved specifications and data storage capability. Two units have been fabricated and one of them has been given to Rajiv Gandhi Cancer Hospital, New Delhi for technical evaluation.

A Nisargruna bio-gas plant of 1 tonne per day capacity has been installed at INS, Kunjali, Colaba for the Indian Navy. The designs are ready for 5 tonnes per day and 25 tonnes per day plants proposed to be installed by Thane Municipal Corporation.

The crop improvement programme of Nuclear Agriculture and Bio-Technology Division continued to make excellent progress. Two new varieties of Trombay Groundnut were recommended for release by the Ministry of Agriculture for commercial cultivation. A new mungbean variety TM-99-37 was also identified for release. It is high yielding, matures early and is tolerant to yellow mosaic virus disease. State Seed Committee of Maharashtra has released soyabean variety TAMS-38 for commercial cultivation in Vidarbha region.

A strain of TBP biodegrading bacterium has been isolated. A highly radio resistant bacterium has been genetically engineered for bio-precipitation of uranium from radioactive wastes.

MAT-LAB facility for ultra purification of gallium and arsenic has been commissioned. The capabilities for producing 6N and 7N purity for Arsenic and Gallium respectively for variety of electronic and semiconductor applications have been demonstrated. The facility for studying singletoxygen initiated chemical reactions has been established. It will be useful for various biological and pharmaceutical applications.

Important developments in material processing include demonstration of the possibility of direct electrolytic decomposition of solid oxides of reactive and refractory metals in a new type of electrolytic cell, production of ultra pure zirconium crystal bar directly from zirconium bearing mill scrap and development of all material components of the solid oxide fuel cells. The challenge of producing monolithic blocks of silicon carbide, boron carbide and certain refractory metal borides have also been successfully met. Several new organic solvents have been synthesized for both the front and the back end of the nuclear fuel cycle. In the quest of new cladding alloys suitable for high temperature, high burn up and partial boiling conditions, a series of Zr-Nb-Sn-Fe based binary, ternary and quarternary alloys have been made and characterized. Zirconium based multi component bulk metallic glasses have been successfully synthesized and characterized.

Using a 128 processor ANUPAM ARUNA Parallel Supercomputer, ab-initio molecular dynamic studies have been carried out for the first time in India on a large complex system, namely, Buckminster Fullerene doped with heteroatoms.

R&D activities in Physical Sciences reached a new height during the year. The indigenously built FOTIA facility was operated at 4.75 MV using SF6 gas which is nearly 80% of the design value of terminal voltage. A Stimulated Brillouin Scattering (SBS) - Compressed Nd:YAG Oscillator producing a high power laser chain giving 150 mJ energy in 300-800 ps duration at 1.064 micron has been installed in laser shock laboratory.

The challenges in these technology developments are enormous and through the participation of our younger colleagues, we will certainly meet these challenges in due course.

Friends, I have mentioned only some of the important achievements and developmental activities carried out in BARC during the last year. I take this opportunity to congratulate all of you for your dedicated and concerted efforts without which these achievements would not have been possible.

Success coupled with excellence has always been the hallmark of BARC; however, let us not rest on our laurels.

Srikumar Banerjee

निदेशक, भाभा परमाणु अनुसंधान केंद्र का नव वर्ष का संदेश

प्रिय सहकर्मियों,

सर्वप्रथम मैं आप सबको नव वर्ष की शुभकामनायें देता हूँ ।

भारत में परमाणु ऊर्जा के गौरवशाली पचास वर्ष पूरे हो चुके हैं । हम इस बात पर गर्व कर सकते हैं कि बीते हुए प्रत्येक वर्ष के दौरान परमाणु ऊर्जा विभाग की गतिविधियों में चार चाँद लगते गये हैं । मैं विभाग की उपलब्धियों को दोहराना नहीं चाहता - यह एक खुली किताब है, जिसे पढ़कर सब प्रशंसा कर सकते हैं ।

पिछले वर्ष का अंत बड़ा ही दुख:द रहा जब हमें प्राकृतिक आपदा के रूप में शक्तिशाली त्सुनामी लहरों का कहर झेलना पड़ा । इस अभूतपूर्व आपदा के कारण हजारों जानें गयीं जिसमें कल्पाक्कम स्थित डीएई टाऊनशिप के हमारे कुछ सहकर्मी तथा उनके परिवार के सदस्य भी शामिल थे । कल्पाक्कम स्थित हमारी सभी परमाणु संस्थापनायें तथा प्रणालियां सुरक्षित रहीं ।अपने विभाग की श्रेष्ठ परंपराओं को अपनाते हुए प्रभावित क्षेत्रों में राहत तथा पुनर्वास हेतु परमाणु ऊर्जा विभाग के सभी सदस्यों तथा उनके परिवार जनों ने अपनी एकता और भाईचारे का परिचय दिया । मैं विशेषत: बारकोआ, चिकित्सकों तथा भापअ केंद्र के अन्य सहकर्मियों की प्रशंसा करता हूँ जिन्होंने राहत कार्य एवं चिकित्सीय सहायता पहुंचाने हेतु विशेष प्रयास किए ।

मुझे यह घोषित करते हुए अत्यन्त प्रसन्नता हो रही है कि पिछला वर्ष भी उतना ही महत्वपूर्ण रहा क्यों कि नाभिकीय विज्ञान एवं प्रौद्योगिकी से जुड़े विद्युत उत्पादन, खाद्य उत्पादन एवं परिरक्षण, स्वास्थ्य देख-भाल एवं उद्योग जैसे विभिन्न क्षेत्रों में हमारे विकासात्मक प्रयास सफल रहे । पिछले वर्ष के दौरान विकसित विभिन्न प्रणालियों और प्रौद्योगिकियों में से मैं केवल कुछ का ही उल्लेख करना चाहता हूँ ।

भापअ केंद्र द्वारा एनपीसीआईएल को आवश्यक अनुसंधान एवं विकास सहायता उपलब्ध कराई जा रही है । 540 मैं.वा.ई. दाबित भारी पानी रिएक्टर की प्रथम ईंधनन मशीन की समर्पित प्रयोगात्मक सुविधा में अनुकारित परिस्थितियों के अंतर्गत स्वीकृति परीक्षण किया जा रहा है । 540 मैं.वा.ई. दाबित भारी पानी रिएक्टरों हेतु भापअ केंद्र द्वारा विकसित रिएक्टर संरक्षा प्रणाली का संपूर्ण कंप्यूटरीकरण, प्रक्रम नियंत्रण एवं सॉफ्टवेयर सत्यापन तथा मान्यकरण हेतु प्रोग्रॉमेबल डिजीटल कंपेरेटर का स्थापन भी महत्वपूर्ण है । इसका पहला रिएक्टर तारापुर में अतिशीघ्र क्रांतिकता प्राप्त करेगा ।

प्रचालित दाबित भारी पानी रिएक्टरों के क्षेत्रों में, स्लिवर सैंपलिंग एवं हाइड्रोजन के विश्लेषण कार्य हेतु आर ए पी एस-1 रिएक्टर के अनेकों दाबनलियों में किए गए एवं प्राप्त डाटा के आधार पर आर ए पी एस-1 को विद्युत उत्पादन के लिए पुन:स्थापित किया गया ।

प्रगत भारी पानी रिएक्टर के विकास के संबंध में अनेक गतिविधियां प्रारंभ की गयी । ए एच डब्ल्यू आर के विस्तृत इंजीनियरी एवं अभिकल्पन मान्यकरण कार्य प्रगति पर हैं । रिएक्टर के कार्य निष्पादन एवं संरक्षा में और भी वृद्धि करने के लिए अभिकल्पन में अनेक अभिनव विशेषताओं को सम्मिलित किया गया । परमाणु ऊर्जा नियामक बोर्ड द्वारा ए एच डब्ल्यू आर के प्रिलाईसेंसिंग सेफ्टी अप्रेजल हेतु तैयारियां जोरों पर हैं ।

भापअ केंद्र में विकसित किए जा रहे अन्य नवीनतम रिएक्टर है - उच्च तापमान रिएक्टर एच टी आर जिसका अभिकल्पन लगभग 1000^0 से. तापमान पर प्रचालन के लिए किया जा रहा है । एच टी आर में प्रयोग में लाये जाने वाले सीसा एवं सीसा बिस्मथ आधारित द्रव धातु शीतलक के तापीय जलगतिकी एवं संक्षारण संगतता के प्रभाव का अध्ययन करने के लिए विविध स्केल वाले प्राकृतिक चक्रण द्वारा चालित द्रव धातु लूपों को प्रतिष्ठित किया जा रहा है । उच्च तापमान रिएक्टर के विकास

से हम यह दर्शाना चाहते हैं कि नाभिकीय ऊर्जा एक प्राथमिक ऊष्मा स्रोत है जिसका प्रयोग न केवल विद्युत उत्पादन के लिए किया जाता है बल्कि निम्न लागत पर हाईड्रोजन के उत्पादन के लिये भी किया जा सकता है ।

कल्पाक्कम में निर्माणाधीन प्रोटोटाईप फास्ट ब्रीडर रिएक्टर (पी एफ बी आर) की सफलता के प्रति भापअ केंद्र का एक विशिष्ट योगदान है । मिश्रित ऑक्साइड ईंधन, बोरॉन कार्बाईड नियंत्रण छड़ पदार्थ, ईंधन हस्तन प्रणाली एवं संबंधित इलेक्ट्रानिकी के साथ संसूचक प्रणाली की आपूर्ति करना भी हमारा उत्तरदायित्व है । उपरोक्त सभी मद अत्यंत महत्वपूर्ण हैं और परियोजना को सफल बनाने के लिए निर्धारित समय के भीतर इनकी आपूर्ति करना आवश्यक है । तीव्र रिएक्टर ईंधन चक्र को पूरा करने हेतु भुक्तशेष ईंधन पुनर्संसाधन एवं अपशिष्ट प्रबंधन के विकास हेतु भापअ केंद्र तथा आइ जी कार के बीच सहयोग होगा । तीव्र रिएक्टर कार्यक्रम को लंबी अवधि तक बनाये रखने के लिए भी यह गतिविधियां आवश्यक हैं । ए एच डब्ल्यू आर के अधिष्ठापन के साथ हम थोरियम से जुड़ी प्रौद्योगिकियों में अनुभव प्राप्त कर सकेंगे जो हमारे परमाणु विद्युत कार्यक्रम के तीसरे चरण के लिए अति आवश्यक है ।

ट्रॉम्बे, तारापुर एवं कल्पाक्कम में उत्पन्न अपशिष्ट के उपचार, विसर्जन तथा निपटान के लिए इन क्षेत्रों में स्थित अपशिष्ट प्रबंधन सुविधाएं सुरक्षित रूप से प्रचालित की गयी । एम ए पी एस-1 में एनमास शीतलक वाहिका के स्थान पर दाब नली एवं एंड फिटिंग के निपटान/भंडारण के लिए सी डब्ल्यू एम एफ कल्पाक्कम में सुविधाओं का उन्नयन किया गया । तारापुर में प्रगत काचन प्रणाली के जूल तप्त सिरॅमिक मेल्टर का सफलतापूर्वक शीत कमिशनन किया गया ।

पिछले वर्ष के दौरान प्रौद्योगिकी विकास के क्षेत्र में प्राप्त महत्वपूर्ण उपलब्धियों में से एक है - 1 कि.वा. क्रायो आसवन इकाई का अभिकल्पन एवं विकास ।

विकास तथा उच्च प्रौद्योगिकी प्रसार से संबंधित अनेक क्षेत्रों में भापअ केंद्र का योगदान लगातार जारी रहा । सुदूर सर्वेक्षण एवं निरीक्षण हेतु एक मोबाईल रोबोट "स्मार्टनव" का विकास किया गया । इलेक्ट्रॉन बीम सेंटर, खारघर, नवी मुंबई में 10 मि.इ.वो. - 10 कि.वा. रेडिओ फ्रिक्वेन्सी इलेक्ट्रान लिनैक का स्थापन कार्य पूरा होने जा रहा है । 650 कि. इ.वो. ऊर्जा का उच्च शक्ति स्पंद इलेक्ट्रॉन त्वरक के ए एल अई - 5000 एवं 40 जी.वा. क्षमता वाले इलेक्ट्रॉन किरणपुंज का कमीशनन किया गया । विनिमय आसवन एवं आयन विनिमय प्रक्रिया आधारित बी-10 समृद्धिकरण प्रौद्योगिकी भारी पानी बोर्ड को सौंपी गयी । 6000 एम्पीएस करेंट रेटिंग वाला फ्लोरीन इलेक्ट्रोलायजर का सफलतापूर्वक कमीशनन कर उसे फ्लोरिनेशन संयंत्र के साथ जोड़ा गया ।

प्रौद्योगिकी हस्तान्तरण हेतु विभिन्न संगठनों के साथ 25 से भी अधिक समझौता ज्ञापनों पर हस्ताक्षर किये गये । परा-निस्पंदन पॉलीसल्फ़ोन झिल्ली प्रौद्योगिकी घरेलू जलशुद्धीकारक के विनिर्माण हेतु 12 उद्यमियों को उपलब्ध करायी गयी । कुछ लोगों ने अपने उत्पादों को बाज़ार में लगा भी दिया है । भू-जल में फ्लोराइड संदूषण का पता लगाने हेतु जनसामान्य के प्रयोग के लिए फ्लोराइड संसूचन किट स्पिन- ऑफ प्रौद्योगिकी का एक महत्वपूर्ण उदाहरण है । एम आई डी सी, महापे, में औद्योगिक उपयोग हेतु इलेक्ट्रॉन बीम वेल्डिंग सुविधा की निदर्शन इकाई का स्थापन प्रयोक्ता अन्तरसंबंध के माध्यम से प्रौद्योगिकी हस्तांतरण के नये स्वरूप की अच्छी शुरूआत है ।

सी एस आई संसूचक पर आधारित सेन्टीनल नोड संसूचन हेतु एक रूपान्ततरित सर्जिकल गामा अन्वेषक का उन्नत विशिष्टताएँ एवं डाटा भंडारण क्षमता सहित आयात विकल्प के रूप में विकास किया गया । दो इकाइयों का संविरचन किया जा चुका है एवं इनमें से एक राजीव गांधी कैंसर अस्पताल, नई दिल्ली को तकनीकी मूल्यांकन हेतु दिया गया है ।

भारतीय नौसेना के लिए आई एन एस, कुंजली, कुलाबा में एक टन प्रति दिन क्षमता वाला एक निसर्गऋण बायोगैस संयंत्र का स्थापन किया गया । थाना नगरपालिका के लिए पाँच टन प्रतिदिन एवं पच्चीस टन प्रतिदिन क्षमता वाले संयंत्रों का अभिकल्पन तैयार है।

नाभिकीय कृषि एवं जैव प्रौद्योगिकी प्रभाग की फसल उन्नयन कार्यक्रम में उल्लेखनीय प्रगति हुई । कृषि मंत्रालय द्वारा वाणिज्यिक कृषि हेतु ट्रॉम्बे मूंगफली की दो नई किस्में जारी करने हेतु शिफारिश की गई । मूंग की एक नई किस्म टी एम 9937 को भी जारी करने की तैयारी की गई जो उच्च उत्पादन देती है, जो शीघ्र पकती है और पीले मोझेक वीषाणु रोग प्रतिरक्षक भी है । महाराष्ट्र की राज्य बीज समिति ने सोयाबीन के टी ए एम एस -38 की किस्म को विदर्भ क्षेत्र में वाणिज्यिक कृषि हेतु जारी किया है ।

टी बी पी बायो डीग्रेडिंग जिवाणु के उपभेद का पृथक्कन किया गया है । सक्रिय अपशिष्ट से यूरेनियम के जैव अवक्षेपण हेतु एक उच्चतम रेडियो प्रतिरक्षी जिवाणु को अनुवांशिक रूप से तैयार किया गया ।

गैलियम एवं आर्सेनिक के अतिशुद्धिकरण हेत मैट-लैब सुविधा का कमीशनन किया गया । अनेक प्रकार के इलेक्ट्रॉनिक एवं अर्धचालक अनुप्रयोगों के लिए 6 एन एवं 7एन की शुद्धता वाले आर्सेनिक तथा गैलियम के लिए के उत्पादन हेतु क्षमता का प्रमाणन किया गया । सिंगलेट-ऑक्सीजन प्रेरित रसायनिक अभिक्रियाओं के अध्ययन हेतु सुविधा का स्थापना किया गया । यह विभिन्न जैविक एवं भेषजी अनुप्रयोगों के लिए उपयोगी रहेगा ।

पदार्थ संसाधन में महत्वपूर्ण विकास में नये प्रकार के इलेक्ट्रोलायकिक सैल में अभिक्रियात्मक एवं परावर्तक धातुओं के ठोस ऑक्साईडों के सीधे इलेक्ट्रोलैटिक अपगठन की संभावना का निदर्शन, जरकोनियम युक्त मिल स्क्रॅप जरकोनियम क्रिस्टल बार के उत्पादन एवं ठोस आक्साइड ईंधन कोशिकाओं के सभी पदार्थ धारकों का विकास भी शामिल है । सिलीकॉन कार्बाइड, बोरॉन कार्बाइड एवं कुछ परावर्ती धातु बोराइडों के मोनोलिथिक ब्लाक के उत्पादन की चुनौती का सफलता पूर्वक सामना किया । नाभिकीय ईंधन चक्र के अग्र एवं पश्च दोनों भागों हेतु नये कार्बनिक विलयकों का संश्लेषण किया गया । उच्च तापमान हेतु उपयुक्त नई क्लैडिंग मिश्रधातु की खोज में उच्च बर्नअप आंशिक क्वथन परिस्थितियों,जेडआर-एनबी-एसएन-एफई आधारित द्विकर्मी, त्रिकर्मी एवं चौकर्मी मिश्रधातुओं की एक श्रृंखला तैयार कर उनका अभिलक्षणन किया गया ।

भारत में सर्वप्रथम विषमाणु लेपित बक्मिन्सटर फुलरीन नामक एक वृहत जटिल प्रणाली हेतु 128 प्रोसेसर अनुपम-अरुणा समान्तर सुपर कंप्यूटर का प्रयोग करते हुए प्रारंभ से आण्विक गतिक अध्ययन किये गये ।

इस वर्ष भौतिक विज्ञान से संबंधित अनुसंधान एवं विकास कार्यों ने एक नवीन उच्चता प्राप्त की । एसएफ 6 गैस का प्रयोग करते हुए 475 एमवी पर एक स्वदेशी फोटिया सुविधा का प्रचालन हुआ । इस गैस की टर्मिनल वोल्टता का अभिकल्पन मान 80% के निकट है । 1.064 माइक्रॉन पर 300-800 पी एस अवधि में 1.50 एम जे ऊर्जा देने वाले एक उच्च शक्ति लेसर उत्पादन करने वाले एक अनुकारित ब्रिलूइन प्रकीर्णन (एस बी एस) सम्पीडित एनडी:वाई ए जी दोलक का लेजर शॉक प्रयोगशाला में स्थापित किया गया ।

इन प्रौद्योगिकियों के विकास की चुनौतियाँ बहुत विशाल हैं और अपने युवा साथियों की मदद से हम अवश्य ही इन चुनौतियों को स्वीकार कर सकेंगे ।

मित्रों, मैंने भा.प.अ. केंद्र द्वारा पिछले वर्ष की कुछ ही महत्वपूर्ण उपलब्धियों तथा विकास कार्यों का वर्णन यहाँ किया है । मैं इस अवसर का लाभ उठाते हुए आप सभी के समर्पित एवं सतत प्रयासों के लिए बधाई दूँगा जिनके बिना यह उपलब्धियाँ संभव नहीं थी ।

सफलता एवं उत्कृष्टता भा.प.अ. केंद्र की पहचान हैऔर हमें इसे यथासंभव आगे भी बरकरार रखना है ।

श्रीकुमार बॅनर्जी

TRANSPORT AND RELEASE PROPERTIES OF GASEOUS AND VOLATILE FISSION PRODUCTS IN NUCLEAR FUELS – RELEVANCE AND STATE OF ART OF THEIR CHARACTERISATIONS IN THE LABORATORY

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Introduction

Safe operation of a nuclear reactor depends to a large extent on the behaviour of different fission products generated within the fuel. While most of the fission products settle down as dissolved state in the fuel matrix or as separate phases, the gaseous products, xenon(Xe), and krypton(Kr), and the volatile products, iodine(I), tellurium(Te), cesium(Cs), and rubidium(Rb), undergo transport and redistribution in the fuel pin [1]. The redistribution leads to significant release of the gases and volatiles from the fuel, and accumulation of the released species at the boundary regions with clad (Fig.1).

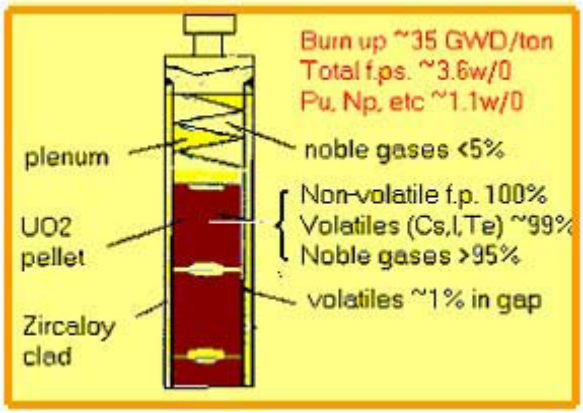

Fig. 1 General view of fission products (f.p). distribution in PWR fuel at high burn up.

The released volatiles mostly concentrate at fuel-clad gap, while the gases expand further filling up the plenum region. The combined fission yield of stable and long-lived isotopes of Xe and Kr is 25-30%. At a typical irradiation level of 10,000 MWD/T of UO_2 fuel, every 1 ml of fuel produces 3 ml of these gases at normal temperature and pressure. Table-1 gives approximate atom yields of Xe and Kr, I and Te, Cs and Rb per 100 fissions. A significant fraction of the accumulated xenon originates as the decay products of the less stable parent isotopes of the two volatile fission products (e.g., ^{131}I, ^{133}I, ^{132}Te). The gas accumulation results in pneumatic pressure built up in the fuel pin assembly and, also, decreases the effectiveness of heat transport of helium gas filling the fuel-clad gap. With the progressive release of the noble gases, the fuel operates at increasingly higher temperatures due to the decreasing effectiveness of heat transport. The volatiles on the other hand can result in clad corrosion and, also, pose radiological hazard problem in the event of accidental release of iodine and tellurium to the surroundings.

Table 1: Fission yields of gaseous and volatile elements

Fuel types	Xe +Kr	Cs + Rb	I + Te
PWR (^{235}U fuel)	22	24	4
PWR (MOX fuel PuO_2~30%)	24	22	4
AHWR (^{233}U fuel)	32	20	6
FBR (^{239}Pu fuel)	24	22	4

It is well known that the volatiles released from the fuel are deposited on inner surface of clad and cause brittle fracturing and stress corrosion cracking of the claddings, particularly when the

clad makes stressed contact with the fuel matrix swelled out of the retained gases and other fission products. The micrographic section of a typically observed clad failure is placed opposite (Fig. 2). The clad develops brittleness by alloying with Te and other volatile metals and metalloids, (Te, Sn, Cd, Sb, In), and through the precipitation of bulky phases like molybdates, zirconates/ chromates along grain boundaries of zircaloy/ steel clads. SCC failure of zircaloy clad can be predominantly due to exposure to elemental iodine vapor that weakens the mechanical strength of the clad by transport and redeposition of zirconium through formation of its volatile iodides.

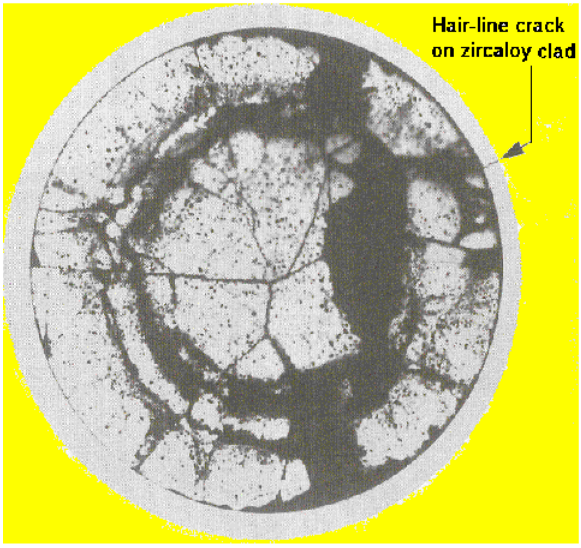

Fig. 2 Typical micrographic image of irradiated PWR fuel pin's section showing the clad failure

The knowledge of various transport processes that govern the redistribution behavior of the fission gases and volatiles is very important for predicting fuel-clad integrity. Detailed studies on their transport properties are necessary to understand the extent of their release from the matrix and to establish confidence in the fuel performance under all irradiation conditions, in particular the cause and limits of fuel failure.

A good amount of work has been carried out for the last few decades in urania and plutonia based fuels and the diffusional properties of fission gases and volatiles are reported [1-3]. However, this is not the case for a thoria-based matrix envisaged as the fuel for advanced heavy water reactors in the third phase of the nuclear energy programme in India [4]. The fluorite lattices of urania and thoria are likely to impart diverse influences on the diffusion behaviours of electronegative species such as I and Te. The diversity arises from the ability of U to deviate from its tetra valency while forming activated complex with the diffusing species.

This article describes results of some of the investigations carried out at Applied Chemistry Division, BARC, to study the release kinetics of the gaseous fission product xenon and the volatiles, iodine and tellurium, in thoria based fuel materials. Before describing the results and the conclusion made thereof, a brief mention is made about the basics of the transport and release processes, the experimental techniques and the evaluation procedures involved in the analysis of the transport properties.

Fission Gas/Volatile Fission Products : Transport and Release Processes

The processes responsible for the escape of fission gases and volatiles can be classified as fission recoil, knock-out, thermal diffusion and others such as pore sweeping and crack propagation in the matrix [1]. During irradiation, all these processes take place in combination. The fission recoil and knock-out processes are primarily governed by the kinetic energies of the fission products and result in stepwise displacements (recoil length <10 μm) of the product atoms. They play dominant role in the gas release from the peripheral region of fuel pin at low temperatures. Thermal diffusion, on the other hand, imparts sustained advancements of the species under steep temperature and concentration gradient towards the boundary for their ultimate release from the matrix. The center to periphery temperatures generally remains 1200 to 500 K for thermal reactor fuel-pin (~10 mm diameter), and 1800 to 900 K for fast reactor fuel-pin (~5 mm diameter). Under the usual operating temperatures of fuel, the primary

mechanism of the transports and releases of the fission gas and volatiles is known to be the thermal diffusion through lattice and grain boundaries. The diffusion rate in the either paths of release is exponentially dependent on temperature, because the diffusion coefficient grows as $D = D_0 \exp(-Q/RT)$, D_0 and Q respectively being the jump frequency and the energy barrier for atoms undergoing diffusion. Derivation of this equation and discussion of various type of diffusion can be found in various places in literature [5].

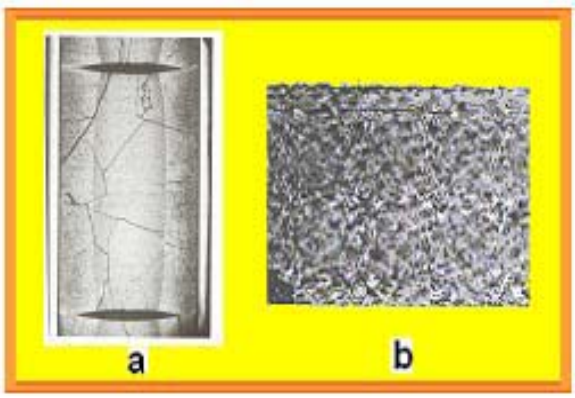

Fig. 3 Typical micrographs of PWR fuel pin at high burn

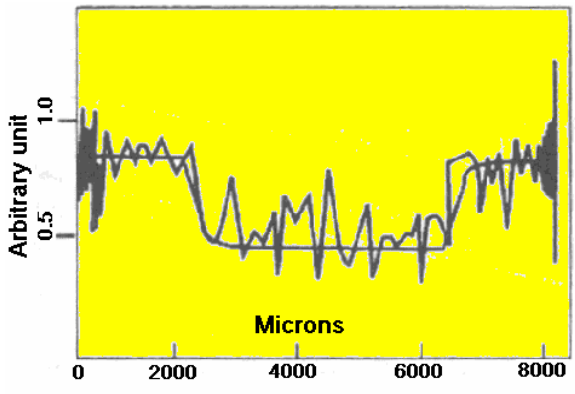

Fig 4. Xe profile across PWR fuel pin

The thermal transport and release properties of the fission gases (Xe, Kr) and the volatiles (I, Te, Cs, Rb) depend on their physico-chemical states. The inert gases having very little solubility remain dispersed in the polycrystalline matrix mostly as micro-bubbles inside fuel matrix [1]. Xe depletion from central part of the fuel pin results in the two distinct regions in the micrographic section in Fig.3a. Magnified view of the dispersed bubbles in the peripheral region of the fuel pin is shown in Fig.3b. Electron probe micro-analysis of the Xe profile across the burnt fuel rod corroborates to the Xe-depletion in the central region (Fig. 4).

The gas atoms transport leading to their final release at fuel-clad interface occurs through the combined paths of diffusion, migration via micro cracks, and thermal sweeping of micro pores and grain boundaries themselves. The atoms residing within grains diffuse intra-granularly under their concentration as well as temperature gradients to reach grain boundaries, voids and micro cracks, where they can accumulate as gas phase. Then they can either undergo resolution inside the grain by impact of fission fragments, or get transported further out by the combined paths. Grain boundary transport is easier in general than the intra grain transport.

The volatiles unlike the gases are not inert to the fuel matrix and to the other fission products. Transport paths of the volatiles are the same as those of the gases, but the driving forces for diffusions are gradients of their chemical potentials, the thermodynamic measures of reactivity of the diffusing species in their various chemical states. Under the gradients, the volatile species are transported from one region of concentration and temperature to another in attaining states of lower potential. Elemental iodine as well as iodides of the alkali metals Cs and Rb has very little solubilities occupying the interstices and ionic vacancies in the fuel lattice. Like the gases, they remain mainly dispersed in the lattice, grain boundaries, voids, and microcracks. Tellurium behaves in same way as iodine, but a significant fraction of Te remains dissolved in the alloy phases of the fission products Pd, Ru, Rh and Mo.

In order to analyse the release processes of the gas and volatile species from their complex states inside the fuel matrix, it is necessary to measure the temperature dependent transport kinetics of the species [1,3]. For this, the matrix should have well defined physical characteristics such as bulk density, porosities, specific surface area and initial concentrations of the diffusing

species. The geometry and the boundary conditions involved in carrying out the diffusional transports of the species should be known.

Experimental Techniques for the measurement of Thermal Transport Process

Techniques for determination of the gaseous fission products from fuel materials fall into two major groups : (i) in-pile measurements during irradiation in reactor, and (ii) out of pile or post irradiation measurements at various temperatures. Although the in-pile measurement technique is useful, it is more complex and difficult to perform. It requires elaborate arrangements for placing the fuel specimen with the heating assembly in the suitable neutron beam hole position of the reactor and continuously sweeping the evolved species with a carrier gas over the specimen. In the out of pile measurements, the most commonly used techniques are 'puncture test' for gaseous release analysis, concentration profiling and post irradiation annealing of fuel samples. In the puncture test experiments, the irradiated capsules are taken into a hot cell where they are punctured with a tube piercing valve. The gases released from the punctured capsule are collected in traps and analysed by radioactive measurements. The concentration profiling techniques are commonly used to know the net distribution of the fission products across radial and longitudinal sections of reactor irradiated fuels. Usually radiometric scanning is made for the purpose. The conventional means of chemical and radiochemical assay on micro-drilled samples are also used, though it is less effective for determining the concentration profiles of gases and volatiles. A more sensitive technique for the gases and volatile fission products uses laser or particle beams to knock out the atoms from micrometer regions of the fuel sample, and the ejected atoms are measured with the help of mass spectrometric or radiometric techniques. Post irradiation annealing (PIA) experiments are widely employed for determining the transport and release of fission gases from fuel materials. The experiments are relatively simple and easy to perform to evaluate the diffusion parameters as a function of temperature, irradiation dose and bulk/grain density of fuel sample.

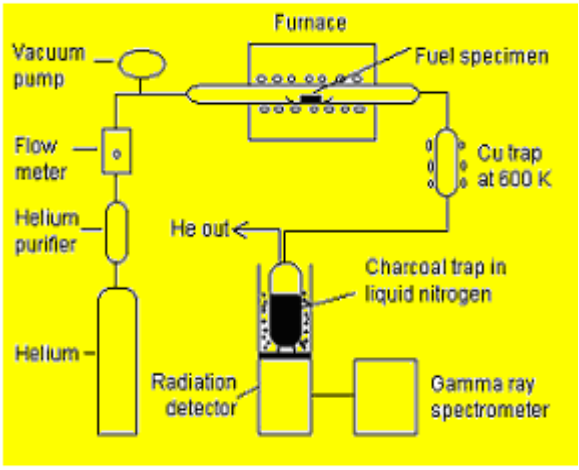

Fig. 5 Schematic of PIA setup for Xe release

In post-irradiation annealing experiments, the specimen irradiated to a known dose is thermally annealed at elevated temperatures of interest and the quantity of a fission product released is measured with radiation detectors. The released gases can be transported by a carrier gas to cooler region where they can be adsorbed in activated charcoal trap cooled in liquid air and placed above the radiation detector for monitoring their activities (e.g., ^{133}Xe with $t_{1/2}$ 5.25 d). The arrangement is schematically shown in Fig. 5.

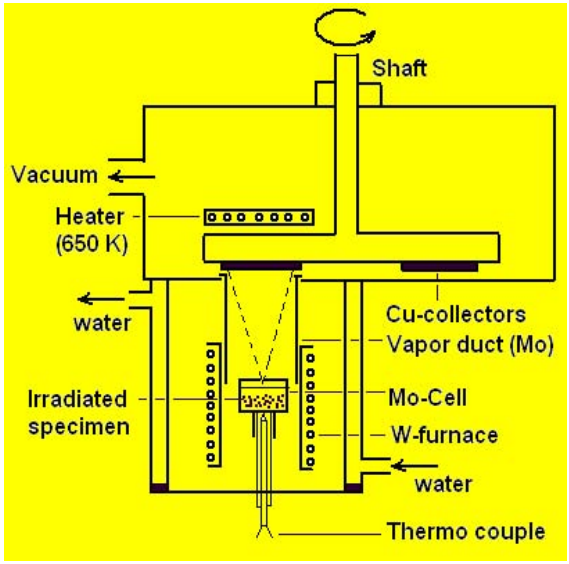

Fig. 6 Schematic of PIA setup for I/Te release

This arrangement cannot be applied to the volatile fission products (e.g. I, Te) as they significantly condense in the transport line before reaching the charcoal trap in the down stream. However, by indigenous development in the basic design of the apparatus, the post-irradiation annealing technique could be adopted for the transport property measurements of volatile fission products too. The design novelty (schematically represented in Fig. 6) involved annealing the sample at high temperatures in a high vacuum apparatus, and collecting the evolved volatiles on hot copper foil-targets where iodine and tellurium got chemical fixed as copper iodide and telluride respectively. Copper target kept at 673 K received a definite fraction of the atomic beams of I and Te emerging from the orifice of a isothermally heated Knudsen cell containing the fuel sample. The collected fractions of the volatiles were radiochemically analyzed for their ^{131}I ($t_{1/2}$ 8.02 d), and ^{132}Te ($t_{1/2}$ 76.3 h) isotopic contents by using HPGe detector coupled to a multichannel analyzer. The released fraction of I and Te were then evaluated considering the collection efficiencies of the respective species obtained by independent experiements with the help of proper standards. The photographs of the two different PIA setups together with the HPGe detector with MCA assembly are included in the experimental section (Fig. 7a, b, and c).

For evaluating the fractional release of the gases and the volatiles, the changes in their active isotopic concentrations by decay process

Fig. 7a PIA experimental setup for Xe release studies

Fig.7b HPGe with MCA facility

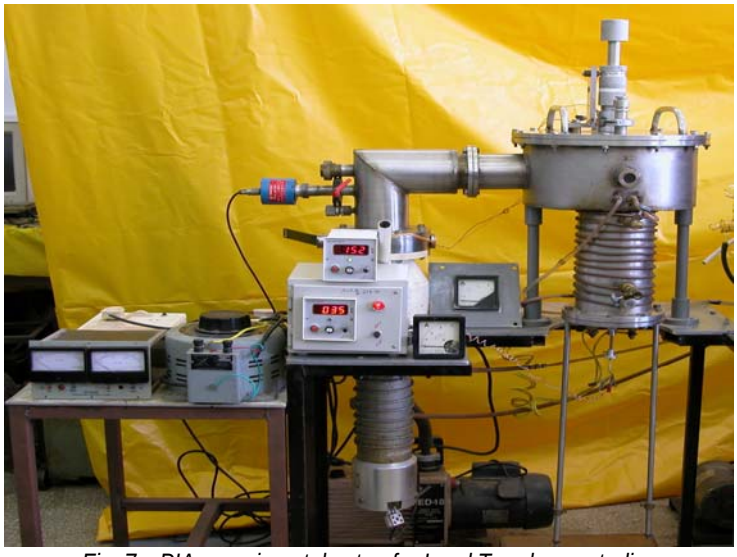

Fig. 7c PIA experimental setup for I and Te release studies

during the study are to be properly accounted. The release data are used to derive the transport property 'D' using statistical model.

Sample Characteristics and its Correlation with Statistical Model used for Analysis of the Transport Kinetics

Interpretation of diffusion property from measurement of cumulative release kinetics of fission products requires sample characteristics in conformity with modelling used for the purpose. The fuel sample is taken in a form with known initial concentration profiles of the diffusing species in a given geometry. A sintered pellet behaves as semi porous matrix wherein the transport leading to release of a species occurs in the mixed modes of thermal diffusion and physical migration in pores. The derivation of thermal diffusion coefficient with pellet specimen of poorly defined porosity distribution is more difficult than with small granular particles of very high grain density with known particle size distribution and specific surface area. Granular particles derived out of the highly sintered pellet through grinding and size-selective sieving processes hardly have left over porosities to pose the difficulty.

Pioneering work of Booth [6] is generally accepted as the most reasonable model for analysing the release of fission gases and volatiles from oxide fuels of the type UO_2. It assumes that uniform spheres of theoretical density can represent the granular particles, and, even the sintered pellets with the same total surface area to volume ratio as that of the samples. The equivalent sphere radius a for a sample of specific surface area S is given by the relation, $a = 3/(\rho S)$ where ρ is theoretical density of fuel. The ρ values for urania and thoria fuels are respectively 10.96 gcm^{-3}, and 10.00 gcm^{-3}. Specific surface S for the particulates depends on grain size and shape and density. The ceramic fuel samples with their densities approaching the theoretical values have quite low specific surface areas (50-250 cm^2 gm^{-1}). S is generally measured by sensitive BET surface analyzer using krypton gas. The a value could be calculated using the above formula.

After representing the statistical system with spheres of known radius, the analysis of transport kinetics for the thermal release reduces to solving diffusion equation in the spherical geometry. The solution attains simplicity when the initial concentrations of the fission products are uniform in the sphere. This is usually attained when the sample is homogenously irradiated at low temperature. For the cases of low cumulative fractional release f (below 20%), the diffusion analysis yields the simple correlation that the chronological growth of f is parabolic in time as $f = 6\,(Dt/\pi a^2)^{1/2}$. Low release rate of the species in practice enables one to establish the linear relationship of f versus $\sqrt{t}$. In the post irradiation annealing experiments, the diffusivity values D are evaluated from the observed slopes of the linear plots of f versus $\sqrt{t}$ of the species using the equivalent sphere radius a of the granular samples. The simple evaluation procedure described for the kinetic property (D) undergoes modification at high irradiation doses where there is significant micro structural changes of the fuel matrix through gas bubbles formations and resolutions, and also through the grain boundary sweeping. The release characteristics of a species is evaluated considering the measured D values together with the knowledge of the other kinetic parameters of the gas resolution, grain boundary sweeping and gas atom trapping in microbubbles [1].

Experiments and Results

Xenon release: Post-irradiation annealing experiments were made on thoria based fuel samples containing respectively 0.1 wt% and 1.0 wt% urania. The urania component was enriched with ^{235}U fissile isotope to the extent of 93%. Two types of (Th,U) O_2 fuel specimens were made for

the purpose. The first type was sintered pellets of theoretical densities ranging from 67 to 94%. The second type was powder specimens prepared by crushing the sintered high density pellets and then sieving to extract the particle size in the range of 37-45 μm. The average density as well as porosity of these specimens was measured by the CCl_4 liquid displacement method. The total surface area was measured by the BET technique and the equivalent spherical radus a for the particles was calculated. The a value calculated from the measured BET surface area of 240 $cm^2 g^{-1}$ was 12.5μm (Table 2).

Table 2 : Characteristics of fuel samples for PIA studies

Particle size	Density	BET surface	Radius of equivalent sphere
37 to 45 μm	> 95% T.D.	240 cm^2 g^{-1}	12.5 μm

Typically one gram of the specimens were irradiated in evacuated quartz ampoules in Apsara or CIRUS at different burn-up in the range of $2.8x10^{20}$ to $2.8x10^{24}$ fissions/m^3 (0.01 to 100 MWD T^{-1}). The sample temperature during irradiation was estimated to be less than 700K. The capsules were stored for about 7 days in order to allow the short-lived activities to decay. The irradiated specimens were transferred into the furnace of the post-irradiation annealing apparatus (schematics already shown in Fig. 5; photograph included in Fig. 7), where they were heated at different annealing temperatures and the released gases were swept out with purified helium. The gas mixture passed through activated charcoal traps kept at liquid nitrogen temperature. The activity due to ^{133}Xe isotope adsorbed in the trap was periodically counted with a gamma ray spectrometer. The Xe^{133} has a very high fission yield of about 6.5%. It is a gamma emitter with a photo peak at 81 keV and with a half life of 5.27 days. The activity data obtained are considered as representative of other isotopes of the fission product xenon released. In order to calculate the fractional release, the total Xe^{133} initially in the specimen must be known. For this, a known amount of the irradiated specimen was dissolved in suitable solvent and the Xe^{133} was adsorbed in the same charcoal trap and the activity was recorded. Detailed description of the equipment, experimental procedure and the data analysis are given elsewhere [2].

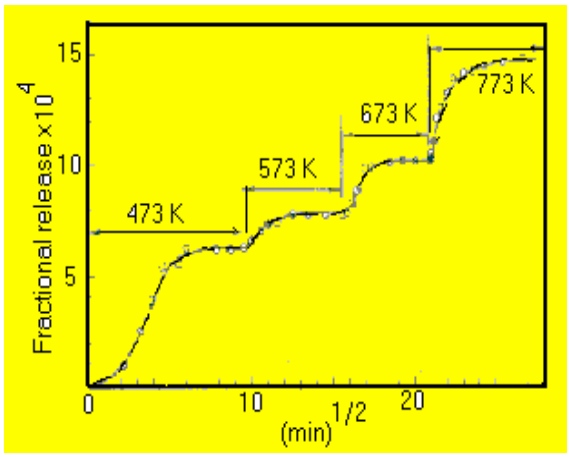

Fig. 8a Typical release behaviour of Xe^{133} at lower annealing temperatures of thoria fuel.

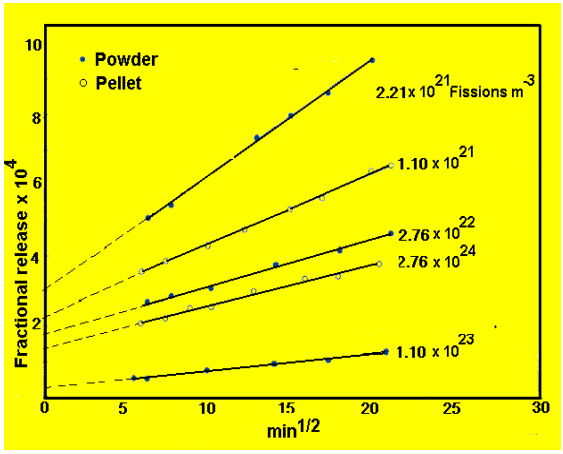

Fig. 8b Typical release behavior of Xe^{133} at higher irradiation doses

A typical release behaviour of Xe^{133} from a 90%T.D. sintered pellet at different ranges of the anneal temperature is shown in Fig. 8a & b. The isothermal cumulative release grow nonlinearly to reach apparently a plateau region at the lower temperatures (Fig. 8a) where the steady state release is negligibly small; the non-linear growth is due to the initial burst-release [2]. At higher temperatures, the steady state release becomes prominent to show linear increase of the cumulative release with time as given in Fig.8b.

The apparent diffusivity D′= D/a^2) was calculated from the slope of the steady state part obtained during six hours annealing time at each temperature. Temperature dependence of diffusivity was found to obey the Arrhenius relation. Typical Arrhenius plots obtained with high density powder samples are shown in Fig.9.

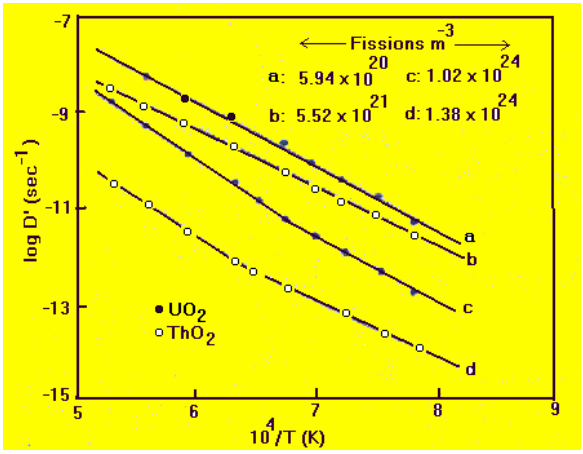

Fig .9 Temperature dependence of thermal diffusivity of Xe in thoria matrix

The activation energy values were evaluated from the plot of log D′ vs 1/T and found to be in the range of 196-242 kJ mol^{-1} which support the mechanism of atomic migration of xenon through the interstitials in ThO_2 lattice [3]. The study with the varying densities of fuel samples showed that the extent of burst release and the diffusivity steeply fall to their limiting values as the density rises above 90%. Sharp fall in open porosity and surface area are mainly responsible for this. The study was extended to trivalent metal oxide (Y_2O_3) doped fuel samples. The nominal fall of the Xe diffusivity in the doped samples supported the absence of the inert gas migration through cation or anion vacancies [3].

The other investigations which was carried out in this laboratory (Naik et al.[3]) was the study on the effect of burn up on the release kinetics of xenon in ThO_2 (1273 - 1673K). It was observed that the diffusivity and the initial burst release are more or less dose independent up to the value of 2x10^{21} fissions m^3, and above it, they fall significantly to level off again beyond a dose of 10^{23} fissions/m^3 (Fig.10). The leveling of Xe transport at higher burn-up was explained on the

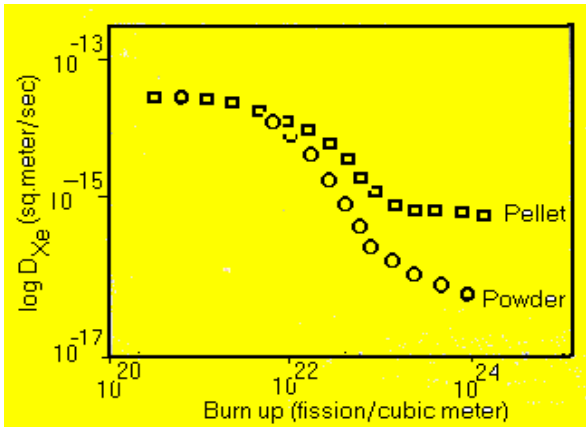

Fig.10 Burn-up dependence Xe transport property

assumption that at high dose irradiation a part of gas atoms are immobilized at the radiation induced trapping centres. The fraction of trapped gas atoms at different doses were calculated and the damaged, or, void volume per fission, were obtained (2-3x10^{-23} m^3/fission) for the ThO_2 matrix. The temperature trends of the measured diffusivities of Xe at the different doses were evaluated. The Arrhenius plot of D_{Xe} values at higher dose of 1.38x10^{24} fissions/m^3 (Fig 9) showed two linear regions; the 41-50 kJ mol^{-1} higher slope in the upper temperature region is due to increase in the activation energy in the absence of radiation induced defects that annealed out at the higher temperatures. A similar effect was observed by Kaimal et al. [2] in the case of pure UO_2 also as shown by the plot 'c' in Fig 9.

Iodine and Tellurium release: Procedurally, the experimental steps in I and Te release were similar to those followed in the case of Xe. Sintered high density pellets of thoria-2mol% urania were used to prepare powder samples with particle size of 37-45 μm, grain density >95% of theoretical value, and BET surface of 240 cm^2 g^{-1}. Following the trace-irradiation at a dose of 5 x 10^{20} fission m^{-3}, and then cooling for seven days, the samples were annealed at different temperatures 1200-1800 K in the PIA apparatus described earlier (Fig. 6). The photograph of the setup developed and used for the purpose is included in Fig. 7. Iodine and tellurium released from the sample inside a

molybdenum Knudsen cell and effused out of the orifice were directed upwards through a moly-duct to get collected on hot copper foils as Cu-iodide and telluride respectively. The collection efficiencies for the two species were pre-calibrated using standards. Radiochemical analysis of ^{131}I and ^{132}Te in the collected deposits and in the fuel samples gave the values of fractional releases of the species.

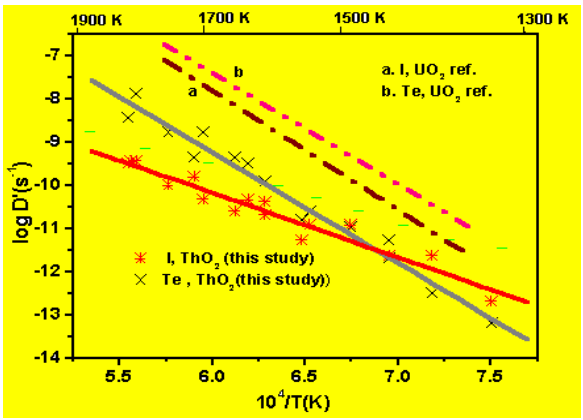

Fig. 11 Temperature dependence of diffusivities of I and Te in thoria-2mol% urania fuel.

Stepwise isothermal annealing showed nonlinear and linear parts of the cumulative release behaviours of I and Te akin to that evidenced in Xe release. Similar to the Xe case, the values of transport coefficients for I and Te were derived from the linear part of cumulative release of the respective species as a function of √time. Since the concentrations of I and Te in the trace irradiated samples were very low, the obtained values essentially represented the single atom diffusion coefficients of the species at the different temperatures. This was also true for the Xe diffusion studied. Arrhenius plots of the transport properties were made to derive the diffusion parameters D_0 and Q of the species [7]. The plots are represented in Fig. 11. For comparison sake, the reported behaviours of I and Te in pure urania fuel matrix [8] are included in the same figure. The figure suggests that both the volatile species are seen to have slower transports in thoria than in urania. The intercepts in Fig.11 representing the frequency factors D_0 for the respective species are seen to be significantly lower in the thoria fuel. The low D_0 values are responsible for the slower transports of the species in the fuel. This is particularly true for iodine that encounters smaller energy barrier exhibited by the lesser steep slope in the Arrhenius plot. The too low frequency factor of I in thoria could suppress the positive effect of the smaller barrier energy in diffusion. As compared to the case of urania, the smaller barrier energy and lower frequency factor derived for I are likely to be due to the inability of Th acquiring higher valency than four. As a result, thoria lattice cannot provide stability of I as iodide ion in its interstitial sites.

Summary

The transport and release properties of xenon, iodine and tellurium in trace-irradiated thoria fuel matrix were studied using the PIA technique developed in the laboratory. Isothermal annealing of the matrix showed parabolic growth of the cumulative release of the species with time. The results were compared with those of urania observed in this as well as other laboratories [2,3,8]. The study revealed that the transport and release behavior of the inert gas Xe is similar, but, those of the two electronegative elements differ in the two fuel matrices. The most likely reason of the difference stems from the inability of Th acquiring higher valency than four, unlike the case of U. The single atom diffusion coefficients of the species generated in the virgin fuel matrix over a wide temperature range will be used as key parameters in the simulation analysis of fuel performance of the Advanced Heavy Water Reactor. Currently, effort is made to generate the transport data in simulated fuel of high burnup. For further reading in details the readers may refer to the publications given in the references [1-9].

References

1. The nuclear fuel of pressurized water reactors and fast reactors, design and behaviour, edited by H. Bailly, D. Menessier, C. Prunier, Lavoisier Publishing Inc. Secaucus, NJ., USA, 1999.

2. K.N.G. Kaimal, M.C. Naik, A.R. Paul, Metals, Materials and Processes, 1(4), (1990) 293. M.D. Karkhanvala, M.C. Naik, K.N.G. Kaimal, and O.P. Chawla, BARC-513 (1970).
3. M.C. Naik, in R.P. Agarwala (Ed.), 'Diffusion process in Nuclear Materials', North Holland, Amsterdam, 1992.
4. R. Chidambaram, in Proc. Indo-Japan Seminar on 'Thorium utilization' (edited by M. Srinivasan, and I. Kimura), 10-13 December 1990, Mumbai, India.
5. W. Jost, in "Diffusion in solids, liquids, gases", Academic Press, New York, 1960,
6. A.H. Booth, G.T. Rymer, report CRDC-720 (1958).
7. K.N.G. Kaimal, A.S. Kerkar, A.N. Shirsat, D. Das, A. Datta, A.G.C. Nair, and S.B. Manohar, J. Nucl. Mater., 317 (2003) 189.
8. S.G. Prussin, D.R. Olander, W.K. Lau, L. Hansson, J. Nucl Mater., 154, (1988) 25.
9. P. Swami Prasad, B.K. Dutta, H.S. Kushwaha, S.C. Mahajan, A. Kakodkar, Fuel performance analysis code 'Fair' BARC/1994/E/013, 1994.

TEST AND MONITORING SYSTEM FOR PLANT CONTROL & INSTRUMENTATION (C&I)

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Introduction

Plant control & instrumentation system gets physical parametric representations as standard current signals (4-20mA). These signals are utilised by various systems like: interlock, regulating, safety, data acquisition and comparator systems for control, safety and instrumentation purposes. Specifically, various comparators compare the incoming 4-20mA signals against stored/set "set points" and create outputs for plant safety, regulation, interlock or/and operation.

Preventive maintenance of plant C&I system, comprising of thousands of 4-20mA current loops, is a very cumbersome time-consuming and laborious process. The maintenance personnel have to remove the 4-20mA field signal, then connect a standard calibrator current source and carry out the functional check of the system. After this procedure, the field wires have to be restored in the same terminal block. This is prone to errors as there always exists a probability of loose connections and wrong connections.

An instrument is thus designed and developed to overcome the above maintenance difficulties and to test and monitor plant C&I systems on line, with live transmitter current (4-20mA). This technology has been transferred to private entrepreneurs by BARC and is having (pending) patent No. MUM/282/200l. In this write up, the novelty of this scheme is described. Prototype has been given to Kaiga Atomic Power Project in 1999 for plant C&I maintenance and on-line calibration.

Principle of Operation

From the field, the plant parameters like pressure, temperature, neutronics etc are proportionately transmitted via 4-20mA current signals. This current per parameter is observed via many terminator resistors by as many systems (limited though by compliance voltage). Refer Fig.1 for such type of electrical connection

showing A, B, C as three different observers (systems) on the same process current loop.

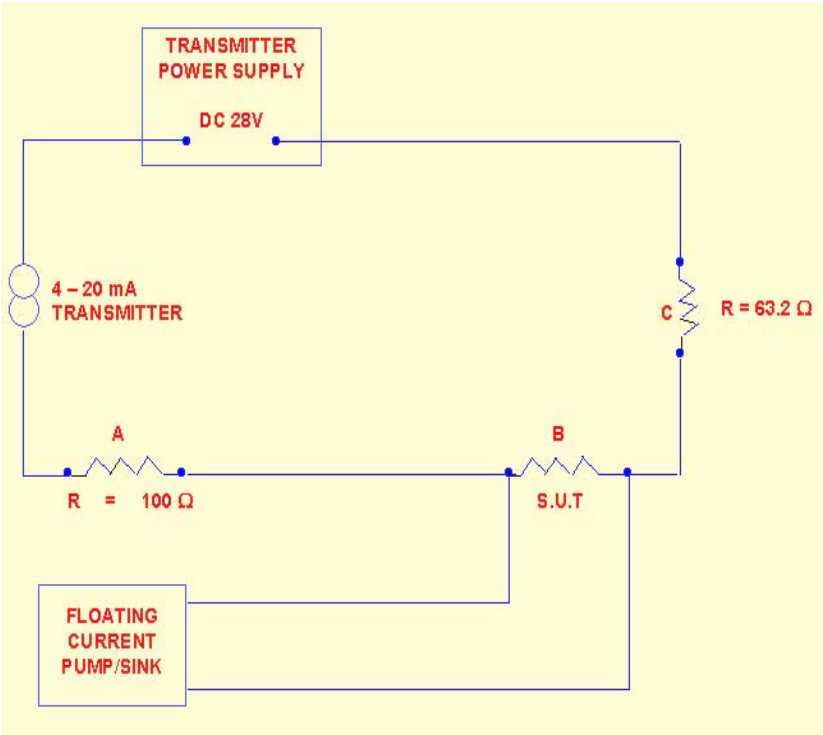


Fig.1 Principle of operation

The instrument is a floating current pump/sink configuration and, say, when connected across System Under Test (SUT) in Fig. 1 is B, sources or sinks balance current as demanded by maintenance engineer. Say, at the instance, the transmitter is giving 12mA as guided by process variable (say, pressure 100 bars), Systems A and C will show 12mA current (or 100 bars) but SUT, being system B, will show the dialed demanded current. Say, for maintenance and calibration, the dialed value is 4mA, then the instrument will sink 8 mA through it and the SUT, i.e. system B, will observe 4 mA. If the dialed value is 16 mA, then the instrument will pump the differential 4mA and SUT, i.e. system B, will observe 16mA. This dialing will not disturb the readings by systems A and C, since they will observe 12mA (or 100 bars).

This concept has been made as two embodiments : (a) Hand held on line live field 4-20mA calibrator, (b) micro-computer based on-line set point servo system (OLSPSS). The basic principle is the same for both.

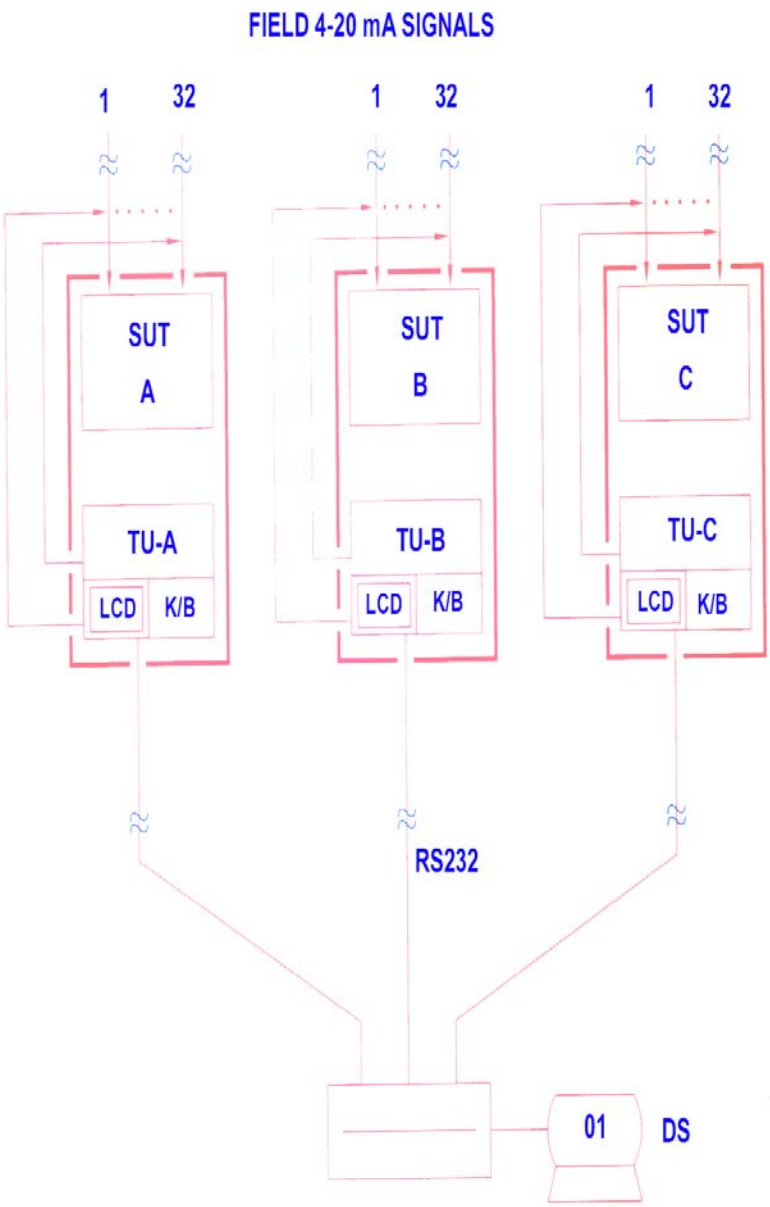
Advantages of this Novel Scheme

i) Field wiring is not disturbed
ii) Fear of loose and wrong connections during maintenance does not exist.
iii) Plant availability improved as maintenance time of C&I calibration drastically reduces.
iv) Set point accuracies can be checked by use of servoing of test signal near and about set point. Servoing can be done from 0-25mA, covering the irrational zone too.
v) Terminator resistor select facility (in hand held version) exists for 100 ohms, 250 ohms, 50 ohms or 63.2 ohms, etc as the case may be.
vi) With special integrations with the comparators, response time can be on-line tested for the comparator (or SUT).
vii) Micro-computer variant can be used to have concepts of Analog Finite Impulse Testing.
viii) Ideal scheme for C&I systems online diagnostics and ease in preventive maintenance.
ix) Human error avoided and requires less maintenance man-days and effort.
x) Dialing is possible through Process Variable setting apart from mA test current setting.
xi) One signal selection at a time for avoiding spurious plant trips on doing the process of maintenance online while plant is working and is operational.

Servoing of Set-Point

A specific example of this microcomputer-based test and monitoring system, when used in Nuclear Power Plant with Indicating Alarm Meters

(IAM), Multi-Indicating Alarm System (MIAS) for SSS&PSS, or Programmable Digital Comparator (PDCS), is illustrated in Fig. 2.



TU : TEST UNIT (EMBEDDED)

K/B : LOCAL KEY BOARD

LCD ; LOCAL DISPLAY

OI : OPERATOR INTERFACE REMOE SCREEN & KEYBOARD

DS : DISPLAY STATION (PC BASED)

SUT : SYSTEM UNDER TEST (MIAS/PDCS etc.)

Fig.2 Organisational diagram of test and monitoring system

On-Line Set Point Servo System (OLSPSS) gives the facility to test IAM, MIAS or PDCS & others without disturbing the field connections. OLSPSS provides facility to test trip points of plant safety system by servoing the input signal around the set point strictly one at a time of System Under Test (SUT). The SUT input current is modified such that the field loop current remains unchanged. The output leads are connected across 4-20mA terminators of the SUT. This automated system aids the plant maintenance as wiring need not be disconnected to calibrate or to test safety/regulation signals.

The embedded units have the components provided in the block diagram of Fig.3. The current source (pump/sink) is routed through the relay demultiplexor and gets connected to the choiced signal of SUT. The dialed set point either via current (mA) set or by process variable set is input to the current pump/sink controller by 14 bit DAC. The set points of servo can be either selected by local panel mounted key board or remote operator Interface terminal (via RS 232C).

Facility is given to the embedded unit (TU) where contacts can be connected from Comparator PDCS/MIAS/IAM to have on-line response time check. Safety features like relay coil current monitor, local watch dog employed in the event of software/hardware failure of the embedded unit (TU) the master relay de-energize, thereby

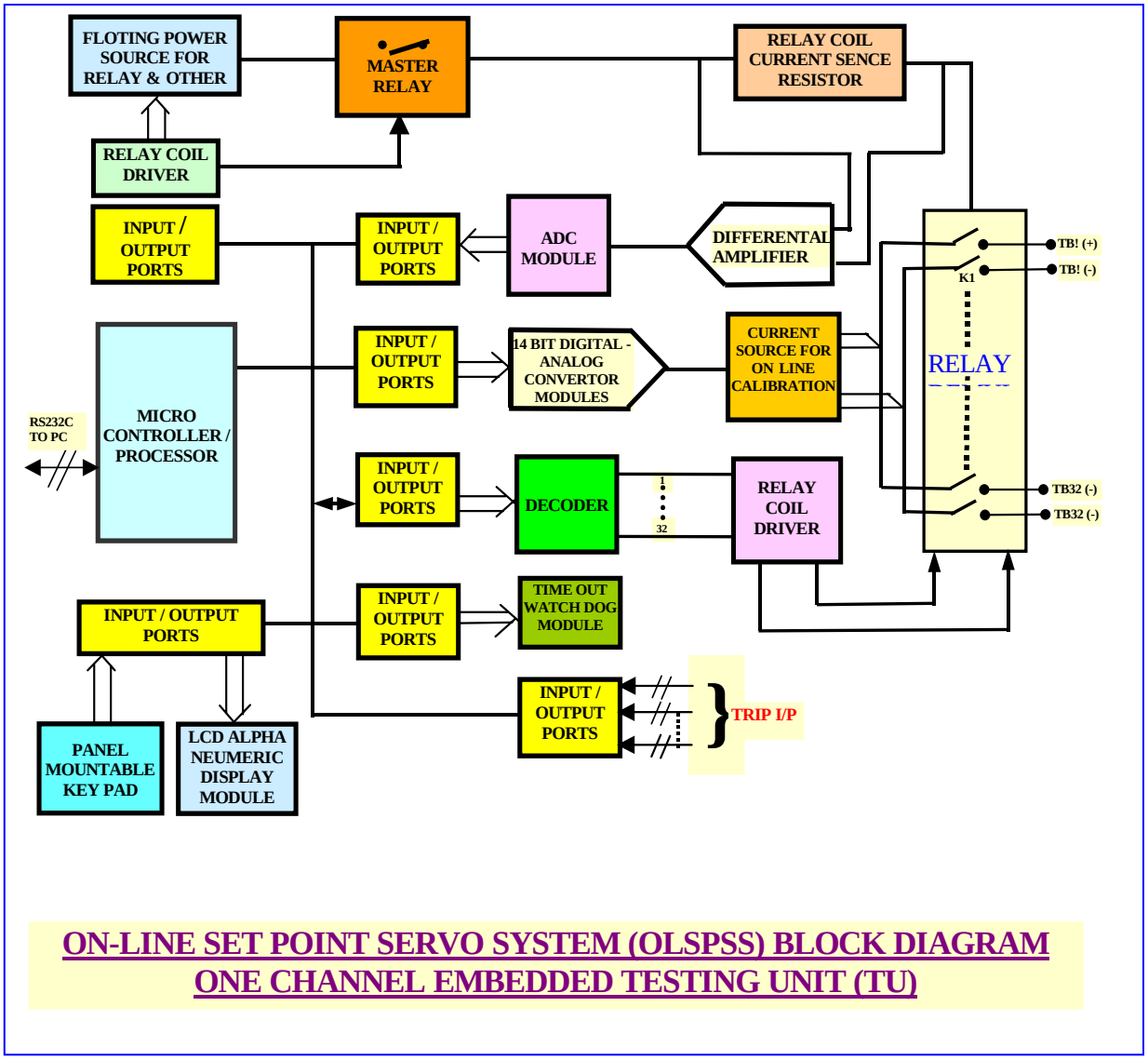


Fig.3 Single embedded channel block diagram

switching off the relay de-multiplexer in order to disconnect the TU totally from PDCS/MIAS/IAM etc.

Conclusion

This technology developed is a totally indigenous concept, and since it has been classified by BARC as OEM product, it can be tailor-made/adapted as per requirement specification. However, the authors were prompted to develop this type of system due to their own cumbersome efforts to calibrate/test 384 field 4-20mA signals during commissioning of PDCS at Kakrapar. The initiative also was motivated by various spurious tours to site just to tighten the terminal block screws, where the plant maintenance had done calibration and left the screws loose or sometime wrongly connected.

After development of the wired prototype, the same was given to Kaiga APP where the remarks obtained from SME(I) were encouraging as this hand-held instrument really did made the life of maintenance engineer easy and tension- free. Thereafter, the microcomputer version was conceived and developed. Strategic facility at IGCAR has utilised this for MIAS validation and is also being used as set point trip unit for MIAS for P4, for on-line diagnostic and calibration.

NOBEL LAUREATE VISITS BARC

Prof. Harmut Michel, Nobel Laureate (Chemistry, 1988), Director, Department of Molecular membrane Biology, Max Plank Institute of Biophysics, Frankfurt, Germany, visited BARC on December 14, 2005 and gave a talk on the topic, "Membrane protein as targets in medicine and agriculture : New perspectives" at the Central Complex Auditorium, BARC.

Prof. Michel described his work on membrane protein involved in photosynthesis process and emphasized the importance of special proteins in cellular membrane for the functions. Structure determination of many membrane proteins is central to developing new technology. Modern sophisticated tools and molecular methods have enabled unraveling the molecular structural details of several membrane proteins but much remains to be done. His work has shown the critical role proteins play in diseases, which needs to be investigated. Post genomic era has much to offer in terms of membrane science and technology for developing molecular devices for sensor and recognition processes. He also emphasised that many patents are against the spirit of invention and innovation. He wished the evolution of a patent free world.

Beginning his academic career at the early age of 21 in the Biochemistry department of the University of Tubingen, he worked in various biochemistry labs at the University of Munich, Max-Planck-Institut fur Biochemie and Max-Planck-Gebellschaft. He received his doctoratein June 1977 from Wurburg University. He joined the Max-Planck-Institut for Biophysik at Frankfurt in October 1987 as its Director. He was awarded the Nobel Prize together with J. Deisenhofer, Dallas, USA and R. Huber, Munich, Germany in 1988 in recognition of his seminal research on "Crystallization of membrane proteins and the elucidation of the three-dimensional structure of the photosynthetic reaction centre from the purple bacterium *Rhodopseudomonas viridis"*

Dr Srikumar Banerjee, Director, BARC with Prof. Harmut Michel, Director, Department of Molecular Membrane Biology, Max Plank Institute of Biophysics, Frankfurt, Germany

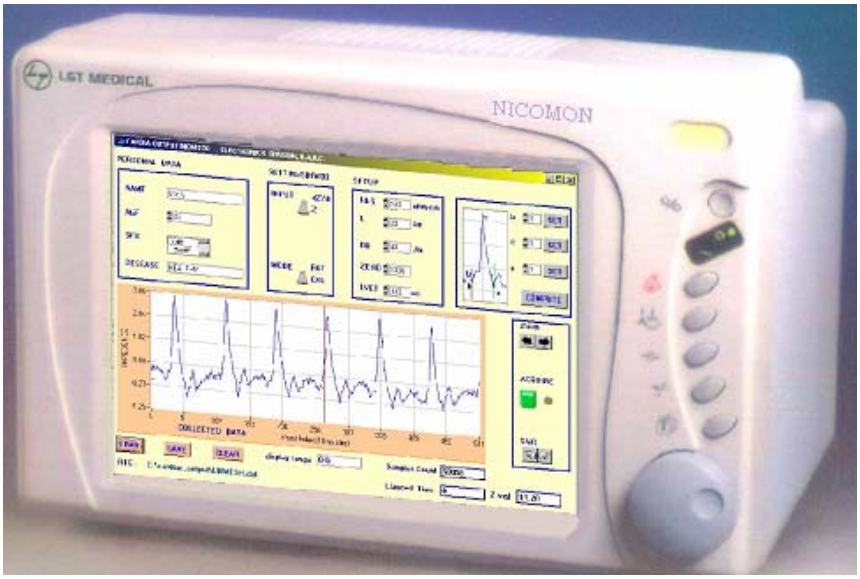
NATIONAL WORKSHOP ON "ELECTRICAL IMPEDANCE TECHNIQUES FOR MEDICAL APPLICATIONS"

A National Workshop on "Electrical Impedance Techniques for Medical Applications, 2004 (EITMA 2004)" was held under the auspices of Board of Research on Nuclear Sciences (BRNS), Department of Atomic Energy, at Multipurpose Hall, Training School Hostel, Anushaktinagar, from September 30 to October 1, 2004. Dr S.K. Kataria, Associate Director, E&I Group, welcomed the dignitaries and the participants. It was inaugurated by Dr Anil Kakodkar, Chairman, Atomic Energy Commission and Secretary, Department of Atomic Energy, Government of India.

In his inaugural address, Dr Kakodkar said that this workshop was innovative in the sense that it had brought R&D scientists as originators, the medical community as users, and Larsen & Toubro Ltd. as the manufacturer on one platform. He expressed his happiness over the successful conversion of this technology into a commercial product. He also cited other similar development like cobalt brachytherapy unit and digital radiography, which are the dire need of the day and available for large-scale production. He wished the workshop a grand success, as the first step towards promotion of this technology.

Dr Anil Kakodkar, Chairman, Atomic Energy Commission & Seceretary, Govt. of India, delivering the inaugural address at the DAE-BRNS National Workshop, EITMA 2004

In his presidential speech, Dr Srikumar Banerjee, Director, BARC, recalled the Medical Instrumentation programme at BARC during past 40 years. Starting with the nuclear medical instrument like Thyroid Uptake Monitor, Renogram, Gamma Scanner, etc., he covered the biomedical-instrument like Electro-myograph, Echocardiography, Magnetic Stimulator and Impedance Plethysmography. He thanked the medical community of Seth G.S. Medical College and K.E.M. Hospital, Grant Medical College and J.J. Hospital, All India Institute of Medical Sciences, Sree Chitra Thirunal Institute of Medical Science and Technology, King George's Medical University, Institute of Nuclear Medicine and Allied Sciences and BARC Hospital for their active collaboration with BARC on the development of this cutting edge technology.



Mr G. Govindarajan, Director, A&M and E&I Group, BARC, formally launched the world class product NICOMON produced by M/s. Larsen & Toubro Ltd. and expressed his pleasure on seeing the BARC technology in the form of an instrument like NICOMON.

Mr R.N. Mukhija, Senior Vice President, Operation and Member of the Board, Larsen & Toubro, released the compilation of work on Impedance Plethysmography in the form of a book entitled "Electrical Impedance and Photo Plethysmography for Medical Applications". He remembered, at this occasion, the long association of Larsen & Toubro Ltd. with Department of Atomic Energy and welcomed the new dimension in the present form.

In the keynote address, Dr Alaka K. Deshpande from Grant Medical College & J.J. Hospital, Mumbai, described her proud association with Electronics Division, BARC, on the joint development programme on biomedical instruments. She described step by step development and addition of new features in the instrument like transition from single channel to three channel for temporary correlation of cardiac events; incorporation of microprocessor for segmental blood flow studies and estimation of differential pulse arrival time; ensemble averaging in real time resulting in a diagnostic yield of 98%; serial linking to PC for continuous monitoring of cardiac output and assessment of pulmonary circulation and now the world class product from M/s. Larsen & Toubro Ltd. In addition to the applications of these techniques in modern medicine, she highlighted the use of this technique for disease characterization, something parallel to that of Nadipariksha and objective monitoring of response of homeopathic medicines.

Mr Rohit Mehta, Head, Medical Equipment and Systems, L&T, gave vote of thanks towards the end of the inaugural session.

Session 2 of the Workshop namely, "Principles and Practices of Impedance Plethysmography", was chaired by Mr P.K. Talpade, Vice President, Electronics, L&T. First speaker of the session, Dr G.D. Jindal, BARC, described the medical applications of impedance plethysmography, which was followed by presentation by Dr K.K. Deepak, AIIMS, on physiological correlates of IPG. Mr Rajesh Kumar Jain, BARC, described

the software package being developed for automatic analysis of impedance vasograms. Towards the end of the session, Mr Kunal Katdare, L&T, described the translation of biomedical instrumentation from research lab., to the industry.

Hands-on-experience was provided to all the participants during session 3 of the Workshop. Live demonstration on a subject with sub-clavian artery block in right hand was given to all the participants. In some demonstrations, temporary compression of femoral artery was performed to show that the recorded blood flow by the instrument was close to zero. Live demonstration on cardiac output monitoring as well as variability study was also given.

The Session 4 of the Workshop, namely “Users’ Experience on IPG Equipments”, was chaired by Dr S.P. Singh, Advisor, Ministry of Health and Family Welfare. In this session, Dr K.K. Deepak, Dr Manish Bajpai, Dr Arunoday, Dr Niranjan Khambate, Dr P.N. Jangle and Dr Tejashree Narkhade shared their experience with BARC-made impedance plethysmograph systems.

An exhibition of medical instruments was arranged on 2nd day of the Workshop for the benefit of the participants and general public. Anu-Med Analyzer, Photo Transmission Rheograph, Non-Invasive Blood Pressure Monitor and Oxygen Saturation Monitor from BARC, and Vital Sign Monitor, Cosmic Monitor, Ventilator, High end Ultrasound Machine and Defibrillator from M/s. L & T Ltd., were exhibited.

Panel discussion chaired by Dr M.E. Yeolekar, Dean, LTMG Hospital, Sion. The panel members were Dr. S.K. Kataria, Dr K.K. Deepak, Mr G.R. Mohan, Dr Manish Bajpai, Dr Arunoday, Prof. Sarla Pandya and Prof. P.C. Pandey. In this session, burning issues of biomedical instrumentation were discussed, like multicentric trials of biomedical instruments, database of observations on patients on a website, certification of biomedical instruments, financial support from Board of Research on Nuclear Sciences, etc.

The Workshop concluded with vote of thanks to Board of Research on Nuclear Sciences, participants of the Workshop and the organizers.

THEME MEETING ON THE "EMERGING TRENDS IN SEPARATION SCIENCE AND TECHNOLOGY"

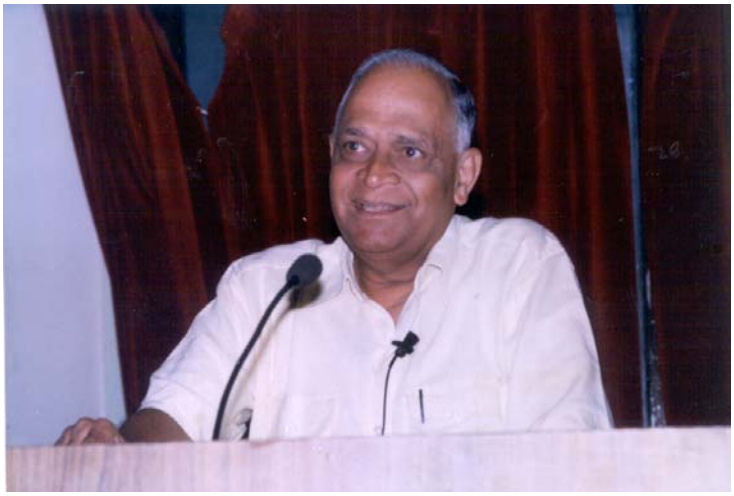
A two-day DAE-BRNS Theme Meeting on the "Emerging Trends in Separation Science and Technology (SESTEC-2004)” was organised at BARC during July 22-23, 2004.

Dr Anil Kakodkar, Chairman, Atomic Energy Commission and Secretary to Government of India, delivering his inaugural address at the DAE-BRNS Theme Meeting

It provided a platform for scientists and technologists to share their experiences and vision in the areas of metal separation, particularly those of relevance to DAE. There were 13 invited lectures from eminent scientists and engineers and about 70 posters from young scientists from various research/academic institutes. A few delegates from industry also participated in the Meeting.

Participants were welcomed by Dr S. Banerjee, Director, BARC, who also outlined the

background of the Theme Meeting. He called upon the delegates to deliberate on the emerging areas, particularly Membrane Separations and Supercritical Fluid Extraction, and take up the challenging problems related to metal separations.



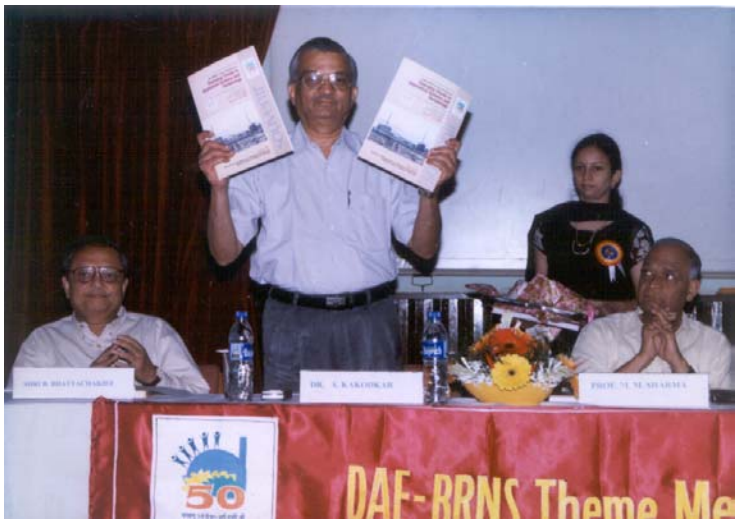
Dr M.M. Sharma, FRS, Emeritus Professor of Eminence, UICT, delivering the keynote address

In his inaugural address, Dr Anil Kakodkar, Chairman, AEC and Secretary, DAE, explained to the delegates the important role of Separation Science and Technology in meeting the new challenges in the Nuclear Fuel Cycle. He highlighted the need to develop robust separation technology for the partitioning of actinides from HLW, cleaning of U-233 from U-232 and recovery of U from secondary sources. The function was presided over by Mr B. Bhattacharjee, Special Advisor to Chairman, AEC.

Dr M.M. Sharma, FRS, Emeritus Professor of Eminence, UICT, delivered a key note address on "Emerging Trends in Separation Science and Technology". Dr V.K. Manchanda, Convener, SESTEC-2004 and Head, RCD, BARC, briefed the delegates on the scope of the Meeting. Dr Anil Kakodkar also released the volume of the proceedings of the SESTEC-2004, which included all invited talks and extended abstracts of 70 posters.

In addition, articles on the activities in the area of Separation Science and Technologies pursued at NFC, BRIT, NRG, BARC, HWB and a general article by Prof. S.M. Khopkar, Emeritus Professor, IIT, Mumbai, messages from Chairman, AEC, Director, IGCAR, Dr M.M. Sharma and Mr B. Bhattacharjee were also distributed to the delegates. In a published interview, Director, BARC, briefly explained the R&D areas of SST where BARC will focus in the next few years. All the posters were distributed in six sections, viz. Synthesis of Reagents/Solvents, Ion Exchange Separations, Process Development/ Solvent Extraction, Novel Separations, Membrane-based Separations and Miscellaneous. There was a session on rapporteuring where senior scientists highlighted the work summarised in the posters.

Each session was chaired by a distinguished scientist. Mr D.S. Shukla, Director, ChE&T Group, BARC, Mr P.D. Sharma, Sr. Exec. Director, NPCIL, Mr T.K. Haldar, Director, HWB, Mr R.K. Garg, Ex-Director, CED, BARC, Dr R.H. Iyer, Emeritus Scientist, CSIR, Mr H.S. Kamath, Director, NFG, BARC, Prof. M. Mukhopadhyay, IIT, Mumbai, and Mr N.K. Bansal, Assoc. Director, NRG, BARC, chaired different sessions.



Dr Anil Kakodkar, Chairman, AEC, releasing the volume of the proceedings of the SESTEC- 2004

During the concluding session, a few topics were identified where Separation Scientists and Technologists, need to focus in the next few years. They include development and use of membranes for metal separations, actinide partitioning and recovery of valuables from High Level Waste (HLW) and Supercritical Fluid Extraction. A professional body, INASAT (Indian Association of Separation Scientists and Technologists) was launched in the concluding session to provide a platform to scientists and technologists working in the area of metal ion separations.

GRADUATION FUNCTION OF BARC TRAINING SCHOOL

The Graduation Function of 47th batch of one-year orientation course for 105 engineering graduates and science postgraduates was held on August 27, 2004 at the Central Complex Auditorium, BARC, Mumbai. Total number of graduates passed from BARC since its inception is 6141. Women share in the total is 7.5%.

The BARC Training School continues to play an anchor role in training and inducting talented candidates for the implementation of DAE programmes and sustained growth in frontier areas of science and technology. Homi Bhabha prizes were given away to outstanding trainees by Dr M.S. Valiyathan, President, INSA. Dr Anil Kakodkar, Chairman, AEC, congratulated all the trainee scientific officers and called upon them to master new technologies like fast breeder reactor technology, thorium utilisation and hybrid reactor technology.

Seen at the graduation function are (from left to right) : Dr S. Banerjee, Director, BARC, Dr M.S. Valiyathan, President, Indian National Science Academy, Dr Anil Kakodkar, Chairman, AEC, and Dr R.B. Grover, Director, Knowledge Management Group, BARC

Dr S. Banerjee, Director, BARC, called upon the trainees to be the donors of knowledge to the society. Dr M.S. Valiyathan, in his address, explained how the Japanese indigenised the technology and grew as a powerful economy in the world. He said that for industrial development, capital, plans and regulations, and spirit of people are essential ingredients. He called upon the trainees to imbibe the spirit of late Dr Homi Bhabha. Dr R.B. Grover, Director, Knowledge Management Group, BARC, gave the welcome address. He gave an overview of the training programmes conducted by DAE in India. Dr Anil Kakodkar, Chairman, AEC, on this occasion, released the *Trainee's Journal.*

40 MWe PHWR FUELLING MACHINE TEST FACILITY INAUGURATED

On September 3, 2004, the 540 MWe PHWR Fuelling Machine Test Facility was inaugurated by Dr Anil Kakodkar, Chairman, AEC, at Hall No. 7 inside BARC.

Fuelling Machine heads of 540 MWe PHWR will be tested on this test facility under simulated conditions of pressure, temperature and flow. The Fuelling Machine Test Facility (FMTF) has been installed and commissioned at RTD, Hall No. 7, BARC. This facility consists of a Full Length Coolant Channel and associated feeder lines, Test Carriage, Oil and Water Hydraulic Systems for operating various actuators of FM and Test Carriage and Electrical/Electronic Instrumentation and Control System.

Mr R.G. Agrawal, Head, RTD, BARC, explaining the importance of the Test facility.Others from left are : Mr K.B. Dixit, ED (Engg.), NPCIL, Mr R.K. Sinha, Director, RDDG, BARC, Mr Dilip Saha, Head, RED, BARC, Mr G. Govindarajan, Director, A&M and E&I Groups, BARC, Mr P.D. Sharma, Sr. ED (P&P), NPCIL, Mr S.K. Jain, CMD, NPCIL, Dr Anil Kakodkar, Chairman, AEC, Dr S. Banerjee, Director, BARC and Mr S.A. Bohra, Sr. ED (T), NPCIL.

भा.प.अ. केंद्र के वैज्ञानिकों को सम्मान /BARC SCIENTISTS HONOURED

• डॉ. सदीप बसु, विकिरण औषध केंद्र, भापअ केंद्र को जून 19-23, 2004 को फिलाडेल्फिया, संयुक्त राज्य अमरीका में आयोजित नाभिकीय औषध की प्रतिष्ठित सोसाइटी की 51 वीं वार्षिक बैठक में प्रस्तुत "पोटैन्शयल रोल ऑफ FDG-PET टू असेस रिस्पांस टू ईमाटेनिब मेसिलेट थेरेपि एण्ड डिटेक्टिंग वायेबल डीसीज इन गेस्ट्रो-इंटस्टिनल स्ट्रोमल टयुमर्स (GIST)" शीर्षक पर अपने सारांश के लिए ट्रॅवल फेलॅाशिप पुरस्कार से सम्मानित किया गया। नाभिकीय औषध की इंडो-अमेरिकन सोसाइटी ने उपर्युक्त सारांश को सर्वोत्तम सारांश धोषित किया ।

Dr Sandip Basu, RMC, BARC, was given the 'Travel Fellowship Award' for his abstract entitled "Potential Role of FDG-PET to assess Response to Imatinib Mesylate Therapy and Detecting Viable Disease in Gastro-intestinal Stromal Tumors (GIST)", presented at the 51st Annual Meeting of the prestigious Society of Nuclear Medicine, held during June 19-23, 2004 in Philadelphia, USA. The Indo-American Society of Nuclear Medicine (IASNM) had adjudged the above abstract as the best in Clinical Sciences category.

• डॉ वी.के मनचंदा, अध्यक्ष, रेडियोरासायनिकी प्रभाग, को प्रतिष्ठित अंतर्राष्ट्रीय पत्रिका, रेडियोकेमिका ॲक्टा की सलाहकार परिषद में शामिल होने का निमंत्रण दिया गया है। यह पत्रिका Oldenbourg Wissenschaftverlag GmbH, मंचेन, जर्मनी द्वारा प्रकाशित की जाती है ।

डॉ. वी.के. मनचंदा के अंतर्राष्ट्रीय पत्रिकाओं में निम्नलिखित क्षेत्रों में 120 से अधिक शोध-पत्र प्रकाशित हुए हैं : (क) लैन्थेनाइड एवं एक्टिनाइड सहित दीर्घचक्री लाइगेन्डस के संमिश्रों की ऊष्मागतिकी एवं बलगतिकी; (ख) प्लूटोनियम आधारित ईंधनों का रासायनिक गुणवत्ता नियंत्रण; (ग) एक्टीनाइडों के नवीन निष्कर्षकों का अभिकल्पन एवं संश्लेषण और; (ध) जलीय पर्यावरण में एक्टीनाइडों का जाति उद्भवन । उन्होंने वर्ष 1985-87 के दौरान UTEP, टैक्सास, संयुक्त राज्य अमरीका (USA) में फुलब्राइट छात्र के रूप में डॉक्टर की उपाधि लेने के पश्चात कार्य किया । डॉ मनचंदा दूसरे भारतीय हैं जो इस सलाहकार परिषद में शामिल किए गए हैं ।

Dr V.K. Manchanda, Head, Radiochemistry Division, BARC, has been invited to join the Advisory Board of *Radiochimica Acta,* a prestigious International Journal for Chemical aspects of Nuclear Science and Technlogy. It is published by Oldenbourg Wissenschaftsverlag GmbH, Munchen, Germany.

Dr Manchanda has more than 120 publications in International journals to his credit in the areas of (a) thermodynamics and kinetics of complexes of macrocyclic liagands with lanthanides and actinides; (b) chemical quality control of Pu based fuels; (c) design and synthesis of novel extractants of actinides, and (d) speciation of actinides in aquatic environment. He had carried out his post-doctorate work as Full Bright scholar during 1985-'87 at UTEP, Texas, USA. Dr Manchanda is the second Indian to join the Advisory Board.

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