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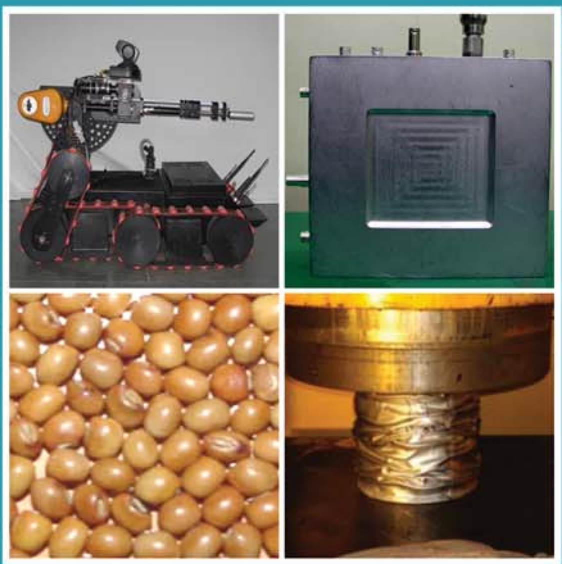
BARC NEWSLETTER

भाभा परमाणु अनुसंधान केंद्र
BHABHA ATOMIC RESEARCH CENTRE



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From the Editor's Desk

Welcome to the fifth issue of the BARC Newsletter published this year. Dr. K.B. Sainis, Former Director, Bio-Medical Group retired after almost 40 years of dedicated service to BARC. His contributions to the Group and the growth and evolution of R&D activities at BMG have been presented in an article published in this issue under the feature "Focus".

The Sep.Oct.2013 issue of the BARC Newsletter carries four Research articles, one Technology Development article and four Brief Communications on various topics of interest. The highlight of this issue is the article on Hull Compaction Systems for storage of intermediate & high level radioactive solid waste. In order to reduce the overall volume of the hull waste generated during reprocessing, a hull compaction system was conceptualized and indigenous development of hull compaction system was initiated to meet growing future requirements. The paper describes the process of compaction, conceptualization of the system and the benefits accrued from it.

Dr. K. Bhanumurthy
On behalf of the Editorial Committee

GMR in Electrodeposited Nanolayered Metallic Magnetic Multilayers

(Materials Group)

Giant magnetoresistance (GMR), discovered in 1988 by two Nobel Laureates Prof. Albert Fert and Prof. Peter Grünberg, is the large change in electrical resistance that occurs when ultrathin stacked layers of ferromagnetic and non-magnetic materials are exposed to a magnetic field. In particular, under no field condition, the magnetization of neighboring layers is antiparallel and gives rise to high resistance and it becomes very low in the presence of magnetic field due to switching of magnetization to parallel. Such change in resistance happens due to differences in scattering of conducting spin-up and spin-down electrons in the individual magnetic layers. Discovery of such nanostructured materials led to the development of extremely small and highly sensitive read heads for magnetic hard-disk drives which facilitated to the invention of high density data storage devices and many magnetic sensors. Sensors using GMR technology have already outperformed traditional Hall Effect and AMR magnetic sensors.

In Materials Processing Division of BARC, we have adopted pulse electrodeposition as a simple and cost effective tool to grow such nanolayered magnetic multilayer structure with alternate nonmagnetic metallic layer having thicknesses in the range 0.2-10 nm. We have fabricated successfully CoCu/Cu and NiCu/Cu multilayers in addition to GMR active CoCu nanogranular alloys. A maximum ~9% negative GMR was achieved at 300 K. For low field applications, we obtained 7% GMR with 70 Oe H_c and a maximum sensitivity of 0.03%/Oe for [CoCu (5Å)/Cu(40 Å)]$_{50}$ multilayer. In case of CoCu nanogranular alloys, we found a maximum 3.2% GMR with coercivity of 32 Oe. Ni being magnetically very soft, a maximum 3.9% GMR was recorded for NiCu/Cu multilayer. From technological view point, such GMR active nanostructures are promising candidate for making various magnetic sensors like GT sensor, position sensor, pressure sensor and in many applications.

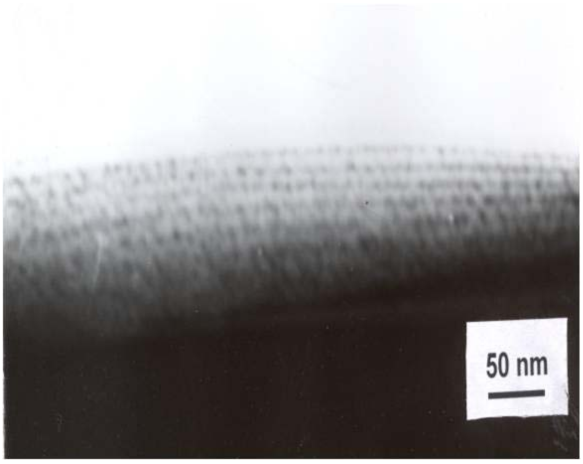


Fig. 1: X-TEM micrograph of CoCu/Cu MLs showing layer structure.

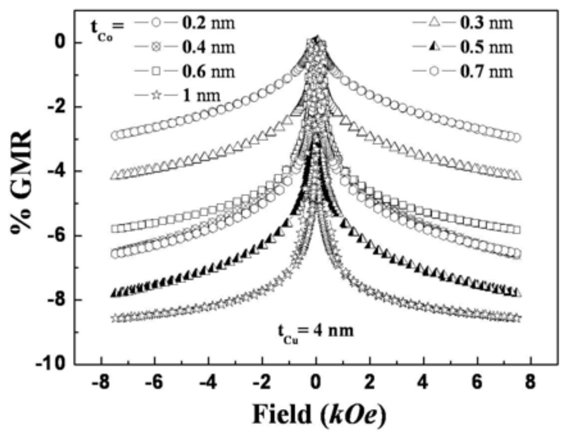


Fig. 2: GMR *vs.* magnetic field curves of CoCu/Cu MLs with different t_{Co}.

Neutron Beam Imaging Detector

(Physics Group)

A 2-Dimensional Position Sensitive Detector (2D-PSD) for neutron beam imaging is developed to record intensity profile of neutron beam at sample positions of various neutron spectrometers at the National Facility for Neutron Beam Research (NFNBR), Dhruva. Multiwire based PSD uses delay line position encoding method. Anode and cathode multiwire grids are made of 10 μm and 30 μm diameter wires respectively, at 1.25 mm pitch. Time delay is 4.2 ns between each consecutive taps of two bunched wires. Position data are obtained by measuring the time difference between the two pulses and converting into digital value, supported by the anode signal as a trigger pulse for coincidence. Total process time of each pulse is 500 ns, which enables to handle the count rate of few hundred kHz. Position resolution is 1.2 mm × 1.2 mm in X and Y directions. PSD is used in transmission mode and implies minimum neutron absorption (< 1%) in sensitive region. Neutron detection efficiency is 0.1 %. The sensitive area of PSD is 90 mm × 90 mm, and ^{3}He (0.05 bar) + CF_4 (1.5 bar) are used as fill gases. Neutron beam images of some test beams at Dhruva are shown in Figures 1b-c. Fig. 1 d shows the linearity scan over the sensitive region using 2 mm collimated beam with a shift of 8 mm.

The 2D-PSD is useful for online monitoring of the neutron beam profile and alignment of neutron optics. This neutron imaging beam detector shows a better dynamic range of intensity and is time effective over the traditionally used photographic method.

Reference

Neutron Beam Imaging at Neutron Spectrometers at Dhruva, Shraddha S. Desai and Mala N. Rao, AIP Conf. Proc. **1447**, 491 (2012).

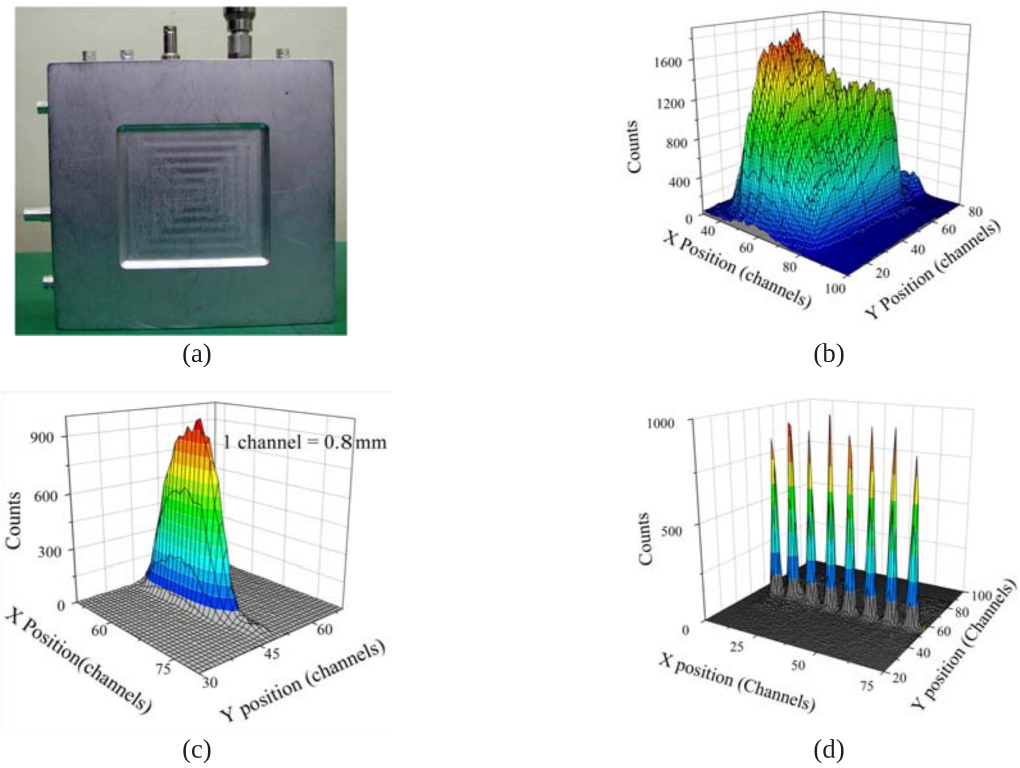


Fig. 1a) Neutron beam imaging Detector, b-c) Neutron beam images of some test beams at Dhruva, d) Linearity scan (8 mm spacing) of a collimated beam over sensitive region of the PSD.

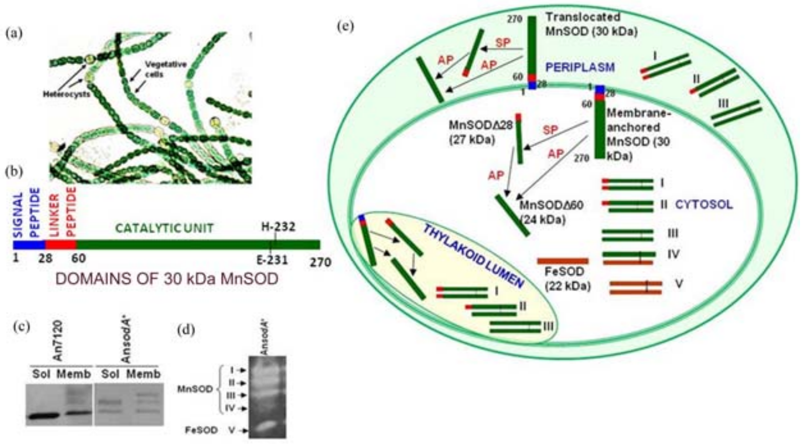
Novel processing generates multiple, active molecular forms of manganese-dependent superoxide dismutase (MnSOD) to facilitate oxidative stress tolerance in the photosynthetic nitrogen-fixing cyanobacterium *Anabaena*

(Bio-Medical Group)

Cyanobacteria can tolerate variety of environmental stresses, including radiation and desiccation. Both photosynthesis and respiration generate Reactive Oxygen Species (ROS) in these microbes in all possible cellular compartments. Cyanobacteria, such as *Anabaena* PCC7120 (Fig. a), have a good repertoire of both enzymatic and non-enzymatic mechanisms of detoxifying ROS. However, exposure to environmental stresses results in enhanced levels of ROS, especially superoxide radical, H_2O_2 and hydroxyl radical which are detrimental to living cells. Superoxide dismutase (SOD) catalyses dismutation of the highly reactive superoxide radical to a more stable H_2O_2.

Of the two SODs, MnSOD is essential for protection against oxidative stress under nitrogen-fixing conditions in *Anabaena.* Though the single gene, named *sodA,* codes for a 30 kDa MnSOD (Fig. b), three molecular forms of MnSOD (30, 27 and 24 kDa) were detected in *Anabaena* 7120 membranes and two (27 and 24 kDa) in the cytosol (Fig. c). Five active SOD dimers were detected on activity staining (Fig. d) (Raghavan et al, 2013). The smaller molecular forms of MnSOD were generated by the proteolytic cleavage of a 3 kDa signal peptide and a 3 kDa linker peptide from the N-terminus of the 30 kDa MnSOD protein (Figs. b and e). This was proven using recombinant *Anabaena* strains expressing truncated variants of MnSOD, either lacking the signal peptide or both the signal and linker peptide or defective in cleavage of either the signal or the linker peptide.

The signal peptide in the 30 kDa MnSOD targets it to the plasma membrane or thylakoids (Fig. c), where it is either (i) translocated across these membranes into the periplasmic or thylakoid lumen, or (ii) remains anchored to one or the other side of the membrane. The action of a membrane-bound Signal Peptidase (SP) cleaves the Signal peptide to release the 27 kDa form into the periplasm/thylakoid lumen or the cytosol respectively. The 27 kDa form is further cleaved proteolytically by Arg-C-like Proteases near the end of the linker peptide to generate the 24 kDa form. This results in generation of the 24 and 27 kDa forms of MnSOD in both the cytosol and membrane, while the 30 kDa MnSOD is found exclusively in the membrane (Fig. c). Homo and hetero-dimerisation of the 24 and 27 kDa forms of MnSOD and the cytosolic FeSOD, result in multiple SOD activities (Figs. d and e), from a single MnSOD gene (*sodA*), to provide a comprehensive oxidative stress tolerance in different cellular compartments of *Anabaena.*



(a) *Anabaena* 7120 (1500X magnification) showing heterocysts and vegeiative cell (b) Schematic representation showing domains of MnSOD (c) Different molecular forms of MnSOD in soluble and membrane fractions (d) Different active SOD dimers in recombinant Anabaena (e) Processing and distribution of MnSOD in cellular compartments

All Terrain Robot for Nuclear Installations

(Design, Manufacturing & Automation Group)

An All Terrain Robot with a standard retractable telescopic radiation detector for remote radiation mapping inside nuclear installations has recently been developed. The robot has been designed to negotiate rough terrain including staircases. The drive mechanism of the radiation detector offers multiple degrees of freedom to facilitate maximum flexibility in measurement and logging of radiation data.

The Robot is driven by six tracked belts with a differential drive and has a payload of 22 kg. It's self weight is 60kg and it can climb ramp/staircases up to 30 deg. with the help of Tele-operable swing arms. It has multiple cameras for navigation including infrared cameras for low light operation. The robot carries onboard batteries for a continuous run time of one hour.

The radiation detector is composed of two GM tube sensors. One tube covers the range from 0.01μSv/h to 10mSv/h and the other tube covers the range from .01mSv/h to 10Sv/h. The sensors are placed on a remote controlled electrically driven retractable telescopic mechanism with three degrees of freedom (Fig.1).

Both the robot and the retractable telescopic mechanism are controlled from a Joystick attached to remote computer via an RF link. A separate RF link is provided for collecting and logging the measurement data from the radiation sensors. The remote computer provides multiple camera view panes, graphical display of the robot pose, real time display of radiation measurement, video and data logging, remote range selection, sensor linearity calibration via keyboard and configurable alarm set points for dose as well as dose rate.

The first successful demonstration of the robot has been carried out at WIP, Trombay for measurement of radiation level inside one HEPA filter bank room (Fig. 2) as well as outside the pre-filter bank area.

Fig. 1: All Terrain Robot with Retractable Radiation Detector

Fig. 2: Robot scanning HEPA Filter bank at WIP, Trombay

Biology & Medicine: Excitement of Research and Deployment of its Outcome–The Twain Do Meet in BARC

Krishna B. Sainis
Bio-Medical Group

The vision of our Founder, Dr. Homi Bhabha extended much beyond making India globally secure in terms of energy production by harnessing nuclear power. He also emphasized the development of non-power applications of nuclear energy and radioisotopes for industry, agriculture and healthcare and building strong directed as well as futuristic-based research programmes. This has been reflected in an ample measure in the activities of the Bio-Medical Group (BMG), BARC pioneered by the late Dr. A. R. Gopal-Ayengar. Application directed basic research as well as curiosity-driven basic research in biological sciences progressed along parallel lines as the former provided a platform for showcasing the now well acknowledged achievements in agriculture and nuclear medicine while the latter provided much needed opportunities to young biologists enchanted by the dramatic developments in molecular and radiation biology.

I entered the hallow precincts of this great institution 42 years ago and as I look back, the achievements of a large score of my former and present colleagues makes me hold my head high with pride. The DAE Golden Jubilee commemoration volumes, "The Chain Reaction" and "Atoms for Health and Prosperity" provide a comprehensive review of the achievements of the Bio-Medical Group. The present article attempts to highlight the developments in the last decade or so. Biological science is in the same class as computer science and electronics in as much as the pace of the development of ideas and technology is concerned.This should also make us aware that we need to take stock of the challenges ahead of us.

Nuclear Agriculture

Since the 1920s it was known that radiations could induce mutations in living organisms. The two obvious ways in which this phenomenon could impact human life were: improvement of crop plants for better yield and other desirable agronomic traits and induction as well as killing of cancer cells. The programme for inducing mutations in crop plants was undertaken with the establishment of the gamma garden in the early 1960s at Trombay. Soon, a small group of scientists began studies with crop plants. The green revolution pioneered by Dr. M.S. Swaminathan in this country found its echo in the crop improvement programme of various agriculture universities as well as institutions like BARC. In BMG, BARC we have concentrated our efforts on oil seeds and pulses but cereals have not been totally ignored. Developing a variety which has a fixed desirable mutation and which breeds true for several generations is a time consuming effort. As ionizing radiation can induce mutations randomly, selection is a critical step. Later these selections have to be further improved by recombination breeding or hybridization. This is followed by a series of trials at different locations and assessment through a demanding process of evaluation developed by the Ministry of Agriculture through the Indian Council of Agricultural Research (ICAR). It was becoming increasingly clear that given the constraints of size of agriculture field facilities, joining hands with the State Agriculture Universities would reap better dividends in terms of credibility as well as reaching the ultimate beneficiary, the Indian farmer. Our first Trombay Groundnut variety, TG-1, a large seeded high yielding variety with 50 days seed dormancy,

Fig. 1: Recently released Trombay crop varieties (Year of Release)

was released in 1973 for commercial production in Maharashtra and Gujarat. Since then the assiduous, dedicated and incessant efforts of a small group of plant breeders have till date resulted in the release of 41 improved varieties of crop plants for commercial cultivation in different parts of the country. Eighteen of these have been released in the last 10 years! These are very popular among the farmers. These include 15 varieties of Groundnut, 3 of Mustard, 2 of Soybean, 1 of Sunflower, 8 of Mungbean-Green-gram, 5 of Uradbean- Black-gram, 4 of Arahar- Pigeonpea, 1 each of Chavali-Cowpea, Rice and Jute. Some of the recently released varieties are shown in Fig. 1.

Of special pride is the fact that out of the 343 mutant varieties developed in the country, 101 are for oil seeds, pulses and legumes and BARC has contributed to 15 out of 18 groundnut, 5 out of 9 blackgram, 4 out of 5 pigeonpea, and 2 out of 7 soybean varieties. It is to be noted that while India has achieved self-sufficiency in the production of wheat and rice, there is a considerable shortfall in production of oilseeds and pulses. Against the annual requirement of 115 lakh tons of oil only 78 lakh tons is available In the light of this fact, the high yielding and early maturing groundnut varieties developed at Trombay have made a very significant national impact. They have contributed to as high as 30% of the national breeder seed indent and get multiplied several fold in the seed chain through various agencies. In the last few years more than 300 quintals breeder seed are being supplied every year to the National Seed Corporation by BARC alone. Universities like the University of Agriculture Sciences, Dharwad are at the forefront of groundnut breeder seed production (4781 Qtl in last 5 years) and proudly supply nearly 50% of the breeder seed indent of new varieties dominated by the Trombay varieties. They have shown consistent high yields touching average yields of nearly 5 tons per ha against the national average of less than 1.5 ton per ha, in addition to offering other variety-specific advantages such as early maturity, large seed size for confectionery use, wider adaptability, resistance to leaf-spot disease etc. Some progressive farmers have also benefited tremendously from cultivation of these varieties and have obtained record yields as high as 9 tons per ha. Extensive farmer to farmer transmission of seeds is perhaps a sure indicator of the popularity of these seeds. Our varieties have captured new states such as Andhra Pradesh in recent years. One of these varieties, TAG-24, has now become a national check variety. Two varieties of Soybean (TAMS-38, TAMS-98-21), three of Mustard (TM-4, TM-2, TPM-1) and one of Sunflower (TAS-82) have also been released but they have not been able to significantly displace well established varieties like JSPS-35 of Soybean. As for the future, recently initiated mutation breeding in Linseed (Flax) and promising results with some of the mustard selections augur well. It's a challenge to sustain our prominence in groundnut breeding and extend it to other oilseed crops.

Pulses are a major source of protein for most Indians. We are today producing approx. 15 million tons while importing between 1 and 5 million tons annually. TAU-1, a blackgram variety developed at Trombay in collaboration with Dr. Panjabrao Krishi Vidyapeeth, Akola is sown over nearly 90% of the cultivated area for Urdbean in the State of Maharashtra. Nearly 30 per cent of the breeder seed indent of Department of Agriculture and Cooperation (DAC) is of this variety. Further, for another pulse crop, the mungbean or green gram, out of the more than 43 varieties released and gazette notified by the Ministry of Agriculture since 1985, 15 are produced by induced mutation and of these 8 have been developed by BARC. They are all better yielding and some of them are disease-resistant too. India's first powdery mildew disease resistant variety is Trombay Mungbean,TARM-2. Likewise, resistance to yellow mosaic virus has been incorporated in another variety TMB-37. Another significant contribution has been in Pigeonpea or Tur/Arahar (4 varieties). In legumes too, we have made a beginning by developing a variety of cowpea, TR-774-Khalleswari with the help of Indira Gandhi Krishi Vidyapeeth, Raipur. We have extended our efforts

Table 1 : Breeder Seed Indent and Expected Certified Seed Production of Trombay Varieties during 2013-14 Source: Dept. of Agri. & Coop., Govt. of India

Crop	Breeder Seed Indent (QTI)	Certified Seed Expected(QTI)
Mungbean (Greengram)		
Pairy Mung (TM-2000-2)	0.20	320.
TJM-3	6.6	10,560
TM-96-2	0.8	1280
TMB-37	23.5	37,600
TARM-1	16.0	25,600
Total	47.1	75,360
Uridbean (Blackgram)		
TU-94-2	7.6	12,160
TAU-1	53.41	85,456
Total	61.01	97,616
Tur (Arahar-Pigeonpea)		
TJT-501	15.0	1,50,000
Grand Total	**123.11**	**3,22,976**

Crop	Breeder Seed Indent (QTI)	Certified Seed Expected (QTI)
Groundnut		
TG-39	20.0	1,280
TG-51	71.0	4,544
TLG-45	10.0	640
TG-38	90.0	5,760
TG-37A	633.25	40,528
TPG-41	210.0	13,440
TG-26	31.0	1,984
TAG-24	1025.0	65,600
Total	**2090.25**	**1,33,776**

to legumes by starting a programme on chickpea (Chana). The demand for the breeder seeds of Trombay pulse and groundnut varieties is reflected in Table 1.

In cereals, a rice variety, Hari, was released several years ago. We need to focus on both rice and wheat, especially, for salinity tolerance and aromatic properties in rice and thermo-tolerance and better bread making qualities in wheat.

India's total cultivable land is about 145 million ha and not likely to increase much given the rapid pace of industrialization and housing projects in rural and semi-urban areas. Sustainability is at stake. It is estimated that residual moisture conditions in rice fallows (after the harvesting of rice crop) will make available nearly 15 Million ha of cultivable area. Two of our pulse varieties (Green gram-TM2000-2 and Blackgram TU-40) are ideally suited for rice fallows. Though India has overcome the famines and shortages of mid-twentieth century by introduction of new varieties of wheat and rice and pulses and oilseeds through mutation breeding, the challenge lies in the need to have more improved varieties of crop plants for different conditions and to deal with biotic and abiotic stresses. There is a need to develop crop plants which can withstand these biotic (bacterial and fungal diseases and insect pests) and abiotic stresses (drought, increasing temperature and salinity). Mutation breeding can be extended to vegetatively propagated plants. Over the years, we have nurtured a strong plant tissue culture activity in BARC and developed protocols for the micro-propagation of several elite varieties of banana. These have even been transferred to Krishi Vigyan Kendras, NGOs and private entrepreneurs. Irradiation in combination with tissue culture is being used to develop virus-resistant banana plants as well as sugarcane.

Younger researchers in agriculture are increasingly attracted by the prospect of using modern biotechnological methods for development of stress-resistant crops. In the late 1970s, BARC tried to keep pace with the exciting developments in molecular biology and developed expertise in identification and manipulation of genes that control some of these traits. The first transgenic plant in India containing a herbicide resistant gene was made in BARC. Since then we have carried out considerable work on transgenics in model systems and in Banana. DNA markers are yet another tool in the modern breeder's hands. We have identified and continue to work on such markers which are small stretches of DNA that can be strongly linked to the genes that control desirable traits. Some of the targeted traits are salinity resistance in rice, rust (fungal disease) resistance in wheat and rice and bacterial disease in pulses. Next, we need to develop TILLING (Target Induced Local Lesions in Genome) approach that combines mutation induction in specific genes and the identification of the mutation by Next Generation DNA Sequencing (NGS). Recent establishment of the NGS facility through collaboration between BARC and ACTREC may help such an endeavor.

An integrated crop improvement programme was conceived 4 decades ago when studies related to the use of radioisotopes and gamma radiations were initiated for estimation of pesticide residues in soil and for controlling certain insect pests in a geographically confined area respectively. These need to be revived. Recent involvement of some young colleagues in this activity is a welcome sign. We need to strengthen our linkages with various agriculture universities and other research institutions within the ICAR system to further extend the influence of our achievements and to make a strong societal impact.

Food Preservation by Irradiation

Another area of major impact of radiation technology on human life relates to food preservation and processing. Mere enhancing of food production is not enough. We must ensure its safety, reduce post-harvest losses and facilitate fair distribution. Today a large quantity of agricultural and horticultural produce (between 20 to 50%) is lost due to post-harvest microbial spoilage, insect infestation etc. Even if the farm produce is of good quality, it would need to be amenable to processing and value addition, withstand rigors of handling, storage, transport and distribution. Furthermore, in the global commercial context, it should meet the requirements of international quality and quarantine. In another twenty years, an additional sixty to seventy million tons of food-grain would be required annually. A significant portion of this requirement can be met by cutting down post-harvest losses.

For over thirty years, scientists of BARC have carried out studies on radiation processing of various foods and food-products. It involves controlled application of the energy of radiation such as gamma rays, X-rays and accelerated electrons. This ensures killing of pathogens and insect larvae or delaying the biochemical processes that lead to sprouting or ripening. As a consequence, it enhances shelf-life of food and food products. Several years of research effort have gone into the study of various biochemical changes taking place in irradiated food materials (e.g wheat, legumes, wheat products, onions, potatoes, fruit, fish and meat), their microbiological and wholesomeness evaluation etc. I recall the hectic activities in FIPLY (Food Irradiation & Processing Laboratory) and Modular Labs soon after I joined BARC that involved several genetic toxicological studies to establish the safety of radiation-processed wheat. These also led to our undertaking evaluation of several chemicals for their mutagenicity and clastogenicity in association with the International Atomic Energy Agency. It took more than a decade to get the approval of the Ministry of Health for radiation processing of food and the first plant to be put up. We now have two technology demonstration units. The one at Vashi, Navi Mumbai is also being commercially used for irradiation of spices and several other food-products requiring medium to high radiation doses. The other demonstration plant, KRUSHAK (Krushi Utpadan Sanrakshan Kendra) using radiation to prevent sprouting in onions and potatoes was commissioned in Lasalgaon near Nashik, Maharashtra in 2002 and is being run today under an MOU with the Maharashtra State Agricultural Marketing Board (MSAMB). A new chapter was written in the history of India's agriculture export, when on 26th April 2007 the first consignment of irradiated Alphonso mangoes was shipped to USA. A dose of nearly 400 Gy kills the fruit fly and the stone weevil that infest this crop. India became the first country to use this technology for export of mango to USA. Since then several hundred tons of Mango have been irradiated in this plant and exported.

Fig. 2: Irradiation and export of Alphonso mangoes

Recently, pomegranate has become the second fruit to be radiation processed for export. More than a dozen gamma ray-based irradiation plants are operating in the private sector for medical as well as for food products. In 1991, the Atomic Energy Act was amended and the Atomic Energy (Control of Irradiation of Food) Rules were notified. These rules have been further amended and the new Atomic Energy (Radiation Processing of Food and Allied Commodities) Rules 2012, allow the scope of irradiation to commodities falling under eight different classes of food. In 1994 the Government of India amended the Prevention of Food Adulteration Act (1954) Rules and approved irradiation of food commodities for domestic market and later the Ministry of Agriculture and Cooperation, Government of India amended the plant quarantine regulations to include irradiation as a phytosanitary treatment. These are very encouraging developments for both domestic market and well as for export of agricultural produce like basmati and non-basmati rice, seafood, spices, poultry, meat, spices, fruit and to some extent onion. Radiation processing can be used for storage of bulk and packed items for retail distribution. Most reassuring thing is the regulatory framework laid down by the Codex Alimentarius Commission, Food and Agriculture Organization and World Health Organization for good manufacturing practices and by the Atomic Energy Regulatory Board for good irradiation practices. Such a processing will also bring indirect benefits in terms of better health. At one time, it appeared to be an almost impossible task to convince opinion makers including some scientists about the safety of irradiated foods. Since then there has been a dramatic change in public perception of irradiated food. It is now certainly considered safe.

Thanks to the untiring efforts of our colleagues in the Food Technology Division and the extensive documentation done by them on this technology, (also recognized internationally), is poised for wider deployment in the country. The future challenges

French beans

Pumpkin

Ash gourd

Bati

Fig. 3: Shelf life extension by irradiation has been achieved for the above products. For each product the image on the left is that of unirradiated sample and that on the right is that of irradiated product

lie in expanding the product basket for an economically viable commercial utilization of this technology, undertaking large scale studies with electron beam sources as cobalt-60 based sources may get phased out, deployment of irradiation facility at ports for import and export and exploring combination or hurdle technologies for sensorily vulnerable products. Development of irradiated food products for immuno-compromised patients (e.g. those receiving radio- or chemotherapy for cancer, HIV patients) and soldiers working at high altitudes, space-craft crew and disaster situations is a new direction to follow in future. We should also consider entering into functional food research given the fact that several young scientists are currently involved in evaluating the chemopreventive (anti-mutagenic, antioxidant), radioprotective and nutraceutical potential of Indian vegetables, medicinal plants, honey etc. Some of the products for which radiation treatment protocols have been recently standardized are shown in Fig. 3.

Nuclear Medicine

Exploitation of non-radiation technologies has not been excluded in our efforts. Very recently both radiation-based and GRAS (generally accepted as safe) chemicals based methods have been developed for enhancing the shelf life of Litchi (up to 60 days in the latter method). The technology for preservation of Litchi has been transferred to two private parties. This augurs well for the litchi producing eastern parts of India.

BMG, BARC pioneered the development of nuclear medicine in the country. Radiation Medicine Centre, a division of BARC recently celebrated its Golden Jubilee this year. It was established as a centre for the use of radioactivity in the diagnosis and treatment of thyroid diseases and thyroid cancer, and to provide nuclear medicine support to the Tata Memorial Hospital. The major work carried out at RMC includes use of radio-labeled molecules, antigens and antibodies for radioimmunoassay, and radiopharmaceuticals and radioisotopes for diagnosis and therapy of several diseases of thyroid gland including cancer. It is based on the principle that different organs may concentrate a particular radioisotope (e.g. Iodine in thyroid) or a radiopharmaceutical (e.g. F-18 deoxyglucose in metabolically active cells). Such a radioisotope can be used for therapy (e.g. I-131 for thyroid cancer) or in diagnosis. In addition, imaging of various organs like, bone, heart, kidney etc. is routinely carried out with I-131 and Tc-99m labeled radiopharmaceuticals. Radioimmunoassay(RIA), a very sensitive analytical tool was developed for the estimation of important biomolecules like thyroid hormones, (total T4 and free T4, total T3), thyroglobulin (Tg), insulin, human serum albumin, TB antigens and antibodies that have clinical value. Immunoradiometric assays were also developed for Tg an important marker for thyroid cancer, anti-Tg autoantibodies and T4 binding protein antibodies. In 2011, 27000 RIA estimations were performed at RMC under its RIA services and 14000 referrals were made to RMC for various investigations and treatments. These included 4000 scans using Single Photon Emission Computed Tomography (SPECT, Fig. 4B), 600 radio-iodine therapies, 200 radio-toxicosis therapies, 30 Lutetium-177-Dotatate therapies (for tumors that do not take up iodine) and 20 ml- I125BG therapies. The radioiodine therapy ward for thyroid cancer patients is the busiest in South East Asia treating nearly 600 patients a year. The identification of non-thyroid tumors concentrating radioiodine helped use radioiodine therapy for their treatment.

The year 2002 was a major landmark for RMC with the installation of the 16 MeV Medical Cyclotron (Fig. 4), 18-FDG (fluorodeoxyglucose) synthesis module and Positron Emission Tomography scanner, the first in the country.

(A) Medical cyclotron

(B) SPECT

(C) PET-CT

Fig. 4: Medical Facilities & Services

The Medical cyclotron produces Fluorine-18 (T1/2 = 110 min) which is used to label deoxy D-glucose and the resultant 18-FDG is being used to detect cancer metastases, inflammation, infectious disease, cardiovascular and psychiatric disorders etc. This proved to be a trend-setter in the country. Methods for the synthesis of several 18-F labeled compounds e.g. 18-F ethyl thymidine to evaluate cell proliferation, 18-F estradiol for imaging breast cancer, 18-FAZA for hypoxia imaging, 18-NaF were standardized recently. Recently the PET scanner has been upgraded to a PET-CT machine (Fig. 4C) and which facilitates the evaluation of 10-15 patients every day. The successful operation of the equipment proved its commercial viability and presently there are 12 cyclotrons and more than 70 PET-CT scanners in India with many more on the way. The Medical Cyclotron Facility at RMC supplies 40-50 patient doses of [F-18] FDG daily to various hospitals in Mumbai and Pune. In 2011, 2000 PET scans were performed at RMC. An outstanding feature of the nearly 300 plus publications in the last 10 years in nuclear medicine has been the extension of the applicability of PET to several diseases including cancers, sarcoidosis and tuberculosis that enabled integration of functional radionuclide imaging with individualized management of patients. The proposed installation of a new 18 MeV medical cyclotron will indeed augment our nuclear medicine services and research. Some of these radiopharmaceuticals (RP) are shown in Table 2.

RMC has also made a major contribution to tuberculosis research by developing a Polymerase Chain Reaction (PCR) based kit for diagnosis of tuberculosis in association with the Board of Radiation and Isotope Technology (BRIT) and a radiorespirometry technique for assessment of the efficacy of anti-TB drugs. It has also genotyped several clinical isolates of drug resistant Mycobacterium tuberculosis strains and recently shown how the inflammatory immune response to

Table 2: Radiopharmaceuticals (RP)

Name of the RP	Uses
$Na^{18}F$ (sodium fluoride)	for bone imaging
^{18}F-FET (fluoro-ethyl-tyrosine)	an amino acid analog for imaging brain tumours
^{18}F-FLT (3'-deoxy-3'-flurothymidine)	a nucleotide analog for imaging cell proliferation
^{18}F-FMISO (fluoromisonidazole)	For imaging hypoxia
^{18}F-FES (fluoroestradiol)	For imaging estrogen +ve breast cancers

virulent and avirulent strains varies but is not related to their drug resistance.

Another key contribution of RMC is in the development of human resources for nuclear medicine in India. It conducts a Diploma course in Radiation Medicine (DRM) for doctors and also a Diploma course in Medical Radio-Isotope Techniques (DMRIT) for technologists. These courses have been the backbone of the nuclear medicine programme in the country and over the years it has provided the required human resources to ~170 nuclear medicine centres now operating in India. RMC has also developed and patented a prophylactic mixture comprising calcium potassium ferrocyanide, as an efficient blocking agent/decorporator for radio-Iodine, radio-Cesium and radio-Strontium.

In the years to come it will be necessary to expand the RMC activities in other locations like Kolkata, Vizag or other places to benefit larger number of patients in association with units like Tata Memorial Centre. The academic programme also needs to be upgraded to MD level.

Health Care Services

Medical Division, BARC is responsible for the delivery of healthcare to nearly 100000 beneficiaries of the DAE Contributory Health Service Scheme (CHSS) in Mumbai. Over the years several new diagnostic and therapeutic equipments have been installed at BARC hospital to increase the patient throughput. Services such as dialysis, dental implants, neonatal ICU, total knee replacements, cochlear implants and complicated surgeries have become available at BARC hospital. During the XII plan period it is expected that a new hospital building will provide the much needed space for coronary angiography, blood component separation, additional operation theatres, computerized tomography and magnetic resonance imaging. Another major development relates to the starting of the Diplomat of National Board (DNB) courses in 10 different disciplines. Concerted efforts by RMC and Medical Division should pave the way for MD/MS degree programmes under the aegis of the Homi Bhabha National Institute in the next few years.

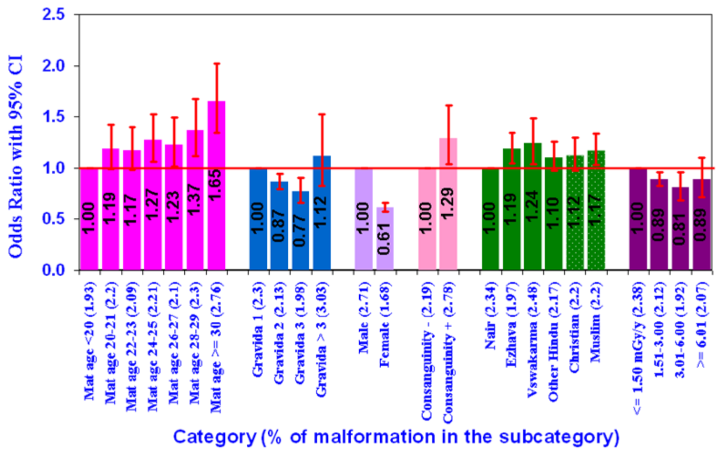
Solid Waste Management

The development and propagation of Nisargruna concept of the Biogas Plant has been a major success story in urban solid waste management (Fig. 5). It is based on the philosophy of repaying our debt to Mother Nature.. It is a case of generating wealth from waste. It uses cellulosic as well as other types of biological waste from households, hospitals or vegetable markets and methanogeneic bacteria. Nearly 150 plants have been constructed and commissioned in various parts of the country and many more are under construction. This concept has caught the imagination of the Ministry of Non-conventional Energy Sources, local self-government bodies and state level environment planners. The indirect but substantial contributions of these developments to preventive healthcare cannot be ignored. The challenge for the future will be the fabrication of plants of larger capacity and running them economically.

Fig. 5: Nisargruna Bio-gas Plant at Solapur

Studies of Effect of High Level Natural Radiation

The study of radiation effects in various biological systems has been the most important mandate of the Bio-Medical Group. These effects are known to be dose dependent. Globally there is a growing interest in the effects of very low doses of ionizing radiation as these have tremendous implications to the IAEA International Council for Radiological Protection (ICRP) prescribed limits of exposure, radiation protection of workers and general public. Radiations have been a part of our environment since times immemorial. We are all naturally exposed to radiation from our surroundings and from radioisotopes in our own body. There are several areas in the world where the level of natural radiation is much more than the global average of 2.4 mSv. In India, the south west coast of Kerala which is rich in monazite sand is one such area. It has a high population density and people have been living there for tens of generations for nearly a thousand years. It is nature's laboratory in which the human population at all stages of development is exposed to ionizing radiation. The external radiation dose varies between 1.5 to 45 mGy. The importance of this area to radiation biology was recognized by the WHO in the early 1960s. In the 1970s a systematic study of this population was undertaken with respect to house dose, demographic profile, reproductive performance, assessment of cytogenetic parameters etc. Early results with rats and in adult human beings did not show increased genetic damage in the exposed population. In the early seventies, a laboratory of Monazite Survey Project of BARC was established in this area, which was later rechristened as Low Level Radiation Research Laboratory (LLRRL) in 1999. Under its aegis, a more extensive study on screening of newborn children was undertaken in which to date over 140,000 newborns have been screened for the incidence of nearly 100 different congenital malformations detectable at birth, still births and twins, Down's syndrome, chromosomal aberrations (stable and unstable, structural and numerical), micronuclei frequency, telomere length etc. None of these showed any significant difference between those born to parents from High Level Natural Radiation Areas (HLNRA) and those born to parents from Normal Level Natural Radiation Areas (NLNRA) (Fig. 6). A recently concluded case control study on mental retardation and cleft-lip and cleft-palate also did not reveal any deleterious effect of high natural radiation. Another recent work published from the Low Level Radiation Research Laboratory, in fact, suggests lesser DNA damage (as estimated by comet assay) in older adults from HLNRA than their age matched NLNRA counterparts. At the molecular level, studies on DNA mutations based on more than 50 hypervariable loci in human DNA and more than 200 families have also not indicated any change due to HLNR exposure. These results have been corroborated by the survey of the nearly 400000 population for incidence of various types of cancer carried out by the Regional Cancer Centre, Thiruvananthapuram. There is no increase in the incidence of any cancer type attributable to radiation. Today these studies are regarded as unique and extensive and have drawn the attention of the low dose researchers and radiation protection community alike. The exposure here mimics the likely continuing exposure scenario after a nuclear accident like the one in Fukushima. In Kerala as well as in China, where a similar high natural background radiation area exists, the excess relative risk of cancer has been found to be marginally negative according to the analysis performed by reputed Japanese epidemiologists. LLRRL was inaugurated shortly after I took over as Head, Cell Biology Division. Today I feel proud of my colleagues in LLRRL for their stupendous achievement. In the years to come we may have to continue to accumulate more data on the parameters being studied at present to get the statistically unquestionable numbers of cases and also undertake screening for development of cataracts and cardiovascular effects. At the same time we need to harness newer developments in genomics to understand global gene and protein expression profiles, epigenetic changes and micro RNA mediated gene regulation as well as look for changes in specific genes as indicators of low dose radiation associated effects or lack of them. Correlating individual exposure to health effects or an end point is a daunting task that also needs to be undertaken.



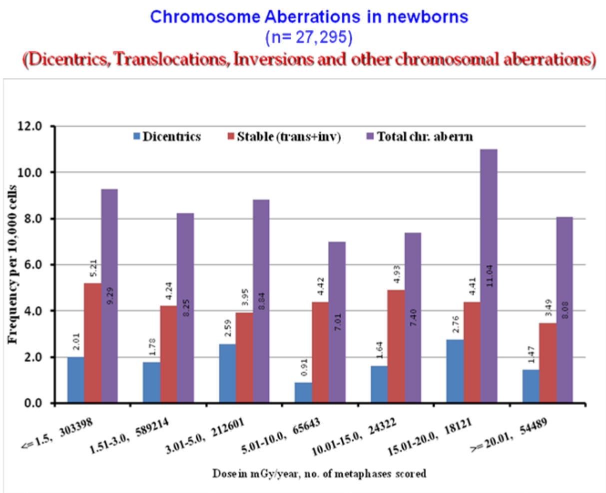


Fig. 6: Logistic regression of Congenital malformation

Basic Research

As mentioned in the beginning, all the success stories I have covered under the achievements of BMG are in the category of application oriented basic research. But all that work required a thorough grooming in basic research methodologies. Basic research in itself is very fascinating to most youngsters in biology. There is no denying that most of those who delivered either products or processes started by first evaluating the effects of radiation on the physiological phenomena of interest. To sustain their interest a variety of programmes in model organisms were undertaken, be it the bacterium *E. coli*, the most radioresistant microorganism, *Deinococcus radiodurans,* cyanobacteria, variety of plants or strains of mice and cell lines. The academically oriented projects were intended to address fundamental mechanistic questions on regulation of response to radiation, recombination in bacteria, photosynthetic regulation in plants, radiation response in animal systems and mechanism etc. In addition to recognition to individual scientists for reporting some of the observations for the first time, these efforts may as yet open up possibilities for useful deployment of technologies or products based on them. The programme on basic research in enzyme immobilization initiated in the early 1970s has now matured to the stage of development of biosensors for a pesticide and urea. Furthermore, these basic research programmes enabled our scientists to establish sensitive, state-of-the-art, high throughput techniques in our laboratories. These include establishment of facilities for genomics, proteomics, gene expression analysis, transgenics and gene cloning, knock-out and silencing, TEM and MALDI,

Transmission Electron Microscope

MALDI-TOF

Fig. 7: Basic Research Facilities

microarray, flow cytometry, confocal microscopy etc. (Fig. 7).

Our scientists have ventured into several areas in molecular biology and radiation biology like study of pathways of genetic recombination in *E. coli* or UV sensitivity in *Haemophilus influenzae*, responses to osmotic, salinity and oxidative stress in cyanobacteria, radiation resistance in *Deinococcus*, cyanobacteria and tumor cells, organization of multiprotein complexes in photosynthetic carbon fixation and DNA repair, redox regulation of radiation protection, apoptosis or programmed cell death in cancer cells as well as in bacteria, modification of tumor cytotoxicity by tumor microenvironment. They have identified many genes that regulate these processes. A proteomic map of *Deinococcus* after radiation exposure has been constructed. Several critical genes regulating DNA repair and radiation resistance in that organism have been identified. Evidence for the existence of a multienzyme photosynthon complex was gathered. Augmentation of cell mediated immune response was shown in low dose exposed mice but for the first time differences were also revealed based on the genetic background of the animals and the type of antigen and response (Table 3). Positive bystander effect of radiation exposure was demonstrated in lymphocytes for the first time and in other bystander systems the mechanism as well as factors mediating the same are being investigated. A host of naturally occurring substances including extracts of medicinal plants was evaluated for their antioxidant and radioprotective actions (Fig. 8). *E. coli* and *Deinococcus,* genetically engineered to express a phosphatase gene were shown to sequester uranium (Fig. 9). Molecular intricacies of radiation and chemical carcinogen induced signaling mechanisms were delineated. Some of these observations may lead to development of appropriate applications.

Table 3: Cell-mediated Immune Response

Type of immune response	In mice C57BL/6	In BALB/c mice
T lymphocyte proliferation by mitogen	↑	↓
Mixed lymphocyte reaction	↑	↓
T cell cytotoxicity	↑	ND
Delayed hypersensitivity to contact sensitizer	↓	↓
Delayed hypersensitivity to Mycobacteria	↓	↑
Apoptosis	↓	↑

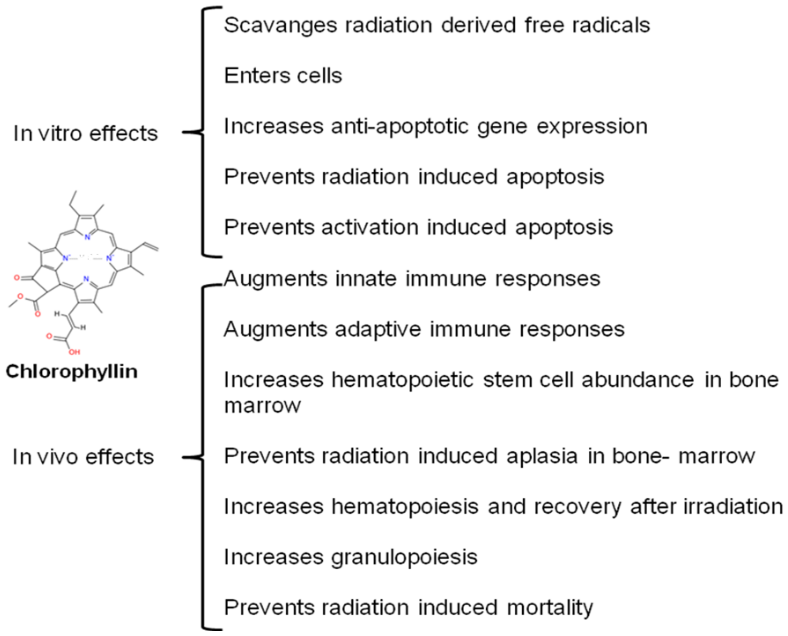


Fig. 8: Biological and Radioprotective Effects of an Antioxidant Chlorophyllin

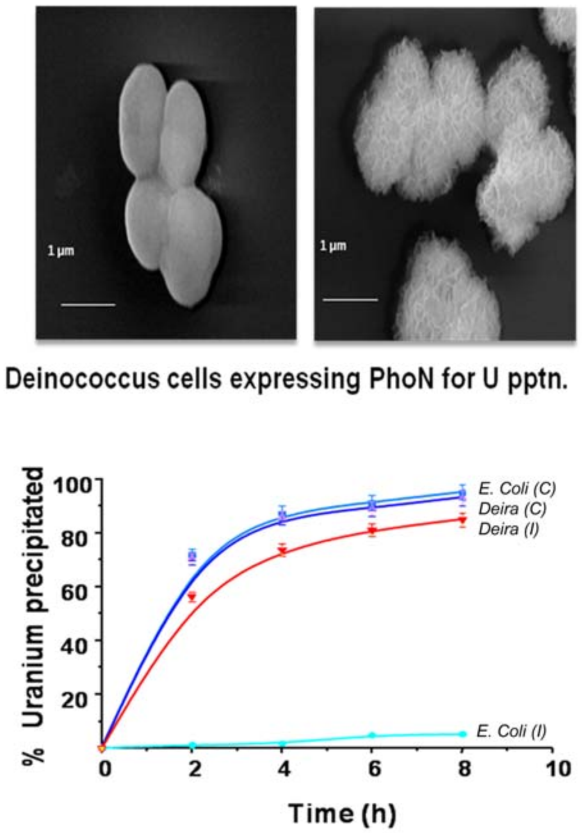


Fig. 9: Uranium precipitation by genetically engineered *E. coli* and *Deinococcus radiodurans*

I have always held the view that basic research is an essential component of a delivery oriented organization. Such an apparent dichotomy helps sustain the interest of creative scientists, facilitates peer recognition and also attracts young students which would later provide well-trained human resources for further development and deployment of technologies. Some of our scientists have been honoured with prestigious national awards (Bhatnagar prize and Young Scientists Medals), fellowships of National Academies as well as DAE's individual and group achievement awards. Therefore, in future too, at least some of our colleagues should continue to be involved in high quality basic research. BARC is one of the few organizations and rather a unique one in DAE system where the ability to undertake significant basic research coexists with the proven capability to deliver societally useful products and technologies. Sustaining the same balance is the most important challenge for the Bio-Medical Group researchers.

I wish to congratulate all those in BMG who have made possible this commendable progress and have played either pivotal or supporting roles in the outstanding achievements of the Group. I am sure that they will handle the newer challenges very confidently and competently.

Thermo-mechanical Behaviour of Coolant Channels for Heavy Water Reactors under Accident Conditions

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Abstract

The objective of nuclear safety research programme is to develop and verify computer models to accurately predict the behavior of reactor structural components under operating and off normal conditions. Indian Pressurised Heavy Water Reactors (PHWRs) are tube type of reactors. The coolant channel assemblies, being one of the most important components, need detailed analysis under all operating conditions as well as during postulated conditions of accidents for its thermo-mechanical behaviour. One of the postulated accident scenarios for heavy water moderated pressure tube type of reactors i.e. PHWRs is Loss Of Coolant Accident (LOCA) coincident with Loss of Emergency Core Cooling System (LOECCS). In this case, even though the reactor is tripped, the decay heat may not be removed adequately due to low or no flow condition and inventory depletion of primary side. Since the emergency core cooling system is presumed to be not available, the cooling of the fuel pins and the coolant channel assembly depends on the moderator cooling system, which is assumed to be available. Moderator cooling system is a separate system in PHWRs. In PHWRs, the fuel assembly is surrounded by pressure tube, an annulus insulating environment and a concentric calandria tube. In this postulated accident scenario, a structural integrity evaluation has been carried out to assess the modes of deformation of pressure tube – calandria tube assembly in a tube type nuclear reactor. The loading of pressure and temperature causes the pressure tube to sag/balloon and come in contact with the outer cooler calandria tube. The resulting heat transfer could cool and thus control the deformation of the pressure tube thus introducing inter-dependency between thermal and mechanical contact behaviour. The amount of heat thus expelled significantly depends on the thermal contact conductance and the nature of contact between the two tubes. Deformation of pressure tube creates a heat removal path to the relatively cold moderator. This in turn limits the temperature of fuel for a sufficiently long period and ensures safety of the plant.

The objective of this paper is to provide insights into this thermo-mechanical behavior by computational studies and to understand the role of underlying parameters (such as material constants, thermal contact conductance and boundary conditions) that control the tube deformation and further damage progression. The deformation characteristics of the pressure tube has been modeled using finite element based program. Experimental data of pressure tube material, generated for this research work, were used in modelling and examining the role of nonlinear stress-strain laws in the finite element analyses.

1. Introduction

At the current stage of the Indian nuclear programme, 220/540 MWe horizontal pressure tube type Pressurised Heavy Water Reactors (PHWRs) are under operation. The primary heat transport system consists of inlet headers from which coolant is fed to the channels in the reactor core through feeder pipes [1]. As the coolant flows through the core, it picks up heat generated in the fuel rods. The hot coolant from the outlet header passes through the steam generator, on the secondary side of which steam is generated. The cold heavy water comes to the other inlet header through the pumps. Coolant channels form heart of these reactors. It consists of a 5 meter long horizontal pressure tube surrounded by a concentric calandria tube [2]. Pressure tube housing the twelve natural uranium fuel bundles is rolled at both the ends to stainless steel end fittings. Material of these pressure tubes is autoclaved and 20% cold worked Zr-2.5Nb alloy. Close coiled helical springs spacers are provided around hot pressure tube to separate it from cold calandria tube so as to reduce heat loss to moderator.

During an accident in a water cooled reactor, the heat removal capability gets impaired resulting in overheating of the components. The Pressurized Heavy Water Reactors have engineered safety systems to restore the reactor to safe states in the event of accidents. Emergency Core Cooling System (ECCS) has been designed to remove the core heat in case of a postulated Loss of Coolant Accident (LOCA). In a postulated event of coincident LOECCS with LOCA, the reactor core gets overheated.

For some specific size of breaks, known as stagnant flow conditions, the system pressure may remain high during this period. During a LOCA with LOECCS, there is no cooling by ECCS. Hence heating of the core continues even at low/high pressure range, when the channels become fully voided. In this scenario, when the flow rate of coolant reduces drastically and the steam quality increases, the overheated clad transfers most of the heat generated to the pressure tube and eventually to cooler moderator at the outside of calandria tube. The mode of heat transfer in this process is predominantly radiation during the initial phase. Further rise in the temperature of the pressure tubes may lead to deterioration of its mechanical properties. This leads to large deformation of pressure tubes even at low stress levels. The heat transfer mode from calandria tube to the moderator is an important phenomenon governing the heat up rate of fuel, clad, pressure tube and calandria tube [3 - 4].

The coolant channel assemblies, being one of the most important components, need detailed analysis under all operating conditions as well as during postulated conditions of accidents for its thermo-mechanical behaviour. Focus of the present paper is on understanding the sagging/ballooning phenomena of a thin metallic tube under internal pressure and temperature transient and developing an efficient numerical model to predict the same. In case of two coaxial thin tubes, it becomes rather important to understand the role of thermal contact conductance at the interface for effective transfer of heat [5].

2. Material Characterisation

Pressure tubes are key class-1 components of the primary heat transport system [1]. Zr-2.5Nb alloy is widely used as pressure tube material for tube type nuclear power reactors cooled by heavy water (PHWRs) as well as boiling light water type Advanced Heavy Water Reactor (AHWR) [6]. Tensile properties of Zr-2.5Nb alloy significantly depend on the heat treatment. In India, for current generation reactors, we are using 20% cold worked Zr-2.5Nb alloy as pressure tube material. To simulate pressure tube sagging/ballooning phenomenon and subsequent contact with cooler calandria tube, flow behaviour of Zr-2.5Nb alloy was experimentally studied as a function of temperature. With this set of data, simplified analytical structural analyses as well as detailed finite element simulations were performed to visualise the thermo-mechanical behaviour of PT-CT assembly during a loss of coolant accident.

In order to carry out the above studies, the stress-strain-temperature behaviour of Zr-2.5Nb alloy, pressure tube material, was characterized by performing tensile tests at temperatures ranging from Room Temperature (RT) to 800 °C at a constant strain rate of 3.0E-4 per second. In addition, tensile tests were also carried out at higher strain rates of 0.003 and 0.03 sec^{-1} for the temperature range of 600 – 800 °C to understand the strain rate effect at high temperatures. Strain rate change tests for the range of strain rates (0.0003 – 0.03 sec^{-1}) were also carried out in the temperature range of 750 °C – 800 °C to examine the strain rate sensitivity of the material. Spool pieces of 250 mm length were cut from a full length pressure tube from three different locations - Back End (BE), Central Portion (CP) and Front End (FE) of the tube. Twenty-four sub-size tensile specimens of 25 mm gauge length conforming to ASTM standards E8-04 [7] and E21-05 [8] were machined from every spool piece with their axis parallel to the longitudinal direction of the finished pressure tube. These tests were conducted on a universal testing machine, fitted with a resistance type electric-furnace with automatic temperature controller.

Temperature dependency of the strength parameters in the temperature range of 25 °C to 800 °C is shown in figures 1 and 2. As illustrated in these figures, the variation of Yield Strength (YS) and Ultimate Tensile Strength (UTS) can be divided into three distinct temperature zones viz. zone–I (25 °C – 300 °C), Zone–II (300 °C – 600 °C) and Zone–III (600 °C – 800 °C). In zone-II, significant drop in strength parameters is observed at test temperatures in the range of 400 °C to 600 °C.

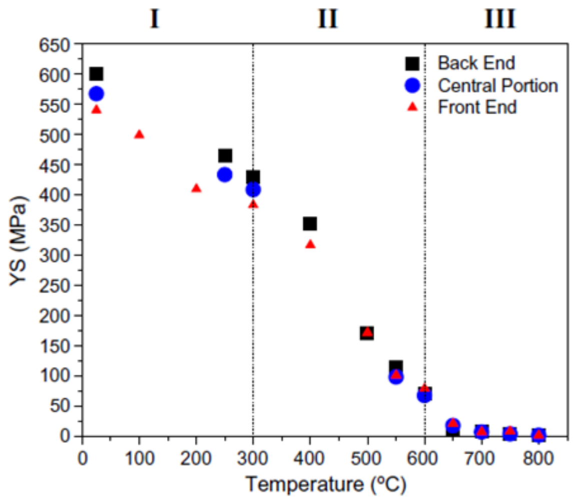

Fig. 1: Temperature dependency of YS of Zr-2.5Nb alloy PT material

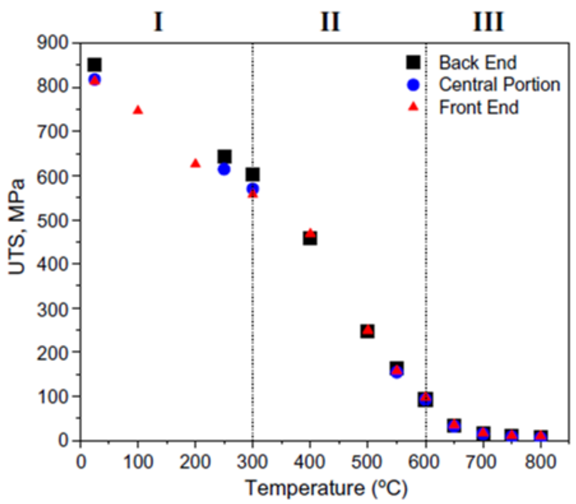

Fig. 2: Temperature dependency of UTS of Zr-2.5Nb alloy PT material

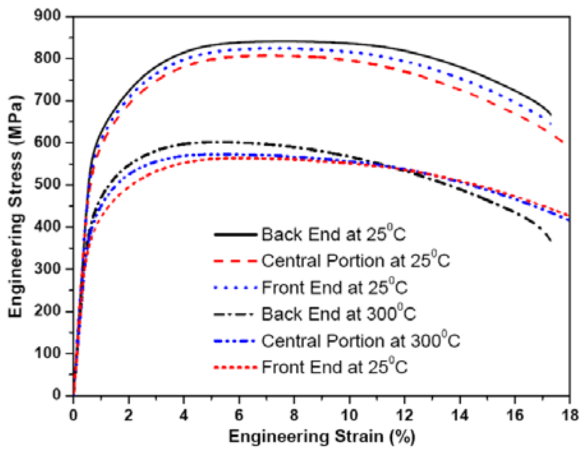

Fig. 3: Flow curves for Zr-2.5Nb alloy PT material up to operating temperature regime

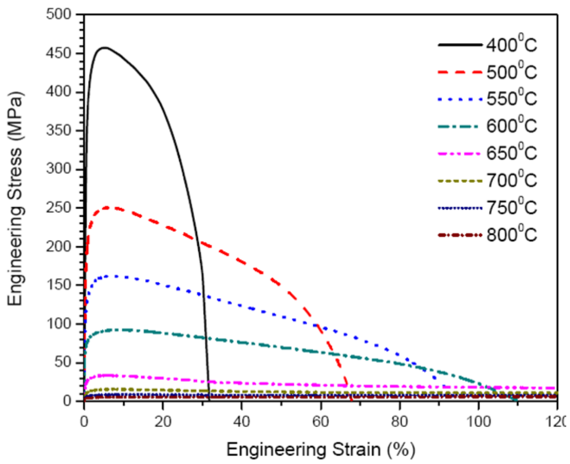

Fig. 4: Flow curves for Zr-2.5Nb alloy PT material at higher temperatures

Flow curves of the longitudinal specimens taken from three axial locations of the pressure tube are plotted for the temperatures of 25 °C and 300 °C (Fig. 3). The flow curves from the different locations are distinguishable in this zone.

Total elongation is almost same for all the three locations at 25 °C but, at 300 °C the difference in total elongation is observed among the samples from the three different locations. The total elongation of the samples increases from back-end to front-end of the tube, while YS and UTS decrease. Flow curves for test temperatures of 400 °C, 500 °C, 550 °C and 600 °C are shown in fig. 4. The flow curves obtained from the specimens of different locations are overlapping in this temperature zone and therefore representative flow curves have been plotted in figure-4. Fracture of the specimen had been observed at 600 °C even though the ductility exceeds 100%. Above this temperature, strains of the order of 700-800% were observed but none of the samples fractured. At temperatures greater than 650 °C, Zr-2.5Nb alloy represents superplasticity. During superplastic deformation, area reduces along the entire gauge length of the specimen instead of localized necking as shown in fig. 5. Grain boundary sliding is generally an accepted argument for superplastic behaviour [9]. Fitting of these tensile data into various constitutive relations [10] indicated that above 600 °C, these constitutive relations do not truly represent the material behavior. Hence actual true stress – true plastic strain data derived out of these experimental data has been used in the finite element modelling of PT.

3. Thermal Contact Conductance Characterisation of PT-CT interface

Thermal Contact Conductance (TCC) is one of the most important parameters in determining the temperature distribution in contacting structures. Thermal contact conductance between the contacting structures depends on the mechanical properties of underlying materials, thermo-physical properties of the interstitial fluid and surface condition of the bodies coming in contact [11]. An experimental facility was developed to measure thermal contact conductance between pressure tube and calandria tube specimens.

TCC of an interface can be measured in many ways. However, the most common among all is an axial heat flow apparatus [11]. In this arrangement, two cylindrical mandrels are placed end to end one above

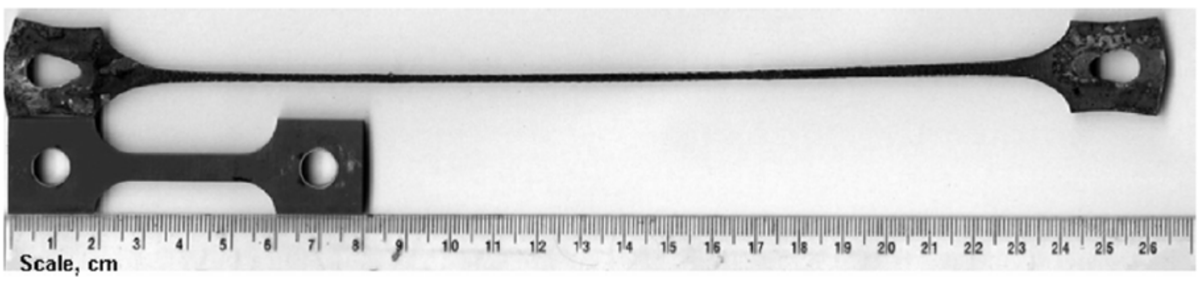

Fig. 5: Comparison of fresh test specimen and specimen tested at 750 °C

the other and the heat is allowed to flow along the axis of the cylinders as shown in the experimental facility arrangement of axial heat flow apparatus in figure-6. Experimental determination of thermal contact conductance between pressure tube and calandria tube specimens require thermal contact conductance of the individual specimens to begin with. Experiments were conducted with the specimens of individual material by varying the contact pressure and the heater temperature to increase interface temperature. Subsequently, experiments were conducted with the contact pair formed by combining the two individual material specimens. These specimens were tested at contact pressure of 1 to 10 MPa in steps of 1 MPa making it 10 experiments for each of the samples. The maximum contact pressure was limited to 10 MPa because the yield stress at 800 °C for Zr-2.5 Nb alloy pressure tube material is of this order. A plastically deforming material can apply pressure to a maximum extent of its yield stress. Determination of TCC for a combination of materials needs three sets of experiments.

These tests were conducted for four different interface temperature levels. In addition to this, initially, a few of the experiments were conducted to validate the experimental setup using stainless steel sample. In all the cases, temperature data for all the thermocouples were recorded with time for each combination of contact pressure and the heater temperature and these experiments were terminated after achieving steady state. The temperature data in each case (defined by specimen type, interface temperature and contact pressure) were processed to evaluate the thermal contact conductance. However, analysis of the data revealed that the value of TCC does not vary much in the studied range of interface temperature. This is in concurrence with the TCC values studied by Rao et al. [12], where they have shown that the TCC exhibits a week dependence on the mean interface temperature. In view of this and our own findings of invariance of TCC with interface temperature, only the contact pressure effect on TCC has been reported here.

Fig. 7 shows the variation of thermal contact conductance evaluated for calandria tube specimen as a function of contact pressure. It is clearly evident that the thermal contact conductance increases with the contact pressure. To empirically utilize this data for calculation of heat transfer, a linear fit has been worked out.

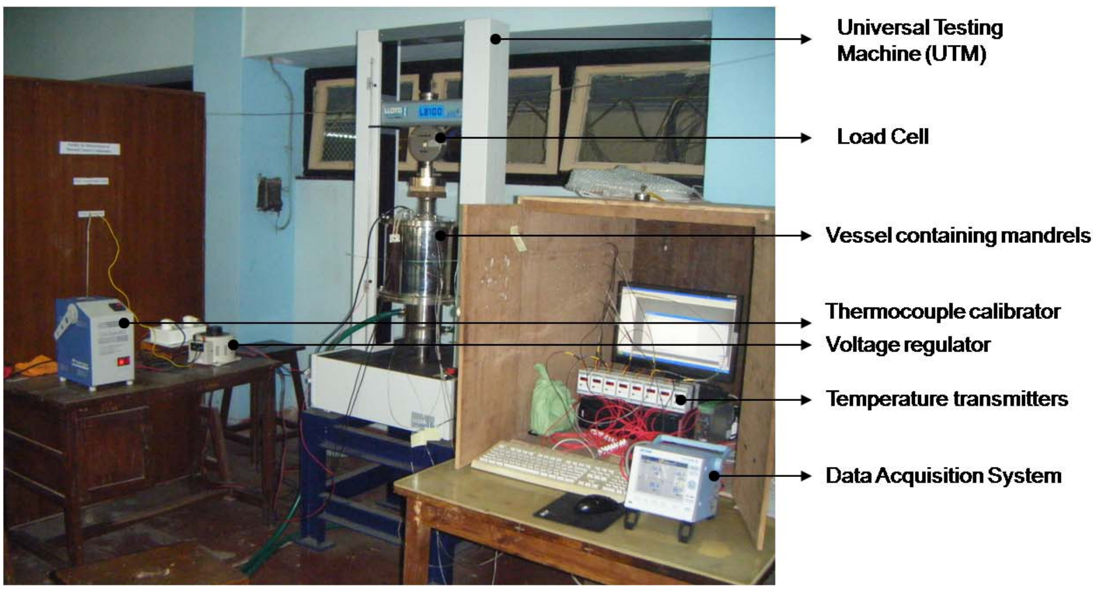

Fig. 6: Experimental facility to measure thermal contact conductance

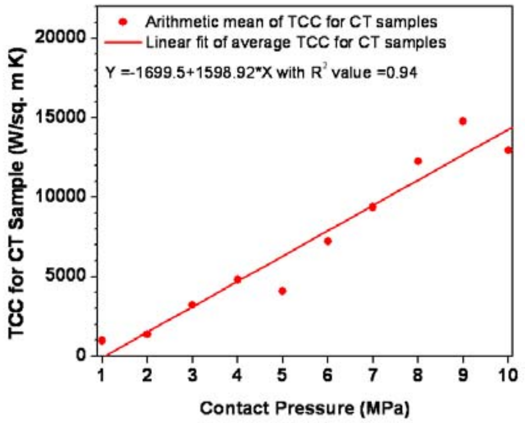

Fig. 7: Actual variation and linear fit of TCC for CT sample with contact pressure

Using the mean thermal contact conductance of individual specimens of the pressure tube and calandria tube for a given contact pressure, the thermal contact conductance of the combination of specimens of the pressure tube and calandria tube has been estimated from the recorded temperature data. The variation of thermal contact conductance values with contact pressure is found to have linear trend. These values of thermal contact conductance are of the same order as determined by Shoukri et al. [6] in their experiments involving contact between full scale pressure tube and calandria tube.

4. Model Validation using 2-D Finite Element Modelling

As the pressure tube-calandria tube assembly in a tube type heavy water nuclear reactor represent an assembly of two coaxial thin tubes. Out of these two tubes, the internal tube serves as pressure boundary and operates at higher temperature as well. In contrast, the outer tube is thinner as it operates at low temperatures and is subjected to only bending mode of deformation in horizontal reactors. In case of vertical coolant channel assemblies, it simply serves as thermal barrier between hot coolant and relatively cold moderator. In terms of structural mechanics, if the bending mode of deformation (Sagging) is less as compared to radial mode of deformation (Ballooning), we can utilize 2-D plane strain models to predict the modes of deformation of these two coaxial tube assembly. An experimental facility was built at Indian Institute of Technology, Roorkee, in collaboration with Reactor Safety Division, Bhabha Atomic Research Centre (BARC) and Board of Research in Nuclear Sciences (BRNS) [13]. The purpose of this facility was to study the ballooning/sagging deformation of the pressure tube-calandria tube assembly under high pressure and temperature condition expected during postulated accident conditions in a tube type nuclear reactor. The experimental setup consists of a single channel (pressure tube and calandria tube assembly) submerged in a large pool of water. The calandria tube was fully submerged in the water and was fixed to the tank at either side through specially designed flanges and packing. The pressure tube was concentrically placed inside the calandria tube. Both the ends of the pressure tube were supported on vertical metallic stands with one end as fixed support and other as floating end to allow for thermal expansion. As these tubes were pressurized using gas and were empty from inside, it is expected that the deformation due to self weight of these tubes would be insignificant. As these tubes are long as compared to its other dimensions, 2-D plane strain models would be sufficient to predict the ballooning mode of deformation of these tubes. In the above experiments, length of the pressure tube was 1 m. and was empty hence sagging mode of deformation is not expected. In view of the above, 2-D plane strain model was utilized to predict the time of contact. A quarter model of the tube with appropriate symmetric boundary conditions was utilised. Nodal temperatures were applied with time to estimate deformation of the tube.

Table-1 lists all the three cases for simulation. Based on the initial and final hoop stresses in the tube, the predominant mode of deformation mechanism was predicted. As in all the three cases operating stresses were well above the yield stress, plastic flow of the material would be the dominant mode of deformation.

Table 1: Initial and final hoop stresses in different cases of internal pressure

Pressure (MPa)	Maximum Temp (°C)	Initial Hoop Stress(Mpa)	Final Hoop Stress in case of contact (Mpa)	Yield Stress (Mpa)	Time of Super-plastic de formation (Secs)	Dominant mode of deformation mechanism (Plasticity/Creep)
2	740	24	35	4.5	~ 150	Plasticity
4	677	47	70	16	~ 140	Plasticity
6	640	71	106	18	~ 200	Plasticity

As plasticity is the predominant mode of deformation, flow curves for the PT material i.e. Zr-2.5Nb alloy, as reported in the section 2 were utilized. As ABAQUS [15] takes these material data in the form of true stress – true plastic strain, the experimental data was suitably converted. Figs. 8 and 9 represent radial deformation of the pressure tube at internal pressures of 2 MPa and 4 MPa respectively. These deformations were monitored at a particular node on outside diameter of finite element mesh of these pressure tube models.

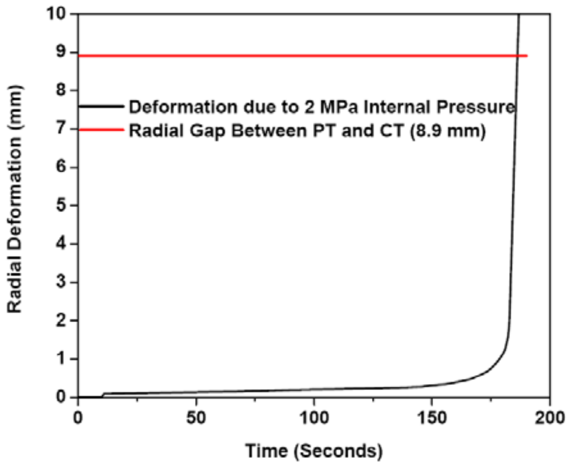

Fig. 8: Radial deformation of PT with time for 2 MPa internal pressure

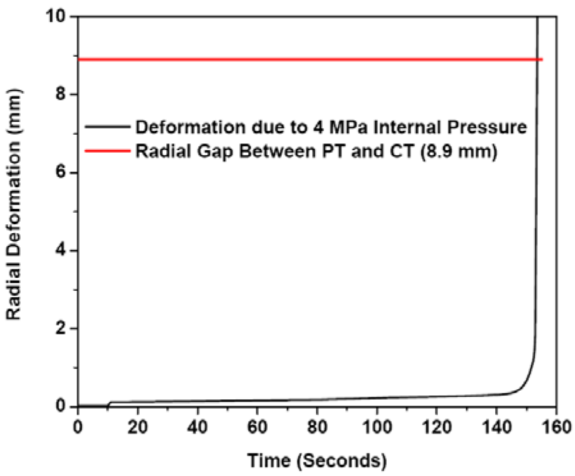

Fig. 9: Radial deformation of PT with time for 4 MPa internal pressure

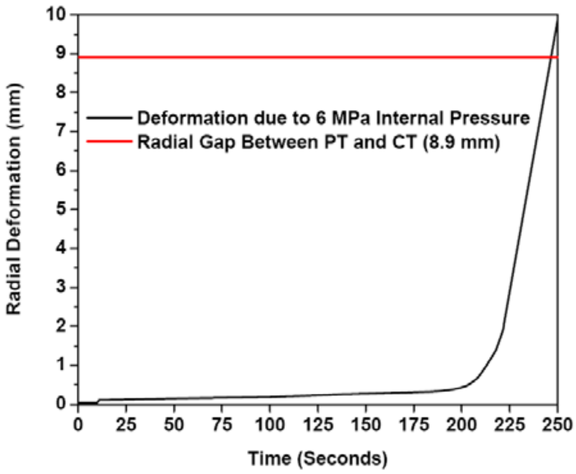

Fig. 10: Radial deformation of PT with time for 6 MPa internal pressure

As illustrated in figs. 8, 9 and 10, the radial deformation of the pressure tube keeps on increasing with time. The rate of change of outer diameter depends on the rate of heating. The radial clearance between PT and CT is 8.9 mm. As soon as the outer diameter of the pressure tube increases by 8.9 mm, the pressure tube is expected to touch the calandria tube by ballooning mode of deformation. This particular event is termed as initiation/onset of contact. The contact time for all the three cases, as predicted by numerical simulation, was compared with the experimental contact time and the same has been reported in table-2.

Table 2: Comparison of experimental and estimated contact time between PT and CT

Internal Pressure (MPa)	Experimental Contact Time (Seconds) [14]	Estimated Contact Time (Seconds)	Percentage Error
2	170	182.1	7.1%
4	185	153.5	-17%
6	275	246.5	-10.4%

Keeping in mind, the experimental variability in maintaining concentricity, measuring such high temperatures and finding the exact time of initiation of contact, the estimated time of contact through numerical model as shown in table-2, may be considered as fair estimates.

Once the hot pressure tube comes in contact with outer cooler calandria tube, the amount of heat transfer to the moderator would strongly depend on TCC [3]. A parametric study was done to understand the effect of TCC on calandria tube temperature as a function of TCC and time. Thermal contact conductance between PT and CT was varied over a range between 1000 W/sq. m °C to 10,000 W/sq. m °C to study its effect on the calandria tube temperature and eventually on the heat dissipated to the moderator. Figure 11 represents the variation in calandria tube temperature with time for two extreme cases of thermal contact conductances.

It is clearly evident that in case of low TCC, the calandria tube does not get heated and therefore would act as an insulator as far as distribution of heat to the moderator is concerned. Through the finite element simulations carried out in the earlier sections, it was found that the heat generated within the channel deforms the pressure tube by ballooning mode of deformation as long as the internal pressure stays to its initially applied values. However, the time required for onset of contact with the outer cooler calandria tube is a function of heat up rate of the pressure tubes. It has also been demonstrated that for higher values of thermal contact conductance, the calandria tube gets sufficiently heated up while for lower values the transfer of heat is minimal. It has been seen that for stagnant values of internal pressures, once the pressure tube makes contact with calandria tube, the contact remains intact and the loss of contact has not been observed.

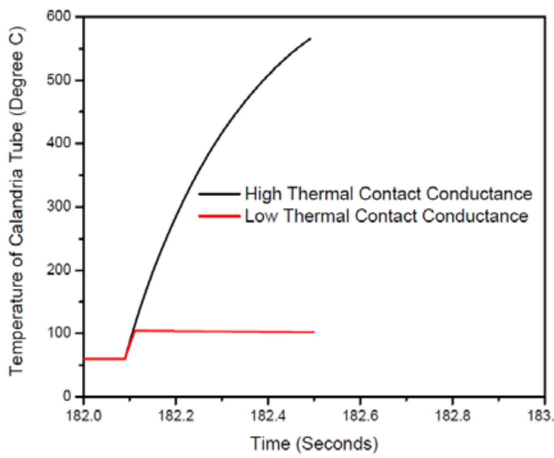

Fig. 11: Time-Temperature curve for contacting PT-CT for extreme cases of thermal contact conductance

5. Conclusions

1. PT-CT contact as a result of sagging/ballooning plays an important role in deciding the course of severe accident progression as the contact can increase the heat removal through PT to CT and finally to the moderator.
2. Pressure tube material parameters, up to 300 °C, behave linearly with temperature and axial locations along length of the tube.
3. The tensile flow curves of Zr-2.5 Nb alloy showed that above 650 °C, the material becomes superplastic
4. Thermal Contact Conductance (TCC) plays an important role in determining the overall temperature distribution in the bodies under

thermo-mechanical contact. In this particular case, the structural response of the PT would depend on the region of contact and TCC.

5. Experimentally determined thermal contact conductance for pressure tube-calandria tube combination showed linear dependence on contact pressure and was found to be weak function of interface temperature
6. Onset of ballooning of pressure tubes under internal pressure depends on the rate of heating and attaining temperature for superplastic deformation
7. For range of TCC studied for PT-CT contact shows that contact between PT and CT, once formed, remains intact.
8. A large deformation contact analysis using finite element technique has been attempted to capture complex interacting modes of deformation of two coaxial thin tubes using 2-D plane stain elements

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Radiotracer Investigations for Sediment Transport in Ports of India

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Abstract

The knowledge of mixing and transport of sediments in coastal region is of vital importance for evaluating suitability of dumping site for dredged sediments produced during maintenance of shipping channels, expansion of existing projects and construction of new projects. Gamma-emitting radiotracers are commonly used for investigation of movement of sediments on seabed using Scandium-46 (scandium glass powder) as radiotracer. The radiotracer is injected on seabed at a desired location and its movement followed over a period of time using waterproof NaI(Tl) scintillation detectors. The recorded data is analyzed to obtain transport parameters and utilized for assessing the suitability of the dumping sites and optimization of the dredging operations. About 70 large-scale investigations have been carried out in different ports in India leading to significant economical benefits to the Ports. Present paper discusses various aspects of the radiotracer technique for sediment transport, methodology of data analysis and a specific case study.

1. Introduction

India has a long coastline of about 7640 km, out of which 2650 km is on the East Coast and 3360 km on the West Coast, and the remaining is in different islands such as Andaman Nicobar, Lakshadweep etc. As compared to the West Coast, the East Coast faces severe wave climate and has relatively steep gradient with narrow continental shelf. There are twelve major ports, six on the West Coast and six on the East Coast of India. In addition to this, there are over one hundred and forty intermediate/minor ports and other marine engineering projects along the coastline. The locations of the major and intermediate size ports are shown in Fig.1.

The existing ports and marine engineering projects are faced with the problem of continuous maintenance dredging and dumping operations for maintaining the depth of the navigation channels. In addition to this, capital dredging is also carried out during the construction of the new projects and expansion of the existing projects. The average annual maintenance-dredging requirement in various major ports in India ranges approximately 5-25 million cubic meters. This huge quantity of the dredge material is to be disposed off at suitable offshore sites from where it does not find its way back to the channel. The selected sites should be such that the turn-around time of the dredger is kept minimal to economize the dredging operation. Therefore, a balance has to be struck between the cost of transport of the dredged sediments and the

Fig.1: Location of major and intermediate seaports of India

eventual return of the disposed material to the dredged areas.

Mathematical models with data inputs like bathymetry, waves, tides, currents, sediment parameters etc. are used to estimate the direction and transport parameters of sediments, and eventually select a suitable offshore site for dumping of dredged sediments. Mathematical models provide approximate information and have their own limitations. Therefore, the results of the mathematical models need to be validated before finalizing the selected site. In addition to this, the dredging and dumping operations may lead to various adverse impacts on the marine environment (turbidity, benthic deposits) and aquatic ecosystem. Therefore, the effect of dumping of dredged sediments needs to be evaluated, which in turn requires knowledge of dispersion pattern of dredged sediments and transport parameters of the sediments prior to the operation.

In such situations, radiotracer techniques are most suitable alternatives to study dispersion of sediments, evaluate suitability of dumping sites and estimate sediment transport parameters such as transport velocity, transport thickness and rate of bedload movement. The investigations are carried out during pre or post monsoon seasons and at different tidal conditions depending upon objectives. In India, the application of radiotracer technique to study the movement of sediment on seabed started way back in 1959 and since then numerous large-scale investigations have been carried out in various Ports in India (1-7). Present paper briefly discusses various aspects of the radiotracer technique used for sediment transport investigation and analysis methodology with a specific case study carried out recently in Hoogly estuary, Kolkata Port, West Bengal.

2. Radiotracer Technique

The radiotracer technique for sediment transport investigation involves preparation of a radioactive particulate tracer having similar physical properties (density, particle size distribution) as the bed material, injection of the tracer at the desired point onto the seabed, tracking of the tracer with underwater nuclear detectors and finally interpretation of iso-activity contours to estimate various sediment transport parameters as mentioned above. The details of the technique are discussed below.

2.1. Radiotracer

Radiotracers offer many advantages such as high detection sensitivity, in-situ detection, physical compatibility, ability to withstand harsh conditions, easy applicability and low cost over conventional tracers. The selection of a suitable radioisotope to be used as a radiotracer in a particular investigation depends upon half-life, type of radiation emitted and its energy, ability to be produced in a suitable physical form, neutron absorption cross-section and radiotoxicity. The selected radioisotope should be amenable to be incorporated in a suitable physical form having similar physical characteristics to that of the sediment being traced. The half-life of the radiotracer should be comparable to the duration of the study. It should be long enough for detection till the end of the experiment and at the same time short enough not to interfere with further experimentation and pose environmental hazards. For *'in situ'* measurements, gamma emitting radioisotopes are used. The energy of the gamma radiation should be sufficiently high to penetrate through the wall of the system for *'in situ'* detection. Lower energy gamma emitting tracers are, on the other hand, easier to transport in view of their modest shielding requirement. The neutron absorption cross-section of the selected isotope should be reasonably high to produce the desired amount of activity. In addition to this, the tracer should have low values of annual limit of intake (ALI) or derived air concentration (DAC). Based on the above consideration, the most commonly used radioisotopes in sediment transport investigations are given in Table 1. The amount of activity required

Table 1: Commonly used radioisotopes in sediment transport investigations and their nuclear properties

Radionuclide	Half-life (Days)	Gamma Energies (MeV with abundance)	Tracing of
Scandium-46 (Sc-46)	84	0.887 (100%), 1.119 (100%)	Mud and Sand
Iridium-198 (Ir-198)	74	0.317(100 %), 0.317(80%), 0.568(48%), 0.589(4.8%) 0.604(9.3 %), 0.612(6.3%)	Sand
Gold-198 (Au-198)	2.7	0.412 (100 %)	Mud and Sand
Chromium-51(Cr-51)	27.8	0.325 (9 %)	Mud and Sand
Tantalum-182 (Ta-182)	115	0.068 (42%), 1.12 (34%)1.22 (56%)	Sand
Silver-110 (Ag-110)	253	0.658 (94%), 0.884 (72.5%) 0.94 (34%), 1.4 (24%)	Pebbles
Indium 113 (In-113)	0.07(1.7 hours)	0.39 65%), 0.24 (20%)	Bed material in hydraulic models

for a sediment transport investigation mainly depends upon efficiency of the detector used for detection, expected spread and loss due to burial, the level of natural radiation level on the sea bed and duration of the study. In India, Scandium-46 as scandium glass powder (200-300 gms) is used with activity ranging from 2-8 Ci depending upon the spread and type of investigation.

2.1.1. Surface Labeling

In this method, the natural sediment is labeled with the selected radioisotope. The selected radioisotope is allowed to get adsorbed onto the surface of the sediment grains after a suitable treatment. Sediment with particle size less than 0.04 mm should be labeled under careful conditions in order not to modify the surface properties and thus their hydrodynamic behavior. Care should be taken to ensure that the radioactivity does not get released under the severest field conditions. The labeling is superficial and hence the activity labeled will be proportional to the surface area of the grains. Gold-198 (Au-198) and Scandium-46 (Sc-46) are the two commonly used radioisotopes used for labeling particulate material and use the labeled material as a tracer. The half-life of Au-198 is 2.7 days and thus is used for short term studies whereas the half-life of Sc-146 is 84 days and thus is used for long term investigations (8).

2.1.2. Mass labeling

In this method, a artificial tracer having the similar physical characteristics as the sediment is prepared. It is usually a glass containing about 1% or less of an activable element like Scandium or Iridium (9). The composition of the glass used in India is as follows: SiO_2=64 %, Na_2O= 18.6%, CaO=15.9%, Sc_2O_3=1%. It is ensured that the Sc_2O_3 is uniformly distributed within the glass matrix during production. The prepared glass having the same density (density: 2.67 gm/cm^2) as that of the sediment is ground and mixed in suitable proportions to have the same grain-size distribution as the natural sediment and irradiated in a nuclear reactor to obtain the radioactive tracer (Scandium-46). Since the activable element has been incorporated in the volume of the tracer, the activity of the radiotracer is proportional to that of the mass of the tracer. The prepared radiotracer is transported to the experimental site in a lead container as shown in Fig.2.

Fig. 2: Lead container used for transportation of radiotracer

Fig. 3: Radiottracer injection system

2.2. Background Survey

Prior to the injection of the radiotracer onto the seabed, an extensive background survey is carried out to monitor the natural radiation levels in the area of expected spread of injected radiotracer using a waterproof scintillation detector mounted on a sledge connected to ratemeter/scaler on board the ship as shown in Fig. 4. The background radiation levels may vary from site to site. However, the levels in a particular site are expected to be constant.

2.3. Injection of Radiotracer

The radiotracer is injected into a suitably selected location on to the seabed using a specially designed injection apparatus. In different countries different types of injection systems are used. The injection system used in India is shown in Fig. 3. The system consists of a steel drum pivoted inside an open-bottomed skirt frame. The drum is about 30 cm diameter and has got one side open, with a closing lid which can be fastened by tension springs. The lid is hinged on one side and will open if springs on the other sides are released. A pneumatic actuator with suitable connections for air/nitrogen sully is fitted inside the drum. The lid is kept in the closed position before operation. There is a small opening on the center of the lid, which can be closed remotely. The tracer container made of brass and having a graphite lid is removed from the lead container and is introduced to the injection drum through the small opening on the lid with graphite lid facing down. The door of the small opening is closed breaking the graphite lid as it gets pressed against a spike. The radiotracer falls into the drum containing 2-3 kg of native sand. The radiotracer is mixed with the sand by oscillating the drum on the stand with a long handled tool. After mixing, the drum is now locked in position with cover facing down. The injection apparatus is lifted using a derrick or small crane available on board and lowered onto the seabed. Subsequently the lid of the drum is opened pneumatically injecting the radiotracer onto the seabed. Then the injection apparatus is pulled up leaving the material on the seabed.

2.4. Detection of Radiotracer: Post Injection Trackings

Radiation detection system similar to that used in background survey and shown in Fig. 4 is used for monitoring of radiotracer concentration on seabed during post-injection trackings. In short term studies

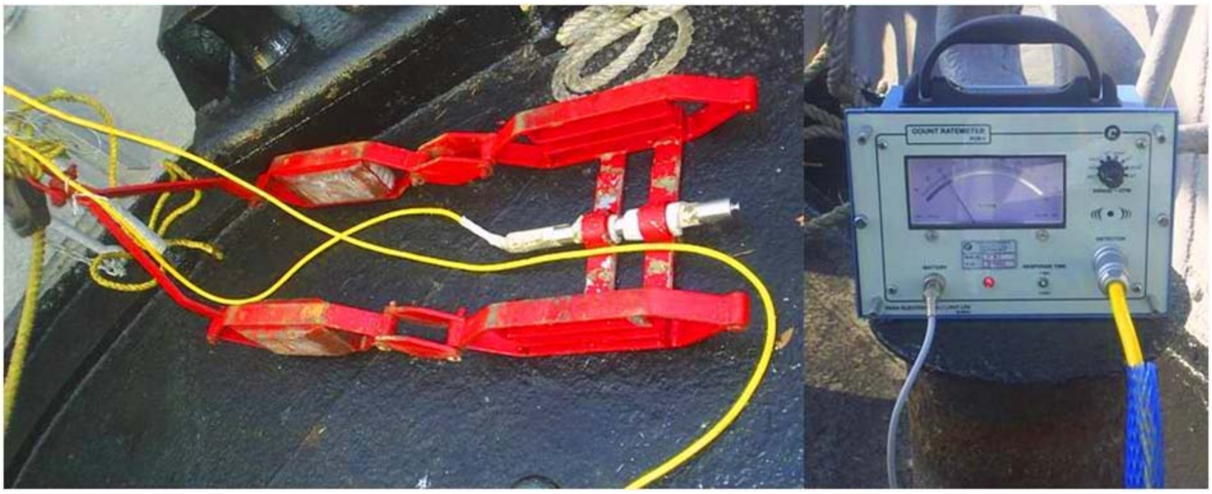

Fig. 4: Sledge mounted with a radiation detector and ratemeter used for monitoring of radiotracer

the tracking is carried out immediately after injection of tracer depending upon the tidal, wave and current conditions. In short term studies where the currents are very strong, it is recommended to track the tracer simultaneously at different locations. However, for long-term studies, a detailed post injection-tracking programme is chalked out depending upon the tide and wave conditions and half-life of the tracer. The duration of the tracking depends upon the extent of spread. In case of Scandium-46 as tracer and long term investigations, 3-4 post injection trackings are carried out. The first post injection tracking is carried out after a few hours of injection allowing the tracer to spread sufficiently with the tide. For monitoring the labeled sediment, the scintillation detector is mounted on a sledge and dragged on the seabed. The concentration at different spatial locations i.e. latitude and longitude is measured and noted. The tracks of the survey vessel are fixed using a Differential Global Positioning System (DGPS) available onboard. The obtained radiotracer data is corrected and analyzed to draw necessary information.

2.5. Radiological Safety Aspects

The use of radiotracers requires trained manpower and approval from competent authorities because of associated radiation hazards. Necessary approvals for safe transport of radiotracer to the experimental site and amount of radiotracer to be used in the investigation are obtained from National Regulatory Authority i.e. Atomic Energy Regulatory Board (AERB), Mumbai. The safety regulations include justification of the use of radiotracer, optimization of radiation exposures and annual dose limits in order to prevent unnecessary exposures. The justification implies that the competent authority should not allow the use of radiation unless there arises a net positive benefit from its use. Necessary radiological safety surveillance is provided by a Health Physicist or Radiological Safety Officer (RSO) accompanying the tracer team. The design of a radiotracer experiment has to ensure optimization of radiation exposures. The members of the investigating team should be suitably qualified and trained to handle radiotracers. All the necessary steps are ensured to keep all the radiation exposures to as low as reasonably achievable (ALARA). The general guidelines for safe handling of radioisotopes issued by International Commission on Radiological Protection (ICRP) and AERB are followed during the investigations (9).

3. Data Analysis

The tracer concentration data recorded at discrete locations around the injection point on the seabed during each tracking is corrected for natural background levels and radioactive decay and iso-activity contours are plotted. From the contours, qualitative information such as general direction of movement, extent of lateral and axial movement are obtained. Following parameters are obtained from analysis of the iso-activity contours.

3.1. Transport diagram and velocity

For estimating the transport velocity of bed load, the cumulative counts multiplied by lateral distance of spread (cpm x m) perpendicular to the general axis of transport along the general transport axis is plotted for each tracking. These diagrams are called transport diagrams and each is characterized by its center of gravity. Center of gravity ($\bar{X}$) is determined by the following formula (10):

$$\bar{X} = \frac{\int C.Xdx}{\int C.dx} \qquad (1)$$

where, C and X are count rate and distance, respectively. From the shift in the centre of gravity of the two consecutive trackings, the mean velocity of the transport is estimated.

3.2. Transport Thickness

The determination of transport thickness is based on the count rate balance. As bed-load moves, the tracer gets mixed within the thickness of the moving bed. This depth of tracer burial is called "transport-thickness". The total integrated count rate N (cpm x m^2) over the whole surface area of tracer patch for each tracking is related to the transport thickness by (10):

$$N = \frac{\beta KA}{\propto E}(1 - e^{-\propto E}) \qquad (2)$$

where, K is the calibration factor of the detector (122 cpm/kBq/m^2), A is the total activity injected (300 GBq), α is the attenuation coefficient which is a characteristic of the isotope, bed material and geometry of detector (15/m for Scandium-46), E is the transport thickness (m), β is a function of transport thickness and the shape of distribution of tracer concentration with depth.

3.3. Transport Rate

The bed load transport rate Q (Kg /day) can be expressed as (10):

$$\boldsymbol{Q = \rho.l.V.E} \qquad (3)$$

Where, ρ is the sediment bulk density (1500 Kg/m^3), l is the width of transport (m), V is the mean velocity of transport (m/d).

4. A Case Study: Radiotracer Investigation at Kolkata Port, Kokata

Kolkata Port is the oldest and the only riverine port in India. Despite being 200 Km away from the sea, the port is the best choice for eastern gateway to India. The Kolkata Port comprises of two major dock systems i.e. Kolkata Dock System (KDS) and Haldia Dock Complex (HDC). Both the Dock Complexes are equipped with all the major and modern facilities and offer good services to its customers. In order to facilitate shipping, the bars and other locations in the shipping channels are dredged throughout the year to maintain navigable depth. Recurring siltation of shipping channels and; dredging and disposal of huge quantities of dredged materials (25 million cubic meters per annum) is a serious problem in Kolkata Port, limiting the navigation of large ships and hence affecting the revenue. The dredged material is dumped at suitable offshore locations based on inputs from various studies. The locations are selected in such a way that the turn-around time of dredger is kept to a minimum. The previous practice of dumping the material in deep pockets inside the estuary could no longer be continued due to shoaling of all such pockets. Presently the dredged material is dumped at sea-face to allow the sediments to be taken into the deep bay. Since such dumping is carried out during flood as well as ebb tides, it was suspected that some of the dredged sediments might be returning back to the estuary during the flood tide.

A radiotracer investigation was carried out to study the dynamics of sediments dumped at one of the newly selected locations in Hooghly Estuary near Sagar Island, to evaluate its suitability for dumping of the dredged sediments produced during maintenance dreading. The location map showing the experimental site is given in Fig.5. The investigation was carried out using Scandium-46 (300 GBq) as Scandium glass powder having the particle size distribution ranging from 40-100 microns as radiotracer. The tracer was injected onto the seabed at the site using a remotely operated injection system and its movement was tracked using waterproof scintillation detector over a period of 62 days and schedule of each tracking is given in Table 2. The iso-activity contours of four different trackings are shown in Figs. 6-10, whereas the transport diagrams are shown in Fig.11. The transport parameters for different trackings were estimated as per methodology described above and are given in Table 3.

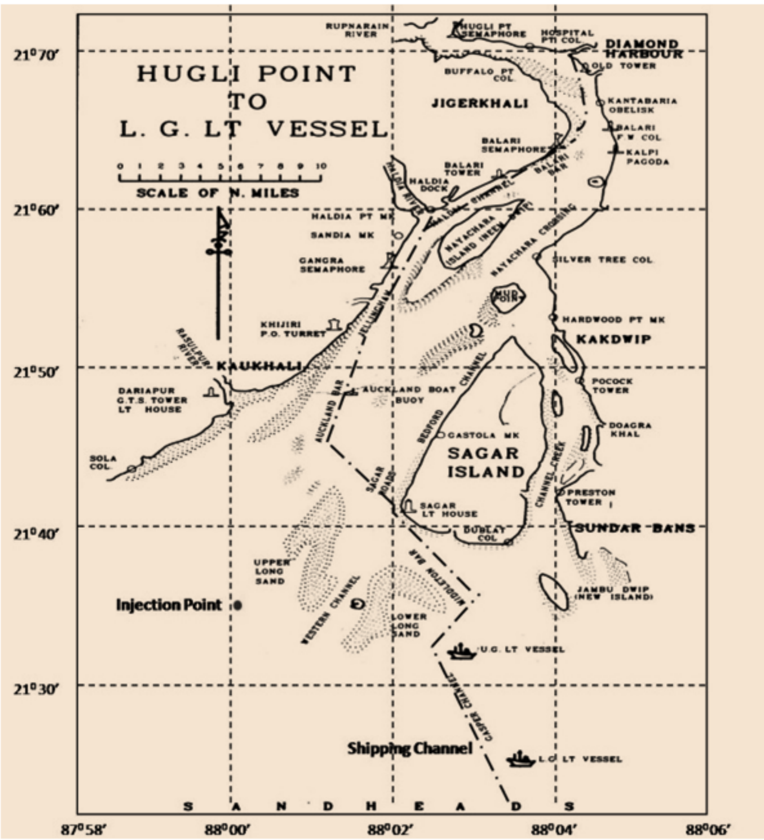

Fig. 5: Study area at Kolkata Port, Kolkata

Table 2: Schedule for post injection trackings

Sr. No.	Tracking no.	Tracking period	Days after injection
1.	Tracer injection	January 9, 2012	—-
2.	1st Tracking	January 10, 2012	1
3.	2nd Tracking	January 22-24, 2012	13
4.	3rd Tracking	February 13-15, 2012	35
5.	4th Tracking	February 28-29, 2012	50
6.	5th Tracking	March 12-13, 2012	62

Table 3: Results of sediment transport investigation

Sr. No.	Days after injection	Location of C.G (m)	Activity spread N(cpm.m^2)	% Activity recovered	Vm (m/d)	E (cm)	Q (T/d/m)
1	1 (1st Tracking)	1870	2.05×10^{10}	51.2	—	—	—
2	13 (2nd Tracking)	5218	4.4×10^{10}	97.5	279	0.3	0.6
3	35 (3rd Tracking)	8181	3.78×10^{10}	93.75	135	0.8	1.7
4	50 (4th Tracking)	9028	2.9×10^{10}	72.0	56	3.6	3.0
5	62 (5th Tracking)	10160	2.57×10^{10}	64.2	95	4.7	6.7

Based on the results of the radiotracer investigation carried out, following conclusions were drawn about the movement of sediments:

- The sediments predominantly moved towards North-East direction during all the five post injection trackings as compared to the South-West direction.

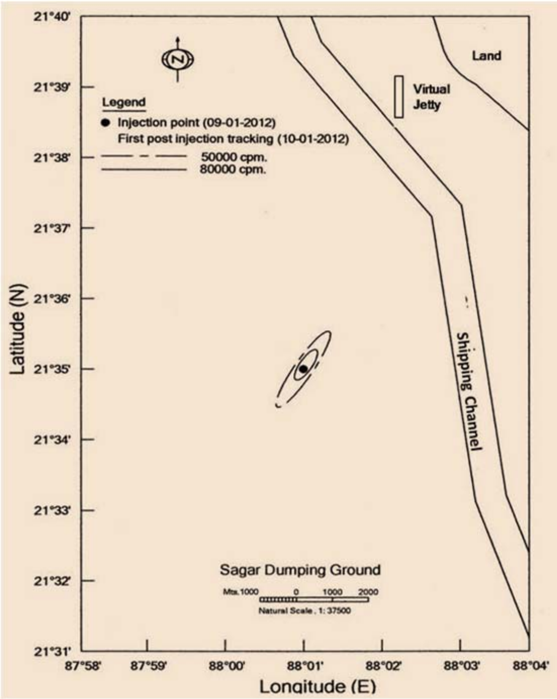

Fig. 6: Iso-activity contour of first post-injection tracking

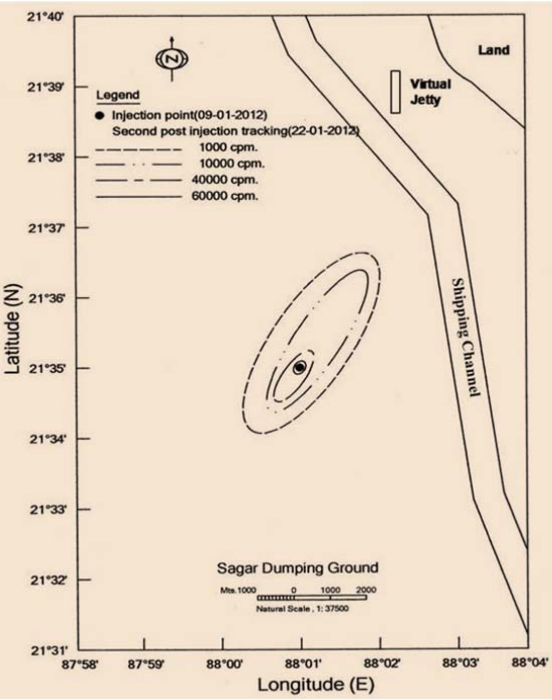

Fig. 7: Iso-activity contour of second post-injection tracking

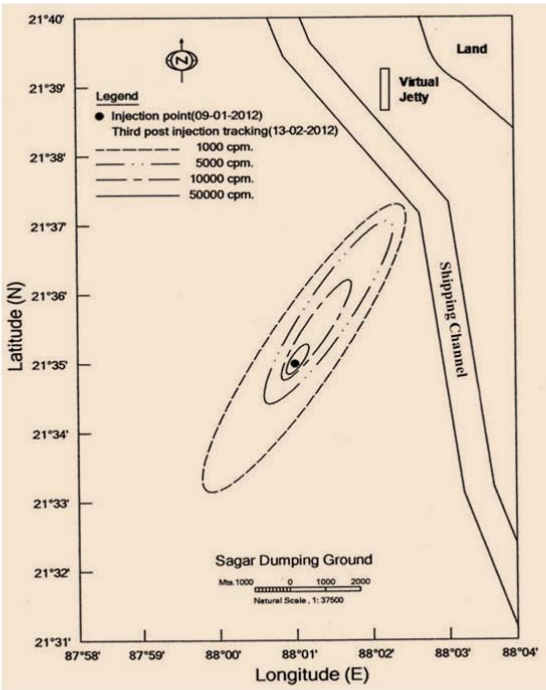

Fig. 8: Iso-activity contour of third post-injection tracking

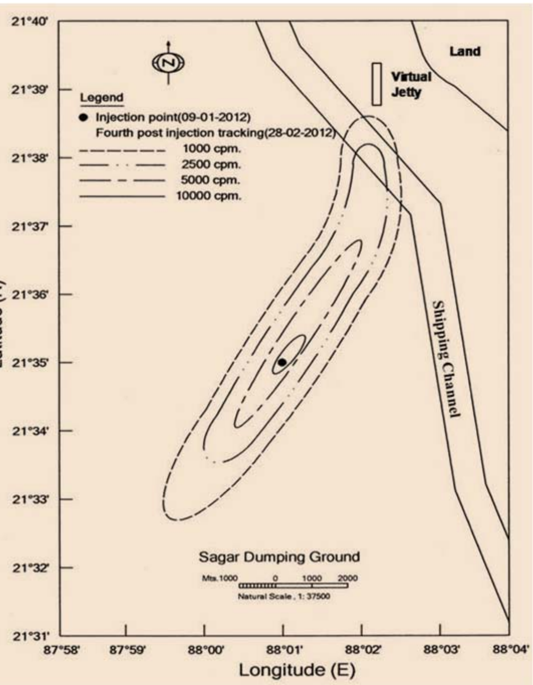

Fig.9: Iso-activity contour of fourth post-injection tracking

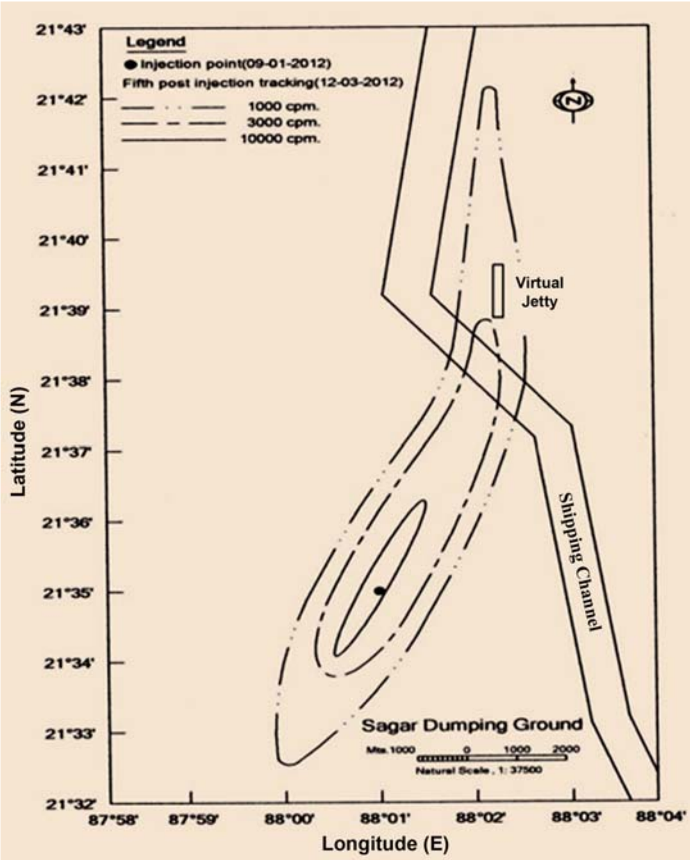

Fig. 10: Iso-activity contour of fifth post-injection tracking

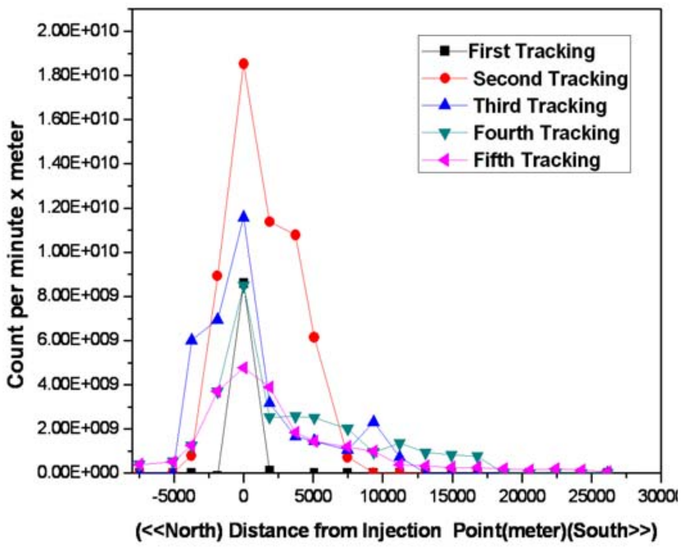

Fig. 11: Transport diagram of post injection trackings

- The sediments moved into the shipping channel after 50 days of injection of radiotracer and subsequently has tendency to move towards North direction parallel to the channel.
- The sediments dispersed about 13000 meters (13 km) in longitudinal direction and about 4500 meters (4.5 km) along transverse direction after 62 days.
- The mean velocity of sediment transport, transport thickness and quantity of sediment transported over a period of 62 days from time of injection were found to be 141 meters/day, 2.35 cm and 3 tons/day/meter.
- Based on the radiotracer investigation conducted, it is concluded that the proposed dumping site is not suitable for dumping of the dredged material produced during maintenance dreading during season January-March as the dumped material will its way into the shipping channel.

Similar investigations as discussed above have been successfully carried out recently in Kandla, Cochin, New Mangalore and Vishakhapatnam Ports. About 70 large-scale radiotracer investigations have been carried out for investigating sediment transport in various ports in India since 1959. In Hoogly estuary, Kolkata Port alone, twenty investigations have been carried out since 1961.

5. Conclusions

Radiotracer techniques have been extensively applied in most of the major ports in India for evaluating the suitability of the dumping sites, optimizing the dredging and dumping operations, selecting suitable alignments for navigation channels, implementation of the River Regulatory Measures and environmental regulations; and investigation of littoral movement of sediment along the coast leading to huge economical benefits to the end-user industries. The cost to benefit ratio has been estimated and found to be ranging from 1:150 to 1:200 (2). However, the cost to benefit ratio would be much higher, if long term savings due to infructuous expenditure are considered. The investigations have been conducted with utmost care and safety precautions following the ALARA principle. No untoward incidence and case of over exposure of radiations to the personnel involved has occurred or reported in any of the investigations carried out so far. In addition to this, there has been no radiation exposure to members of the public and adverse impact on environmental during any of the radiotracer investigations carried for sediment transport in India.

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Continuous, solvent free, high temperature synthesis of ionic liquid 1-butyl-3-methylimidazolium bromide in a microreactor

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Abstract

In this work, feasibility of continuous, solvent free high-temperature synthesis of an imidazolium-based ionic liquid 1-butyl-3-methylimidazolium bromide ([BMIM][Br]) in a microreactor is explored. [BMIM][Br] could be produced continuously at 120^{0}C. Effects of residence time, reaction temperature and feed molar ratio on space time yield are studied. Maximum space time yield obtained is 506 kgs/lit-day, which is much higher compared to space time yield reported in conventional batch synthesis.

1. Introduction

Ionic liquids (ILs) has been an arena of intense research in the recent past. ILs have intrinsic ionic conductivity at room temperature, offer a wide electrochemical window, and are non-volatile. Their chemical and physical properties can be readily adjusted by selection of suitable cation and anion. ILs find numerous applications as novel solvents in organic synthesis, catalysis, and electrochemistry. Several studies reported in literature suggest potential applications of ionic liquids in nuclear fuel cycle1,2. Synthesis of imidazolium based ionic liquid usually involves a highly exothermic and fast alkylation reaction. In batch synthesis a solvent has to be used to ensure low operational temperature to avoid thermal degradation of the product. Use of solvent, however, reduces reaction rate. For example in the synthesis of 1-butyl 3-methylimidazolium bromide ([BMIM]Br), time required for complete conversion is reported to be more than 50 hours3. Additionally, solvent needs to be separated to get a pure product. Several studies on solvent free continuous synthesis of ionic liquids in miniaturized or microreactors have been reported 4,5. Microreactors are extremely useful for continuous, solvent free and high temperature synthesis of ionic liquids due to high surface to volume ratio ensuring intensified heat transfer. This preempts the possibility of thermal degradation of the product if wall temperature is controlled. Also this obviates the need of using a solvent to prevent thermal runaway.

In this work, we report continuous solvent free high temperature synthesis of 1-butyl-3-methylimidazolium bromide ([BMIM]Br) (Fig .1) in a microreactor. The heat of reaction is -96 kJ/mol. The study consists of three parts. In part-1, feasibility of continuous solvent free synthesis of [BMIM] Br is demonstrated. In part-2, parametric studies to quantify the effects of reaction temperature, residence time, and feed molar ratio on yield are reported. In the part-3, the different combinations of residence time and temperature are tried to find out the maximum space time yield possible with the microreactor.

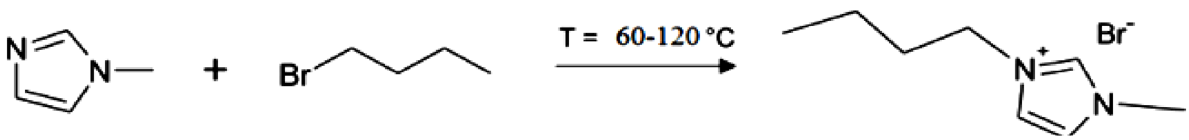

Fig. 1: Reaction for synthesis of 1-butyl-3-methylimidazolium bromide ([BMIM]Br)

2. Experimental Procedure

2.1 Chemicals

The reactants, 1-bromobutane (purity > 99 %) and 1-methylimidazole (purity > 99 %), were purchased from Merck. The reactants were used directly without any further purifications.

2.2 Experimental Setup

Schematic diagram of the experimental setup and microreactor are shown in Fig. 2. Two positive displacement pumps (0-10 ml/min flow rate range) feed reactants to the microreactor. The product from the microreactor is collected in a bottle kept in an ice bath to quench the reaction. Residence time, reaction temperature and feed molar ratio are varied to study their effect on yield. Residence time is varied by varying the flow rate. The microreactor used in this study has serpentine microchannels etched in glass chip. The volume of the microreactor is 250μL. Out of the three inlets of the microreactor, only two are used in the present study and the third one is kept closed. The microreactor is mounted on a hotplate to maintain reaction temperature.

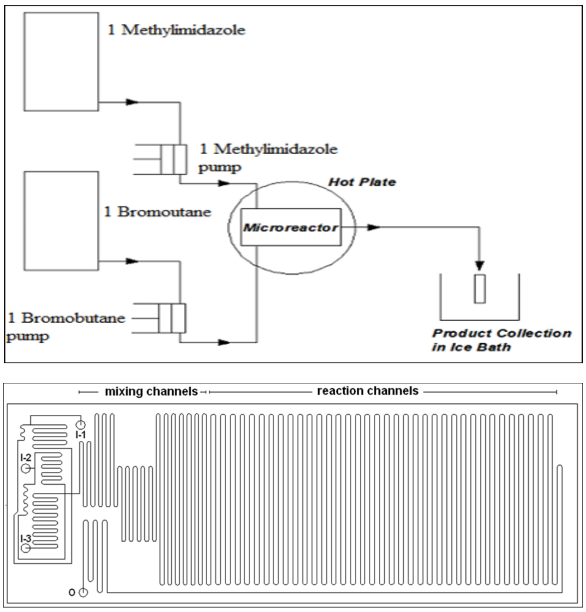

Fig. 2: Schematic diagram of the experimental set up and microreactor

2.3 Analysis

The yield of the synthesized ionic liquid [BMIM] Br is evaluated using Volhard titration (for the estimation of Br- ion). The presence of [BMIM]Br in the product obtained in the part-1 of the study is confirmed using a proton NMR spectrum.

3 Results and Discussion

3.1 Demonstration of Synthesis of [BMIM]Br in the Microreactor

Reaction was carried out at two different temperatures of 90^{0}C and 120^{0}C, by keeping the residence time (500 sec) and reactant feed molar ratio (1.2) constant. Unreacted 1-bromobutane phase was at the top of the collected sample due to the density difference and was discarded. The bottom layer was analyzed. Yield was found to be 53% and 72% at 90^{0}C and 120^{0}C respectively. To get the pure product, ionic liquid phase was washed thrice with hot ethyl acetate to remove any unreacted 1-methylimidazole. Then the product was evaporated under vacuum to remove any volatile impurities and thereafter, kept at 10^{0}C for overnight. This process yielded a solid product of [BMIM]Br. The observed m.p of the product 65-70^{0}C, is very close to the value reported for pure [BMIM]Br. Proton NMR spectrum of the product (Fig. 3) confirms the formation of the desired product [BMIM]Br.

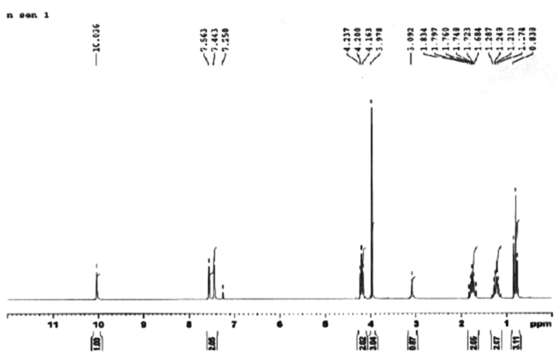

Fig. 3: Proton NMR spectra of the product synthesized in microreactor at temperature of 90^{0}C

3.2 Parametric Studies

Parametric studies are carried out to find out the effects of residence time, reaction temperature, and feed molar ratio on yield. One parameter is varied at a time by keeping the other two parameters constant. Fig. 4, Fig. 5 and Fig. 6 show the variation of yield with reaction temperature, residence time, and feed molar ratio, respectively.

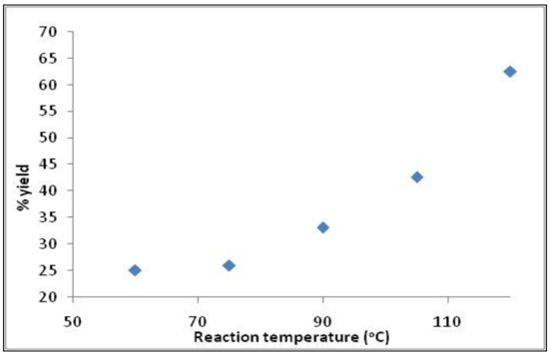

Fig. 4: Effect of reaction temperature on the yield of [BMIM]Br (residence time 150 sec; feed molar ratio 1.72).

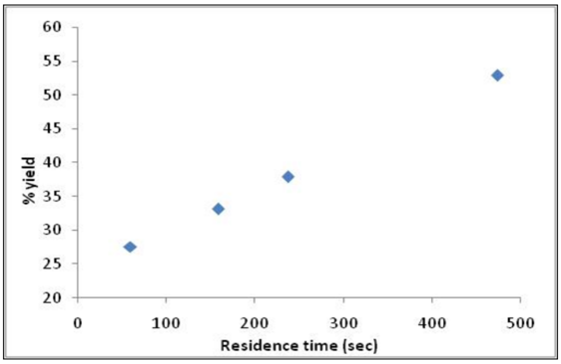

Fig. 5: Effect of residence time on the yield of [BMIM]Br (reaction temperature 90^{0}C; feed molar ratio 1.72).

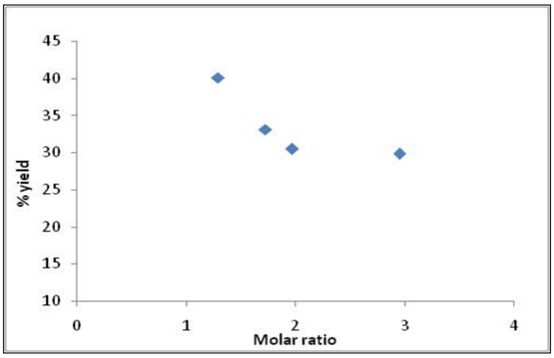

Fig. 6: Effect of feed molar ratio on the yield of [BMIM]Br. (reaction temperature 90^{0}C: residence time 150 sec).

Fig. 4 shows that the reaction strongly depends on temperature, as the yield increased by a factor of 2.5, when the temperature is raised from 60^{0}C to 120^{0}C and a maximum yield of 64% is obtained at 120^{0}C. The reaction is reported to be a homogeneous reaction initially. However, as IL is produced, reaction becomes bi-phasic with 1-methylimidazole predominantly dissolving in the IL phase4. Under this bi-phasic condition, the observed reaction rate will depend on both the mass transfer and intrinsic reaction rates. Fig. 4 shows clearly that the yield increases with increases in temperature. This may be either due to increase in reaction rate at higher temperatures or an increase in overall volumetric mass transfer coefficient due to lower values of viscosities and interfacial tension at higher temperature leading to finer dispersion or both. Hence, even in mass transfer controlled regime yield is likely to increase with increase in temperature. Further experiments involving imaging of two-phase flow pattern are required to ascertain whether the reaction for the conditions of the experiments reported in this study is mass transfer controlled or kinetically controlled. Fig. 5 shows clearly that the yield increases with increase in residence time and is as expected. Fig. 6 shows that on increasing feed molar ratio (1-bromobutane to 1-methylimidazole), the yield first reduces and then becomes constant. Since 1-bromobutane is less viscous, it is likely to be the dispersed phase. On increasing feed molar ratio keeping residence time constant, flow rate of 1-bromobutane increases while flow rate of 1-methylimidazole reduces. This is likely to make dispersion coarser which in turn may lead to reduced specific interfacial area. With reaction occurring at the interface3, the yield is likely to come down due to reduction in specific interfacial area. However, on further increase in feed molar ratio, a stage is likely to come when 1-bromobutane no longer disperses and flow will be parallel or annular flow. Under this condition, the specific interfacial area will not change with increase in feed molar ratio and hence yield is

Table 1: Yield, space time yield and production rate for different combinations of residence time and reaction temperature

Residence time (sec)	Reaction temperature (0C)	%Yield	Space time yield (kgs/lit-day)	Production rate (gm/day)
500	60	36.2	57.56	14.39
500	120	71.6	113.86	28.46
60	60	24.8	315.17	78.79
60	120	40.0	506.65	126.66

expected to become constant. However, these explanations need to be substantiated with flow visualization experiments.

3.3 Space Time Yields

After carrying out experiments to study the effects of various parameters, reaction was carried out at the low-low, low-high, high-low and high-high combinations of reaction temperature and residence time with the objective of studying the space time yields and production rate. In all experiments molar ratio was kept constant at 1.72 and the results are shown in Table 1.

It may be noted that while the yield is highest (about 72%) for the high-high combination of the residence time and temperature, the highest space time yield (506 kgs/lit-day) is obtained for the low-high combination of the residence time and reaction temperature. This corresponds to a production rate of about 127 gms/day of ionic liquid. In comparison, space time yield reported in typical batch synthesis is of the order of 1 kgs/lit-day4.

4. Conclusions

Continuous, solvent free high temperature synthesis of [BMIM][Br] in a microreactor is demonstrated. Effects of reaction temperature, residence time and feed molar ratio on yield are studied and explained. A high space time yield of about 506 kgs/lit-day is achieved at residence time of 1 minute at 120^{0}C, which is much higher compared to space time yield reported for batch synthesis. This space time yield corresponds to a production rate of about 127 grams/day of IL.

Acknowledgement

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Seismic Response of Piping System with Passive and Semi-active Supplemental Devices under Tri-directional Seismic Excitation

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Abstract

In this article, passive and semi-active supplemental devices have been studied to mitigate seismic response and vibration control of piping system used in the process industries, fossil and fissile fuel power plant. A study is conducted on the performance of passive and semi-active supplemental devices due to variation in parameters of devices and or with different control algorithms of the damper and subsequently optimum parameter of devices are obtained. The effectiveness of these devices in terms of reduction in the responses of the piping system is investigated by comparing uncontrolled responses under four different artificial earthquake motions with increasing amplitudes. The results demonstrate that these devices under particular optimum parameters are very effective and practically implementable for the seismic response mitigation, vibration control and seismic requalification of piping systems.

1. Introduction

Piping systems considered as the lifeline of industrial units such as process industries, fossil and fissile fuel power plant. Piping systems are normally installed on those structures in which acceleration at the location of piping support is higher than the ground acceleration. Seismic loads generated in addition to normal load on piping systems due to earthquakes can cause excessive vibrations, which can lead to high stresses resulting in damage or complete failure. Presently, piping systems and mountings are generally supported by seismic supports called snubbers. Moreover, snubbers are associated with operational problems like oil leakage, inadvertent locking-up, undesirable load on piping system due to malfunctioning of snubber and need frequent attention (Olson and Tang, 1988; Jonczyk and Gruner, 1991). At the same time, different structural control methods like passive, active, semi-active and hybrid control devices also known as supplemental devices have been successfully implemented in vibrating systems to reduce structural response due to earthquake and wind loadings (Housner *et al*., 1997). These devices can replace the snubbers. However, simplified finite element analysis and systematic design procedures for optimal sizing and placement of these protective devices in 3-D piping system subjected to tri-directional seismic excitation are needed and same is not investigated so far.

From the literature review, the X-plate damper(XPD), fluid viscous damper, visco-elastic damper, tuned mass damper (TMD) and multiple tuned mass dampers (MTMDs) as passive devices and MR damper, variable friction damper and variable stiffness damper as the semi-active devices are proposed to use as supplemental devices to mitigate the seismic response of the piping systems. Four different artificial earthquake motions with increasing amplitudes are proposed to apply at the support of the piping systems. These devices can also be used to upgrade and retrofit existing industrial and nuclear power plant facilities without much hassle.

The main objective of the present study is to develop: Optimum design parameter of the piping system equipped with various supplemental devices; Optimum parameter of control algorithms for semi-active dampers; To investigate the hysteretic energy dissipation behaviour of the various supplemental devices; To investigate numerically the feasibility and efficiency of supplemental devices in comparison to uncontrolled piping system; Integrated computer program of the complex 3-D piping systems equipped with supplemental devices.

2. Modelling of Piping System with Damper

Initially tests were conducted on 3-D piping system without and with XPD under four different artificial earthquake motions with increasing amplitude (refer Table 1) as shown in Fig. 1. Numerical investigations are then carried out for same piping system without and with different passive and semi-active supplemental devices and schematic of piping system with supplemental devices as shown in Fig. 2. Analysis is carried out using a computer code developed, in which straight element in the piping system are modeled as 3-D beam and elbows as 3-D curved beams whose moment of inertia is modified as per ASME codes to account for flexibility and having six degrees-of-freedom at each node. The mass of each member is assumed to be

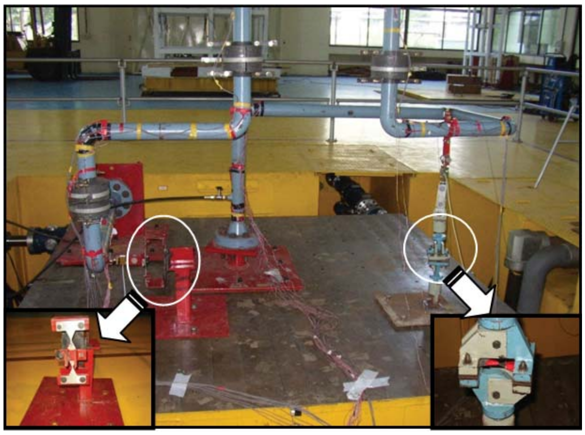

Fig. 1: Experimental setup of piping systems with XPDs

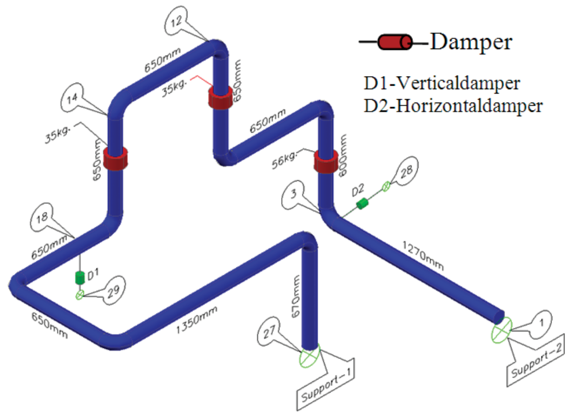

Fig. 2 : Schematic of piping system with passive dampers

Table1: Peak ground acceleration of different artificial earthquake motions

Artificial earthquake motions	Peak ground acceleration (m/sec^2)			Duration of earthquake sec.
	x-component	*y*-component	*z*-component	
TH10	2.38	2.15	1.88	33.50
TH20	4.85	4.15	3.22	33.64
TH30	7.17	6.31	4.91	33.68
TH40	10.01	8.65	6.25	33.89

distributed between its two nodes as a point mass. In addition to the mass of the piping system, the externally lumped masses are assumed to be effective in the three translational degrees-of-freedom. The dampers attached to the piping system in various combinations during analysis are: vertical, horizontal and both vertical and horizontal. Responses are obtained using Newmarks's step-by-step time-integration technique. The responses evaluated are displacements, accelerations and support reactions/base shears of piping system. Seismic energy dissipation in the piping system governed by the hysteretic characteristics of damper is also evaluated.

3. Governing Equations of Motion

The equations of motion of the piping system attached with supplemental devices, and subjected to earthquake motion, are expressed in the following matrix form:

$$[M]\{\ddot{u}\} + [C]\{\dot{u}\} + [K]\{u\} + [\Gamma]\{F\} = -[M]\{\Lambda\}\ddot{u}_g \quad (1)$$

$$\{u\} = \{x_1, y_1, z_1, \theta_{x1}, \theta_{y1}, \theta_{z1}, x_2, y_2, z_2, \theta_{x2}, \theta_{y2}, \theta_{z2}, \ldots, x_N, y_N, z_N, \theta_{xN}, \theta_{yN}, \theta_{zN}\}^T \quad (2)$$

$$\ddot{u}_g = [\ddot{x}_g \quad \ddot{y}_g \quad \ddot{z}_g]^T \quad (3)$$

where $[M]$, $[C]$ and $[K]$ represents the mass, damping and stiffness matrix, respectively; $\{\ddot{u}\}$, $\{\dot{u}\}$ and $\{u\}$ represent acceleration, velocity and displacement vectors, respectively; $[\Gamma]$ is the location matrix for the restoring force of damper; $\{F\}$ is the vector containing the restoring force of damper; $\{\Lambda\}$ is the influence coefficient vector; is the vector of earthquake ground accelerations; $\ddot{x}_g$,$\ddot{y}_g$ and $\ddot{z}_g$ are the earthquake acceleration along X-, Y- and Z-directions, respectively and x_i, y_i and z_i are the displacements and θ_{xi}, θ_{yi} and θ_{zi} are the rotations of the i^{th} node in the piping system in X-, Y- and Z-directions, respectively.

4. Numerical Study of Piping System with passive devices

Free vibration characteristics up to four modes with different location of XPD and without XPD in the piping system are listed in Table 2. The analytical and experimental results of XPDs are in very close agreement. It is observed that there is significant reduction in responses such as displacement, acceleration and support reaction in the range of 47 to 67%, 48 to 53% and 48 to 63%, respectively for the piping system with XPDs in Z-direction at D1. The energy dissipated in the hysteresis loops increases as the base acceleration increases from TH10 to TH40. The study on the effect of damper parameters (i.e. height, width and thickness of the XPD) is also investigated under the earthquake motions to find the optimum design of XPDs.

The optimum design parameters of fluid viscous and visco-elastic (VE) dampers are obtained for the same piping system. It is observed that there is significant reduction in responses such as displacement, acceleration and support reaction in the range of 45 to 50%, 48 to 50% and 25 to 39%, respectively for the piping system with fluid viscous dampers in Z-direction at D1. The displacement, acceleration and support reaction is reduce in the range of 53 to 57%, 51 to 52% and38 to 40%, respectively for the piping system with VE dampers in Z-direction at D1. The inherent modal damping in the piping system in the fundamental mode, which was initially 1.2%, is increased to 8.98% and 6.87% in the piping system with fluid viscous dampers and VE dampers, respectively. Response reduction in VE damper is slightly better than viscous damper, this is because of the additional stiffness property in the VE damper. It is observed that there exist design parameters or optimum parameters of TMD and MTMD system for which minimum response of the piping system is obtained. The design parameters of the TMD system (Jangid, 1997) are obtained for seven values of damping ratios of the main system

Table 2: Free vibration characteristics of piping system with and without XPDs.

Mode	Without XPD		Both vertical and horizontal XPDs		Horizontal XPD		Vertical XPD		Effective mass participation without XPD		
	Frequency, Hz		Frequency, Hz		Frequency,Hz		Frequency,Hz		X-dir,(%)	Y-dir, (%)	Z-dir,(%)
	Anal.	Expt.	Anal.	Expt.	Anal.	Expt.	Anal.	Expt.	Anal.	Anal.	Anal.
1	4.03	4.06	4.51	4.25	4.03	4.00	4.40	4.25	9.58	17.79	42.82
2	4.54	4.45	6.05	5.75	4.71	4.50	5.85	5.75	32.24	34.41	0.42
3	7.73	*	8.60	*	7.93	*	8.60	8.75	5.24	1.34	0.19
4	8.96	8.90	9.81	9.50	9.30	9.25	9.42	-	27.58	11.61	35.35

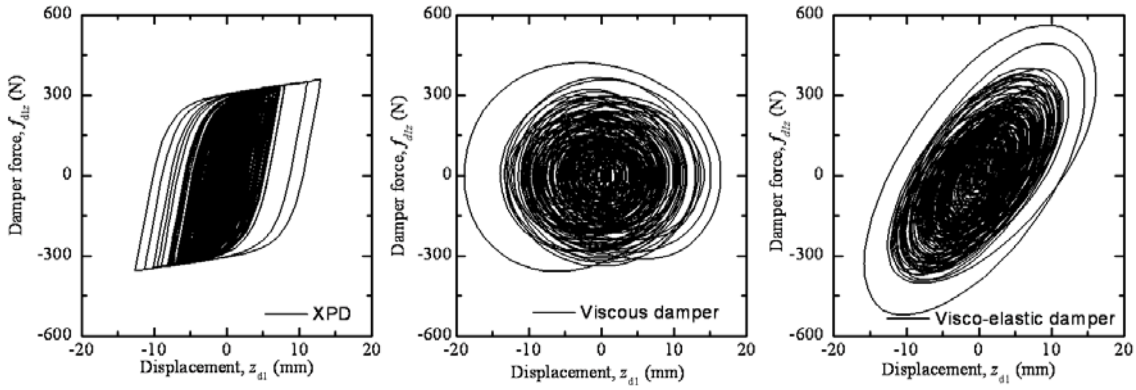

Fig. 3: Force-displacement variations at D1 for the piping system with both vertical and horizontal passive devices under TH20.

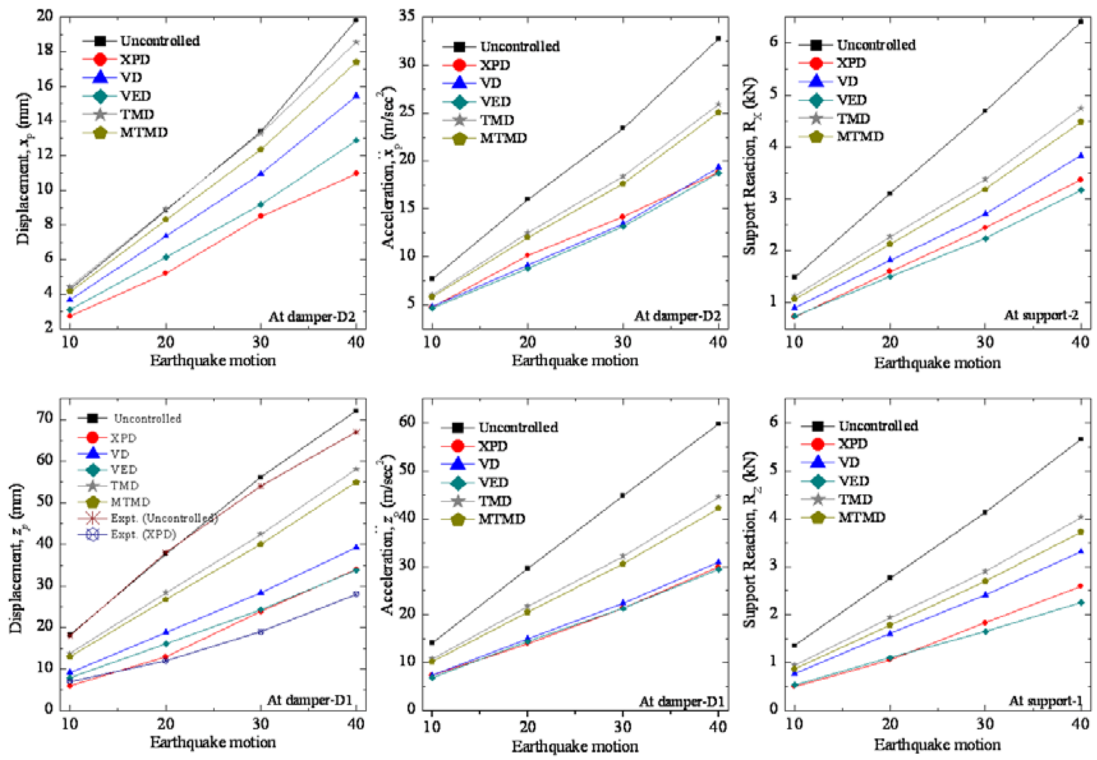

Fig.4: Variation of piping responses without and with passive devices subjected to earthquake motions.

(i.e. ξ_S = 0, 0.01, 0.02, 0.03, 0.05, 0.075 and 0.1) for different mass ratios in range of 0.005 to 0.1 at an interval of 0.005. One TMD is designed for damping the first mode of the piping system, which has maximum mass participation. Similarly, number of TMDs in MTMD as 2, 4 & 7 and are designed for reducing the responses in the piping system. It is observed that the inherent modal damping in the piping system in the fundamental mode, which was initially 1.2%, is increased upto 6.14%.

It is observed from the Fig. 3 that good amount of energy is dissipated by the dampers under all the earthquake motions. It is also observed from Fig.4 that XPD, viscous damper and VE damper are very effective in reducing the seismic response of the piping system.

5. Modeling, control law and numerical study of piping system with Semi-active devices

Semi-active supplemental devices investigated are MR damper, variable friction damper and variable stiffness damper. Semi-active control systems are highly non-linear. One of the main challenges in semi-active control is to develop an appropriate control algorithm. Also, modeling of the control devices is essential for adequate prediction of the behavior of the piping system. The schematic of the piping system with semi-active supplemental devices and the mathematical models of semi-active dampers are shown in Figs.5 and 6, respectively.

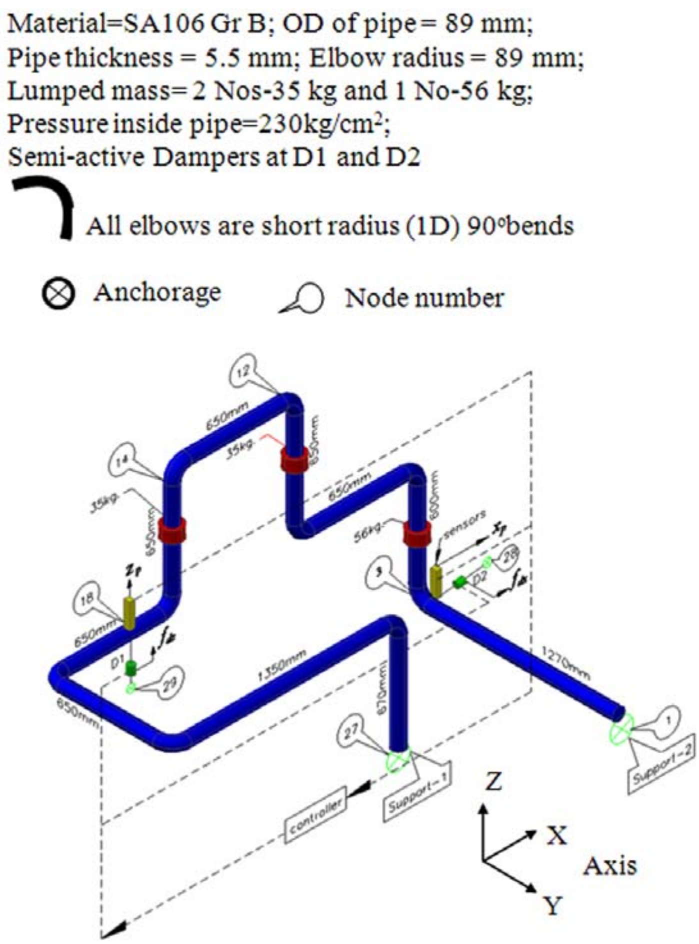

Fig. 5: Schematic diagram of piping system with semi active dampers and control feedback system

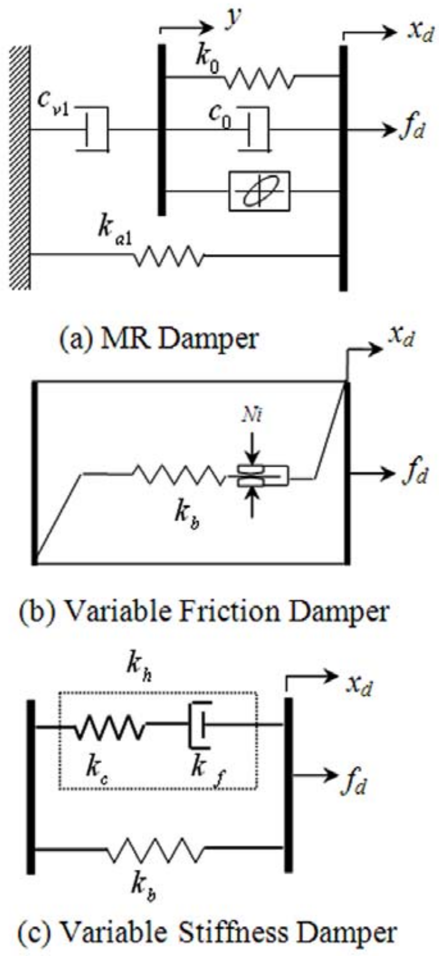

Fig.6: Mathematical model of semi-active dampers

Here two versatile and effective control algorithms are selected in the current study and these are; the Bang-bang controller and the Lyapunov controller. The governing equation of the force predicted (f_d) by this model is

$$f_d = c_{v1}\dot{y} + k_{a1}(x_d - x_0) \quad (4)$$

where c_{vi} is viscous damping at lower velocity in the model to produce the roll-off; k_{a1} is the accumulator stiffness; x_d is the damper displacement; x_0 is the initial displacement of spring; x_d is the velocity across the damper. The response of the MR damper is depends on the local motion of the piping system and also on the maximum input command voltage to the current driver. Hence it is important to know the optimum input command voltage, so that resulting MR damper force in a piping system causes optimum reduction in the piping responses. Praveen *et al.,* 2012 studied the response of piping system with MR damper under tri-directional seismic excitation. To obtain the optimum input command voltage a parametric study is made in the range 0 to 2.25V, keeping all other parameters of the MR damper constant. It is observed that, the command voltage plays an important role in the response of the piping system. It is observed that there is significant reduction in responses such as displacement, acceleration and base shear in the range of 69 to 88%, 57 to 73% and 39 to 45%, respectively for the piping system with MR dampers in Z-direction at D1 under the different earthquake motion.

In semi-active variable friction damper (SAVFD), predictive control algorithm (Lu,2004) with direct output feedback concept is considered. In predictive control algorithm, the critical friction force is dependent on the optimal gain multiplier. Thus, the control force vector when all the dampers are brought into slip state is given by

$$F[t] = \alpha(G_z z[t-1] + G_u F[t-1] + G_w \ddot{u}_g[t-1]) \quad (5)$$

The factor α is a ratio of damper force to critical friction force and also α is treated as gain multiplier. The matrices G_z, G_u and G_w are the control gains. A parametric study is made by variation of gain multiplier in the range 0 to 0.99. It is observed that there are significant reduction in responses such as displacement, acceleration and base shear in the range of 93.5 to 94%, 89.3 to 90.4% and61.4 to 66.5%, respectively for the piping system with SAVFD in Z-direction at D1 under the different earthquake motions.

In semi-active variable stiffness damper (SAVSD), switching control law (Yang *et al*., 2000) and modified switching control law (Xinghua, 2000) are considered in which its performance is based on the information of structural displacement and velocity. The damper force (f_{di}) at i^{th} location can be calculated as

$$f_{di} = K_{di} v_{si} \bar{x}_i \quad (6)$$

where K_{di} is the $(n \times n)$ effective stiffness matrixfor SAVSD installed in the ith damper location, in which K_{di} is zero, except for $K_{di}(i-1,i) = -k_{hi}$; $\bar{x}_i$ is the drift at location of damper; and v_{si} is based on switching control law for the SAVSD installed in the i^{th} location. Here, the effects of optimal damper stiffness ratio based on the different configurations of damper placement under different earthquake motions are investigated.Praveen *et al*., 2013studied the response of piping system with SAVSD under tri-directional seismic excitation. Parametric study is made in variation of α_k in the range 0 to 0.06 andobserved that the parameter plays an important role in the piping system responses.It is observed that there is significant reduction in responses such as displacement and base shear in the range of 78 to 79.2% and37.4 to 40.6%, respectively for the piping system with SAVSD in Z-direction at D1 under the different earthquake motions.

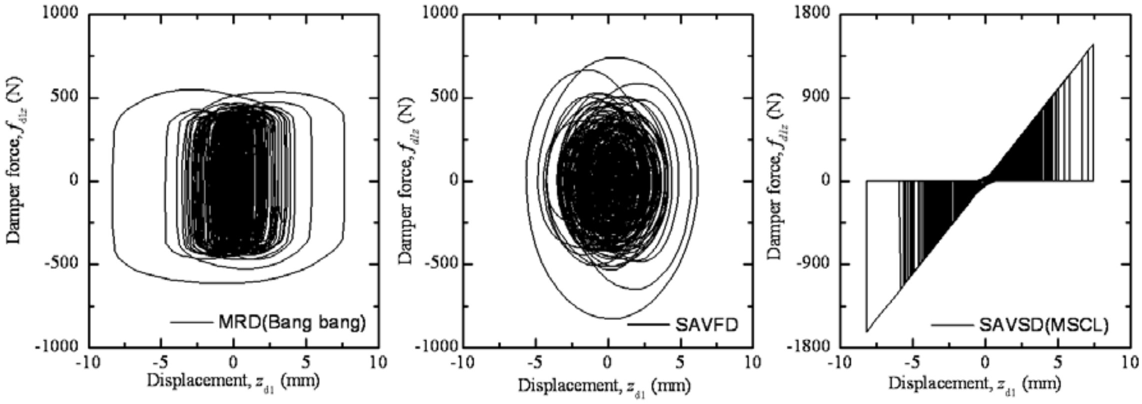

Fig. 7: Force-displacement variations at D1 for the piping system with vertical semi-active devices under TH20.

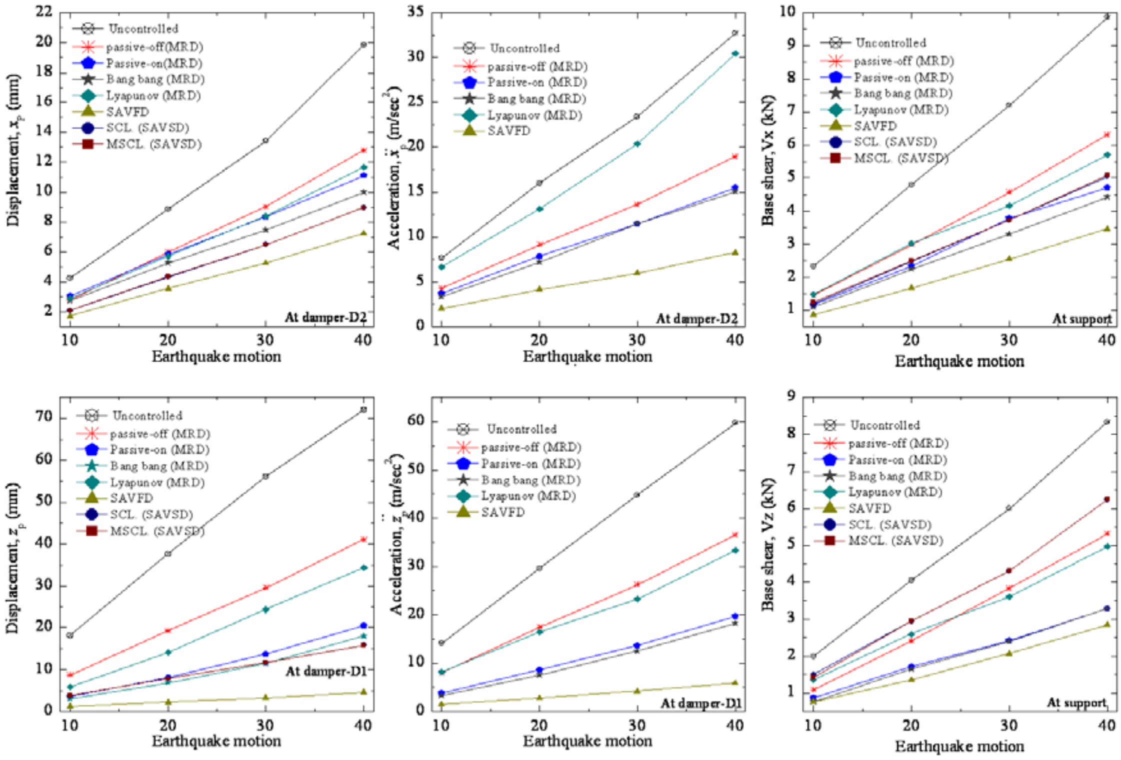

Fig. 8: Variation of piping responses without and with semi-active devices subjected to earthquake motions.

It is observed from the Fig.7 that good amount of energy is absorbed by the dampers under all the earthquake motions. It is observed from Fig.8 that semi-active dampers are very effective in reducing the seismic response of the piping system.

6. Conclusions

Based on the investigation carried out in this study on seismic response control of the piping system, the following major conclusions are drawn:

1) It is seen that passive and semi-active supplemental devices are very effective in reducing the seismic response of piping system.
2) Natural frequency of the piping system increases with XPD and VE damper as stiffness is added in the piping system whereas in case of the fluid viscous damper it is unaffected. Inclusion of

viscous and VE dampers in the piping system significantly increases the modal damping of the piping system.

3) The response of the piping system decreases with increase in both, the mass ratio and the damping of the main system. For the same mass ratio and damping in the piping system, the MTMD is found to be more effective than single TMD.
4) An optimum value of the voltage input depending upon the damper locations in MR damper. Bang-bang control algorithm performed better than Lyapunov control algorithm.
5) The evaluated optimum parameter, α, in the range of 0.4 to 0.7 of the predictive control law for the SAVFD and , of switching control law and modified switching control law for the SAVSD are found to be very effective in reducing the seismic responses for the piping system.
6) Experimental results of piping system with XPD are very well matched with analytical results. Remaining Passive damper and Semi-active damper results shown are analytical results. However, it is proposed to conduct experiment with Semi-active dampers.

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Development of Hull Compaction System for Nuclear Recycle Facility

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Nuclear Recycle Board

Abstract

India has adopted closed fuel cycle strategy for efficient management of available resources to meet long term energy requirements. Nuclear Recycle Facility (NRF) provides a vital link in three-stage Indian nuclear power programme. In a NRF for PHWR fuel cycle, reprocessing of spent fuel bundles from PHWRs is carried out using a chop-leach process where the spent fuel bundles are chopped into small pieces using a spent fuel chopper and the contents inside the zircaloy clad are dissolved using concentric nitric acid. This process generates empty zircaloy shells called 'hulls'. The present practice followed for management of hulls is to transfer them into SS drums and store these drums in underground RCC tile holes at a Waste Management Facility (WMF). This waste needs to be stored in an engineered WMF for at least 30-60 years before transferred to a final repository. The storage volumes required for this hull waste will keep increasing as the reprocessing capacity is being enhanced multi-folds. Compaction of hull waste has been employed internationally to reduce the volume required for storage. Hence indigenous development of hull compaction system was initiated by NRB to meet the future requirements. This is being achieved through a set of experiments and analysis with the available resources within the country. This paper describes the process of compaction, conceptualization of the system and benefits accrued from it.

Introduction

For many years now, it has been common practice to store intermediate & high level radioactive solid waste pending further treatment prior to final disposal. With expansion of Back End of PHWR fuel cycle and planning of new recycle facilities, it is imperative to manage radioactive waste in an improved way. In order to reduce the overall volume of the hull waste generated during reprocessing, a hull compaction system has been conceptualised.

Presently hulls are transferred into a SS drum for storage, which occupies a huge and costly storage space in WMF. There is a vast scope in reduction of volume requirement for storage space, if compaction technique is used for these hulls by solidifying the open shells. The concept of hull compaction has been discussed in literature and the system has been implemented on plant scale by reprocessing plants at La Hague, France [1] and Rokkasho, Japan [2].

Pre-processing like batching and drying of the hull waste before compaction is required to be done to suit to vitrified waste glass canister size which is used for storage of waste after compaction. During batching operation, hull pieces are poured into smaller size SS cans, specially designed for the compaction. The hull waste containing SS can is then heated up in special heating chamber so that liquid content, principally water, is removed from the hull waste by vaporization. The dried hull waste, which is having a considerable void volume distributed throughout its bulk, is fed to a compactor. The compactor applies extremely large compressive force to SS can and hull pieces, so as to compress them to a minimum volume by squashing the void flat. The compacted disc from this process is called a 'puck'. In order to limit the maximum outer dimension of the puck to less than internal diameter (ID) of the canister, a mould (sleeve) of suitable size is provided. The sleeve encases the can before start of compaction. After compaction, the pucks are loaded into waste canisters remotely and sent to waste storage facility. In this way, the size of the final product is considerably less than that of the original and the final solid form is more suitable for further storage. Fig.1 shows the block diagram for material flow for hull waste management. The hull waste being highly radioactive in nature, it is necessary to carry out these operations inside a hot-cell. The hot-cell housing the compactor has viewing windows, Master Slave Manipulators (MSMs), remote handling crane/ gantry to carry out the remote maintenance of the equipment employed.

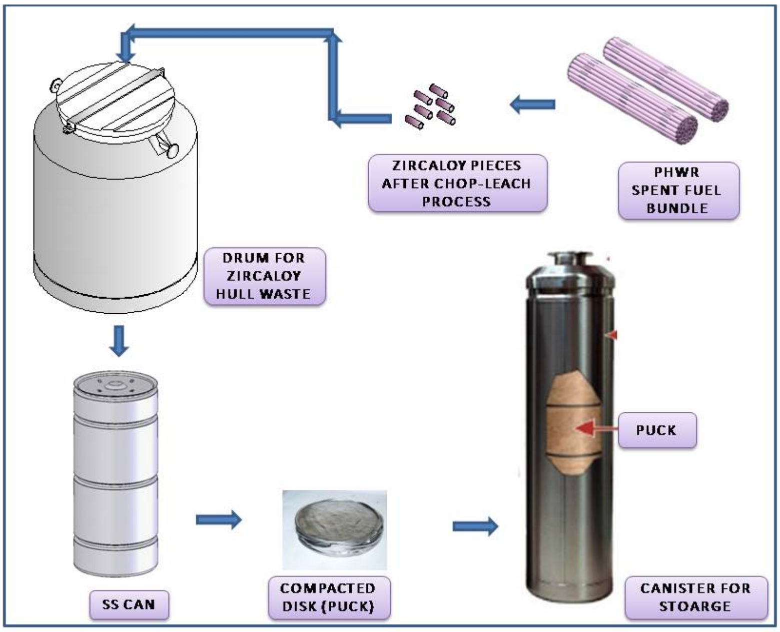

Fig. 1: Block diagram of hull waste management

Concept description

In view of very high loads required by the compaction operations, a Supercompactor (high tonnage hydraulic press) suitable for nuclear facilities has been conceptualised. It gives constant heavy press force throughout the pressing stroke & can hold for quite a long duration. No wear & tear of press components is expected because no rotating parts are involved as compared to mechanical presses. The overall design of the equipment is carried

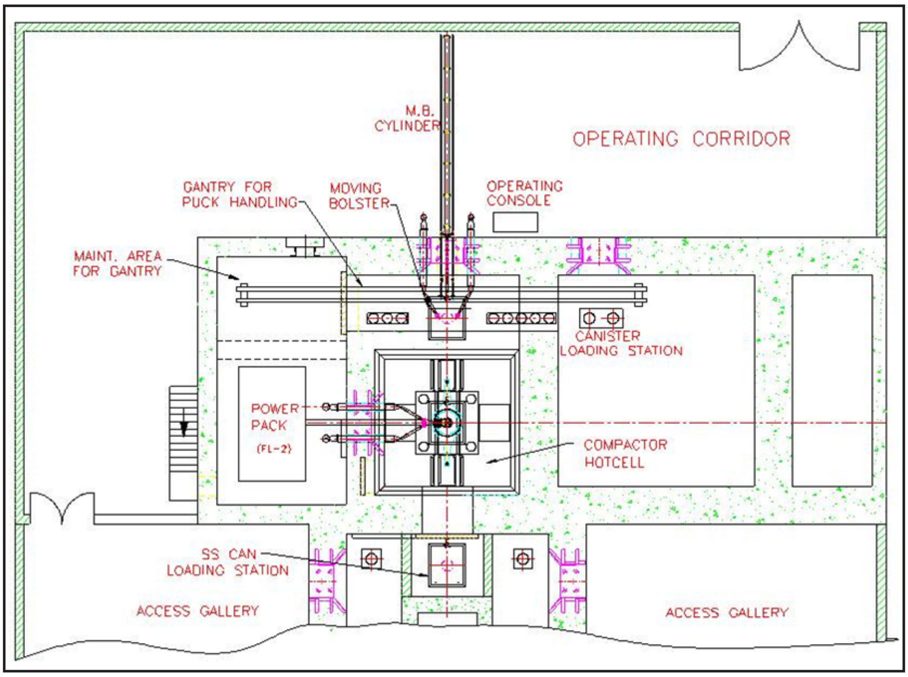

Fig. 2: Equipment layout of Supercompactor

out taking into account of remote maintenance of equipment.

The Supercompactor consists of three independent sub-assemblies :

- Hydraulic press along with sleeve
- Moving bolster which facilitates loading of SS cans and delivery of pucks
- Monorail gantry for handling and loading pucks into waste canisters

The hydraulic power pack of the press is located on top of hot-cell and the press replaceable components viz. ram liner, sleeve liner and wear plate of moving bolster which are inside hot-cell can be remotely removed from non-radioactive and accessible areas for maintenance. Fig.2 shows the equipment layout of Supercompactor.

Following points were considered for Supercompactor development:

1) Capacity requirement for obtaining required volume reduction
2) Design of SS cans
3) Layout of Supercompactor to enable remote operation and remote removal of wear parts
4) Safety systems (e.g. fire, decontamination, etc.) to be incorporated

Experimental work

In order to establish capacity requirement of the Supercompactor, a series of compaction trials on dummy SS cans containing simulated hull pieces and zircaloy pieces were carried out in two phases at the existing hydraulic presses to confirm following parameters:

- Volume reduction vis-à-vis unit pressure for the compaction i.e. applied force per unit resisting area of SS can
- Optimisation of the can geometry
- Compacity and toughness of the puck

Phase I :

Full scale compaction tests on SS cans containing simulated hull pieces (made of SS) were carried out in a 1000Te hydraulic press at CDCFT, BARC. The compaction forces were measured at different stages during compaction and plotted against volume reduction. The tests were conducted without using sleeve due to difference in size of the can and sleeve. Fig. 3 shows the test set up. A number of convolutions on periphery of SS can at different elevations were provided for uniform compaction. SS tube pieces of identical size of fuel pins were used as simulated hull pieces.

Phase II :

Compaction trials on SS cans containing fresh zircaloy pieces (rejected cladding tubes) were carried out in a 2000 Te hydraulic press at NFC, Hydrabad. Due to limitation in the mould size of the press

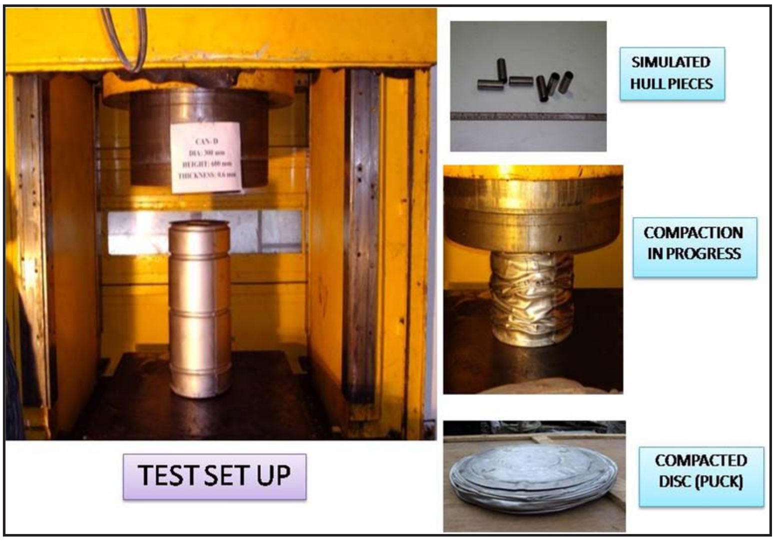

Fig. 3: Compaction tests at 1000 Te CDCFT press

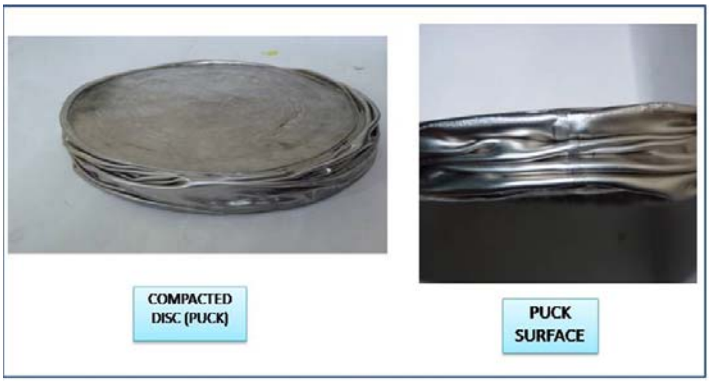

Fig. 4: Compacted puck after tests at 2000 Te NFC press

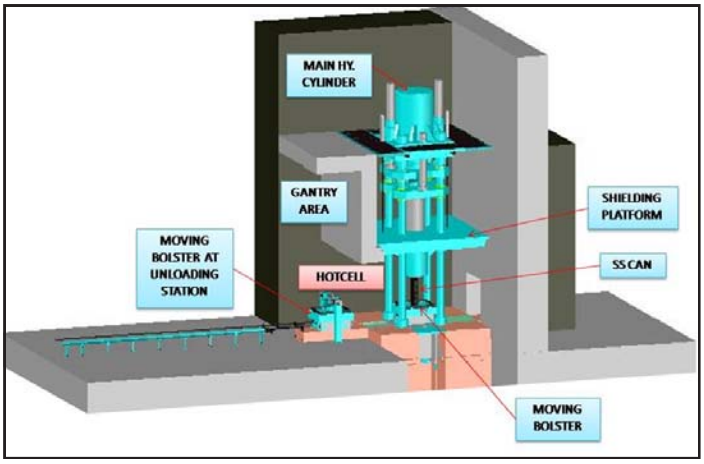

Fig. 5: 3-D model of Supercompactor

which is used for preparation of zirconium briquette, the tests were conducted on SS cans with reduced scale.

Results:

- The overall behaviour of the compaction system was found satisfactory for the can geometry. Uniform compaction was observed.
- After compaction, the visual appearance of the puck revealed no cracks in SS can. See Fig.4
- In phase-I experiments, the can height was reduced by 1/12th of original height and diameter increased by 15% at 700 Te compaction force. Density of the puck was 50% of theoretical density of SS. The unit pressure for the compaction was 100 MPa.
- In phase-II experiments, the can height was reduced by 1/15th of original height and diameter increased by 20% at 210 Te. Density of the puck was 64% of theoretical density of zircaloy. The unit pressure for the compaction was 110 MPa. As seen from the above results, SS can volume was reduced by about 86% at 110 MPa compaction. It was further observed that increase in volume reduction was quite small (88%) by increasing the unit pressure (over 200MPa)

It was concluded that the compaction at unit pressure of 200 MPa will provide a desired volume reduction and further increased pressure will not yield any significant results. Extrapolating this data, it was estimated that the compaction force required for SS cans of desired size with hulls at 200 MPa unit pressure would be approx. 1500 Te.

Based on above experimental data and keeping the margin for operation, the capacity of the Supercompactor was arrived at with sufficient margin.

Details of Supercompactor

The major sub-assemblies of the Supercompactor are top head, bottom head, columns and moving bolster.

The single acting main cylinder provides force for the main ram for the compaction which is built in the top head (crown) of the press and the top head is directly mounted onto the four columns forming a rigid construction. (See Fig.5) The top head itself is fabricated in such a way that all the stresses and strains developed during pressing are borne easily without causing undue deflection in its members. The columns will be acting as joining members between top head, bottom head & slide as well as provides guides to slide during press movement. This assures sustained excellent geometrical accuracies which in turn lead to even load distribution & enhanced sleeve life. A sleeve has been provided which encloses the can before main ram comes down. This sleeve acts as mould for the can and is actuated by means of another two auxiliary double acting cylinders, which are located on the side of the top head. The main cylinder wall is very well protected against contamination sometime coming over the top of the sleeve by means of a shield. This shield is also connected to the ventilation system to route fines through the outlet to the HEPA filters. A puck ejection system is provided to remove the puck from the ram if the puck is attached to the ram.

Pressure retaining components such as bed, ram, sleeve, etc. are provided with a suitable liner which has high wear resistance. The fixing arrangement of liner is suitable for remote maintenance. Hydraulic power-pack consisting of motor, hydraulic pumps, control valves, pressure regulating valves and accessories is suitably provided as a separate unit, which is mounted away from the main press at the top for easy maintenance. The hydraulic pipe circuit has safety provisions against over pressurization of system like anti-leakage fittings.

Special features provided for Supercompactor are as follows:

- The press is equipped with features, such as automated loading and unloading equipment. The position of the ram is controlled/monitored by a linear way transducer which also indicates the actual height of the puck in the press.
- The press area is sealed so that air escapement during compaction discharges only through the HEPA air filtration system. The enclosure consists of a stainless steel construction with polycarbonate windows and is pneumatically operated for entry and exit of moving bolster with SS can and puck
- The press top is provided with stepped sides for tight shielding with hot-cell roof. On top of it, an extra steel shielding ring is provided to prevent radiation streaming through the thinnest hot-cell concrete thickness.
- In case wear of parts occurs, the liners of sleeve and press plate are equipped with the remote removable feature. The liners are disassembled by unscrewing the holding bolts from outside the hot-cell and kept on the moving bolster with supporting device. Then these wear parts can be removed from the bolster once it comes in the approach of crane. All bolts are equipped with a dome shaped head and all have the same dimensions to enable quick and easy working conditions. These bolts are to be handled with MSM.
- Cameras at appropriate locations are provided. The camera images are displayed on control console on a separate screen with facility for selection of camera
- DM water spray nozzles are provided in the enclosure to decontaminate the ram, sleeve, ram plate area, etc. during regular cleaning process or before taking it out for maintenance. The contaminated water is collected by a ring-shaped drain in the lower part of the system. The liquid will be directed into a SS tank by gravity by suitable piping for further treatment and disposal.

Safety features

The Supercompactor has been provided with following built-in safety features:

- Zircaloy has pyrophoric properties including risk of ignition for fines and it is important to secure the process of hull waste treatment against this. Ignition risk of the fines depends on various parameters such as particle size, quantity, temperature and oxygen content. It is important to note that that nitrogen increases the ignition temperature and under nitrogen atmosphere, the fines become inert. Though the risk of ignition for hull pieces is low, an elaborate arrangement for evacuation of the chamber and nitrogen purging before compaction has been provided. It has been interlocked with compaction process. The escapement of air-nitrogen mixture form the system is treated separately as off-gas.

- Auto tripping for ram of the compaction system movement at extreme low and extreme high position.
- On-line dynamic pressure readings for each cylinder and ram position indicator.
- Proper enclosement system is made around compaction area so that the displaced air escaped during compaction shall be routed through a defined passage and restricting the spread of airborne particles.

Conclusion

In order to meet the growing demands for reduction in large storage volume of radioactive solid waste on account of enhancement of reprocessing capacities, a Hull Compaction System is being provided for new Nuclear Recycle Facilities. This process simplifies waste storage and final disposal providing drastic ultimate volume reduction. In this process, an overall volume reduction factor of 4 is achievable. Based on the in-house compaction tests, design of a Supercompactor adapted to remote maintenance criteria is ready and manufacturing of the same has been taken up.

Acknowledgement

The development of Hull Compaction System would not have been possible without the continued support and motivation from Shri Sekhar Basu, Director, BARC for which authors are extremely grateful to him. Acknowledgements are due to engineers and staff at PDD, NRG and NFC where the compaction tests have been carried out in the existing presses.

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DAE-BRNS Theme Meeting on Membrane Separations for Fuel Cycle Applications (MEMSEP-2013): A Report

The DAE-BRNS Theme Meeting on "Membrane Separations for Fuel Cycle Applications (MEMSEP-2013)" was held at BARC Training School Hostel, Anushaktinagar, Mumbai during September 16 – 18, 2013. The objective of this Theme Meeting was to provide a forum to scientists, engineers and young researchers to discuss the recent advances in the membrane separations with particular emphasis on nuclear fuel cycle applications. The Theme Meeting was inaugurated by Dr. P.R. Vasudeva Rao, Director, IGCAR who was the chief guest. He delivered a key note address on the role of membrane science in society in general and in nuclear fuel cycle in particular. Dr. A. Goswami, Head, Radiochemistry Division who welcomed the delegates also gave a brief introduction on the importance of membrane separations in energy sector, particularly in the area of renewable energy. Dr. P.K. Mohapatra, Convenor, MEMSEP-2013 introduced to the delegates the scope of the Theme Meeting and also the need to develop radiation resistant membranes which may find application in membrane separations aimed at radioactive waste processing. Dr. K.L. Ramakumar, Director, Radiochemistry & Isotope Group, BARC gave the presidential address and mentioned how the large scale applications of membrane separations in water desalination can be extended to industrial waste water treatment including those emanating from nuclear industry. Dr. S.A. Ansari, Secretary, MEMSEP-2013 delivered the vote of thanks.

There were about 125 delegates who attended MEMSEP-2013. There were 2 plenary and 21 invited speakers including 3 from overseas, one each from USA, Poland and Spain and 31 contributory papers received from various research / academic institutions, viz. BARC, CSIR Labs, IITs, etc. The opening plenary lecture was delivered by Prof. Miriam Balaban, a very senior professor, and Editor-in-Chief of the International Journal, *"Desalination and Water Treatment"*.

A wide range of topics related to membrane separation processes were covered including preparation and characterization of membranes, design and development of membrane modules for various applications, membrane stability / membrane fouling, ceramic membranes, membrane Photocatalytic reactors, supported liquid membranes and emulsion liquid membranes. The valedictory function saw very positive remarks from the participants. Association of Separation Scientists and Technologists (ASSET), which co-organized the event, encouraged four young researchers with the "Best Paper" prizes (selected by a distinguished jury) given by Dr. K.L. Ramakumar, who is also the President of ASSET. Finally, the Theme Meeting was concluded with a hope for directed and collaborative efforts between various research groups.

A Photograph taken during the inaugural function of MEMSEP-2013

हिंदी दिवस 2013 के उपलक्ष्य में आयोजित समारोह की संक्षिप्त रिपोर्ट

भापअ केंद्र में हिंदी दिवस के उपलक्ष्य में दिनांक 16 सितंबर 2013 को **"त्वरकों का अनुप्रयोग और औद्योगिक संरक्षा"** विषय पर हिंदी में एक **वैज्ञानिक संगोष्ठी** तथा सांस्कृतिक कार्यक्रम का आयोजन किया गया।

पूरे दिन चलने वाले इस कार्यक्रम के उद्घाटन सत्र की अध्यक्षता केंद्र के नियंत्रक श्री सुहास जी. मार्कंडेय ने की और केंद्र के जैवचिकित्सा वर्ग के निदेशक डॉ. कृष्णा बी. सैनीस कार्यक्रम के मुख्य अतिथि के रूप में पधारे। सर्वप्रथम हिंदी दिवस के अवसर पर भारत के गृहमंत्री तथा परमाणु ऊर्जा विभाग के सचिव द्वारा जारी संदेश पढ़े गए। तत्पश्चात संगोष्ठी का शुभारंभ हुआ। टाटा स्मारक केंद्र, मुंबई के प्रोफेसर डॉ. एस.के. श्रीवास्तव द्वारा कैंसर पर दी गई विशेष वार्ता से। इस संगोष्ठी में वरिष्ठ वैज्ञानिकों द्वारा विभिन्न वैज्ञानिक विषयों पर कुल चार वार्ताएं सरल हिंदी में प्रस्तुत की गईं ताकि सामान्य व्यक्ति भी इन विषयों को समझ सकें। त्वरक एवं स्पंद शक्ति प्रभाग के अध्यक्ष डॉ. के.सी. मित्तल ने संगोष्ठी के सत्राध्यक्ष की भूमिका निभाते हुए वार्ताओं पर अपनी सार्थक टिप्पणियां दीं।

संगोष्ठी के बाद अपराह्न में **"काव्य-सरिता"** का आयोजन किया गया जिसमें सुप्रसिद्ध हास्यकवि श्री दिनेश बावरा तथा सुप्रसिद्ध कवयित्री सुश्री लता हया ने अपनी रचनाओं से श्रोताओं को भावविभोर कर दिया। इन कवियों ने जहाँ एक ओर हास्यरस से सराबोर किया वहीं चुटीली व्यंग्य रचनाओं ने समाज की विडंबनाओं को रेखांकित किया।

कार्यक्रम में केंद्र के वरिष्ठ अधिकारियों सहित बड़ी संख्या में लोगों ने भाग लिया और ज्ञान के साथ मनोरंजन से परिपूर्ण कार्यक्रम के दोनों सत्रों का आनंद उठाया।

सुप्रसिद्ध कवयित्री सुश्री लता हया

मंच पर आसीन बाएं से प्रोफेसर डॉ. एस.के. श्रीवास्तव, टीएमसी; श्री डी.के. शुक्ल, अध्यक्ष रिएक्टर पचालन प्रभाग; मुख्य अतिथि डॉ. कृष्णा बी. सैनीस, कार्यक्रम अध्यक्ष एवं नियंत्रक श्री सुहास जी मार्कंडेय।

सुप्रसिद्ध हास्यकवि श्री दिनेश बावरा

IAEA Technical Meeting on Instrumentation & Control (I&C) Security

The Control Instrumentation Division, Electronics & Instrumentation (E&I) Group, BARC organized an IAEA Technical Meeting on "Guiding principles for applying Security Controls to I&C Systems at Nuclear Facilities" during 23-27 September 2013 at Navi Mumbai. The meeting was supported by GCNEP, DAE. The objective of the meeting was to prepare a guidance document to address the increasing concerns of cyber security for computer-based I&C Systems at nuclear facilities.

Twenty delegates from various countries including India, Russia, USA, Germany, Armenia, Canada and Korea participated in the meeting. They represented R&D institutes (BARC, IGCAR, KAERI), Regulators (AERB & CNSC), Utility (NPCIL, Rosatom) and Vendors (Areva). Indian delegates comprised of the I&C developers from various power and research reactors and waste management facilities.

Mr. R.M. Suresh Babu, CnID, BARC - Indian coordinator of the meeting - welcomed the delegates on the opening day of the meeting. Mr. C.K. Pithawa, Director E&I Group, BARC delivered a talk on the I&C security issues and emphasised the urgent need to have an international guidance document on this topic. Speaking on the occasion, Dr. K.L. Ramakumar, Director Radiochemistry & Isotope Group, BARC and Chairman, Advisory Council, GCNEP, introduced the objectives and activities of GCNEP. Mr. Donald Dudenhoeffer - IAEA coordinator - explained the meeting objectives. Mr. SAV Satya Murty, Director E&I Group, IGCAR outlined various security features and controls for I&C systems.

Talks from various delegates on their country-specific experience with activities related to and implementation of I&C security were followed by extensive discussions to finalise the structure and contents of the document. In due course of the weeklong meeting, 25 guiding principles and 145 detailed guidelines for security were discussed and finalized.

Delegates of the IAEA Technical Meeting at Mumbai

(L-R) Dr. K. L. Ramakumar and Shri. C. K. Pithawa on the opening day of the Technical Meeting

(L-R) Shri. R. M. Suresh Babu, BARC and Dr. Donald Dudenhoeffer, IAEA at the Technical Meeting

The document is in a good mature form for various Indian stakeholders – utilities, I&C developers and regulators – to initiate preparation of I&C security implementation guidance / regulatory document for Indian nuclear facilities. E&I Group, BARC has already initiated preparation of a security plan document for implementing an effective security program for I&C systems.

Report on Fifth ISEAC Triennial International Conference on Advances and Recent Trends in Electrochemistry (ELAC-2013)

The Fifth ISEAC Triennial International Conference on Advances and Recent Trends in Electrochemistry (ELAC-2013) was held at Hyderabad, India during January 16-20, 2013. The Conference was organized under the aegis of the Indian Society for ElectroAnalytical Chemistry (ISEAC) with its secretariat at Fuel Chemistry Division, BARC. The Conference was organized with the aim to outline the advances and recent trends in electrochemistry as well as to accentuate the multidisciplinary nature and impact of electrochemistry in today's world.

The Conference was attended by 143 participants including 35 foreign nationals from 12 countries and delegates from different parts of India. During the inauguration, Prof. S.K. Aggarwal, President, ISEAC and Chairman, Organising Committee welcomed all the delegates of ELAC-2013 and briefed about the activities of ISEAC since its inception in October, 2003. Mr. Saurav K. Guin, Secretary, ISEAC and Convener, Organising Committee presented a summary about the various topics of both fundamental and applied Electrochemistry to be discussed during ELAC-2013. Dr. (Ms.) J.V. Kamat, Treasurer, ISEAC and Co-Convener, Organising Committee, briefed the delegates about the program of the Conference as well as about the Awards instituted by ISEAC. Prof. (Mrs.) Ana Maria Oliveira Brett from Portugal, President of Bioelectrochemical Society (BES) formally released the Conference Proceedings. Prof. S.K. Aggarwal also released the Souvenir-cum-Bulletin of ISEAC "Highlights in ElectroAnalytical Techniques (HEAT)", Volume 2, Issue I, 2013. Three scientists were awarded ISEAC Eminent Scientists Award-2013 and one young scientist (below 40 years) was awarded ISEAC Young Scientist Award 2013. Six best publications (in peer reviewed international journals) by ISEAC members were awarded ISEAC Journal Publication Awards for the publication years 2010 and 2011. Mr. Arvind S. Ambolikar, Secretary, Organising Committee proposed vote of thanks.

ELAC-2013 was spread over 17 technical sessions covering 31 invited talks, 8 short invited lectures, 61 poster presentations, 9 oral presentations by research scholars and 1 vendor's presentation. Interactive discussions took place during the technical sessions on the applications of scanning probe microscope, nuclear magnetic resonance spectroscopy, X-ray photoelectron spectroscopy etc. and other *in-situ* characterization techniques during electrochemical experiments. Other areas of discussion were advanced batteries, fuel cells, electrochemical capacitors, analytical environmental electrochemistry, bioelectrochemistry, biosensors, biofuel cells, corrosion science and engineering, role of electrochemistry in health, medical and nuclear science, electrodeposition, electrochemical engineering, impedance spectroscopy, electrochemistry in ionic liquids and molten salts, physical, theoretical and computational electrochemistry.

Photograph of the invited speakers and the organizing committee members

BARC Transferred "Auto TLD Badge Reader" Technology

PC based automatic TLD badge reader (Auto-TLD BR) has been developed to ensure health and safety of persons working in radiation environment, to monitor the radiation dose received by them and maintain a record. A PC based auto TLD badge reader can process up to 50 TLD badges loaded in a magazine at a time. The readout time is typically 100 sec. per badge and 50 badges are read in about 90 minutes.

This technology has earlier been transferred to 3 parties during the year 2001-2008. There was a further demand for this technology; the know-how of "**Auto TLD Badge Reader**" was transferred to following two more parties:

1. **M/s Seebha Consultancy Services, Mumbai on February 14th, 2013.**

Photograph after signing the agreement with M/s Seebha Consultancy Services, Mumbai, seen from left to right Mr. Siddhesh Nare, M/s Seebha, Shri. R. N. Khanderao, RP&AD, Smt. Ratna Pradeep, RP&AD, Dr. M. S. Kulkarni, RP&AD, Shri. A. R. Babu, Head RP&AD, Shri. Seetapathi, M/s Seebha, Shri. B. K. Pathak, TT&CD, Smt. S. S. Murudkar, TT&CD.

M/s Adithisri Radiation Services, Tirupati on July17th, 2013

Photograph after signing the agreement with M/s Adithisri Radiation Services, Tirupati, seen from left to right Smt. S. S. Murudkar, TT&CD, Dr. M. S. Kulkarni, RP&AD, Shri. D. A. R. Babu, Head RP&AD, Dr. D. N. Sharma, Director, HS&EG, Shri Rajesh Bapu. S, M/s Adithisri, Dr. S. P. Kale, Head, TT&CD, Shri. B. K. Pathak, TT&CD, Smt. Ratna Pradeep, RP&AD, Shri R.N. Khanderao, RP&AD.

The Technology Transfer and Collaboration Division coordinated all the activities related to the transfer of this technology.

BARC Scientists Honoured

Name of the Scientists	:	**Dr. P.K. Tewari (Team Leader), Dr. R.C. Bindal, Shri D. Goswami, Shri K.P. Bhattacharyya, Dr. A.K. Ghosh, Shri S. Shivayyanamath, Shri S.A. Tiwari, Dr. (Mrs.) Sangita Pal**
Affiliation	:	Desalination Division, BARC
Name of Award/ Honour	:	Nina Saxena Excellence in Technology Award, 2013
Instituted by	:	IIT, Kharagpur for technical innovation “Hybrid membrane technology for removal of Uranium from groundwater”

Name of the Scientist	:	**Dr. H. S. Misra**
Affiliation	:	Molecular Biology Division
Name of the Award	:	Fulbright-Nehru Senior Fellowship
Awarding Organization	:	United States-India Educational Foundation & J. W. Fulbright Commission, USA
Year of Award	:	2012-13

Name of the Scientist	:	**Dr. A. K. Tyagi**
Affiliation	:	Chemistry Division, BARC
Award/Honour	:	ISCB Award for Excellence in Chemical Sciences
Conferred by	:	Indian Society of Chemists and Biologists

Name of the Scientist	:	**Dr. Jitendra Kumar**
Affiliation	:	Nuclear Agriculture & Biotechnology Division, BARC
Award	:	ISEAC Journals Publication Award 2011 by the Indian Society for Electro Analytical Chemistry (ISEAC)
Publication	:	*“Microbial biosensor for detection of methyl parathion using screen printed carbon electrode and cyclic voltammetry”*
Presented at	:	Fifth ISEAC Triennial International Conference on Advances and Recent Trends in Electrochemistry (ISEAC-ELAC 2013), Hyderabad, January 16-20, 2013

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