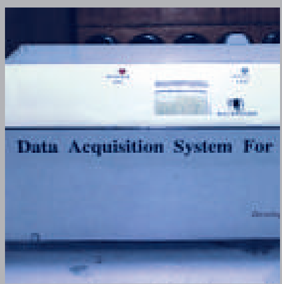
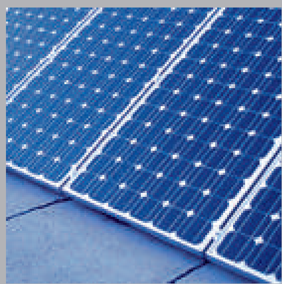
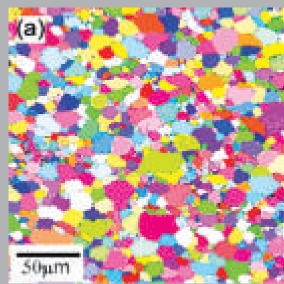
BARC NEWSLETTER

Bi-monthly | Jan - Feb | 2010







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Foreword

As the premier research institute on Nuclear Science and Technology in India, BARC has been at the frontline of both basic and applied research. One of the strengths of BARC is the interdisciplinary nature of its research and a strong emphasis on the transformation of research into deployable technologies.

Over the years, BARC Scientists and Engineers have made significant contributions towards R&D in core areas such as Physical Sciences, Chemical Sciences, Life Sciences and Engineering. Apart from these core areas, BARC is also actively involved in R&D on Societal Applications of Nuclear Science and Technology. Information on all these R&D activities needs to be highlighted to the Scientific Community at large, both within and outside BARC. In this respect, the BARC Newsletter has been playing a major role in highlighting and disseminating these activities of BARC.

The BARC Newsletter is published by the Scientific Information Resource Division. To further improve the Newsletter, an Editorial Committee comprising Senior Scientists and Engineers from BARC has been constituted. The consolidated efforts of the Editorial Committee are quite evident in this current issue and it is felt that this issue may be circulated to officers of BARC.

I urge the BARC fraternity to make use of this Newsletter to communicate their accomplishments (in R&D activities) at individual, divisional and group levels to any of the members of the Editorial Committee.

With best wishes!

Srikumar Banerjee
Director, BARC

Preface

The Scientific Information Resource Division has been publishing the BARC Newsletter for the last three decades. Over the years, BARC Newsletter has been evolving continuously, in response to new challenges and it still remains the main platform of exchange, for BARC Scientists and Engineers.

This and the forthcoming issues will see a few changes in the structure and content of the newsletter. Firstly, it will be published once in two months. That means there will be six issues in a year and also the Founder's Day Special issue. Secondly, an Editorial Committee has been formed on the recommendation of Director, BARC. Members of this Committee will bring their expertise and experience to further widen the scope of the newsletter.

I hope that the BARC Scientific Community continues to support this publication, by sending us their R&D contributions.

Wishing you all a very happy and prosperous New Year!

Dr. R.B. Grover
Director, Knowledge Management Group
BARC

From the Editor's Desk

We are very happy to bring to you, the first issue of the BARC Newsletter, for the year 2010.

In its new format, apart from the regular features such as News items and forthcoming events, reports on recently concluded Seminars, Workshops and Conferences and Announcements of Awards and Honours received by BARC Scientists and Engineers, every issue of the newsletter will also carry contributions from Young Scientists and Engineers. In addition, we have feature articles from senior researchers.

We have made sincere efforts to include diverse areas of both pure and applied research and also to publish articles in unexplored areas.

Your comments, suggestions and feedback about the issue are most welcome and would be of great help to us, in further strengthening our Newsletter.

K. Bhanumurthy

On Behalf of the Editorial Team

डॉ. श्रीकुमार बॅनर्जी

निदेशक, भापअ केंद्र के गणतंत्र दिवस के अवसर पर दिए गये संबोधन का सारांश

"प्रिय सथियों,

सर्वप्रथम मैं अपने देश के 61वें गणतंत्र दिवस समारोह में आप सभी का हार्दिक स्वागत करता हूँ। अपने राष्ट्रीय ध्वज के प्रति सामूहिक रुप से आदर प्रकट करने के लिए हम सभी प्रतिवर्ष गणतंत्र दिवस के पावन पर्व को मनाने के लिए एकत्रित होते हैं।

गणतंत्र दिवस के अवसर पर हमारा यह कर्तव्य है कि हम अपने सैन्य बलों के उन सदस्यों का अभिवादन करें जो हमारे देश को सुरक्षा प्रदान करते हैं।

जैसाकि आप जानते हैं, वर्ष 1950 में इसी दिन भारत एक सार्वभौम गणतंत्र के रुप में अस्तित्व में आया। और इसी दिन विश्व में सबसे बडे लोकतंत्र का जन्म हुआ।

गणतंत्र दिवस हमारे जीवन में एक ऐतिहासिक दिवस है, यह हमारे आत्मविश्लेषण करने का भी दिन है। भापअ केंद्र विश्व के सबसे बड़े अनुसंधान एवं विकास केंद्रों में से एक है जहां एक ही छत के नीचे नाभिकीय विज्ञान एवं प्रौद्योगिकी की विविध गतिविधियों पर उत्कृष्टतापूर्वक कार्य किया जा रहा है।

हमारे वर्तमान कार्यों का संक्षिप्त विवरण मेरे अंग्रेजी भाषण में दिया है जो इसी अंक में उपलब्ध है।

इस समय हम हमारी 11वीं योजना की परियोजना गतिविधियों को आधे से अधिक पूरा कर चुके हैं। यह समय है कि हम अपनी विभिन्न परियोजनाओं की प्रगति की वित्तीय एवं भौतिक दोनों पहलुओं की ध्यानपूर्वक समीक्षा करें ताकि योजना अवधि की समाप्ति तक हम, अपने लक्ष्यों की प्राप्ति हेतु तैयार हो सकें।

मैं अपने साथियों से आग्रह करता हूँ कि वे कार्य की प्रगति को रिपोर्ट करने एवं परियोजना रिपोर्टों में परिभाषित लक्ष्यों को प्राप्त करने के लिए हमारी प्रगति के वस्तुनिष्ठ मूल्यांकन करने हेतु PARINAY का अत्यधिक प्रयोग करें।

मुझे यह बताते हुए खुशी हो रही है कि भापअ केंद्र द्वारा अपनाया गया ऑनलाईन ओसीआर सिस्टम अत्यंत सफल रहा एवं इस केंद्र के लगभग सभी अधिकारी उनके पिछले वर्ष के ओसीआर समय पर प्रस्तुत कर सके। आप लोगों से प्राप्त कुछ सुझावों के आधार पर ओसीआर सिस्टम में और भी सुधार करने के प्रयास किए जा रहे हैं।

दिनांक 29 दिसंबर 2009 को मॉड लैब में हुई दुर्भाग्यपूर्ण आग की दुर्घटना से, हमें अत्यंत कष्ट हुआ इसमें हमारे दो युवा पीएचडी अध्येता, श्री उमंग उदय नारायण सिंह, वरिष्ठ अनुसंधान अध्येता, एवं श्री पार्थ प्रतिम बाग, कनिष्ठ अनुसंधान अध्येता, ने अपनी जान गंवाई हैं। इस अवसर पर हम उनकी दिवंगत आत्मा को श्रध्दांजलि अर्पित करते हैं। यह

अवसर है आत्मविश्लेषण का, हमें सुनिश्चित करना होगा कि केंद्र में ऐसी दुर्घटना फिर कभी न हो।

मैं मेरे सभी साथियों से आग्रह करता हूँ कि वे भापअ केंद्र संरक्षा परिषद द्वारा समय-समय पर लागू संरक्षा मार्गदर्शी सिध्दांतों एवं क्रियाविधियों का सख्ती से पालन करें एवं संरक्षा को प्राथमिकता दें। मैं आप सभी से दृढतापूर्वक अपील करता हूँ कि आप सभी अत्यंत सतर्क रहें और यदि कोई कमियां देखी जाएं तो उसकी सूचना उपयुक्त प्राधिकारी को दें ताकि गलती करने वालों के विरुध्द कठोर कार्रवाई की जा सके।

अपने केंद्र एवं इसकी विभिन्न संस्थापनाओं का भौतिक संरक्षण हमारे लिए अत्यंत महत्वपूर्ण है। मुझे, विश्वास है कि मेरे सभी साथी, वर्तमान में सुरक्षा की बढती हुई मांग को समझेंगे। मैं बीएआरसी की फायर सर्विस के कर्मचारियों से अनुरोध करता हूँ कि हमारे केंद्र की विभिन्न स्थापनाओं की लगातार चौकशी के कार्य में लगे रहें तथा संबंधित प्रभागों व सुरक्षा अनुभाग से संपर्क बनाएं। मैं इस केंद्र के सभी अधिकारियों और स्टाफ को भी बधाई देता हूँ जो उच्च सुरक्षा व्यवस्था बनाये रखने में सुरक्षा कर्मचारियों को अपने कर्तव्यों के निर्वहन में सहयोग कर रहे हैं। अंतः मैं इस केंद्र में अपने सभी साथियों से अनुरोध करुंगा कि वे वर्तमान परिस्थिति में हमेशा सतर्क और जागरुक रहें।

अंत में मैं इस बात को रेखांकित करना चाहूंगा कि हमारे सामने अनेक चुनौतियां हैं। मुझे विश्वास है कि भापअ केंद्र में हम अपने सभी वैज्ञानिकों, तकनीशियनों और प्रशासकों के एक जुट प्रयासों से बीएआरसी की परंपरा के अनुरुप भावी चुनौतियों का सामना करने में सफल होंगे।

मित्रों, अंत में इस विशेष दिन पर हम यह दृढ़ संकल्प करें कि अपने लोगों के जीवन को बेहतर करने के लिए नाभिकीय विज्ञान एवं प्रौद्योगिकी के अग्रणी क्षेत्रों में निरंतर कार्य करते रहेंगे।

जयहिंद!"

61st Republic Day of India

Address by
Dr. Srikumar Banerjee
Director, BARC

"Dear colleagues,

Let me first extend a warm welcome to you all, to celebrate the 61st Republic Day of our country. As a mark of our collective salutation to our national flag, every year we assemble on this auspicious morning to celebrate the Republic day. Let me also take this opportunity to extend my greetings and best wishes for the New Year to each one of you and your family.

On the occasion of Republic Day, it is our duty to salute the members of Armed Forces who have been providing the security for this country.

As you all are aware, on this date in the year 1950, the constitution of the sovereign democratic Republic of India was adopted and the world's largest democracy was born.

While the Republic Day is a historic day in our life, it is also the day for some introspection on our part.

BARC is one of the world's largest R&D centres, where we pursue excellence in nuclear science and technology, covering a very wide spectrum of activities under a common umbrella.

Amongst the major achievements of the last year, the launching of nuclear submarine ARIHANT, bringing the reprocessing plant KARP at Kalpakkam back in operation, starting the operation of multistage flash evaporation unit of nuclear desalination project and of the 10 MeV electron accelerator deserve special mention. I shall now give a brief account of a few other notable achievements.

Research Reactors

As you are aware, the research reactor APSARA was shut down on 6th June, 2009 for upgradaes. Subsequently, as part of partial decommissioning, the core has been fully defueled and the removed fuel assemblies have been safely stored in a separate water pool. The primary and secondary coolant systems were also decommissioned. The dismantling of electrical system equipment and nuclear and control instrumentation were taken up, which are also nearing completion.

The other two research reactors, CIRUS and DHRUVA continued to operate satisfactorily with high level of safety and availability.

CIRUS reactor was generally operated at 20 MW (th) with the availability factor of about 82 % during the year. The neutron radiography setup of APSARA reactor for imaging small-size material coupons has been shifted to CIRUS and commissioned successfully. Another neutron radiography setup to facilitate post-irradiation examination of irradiated fuel pins of power reactor is being established, at one of the beam holes of CIRUS.

Research reactor DHRUVA attained the availability factor of more than 78% during the year. The reactor was generally operated at 55 MW(th). DHRUVA continued to be the major facility for radioisotope production. About 680 samples were irradiated during the year. The reactor also served as a national facility for neutron beam research. A number of research scholars from various academic institutions in the country, utilized the reactor under the aegis of the UGC-DAE Consortium for Scientific Research. DHRUVA reactor has also seen a service life of 25 years. As a result, refurbishment / replacement of various equipment and components has now become inevitable to ensure its continued availability and safe operation and the refurbishment and replacement of important electrical equipment and switch gears are currently in progress.

Critical Facility for Heavy Water Reactors was operated on 67 occasions for conducting various experiments. As APSARA reactor was shut down for upgrades, the critical facility is also being used for nuclear detector testing and large volume sample irradiations for Neutron Activation Analysis (NAA).

While the conceptual design of high flux Multi Purpose Research Reactor (MPRR) has been completed, feasibility study for incorporation of an external spallation neutron source in the MPRR core is in progress.

AHWR Programme

AHWR Thermal hydraulics Test Facility and Fuelling Machine Test Facility are being set up at R&D Centre, Tarapur. While generation of critical heat flux data in the thermal-hydraulic facility would establish feasibility of power up-rating in AHWR, performance of AHWR fuelling machine would be assessed in the other facility.

Based on the studies performed for Thorium/LEU-based fuel for AHWR, high burn up of 64000 MWD/T seems to be achievable. Though uranium and plutonium obtained from discharged fuel would still have appreciable amount of fissile content of U and Pu, it will be proliferation-resistant because of the presence of radioactive isotopes in both of them.

HTR programme

A new feature of Burn-up Compensation Rods (BCRs) is introduced in the CHTR core design and detailed physics analysis has been done. The use of BCRs would help in controlling the excess reactivity during the long reactor core life, which in turn would help to reduce the worth of each control rod during reactor operation.

The Indian High Temperature Reactor is being primarily designed for production of hydrogen. The detailed physics design analysis for the 600 MWth Pebble-bed HTR is in progress. The initial core containing fresh pebbles has been designed by reducing the content of U-233 in the pebble to 4.25 %.

Fuel for Fast Reactors

As part of the continued production of Uranium Plutonium mixed carbide fuel for FBTR, fuel pins for seven fuel sub-assemblies have been shipped to IGCAR last year, which included one Fuel Sub-assembly pin made with reprocessed plutonium from FBTR fuel. This notable event marks the closing of the fast reactor fuel cycle in India. The PFBR experimental MOX fuel pins fabricated at AFFF, Tarapur, loaded in the very centre of FBTR core, has now reached a burn up exceeding 92,000 MWd/T.

Fabrication of six million Deeply Depleted UO_2 pellets required for axial breeder blanket of the first core of PFBR has also been completed. End plug welding of D-9 clad tubes using Nd – Yag laser has been qualified with fabrication of more than thousand full length MOX fuel pins, the optimum parameters for large production of PFBR MOX fuel have been finalized.

As part of metallic fuel development programme for fast reactors, a new thermo-physical property evaluation lab has been set up in the Radiometallurgy Division. Thermo-physical and thermo-mechanical properties of several Uranium Plutonium alloys and fuel-clad chemical compatibility studies are presently in progress.

Post-Irradiation Examination

The mechanical properties of PHWR fuel clad irradiated to burn-up of 15,000 MWd/T have been evaluated, which showed about 30% loss of ductility as compared to virgin material. Two main damage processes, namely irradiation damage and hydride induced degradation appear to be contributing towards loss of ductility.

Reprocessing and Waste Management

It is a matter of great rejoice, that all the three reprocessing plants are in operation. At KARP, Kalpakkam, a record of chopping and processing of spent fuel bundles has been achieved in the recent past. PREFRE, Tarapur continued to operate safely despite being a vintage Plant. The Plutonim Plant at Trombay operated well and processed the entire spent fuel inventory received from CIRUS & DHRUVA reactors.

At Revamping Of PREFRE (ROP), Tarapur, commissioning of various systems and equipment has made good progress. For the first time, a state-of-the-art spent fuel chopper has been deployed in this plant, to enhance the throughput.

At WIP, Trombay, modification jobs for waste concentration system have been completed and installation of sulphate separation and acid recovery systems are in progress. At WMF, Tarapur, about 200 m^3 of Intermediate Level Waste (ILW) has been treated by ion exchange process and about 250 m^3 of HLW has been concentrated to ensure uninterrupted operation of PREFRE.

The engineering scale demonstration facility, for partitioning of High Level Waste is in an advanced stage of completion at Tarapur. This facility is with the state-of-the art technology and will be a step forward in reducing radiotoxicity associated with long-lived radioisotopes, present in high level waste.

At CWMF, Kalpakkam, a facility for melt densification of plastic / polythene waste has been successfully adopted for treatment of such waste from MAPS.

R&D Support for Power Programme

A Sludge Lancing Equipment (SLE), designed and assembled by BARC and supplied to NPCIL, was successfully operated for sludge removal, from all the four steam generators of the Kakrapar Atomic Power Station. About 45 kg of wet sludge was removed successfully from these steam generators.

Ultrasonic Measurement of Axial Creep (UMAC) has been developed in RTD to replace the old TMAC i.e., Technique for Measurement of Axial Creep system. The new system which reduces the time required for measurement, was handed over to NPCIL.

Ultrasonic Phased Array System for reliable flaw detection and accurate flaw characterization has been commissioned. This technology will be useful for periodic in-service inspection of critical nuclear power plant components, with minimum man-rem consumption.

The Containment Studies Facility built near Hall 7 has become operational now. Blow down tests have been conducted successfully at 30 Kg/cm^2 pressure and 235°C temperature. The recorded pressure and temperature transients were found to be in agreement with pre-test analytical predictions.

In a reinforced concrete framed structure, under seismic excitations, the most vulnerable zone is the beam-column joint. Experiments were performed on full-scale beam-column joints under quasi-cyclic excitation, to evaluate their performance under the event of earthquakes.

A new model of IERMON system was developed with multiple radiation detectors for enhanced performance, with particular attention to early detection of nuclear emergency. The system is now being manufactured by ECIL, Hyderabad under the XI Plan. IERMON Central Station is established at Anushaktinagar, Mumbai for centrally monitoring and managing the countrywide network.

Materials Research

Several facilities. viz., fluoride effluent treatment facility, UF_4 production facility, Ammonia Di-Uranate (ADU) calcining facility have been successfully commissioned. A new analytical laboratory at RUMP has been made fully functional.

Process flow sheet has been successfully developed to exploit the uranium ore deposit, located at Gogi (in Karnataka). The process development studies were carried out in the Technology Development Pilot Plant (TDPP) at Jaduguda.

Beryllium components in specific shapes have been fabricated by powder metallurgy route, to meet the in-house requirement for neutron physics studies.

A processing sequence has been successfully developed for the synthesis of control rod material, boron carbide powder (enriched in B^{10}), and its subsequent fabrication into B_4C pellets, meeting the stringent specifications with respect to chemical composition, density and dimensions. 111 enriched boron carbide pellets ware successfully fabricated and supplied for PFBR.

A total of 75 special boron alloy [Ti (Cr) B_2 & $MoSi_2$] pellets of 95% theoretical density were synthesized, characterized and supplied for PRP.

Processes for production of bulk metallic glass and tungsten reinforced glass composites, for application as tank penetrator were developed. Bulk metallic glass has been produced in cylindrical and bar geometries by suck casting.

The technology for preparation of Ni-Ti alloys and heat shrinkable ferrules for the Light Combat Aircraft is being transferred to HAL, Bengaluru, under a tripartite MoU. The construction of a new workshop dedicated to this project, was recently completed at HAL.

BARC has initiated development and fabrication of cable-in-conduit conductor, for various configurations for Nb_3-Sn based superconducting magnets, required for fusion research work at IPR. The flow sheet for this advanced superconductor fabrication has now been developed and trials are in progress.

Chemical Engineering

Indian Design Description Document (DDD) for (a) Helium coolant purification system; (b) hydrogen isotope removal system from helium purge gas; and (c) tritium extraction system from Pb-Li loop was prepared for Tritium Blanket Module (TBM) of ITER. Approval was obtained from the International TBM Port Management Group for conceptual Tritium Extraction System loop design, which is a key step for sustained operation of ITER.

Indigenously developed micro cryo-cooler unit, to be used in hand-held infrared cameras, has been fabricated and tested with no load. A minimum temperature of 59 K was achieved during experiments.

The complete flow sheet for preparation of pure V_2O_5 has been optimized and all unit operations have been individually investigated on kilogram scale. A separation cascade consisting of 8 stages of extraction and 16 stages of scrubbing with DHEHPA as extractant has been operated for producing nuclear grade Dy_2O_3 on a laboratory scale. Purity of Dy_2O_3 achieved with reference to Gd, Tb and lighter rare earths was over 99%.

Design, Manufacture & Automation

The Centre for Design and Manufacture (CDM) has completed the design, manufacture, assembly, testing and demonstration of Linear Distancing System Assemblies as well as training of ECIL personnel against an MoU.

Bhabhatron-II machines have been finding increasing acceptance . In all, 14 such teletherapy machines have been installed in various Cancer hospitals.

Physical & Chemical Sciences

Equation of state of natural uranium has been determined up to a quarter megabar, through high pressure experiments carried out for the first time at EDXRD beamline of Indus-2.

Thermoelectric devices consisting of 8 pellets each of n-type PbTe and p-type TAGS-85 alloy have been fabricated. The devices have 6% efficiency and provide a power output of 4.1 watt at 300 mV.

Using an in-house process, Carbon-doped alumina has been prepared in 40 gm batches. This material is suitable for dosimetry in thermally stimulated luminescence as well as optically stimulated luminescence modes. Detailed characterization of the material is being carried out.

A double focusing neutron monochromator has been installed on the filter detector spectrometer at Dhruva and it has led to a substantial increase in neutron flux for experiments. A new neutron radiography set-up has been installed at CIRUS which is useful for nondestructive imaging of various samples.

Experiments on delayed neutron counting following photofission of U have been done, using Bremstrahlung radiation produced by bombardment of 10 MeV Electron beam on Ta foil. Decay profile of delayed neutrons from fission products was obtained from varied amounts of U-targets and yields of delayed neutrons increased with U-target amounts. These are preliminary experiments aimed at detection and measurement of U/Pu in sealed containers.

Lasers and Accelerators

The 10 MeV RF electron accelerator at Electron Beam Centre, Kharghar, Navi Mumbai became operational and has reached a Beam Power of 4.5kW. It has been used to produce X-rays in the energy range of 3.0 MeV to 3.8 MeV using a tantalum target placed on beam dump.

The 3 MeV DC electron accelerator was tested up to 1 MV with 6 kgs/cm^2 nitrogen gas pressure. An electron beam of 1 MeV at 500 μA to 1 mA was produced. The electron beam has been scanned, extracted out of the beam window and characterized by dosimeter film.

A 9 MeV, 2kW, RF electron linac for X-ray radiography of large container scanning system is being developed in collaboration with ECIL. The system was operated to a maximum of 150 Pulse Repetitive Frequency (PRF), 2.5 MW peak forward, power and 35mA beam current. X-ray imaging experiments were conducted with different PRF and exposure times.

As part of the LEHIPA project, a test bench facility has been set up with an RF ion source, solenoids and other beam diagnostics, to understand more about low energy beam transport.

As an important step in the clean-up programme, the isotope shift between U-232 and U - 238 was measured in the spectral range of 15000 cm^{-1} to 18000 cm^{-1} by Fourier transform spectroscopy using specially designed Electrodeless Discharge Lamps (EDL) with 30-40 microgram quantities of uranium as the radiation source.

Design of Magnetohydrodynamic experimental facility employing mercury, to study flow phenomena at high Hartmann and Interaction parameters for Indian TBM has been completed.

Significant progress has been made in the design of 18MW electron/positron Beam Dump for the proposed International Linear Collider by BARC and the Stanford Linear Accelerator Centre, USA.

Electronics & Instrumentation

A PC-based laboratory system for face recognition was developed, for carrying out robust face identification employing a facial matching technique, based on 2D Pseudo Hidden Markov Modeling (HMM) technique.

The Centre for Micro Electronics and Micro-electro-mechanical Systems (CMEMS) has been set up at Prabhadevi, in collaboration with ECIL. The centre has VLSI-CAD lab with full-suite of IC design tools and TCAD tools on robust computational platform, for fab-less design and development of semiconductor devices, process technologies and ASICs.

The hand-held Tele-ECG has been developed for Mobile as well as LAN application and supplied to Post Graduate Institute of Medical Education & Research, Chandigarh, Grant Medical College and J.J.Hospital, Mumbai, for validating its application in rural health care. The technology was transferred to M/s CHESS Medicare Pvt. Ltd., in November 2009.

New arrangements for 8 lane access control system have been implemented at the North Gate of BARC.

With the establishment of the Facility of Electromagnetics in Autonagar, Vizag, some important BARC activities have been shifted to Vizag, where a Computing Centre with a capability of 4 teraflop capacity has been successfully commissioned.

Desalination Programme

The barge-mounted mobile seawater RO desalination plant developed by BARC, has been registered under the name 'SUJAL'. An MOU on custody and operation of this plant was signed with M/s. Indian Rare Earths Limited (IREL) and the plant is working at OSCOM, Orissa.

5000 litres per day capacity Electro-Dialysis Ionization (EDI) unit for ultra-pure water of <0.1 micro-siemens/ cm conductivity was commissioned and being operated to generate design data. It is also being used to supply ultra-pure water to the various facilities of BARC on demand.

The multistage flash evaporation plant at Kalpakkam has become operational and the production capacity is being steadily raised to the name plate capacity.

Nuclear Agriculture

Trombay Dharwad Groundnut variety TDG 39, a confectionary-grade, large-seeded variety has been released by the Ministry of Agriculture, Government of India in 2009, for commercial cultivation in northern transitional

Zone 8 and northern dry Zone 2 and 3 of Karnataka.

Food Technology

A novel radiation-resistant bacterial strain was isolated from black pomfret and it was identified as a novel species of *Deinococcus* based on its characteristics. It has been named *Deinococcus piscis sp. nov.* and it has been included in the approved list of bacterial names.

The Yield of protein in soymilk produced from radiation processed (10kGy) soybean appreciably increased resulting in increased yield of tofu.

A synthetic pomegranate aroma was formulated for commercial flavouring application for the first time.

Radiation Biology and Health Sciences

For the first time, the frequency of spontaneous micronuclei was estimated among the 210 newborns from a natural high background radiation area (HLNRA) using cord blood samples. This was compared with that from 61 newborn from normal level radiation background area (NLNRA). The studies concluded that elevated level of naturally occurring radiation has no significant effect on the induction of micronuclei frequency among the newborns.

Telomere length, which is reported to shorten on exposure to high doses of ionizing radiation, is a good biomarker for aging, stress and cancer. In a first study of its kind, the telomere length was estimated in 310 adult individuals, which included 233 from High Background Radiation Area and 77 from NLNRA. Again, the elevated level of natural background radiation showed no significant effect on telomere length among the adult population.

Radiation Medicine

The protocols for the synthesis of two Fluorine-18 labeled radiopharmaceuticals namely, 18-F-MISO (fluoro-miso-nidazole) for imaging areas with low oxygen content in tumours and 18-F-thymidine for imaging tumours (cell proliferation) have been standardized. These two compounds have been approved by the Radiopharmaceuticals Committee for commercial production which may start in a few months.

XI Plan Activities

We are at the moment more than half way through our XIth plan project activities. It is time to examine very critically the progress of our various projects, both financial and physical, so as to fully gear up to achieve the deliverables at the end of the Plan period.

I shall urge my colleagues to extensively use PARINAY for reporting the progress of work and for making an objective assessment of our progress towards achieving the goals defined in respective project reports.

I am happy to say that the OCR system adopted by BARC has been very successful and almost every officer

of this Centre could submit his last year's OCR in time. Efforts are on, to further improve the OCR system based on suggestions received from some of you.

We are all deeply saddened by the unfortunate fire incident in the Modular Laboratories on 29th December, 2009, when two young Ph.D students, Mr. Umang Uday Narayan Singh, Senior Research Fellow and Mr. Partha Pratim Bag, Junior Research Fellow lost their lives. On this occasion, we also pay our homage to the departed souls. It is time for all of us to introspect and ensure that such an incident must never take place in the centre.

I am urging all my colleagues here to scrupulously follow the safety guidelines and procedures laid down by the BARC Safety Council from time to time and give due priority to safety. I strongly appeal to all of you to be extra vigilant and bring any lapses, to the notice of the appropriate authorities for stern action against the defaulters.

Physical Protection

Physical protection of our Centre and its various installations is of paramount importance. I am sure, all my colleagues will understand that the concern of security has further increased in the present time. I strongly urge our Fire Service personnel to maintain a constant vigil on the various establishments of our centre and strive to improve their coordination with security and the concerned Divisions.

I also compliment all officers and staff of our Centre for extending their cooperation with the security personnel in discharging their duties effectively for implementing the higher level of security procedures. Finally, I urge all my colleagues in our Centre to remain vigilant and alert in the present environment.

Landscape & Cosmetic Maintenance

The contribution made by the personnel of our Landscape & Cosmetics Maintenance Section is aptly demonstrated by the beautiful ambience of this venue.

Conclusion

While concluding my address, I would like to emphasize that we have plenty of challenges ahead. With the Bhabha Centenary Year celebrations coming to an end, it should be our prime objective to pursue excellence, by synergising the efforts of all of us in BARC – scientists, technicians and administrators. I am sure we will be able to rise to the occasion to meet future challenges in a manner consistent with the traditions of BARC.

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

Jai Hind "

RESEARCH ARTICLE

Regulation of Differential Pressure in Liquid Zone Control System using Fuzzy Logic Control Scheme

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Reactor Control Division

1. Introduction

Nuclear reactor control is one of the areas with a huge potential for application of intelligent systems including fuzzy logic, in which, however, the development is still in its infancy, despite its success in other domains. Fuzzy logic control provides a formal methodology for representing, manipulating and implementing a human's heuristic knowledge about how to control a system. Despite many on–going research activities on fuzzy logic controller in nuclear reactors, on-line applications of fuzzy logic controllers in nuclear power plants with a license issued by the nuclear safety authorities are rare [1].

The operation of large Pressurized Heavy Water Reactors (PHWRs) *e.g.*, the 540 *MWe* PHWR with flattened radial and axial flux distributions coupled with xenon poisoning effect [2] leads to complex operational and control problems. The Liquid Zone Control System (LZCS) is provided in large PHWRs, for continuous fine control of the reactor power level and power distribution. The LZCS is a complex hydropneumatic system, in which maintaining the differential pressure between gas outlet header and delay tank is an important function, from the point of view of reactivity control. In the existing systems in India, a conventional PI controller is employed. In this paper, fuzzy control scheme has been proposed for maintaining the pressure difference between gas outlet header and delay tank, close to a specified setpoint.

2. Overview of LZCS

The LZCS consists of six vertically oriented tubes running interstitially between the calandria tubes from the top to the bottom of the core, as shown schematically in Fig.1. The two central tubes are divided into three compartments each, by appropriately placed bulkheads and the outer four tubes are divided into two compartments each, to give a total of 14 individually controllable compartments in the reactor. These compartments

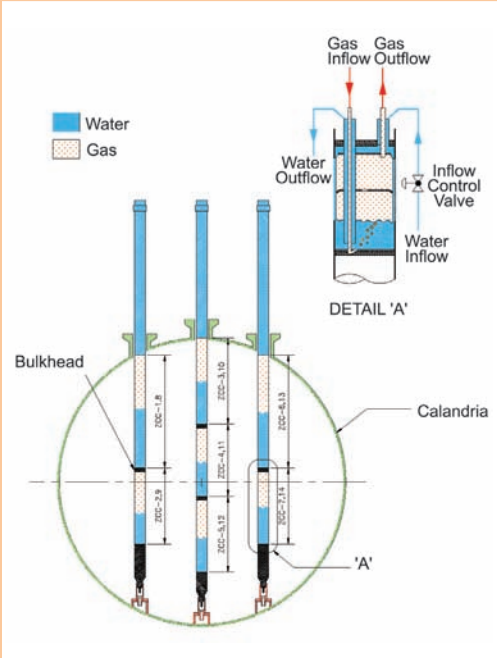

Fig.1: General arrangement of liquid zone control assemblies in a large PHWR

are called Zone Control Compartments (ZCCs). The level of water in each compartment can be individually controlled, by varying the inflow rate while outflow is maintained at a constant rate [3]. The water level in each compartment is varied individually for spatial control and in unison with other compartments for bulk power control [4].

A simplified flowsheet of the LZCS is shown in Fig.2. The water level in each ZCC is measured and gas is maintained under continuous circulation by a bubbler arrangement. For maintaining the water outflow rate at a constant value, the differential pressure between the ZCCs and the delay tank should be kept constant. As all the ZCCs are directly connected to the gas outlet header, at equilibrium, the pressure in the ZCCs is approximately equal to the pressure in the gas outlet header. The differential pressure between the gas outlet header and the delay tank is sensed by a ΔP instrument and maintained constant by means of a feed–bleed arrangement, consisting of a set of feed control valves, a set of bleed control valves and a feed and bleed controller.

Feed control valves are located between gas storage tank and gas outlet header, and bleed control valves are located between gas outlet header and delay tank. The feed and bleed controller generates the control signals for feed control valves and bleed control valves, based on the difference between the measured value and set value of differential pressure storage tank to flow into the gas outlet header, so that the pressure in gas outlet header increases and consequently the differential pressure between gas outlet header and delay tank is restored. On the other hand, if the differential pressure is larger than the set value, then bleed control valves are opened and gas flows out from gas outlet header to the

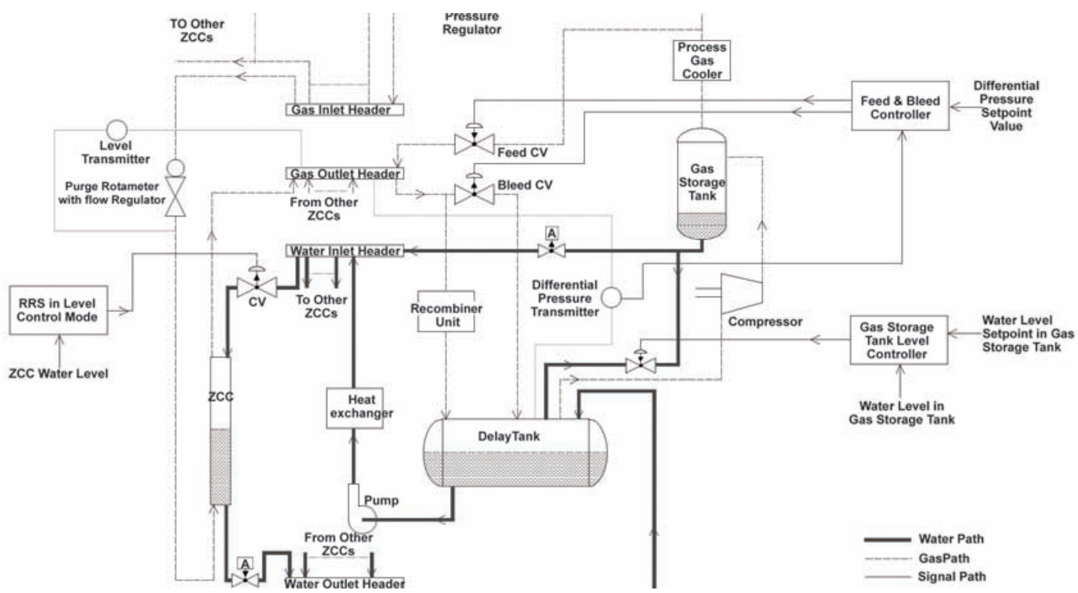

Fig.2: Simplified flow sheet of LZCS

delay tank, thus decreasing the differential pressure between gas outlet header and delay tank, towards the set value.

For understanding the behaviour of the LZCS before its installation in large PHWR units in India, a full scale test setup of LZCS was installed at the Reactor Control Division. Process fluids in the test setup are water and air. The control system of LZCS test setup is a PC-based system having a data acquisition module, a controller module, and an operator interface module.

3. PI type feed and bleed control system

A Proportional plus Integral (PI) controller is used, for control of differential pressure between gas outlet header and delay tank in CANDU reactors and in PHWR units in several countries. The PI controller accepts the sensor signal corresponding to differential pressure between gas outlet header and delay tank as input and generates control signals for the feed and bleed control valves, depending upon its deviation from the set differential pressure. Let ΔP and e be respectively the differential pressure and differential pressure error, defined as:

$$\Delta P = P_{GO} - P_{DT} \quad Kg/cm^2$$
$$e = \Delta P_S - \Delta P \quad Kg/cm^2 \qquad (1)$$

where ΔP_S , P_{GO} and P_{DT} denote respectively the set value of differential pressure between gas outlet header and delay tank, gas outlet header pressure and delay tank pressure. Then from e, the PI controller generates

$$I_C = K_P \times e + \frac{K_P}{T_I}\int e dt + 12 \quad mA \; ; 4 \le I_C \le 20 \, mA$$

where K_P is the proportional gain and T_I is the integral time constant of the controller. Control signals for feed and bleed control valves are derived by split ranging PI controller output I_C .

4. Fuzzy logic controller for regulation of differential pressure in LZCS

A fuzzy logic controller can be employed in lieu of the PI-type feed and bleed controller, introduced in Section 3 to control the differential pressure between gas outlet header and delay tank in LZCS. The fuzzy logic controller, as shown in Fig.3, has four major parts: Fuzzification, Rule Base, Inference Engine and Defuzzification. The input to fuzzy logic controller is *e*, defined earlier by (1). The output of fuzzy logic controller is *L* (% *open*), based on which the control signals for feed and bleed control valves are derived.

The fuzzification module converts the crisp variables into linguistic variables (fuzzy sets), as defined by their membership functions. According to observation and experience, when $e \ge -2\%$, then feed control valves opened fully and if $e \le -2\%$ then bleed control valves opened fully. The symmetric triangles with equal base and 50% overlap with neighbouring membership functions are used, to convert *e* into seven linguistic terms: NL (Negative large), NM (Negative medium), NS (Negative small), Z (Zero), PS (Positive small), PM (Positive medium) and PL (Positive Large) as shown in Fig.4. The seven triangles are used to express *L* in the seven linguistic terms: BL (Bleed large), BM (Bleed medium), BS (Bleed small), Z (Zero), FS (Feed small), FM (Feed medium) and FL (Feed Large) as shown in Fig. 5. The universe of discourse for output is between gas outlet header and delay tank. Feed control valves are opened if this differential pressure is less than the set value, allowing gas from gas chosen in the range from "134 to 134 so that controller uses the full output range.

The following seven *if-then* rules are used, to control the differential pressure between gas outlet header and delay tank:

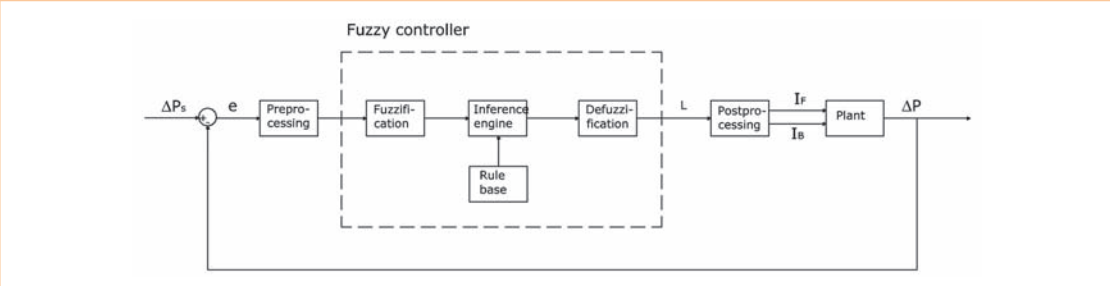

Fig.3: Fuzzy logic controller for feed and bleed control valves

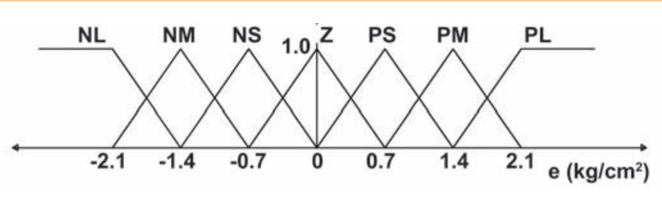

Fig.4: Membership functions for error

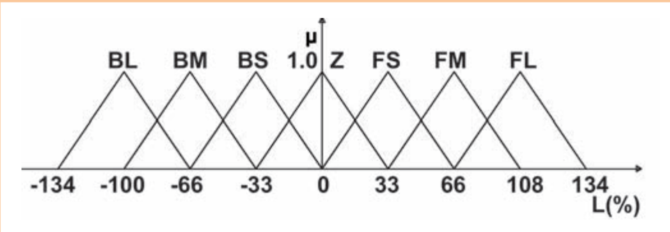

Fig.5: Membership functions for % opening of valve

1. *if e* is NL, *then L* is BL.
2. *if e* is NM, *then L* is BM.
3. *if e* is NS, *then L* is BS.
4. *if e* is Z, *then L* is Z.
5. *if e* is PS, *then L* is FS.
6. *if e* is PM, *then L* is FM.
7. *if e* is PL, *then L* is FL.

The Mamdani implication [5] with union aggregation is used to infer the output contribution from each rule and the centroid technique is employed, for performing defuzzification operation. Finally, the control signals for feed control valves (I_F) and bleed control valves (I_B) are derived from L in the postprocessing block.

5. Validation of fuzzy logic controller

On-line tests for evaluation of fuzzy logic controller proposed in Section 4 were performed on the test setup of LZCS. The experiments were conducted with transients involving step change in the set point of differential pressure and variations in average ZCC water level.

The responses of the system with PI controller and fuzzy logic controller for reduction in differential pressure setpoint from 4.5 Kg/cm^2 to 2.5 Kg/cm^2 in step manner, are shown in Fig.6. This experiment was being conducted with only air circuit in operation and water circuit was kept isolated to avoid undesired entry of water into pneumatic lines. With PI controller differential pressure settled with a little undershoot but with fuzzy logic controller differential pressure settled to final value without any undershoot. The fuzzy logic controller performs better than the conventional PI controller.

The performances of the PI and fuzzy logic controllers during simultaneous filling of all ZCCs (such that the average ZCC level rises from 30% FL to 70% FL nearly in a ramp manner) are illustrated in Fig.7. As the average ZCC water level starts rising, the pressure inside the ZCCs also starts increasing

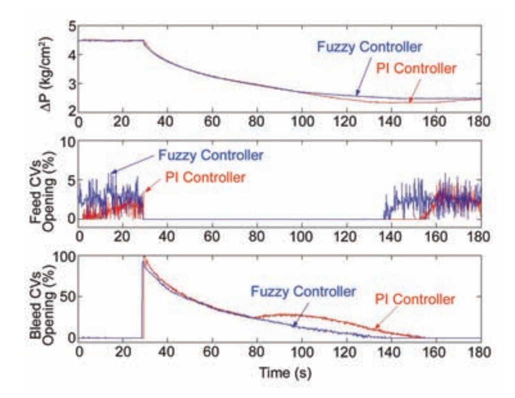

Fig.6: Response of PI and Fuzzy controllers to step change in set differential pressure from 4.5 kg/cm^2 to 2.5 kg/cm^2

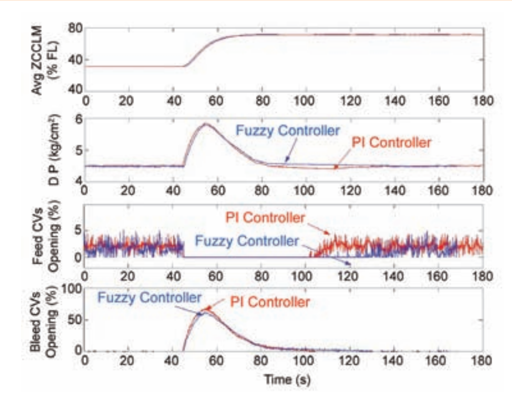

Fig.7: Response of PI and Fuzzy controllers during ramping up of average ZCC water level from 3% FL to 70% FL

and consequently the differential pressure between gas outlet header and delay tank is also increased. It is evident from Fig.7 that the differential pressure increased from 4.5 Kg/cm^2 to 5.85 Kg/cm^2 when PI controller is applied and it is increased to 5.78 Kg/cm^2 when fuzzy logic controller is applied for the same transient. Hence overshoot with fuzzy logic controller is smaller than that with PI controller. The settling time with fuzzy logic controller was also smaller than that with PI controller as seen from Fig.7. Therefore fuzzy logic controller performs better than PI controller.

The fuzzy logic controller was also validated for compressor on-off cycle, step rising in set differential pressure and simultaneous draining of all ZCCs in a controlled manner.

6. Conclusions

The fuzzy logic controller has been validated by performing a variety of experiments on LZCS test setup. In comparison to the existing PI controller, the fuzzy logic controller's performance is superior in all cases considered. Specifically, with fuzzy logic controller:

1. There is no overshoot during all setpoint change transients.
2. Settling time is shorter or almost equal to that with the PI controller for all transients.
3. The feed and bleed control valves operation is comparatively smoother.

Research involved in this project included a real test case and is a step forward in future fuzzy logic controller applications in nuclear power plants.

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Solar Desalination

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1. Introduction

Membrane-based desalination technologies such as Reverse Osmosis (RO), need considerable amounts of energy in the form of electricity, to achieve separation of pure water from saline water (Fig.1). The greenhouse effect of carbon dioxide in the

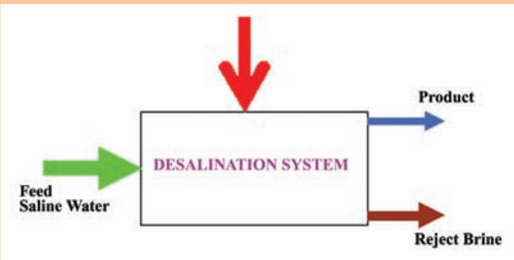

Fig.1: Principle of Water Desalination

atmosphere, caused by burning of fossil fuel for power production leading to climate change, is of concern all over the world. Power production utilizing environment friendly renewable energy sources, is the alternate solution in such situations (Markus Forstmeier)[1]. Also, they are essential for remote locations, where electricity is either scarcely available or not at all. It is reported that, there are thousands of Indian villages which cannot be connected to the grid power network, due to their remoteness.

The most widely used renewable energy source is the sun. The source of solar energy is inexhaustible and it is free. No harmful gases such as nitrogen oxide, mercury, carbon dioxide, or sulphur dioxide are emitted (Dirk Herold) [2]. In addition, there are various financial incentives that are offered by the government for the production of solar power (reliancenergy)[3].

The solar energy reaches the earth's surface, at a rate of around 3.9 X 10^{26} W (Nuclear Fusion)[4]. Besides powering the natural systems on earth, it can be converted into electrical energy through photo-voltaic (PV) cells. The photons in the sunlight hit the PV cells, made up of a semi-conducting material such as silicon and excite the electrons (Gil Knier)[5]. The energized electrons flow to produce a direct electric current (DC). This current can be directly used or be converted to AC with the help of an inverter. Solar PV-powered desalination systems are more suited for small community level plants, considering the techno-economic viability. RO is a pressure driven process, where pure water

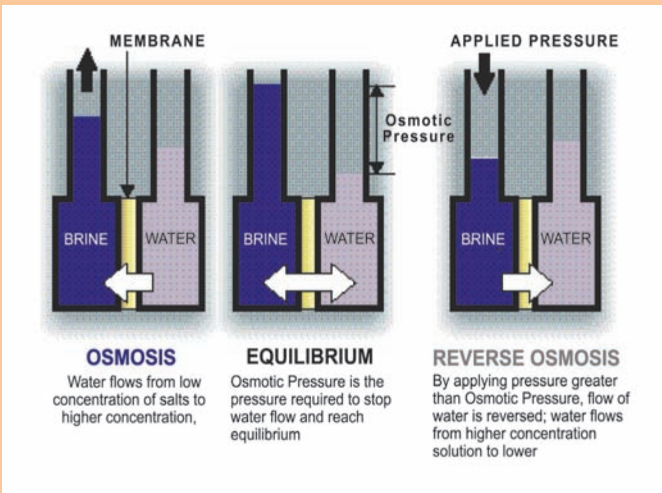

Fig. 2: Osmosis and Reverse Osmosis- Schematic Representation

from salty water is continuously drawn through a semi-permeable membrane (Fig. 2). The pressure requirement varies with the amount of dissolved salts. The normally reported brackishness in the ground water is in the range of 1000 – 3000 ppm and the desired limit of Total Dissolved Salts (TDS) in drinking water is 500 ppm as per World Health Organization (WHO) and IS-10500.

2. R&D in BARC on Solar Desalination

The Desalination Division, BARC is engaged in developmental work on desalination systems, based on solar heat and light. Solar energy-based small and community level RO units are developed, for producing safe drinking water from salty ground water.

2.1. Small RO Unit

In the RO unit (Fig. 3), the feed water is passed through the membrane with the help of a DC pump directly connected to the PV panels, without any batteries. The unit can be normally operated for 9 to 10 hrs on sunny days, which can cater to the drinking and cooking requirement of 3-4 families (at an average rate of 5 L/person/day). This unit contains a cartridge pre-filter and a spirally wound RO membrane element. The typical performance data of the unit is given in Table 1.

Fig. 3: Small Solar RO Unit at Trombay

No significant variation in the rate of power production from the PV panels has been observed during the effective operation period. Thus, the pump is able to maintain its duty, keeping the rate of drinking water production constant.

Table 1: Typical Performance Data of the Small Solar RO Unit

Capacity (m^3/day)	0.1
Feed Salinity (ppm)	1000 – 2500
Pressure (kPa)	400 – 500
Power Input (w)	10 -15
Product Salinity (ppm)	100 - 200

2.2. Community Level RO Plant

Water conservation becomes an issue when the natural recharge rate of the source is slow as in the case of groundwater. For this reason, a significant fraction of the reject flow is recycled back, so that fresh feed as well as discharge volumes can be minimized. The energy also can be recovered if water is redirected back through the membrane instead of being discharged. To enhance the RO membrane life, the RO feed water is to be physically and chemically conditioned. All the suspended / colloidal and biological matter is to be filtered out and measures are to be taken for preventing precipitation of the sparingly soluble salts on the membrane surface.

This solar RO plant consists of PV panels, inverter, charge regulator and battery storage at the power side and UV for disinfection, pre-filters, chemicals dosing systems, pumps and RO modules at the desalination side. The schematic of the plant is shown in Fig. 4.

The technical specifications are given in Table 2.

Table 2: Technical Details of the Community Level RO plant

Capacity (m^3/day)	2
Feed Salinity (ppm)	2000 – 2500
Product Recovery (%)	70 - 80
Pressure (kPa)	1.1 x 10^3 – 1.2 x 10^3
Power Requirement (kw)	1.6 - 1.8
Product Salinity (ppm)	200 - 250

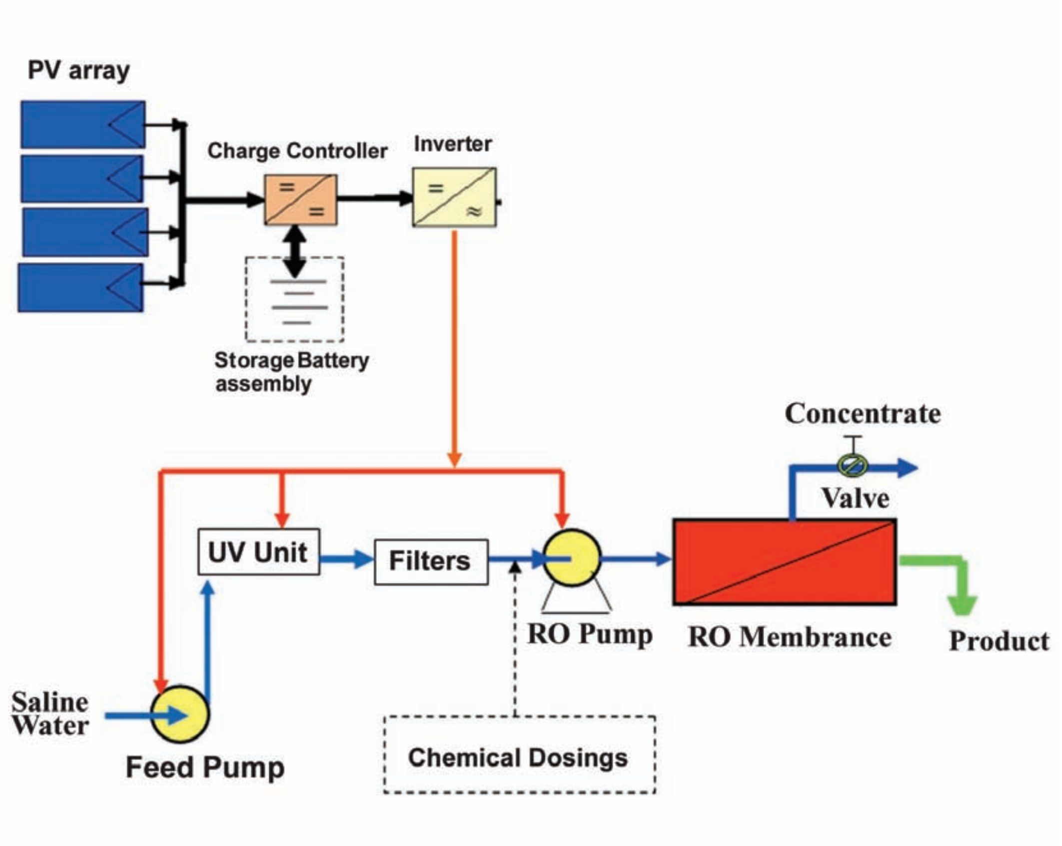

Fig. 4: Schematic of Solar Energy-Driven RO Plant

Fig. 5: Community Level RO Plant along with PV Panels at Trombay

Fig. 5 shows the community size RO plant along with the solar PV panels undergoing performance evaluation at Trombay.

3. Conclusion

Integrating desalination units with renewable energy sources is important for addressing the issues related to adverse impacts of climate change. Also, for remote areas, where scarcity of power and water co-exist, the one and only solution to produce safe drinking water is to go in for renewable energy sources. With improvement in PV efficiencies and the subsidies available, cost of PV systems is expected to come down, making the solar PV based desalination systems more cost-effective.

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Development of Mo base TZM (Mo-0.5Ti-0.1Zr-0.02C) alloy and its shapes

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1. Introduction

Refractory metals and their alloys possess high temperature strength, creep resistance, low coefficient of thermal expansion, high thermal conductivity and favourable nuclear properties, which enable them to withstand prolonged exposure to aggressive environments of radiation, temperature, corrosion (gaseous and liquid metal) and stress. These materials have an edge over conventional superalloys as high temperature structural materials and are, therefore, being considered for new generation reactors such as, accelerator driven systems, advanced high temperature reactor, fusion devices [1,2] and reusable launch vehicles [3].

Amongst the high temperature alloys, the refractory metal alloys are the only materials for structural applications beyond 900°C. Molybdenum base alloys such as, TZM, are the most suitable ones amongst the refractory metal alloys for application temperatures up to 1500°C. Amongst the different molybdenum base alloys, TZM (Mo-0.5Ti-0.1Zr-0.02C)) is the most suitable one, in terms of yield strength to density ratio, at temperatures above 900°C [4]. In this alloy, small amounts of titanium, zirconium and carbon are added, so as to obtain a coarse distribution of carbides with some titanium and zirconium remaining in solid solution [5]. The high strength of this alloy at elevated temperatures and its excellent corrosion resistance against liquid metals, makes it suitable for application in advanced high temperature nuclear reactors. Other alloys of this class include: TZC (1.2% titanium, 0.3% zirconium, 0.1% carbon), MHC (1.2% hafnium, 0.05% carbon), and ZHM (1.2% hafnium, 0.4% zirconium, 0.12% carbon).

The preparation and fabrication of TZM components is challenging due to its high melting temperature (~2600°C). Of the feasible methods of preparation and fabrication of TZM alloys, viz. (i) aluminothermic reduction of mixed oxides followed by arc or electron beam melting, (ii) component melting and (iii) powder processing, the last route has the advantage of ease of operation, consistency of alloy composition, homogeneity and phase distribution. The present work was taken up with the aim of producing TZM and its components by the powder processing route consisting of the following steps: preparation of pure Mo powder by hydrogen of reduction of MoO_3, preparation of TZM alloy powder from elemental powders by mechanical alloying, compaction of powders into green compacts and sintering for densification. Each of these steps are described in the following sections.

2. Hydrogen Reduction: Preparation of Molybdenum powder

In our investigation, a detailed kinetic analysis of the hydrogen reduction of MoO_3 powder was carried out under isothermal and non-isothermal heating conditions. The reductions were performed with varying percentage of hydrogen (10 to 100%) in the inlet gas mixture containing helium and hydrogen.

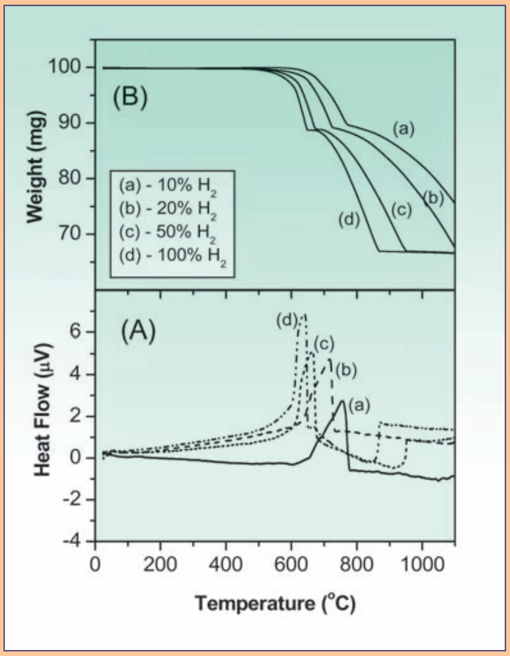

Fig. 1: (A) DTA plot of different thermal peaks and (B) TG plot showing completion of reactions at different temperatures as hydrogen percentage is varied

The Thermo Gravimetry and Differential Thermal Analysis (TG-DTA) of reduction of MoO_3 in hydrogen containing atmosphere shows some interesting facts. Fig. 1A shows, that the reduction takes place in two stages (as obtained from the observed two-stage weight reduction). X ray diffraction (XRD) analysis showed that MoO_3 is reduced to MoO_2 in the first stage and Mo is obtained from MoO_2 in the final stage. The figure shows that the second stage of reduction is affected by the hydrogen content in the atmosphere: it achieves completion at 873°C with 100% H_2, it is complete at around 955°C with 50%H_2 and is incomplete even at 1100°C with 10% H_2. Fig. 1B, on the other hand, shows that the peak temperature for MoO_2 formation (first stage) shifts to higher temperature as the hydrogen content of the atmosphere is increased: it is around 642°C when the hydrogen content is 100% and 755°C when it is only 10%. DTA, however, did not show any distinct peak for the second stage of reaction, which could be due to the low enthalpy of the MoO_2-Mo reaction.

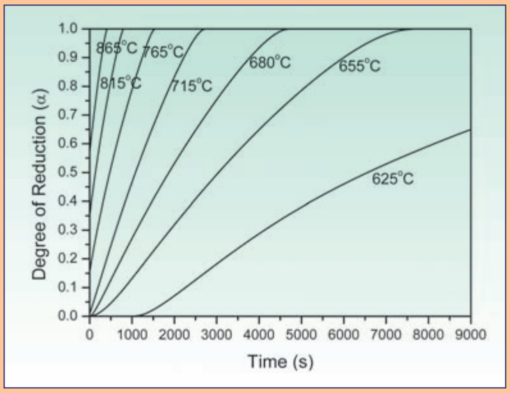

Fig. 2: Kinetic data for isothermal reduction of MoO_2 in pure H_2

Isothermal experiments of MoO_2–Mo reduction in presence of 100% H_2 were carried out at seven different temperatures. The degree of reduction (α) with time, Fig. 2, shows the typical sigmoidal shape. Analysis of the data showed that it followed the Johnson, Mehl, Avrami and Kolmogorov model of reaction kinetics:

$$g(\alpha) = [-\ln(1-\alpha)]^{1/n} = kt \quad (1)$$

Where, n is Avrami exponent, t is time, and k rate constant. It is observed that n varied from 1.5 to 2 with increase in temperature of reduction, while the activation energy of for the isothermal reduction is136 $kJmol^{-1}$.

Fig. 3 shows the SEM micrographs of powders obtained by the reduction of MoO_3 in pure hydrogen atmosphere for 150 minutes at six different temperatures. The MoO_3 powder used in these experiments had an average size of 3.25μm and a rod or acicular morphology. At 625°C, the powder was only partially reduced, the micrographs showing irregularly shaped Mo particles, platelets of the intermediate phase, MoO_2, and rod shaped particles of unreduced MoO_3. At 655°C, the reduction was complete, but the Mo particles showed significant amount of porosity and edge cracks. With increasing temperature of reduction, porosity and cracks reduce

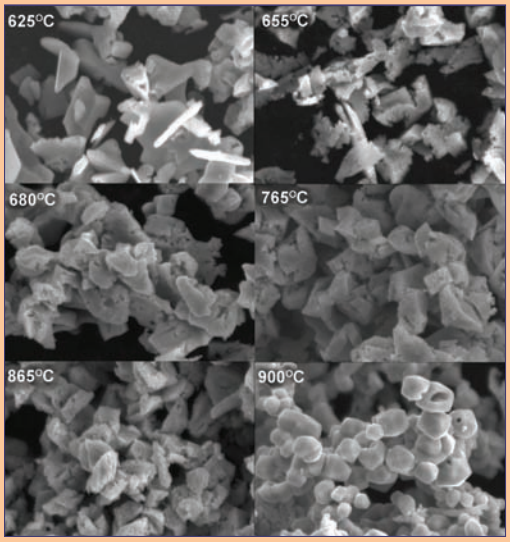

Fig. 3: Change in morphology of Mo powder with temperature of reduction in pure hydrogen for 2.5 hrs

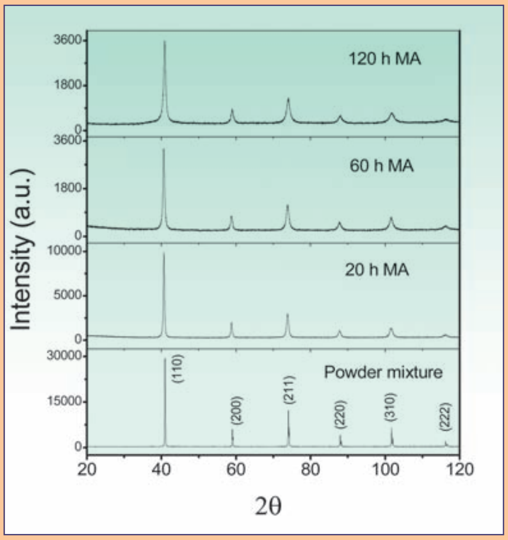

Fig. 4: XRD patterns of powder mixture, 20 h MA, 60 h MA, and 120h MA powder

and edges of individual particles start rounding off till a near equiaxed shape is obtained at 865°C. Finally, at 900°C, spherical Mo particles were obtained that are completely devoid of edge cracks and porosity.

Based on these studies, the optimum conditions for producing Mo by hydrogen reduction of MoO_3 were determined to be: controlled heating up to 900°C followed by an isothermal holding for 2.5 hrs in a flowing atmosphere of pure hydrogen. Large quantities of molybdenum powder have been successfully produced using these optimized conditions.

3. Mechanical Alloying: Preparation of TZM alloy powder

Mechanical alloying is a technique that allows production of homogeneous materials starting from blended elemental powder mixtures. Here, the repeated welding and fracturing process during milling tools leads to a gradual alloying of the elemental powders. The aim of the present work was to determine the optimum conditions for the production of TZM alloy powders by mechanical alloying.

The Mo powder produced by hydrogen reduction was mixed thoroughly with pure titanium, zirconium and graphite (C) powder of required quantity and of nearly similar size range. The powder mixture was milled in a planetary ball mill with 10mm diameter WC balls (3:1 balls to powder weight ratio) for varying periods of time up to 120 hours at a constant milling speed of 400 rpm.

XRD patterns of the starting powder mixture and mechanically alloyed powder are shown in Fig.4. As the amount of Ti and Zr was very low in the powder mixture, its XRD pattern shows reflections of only bcc molybdenum. On the other hand, mechanical alloying expectedly results only in the marginal shift of bcc reflections, as Ti, Zr and Mo have similar atomic sizes. The gradual broadening of the reflections with milling time is due to refinement of crystallite size and accumulation of lattice defects. However, there was no significant increase in peak broadening beyond 60 hours of milling.

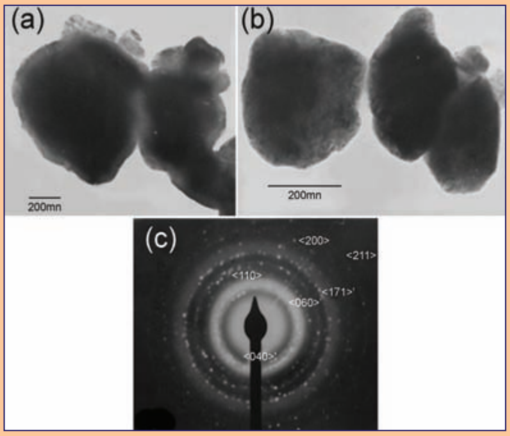

Fig. 5: TEM images of (a) 60 h MA, (b) 120 h MA and (c) SAD pattern of MA powder; reflections from (110), (200) and (211) are for Mo, and (040), (060) and (171) for $(Mo_{0.72}Ti_{0.28})C$ carbide .

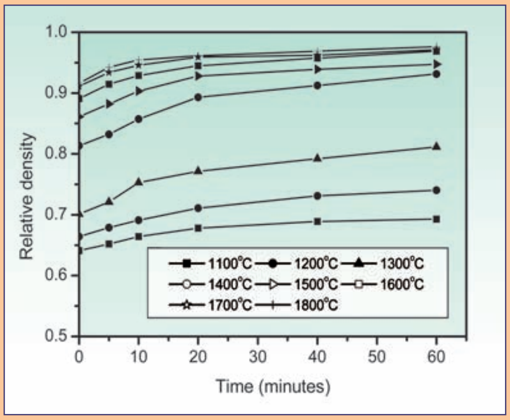

Fig. 6: Densification with time at different temperature of sintering for TZM compacts.

A confirmation that alloying had been achieved during mechanical milling was obtained from Transmission Electron Microscopy (TEM) of powders milled to 60 and 120 hours. Fig. 5 shows that the microstructure consists of fine second phase particles distributed uniformly within a bcc matrix. Analysis of the ring diffraction patterns obtained from selected areas of the powder indicated the formation of the orthorhombic $(Mo_{0.72}Ti_{0.28})C$ phase. The presence of complex carbides along with a slight shift of XRD reflections is evidence enough of the successful creation of the TZM alloy by mechanical alloying.

The particle size of powders measured by Scanning Electron Microscopy (SEM) was found to reduce with milling time, from about 730nm to about 230nm. However, there was not much of reduction of particle size between 60 h and 120 h of milling as steady-state equilibrium was probably attained: in this situation a balance is achieved between the rate of welding and the rate of fracturing. Smaller particles are able to withstand deformation without fracturing and tend to be welded into larger particles, the overall tendency driving very fine and very large particles towards an intermediate size [6].

4. Sintering of TZM powder

Sintering is a thermally activated process that leads to densification. Isothermal sintering studies at nine different temperatures between 1000 to 1800°C were conducted on compacted pellets of TZM powders. Fig. 6, which presents the densification behavior of the pellets as a function of time, shows that the relative density varies with time in a nonlinear manner during the initial stage of sintering. There is a spurt in the rate of densification at around 1400-1500°C, the maximum relative density of 0.97 being obtained at sintering temperature of 1800°C. It must be mentioned that very little densification is obtained at sintering temperatures below 1300°C.

In order to understand the grain growth behaviour of TZM during sintering, pellets of both pure Mo and TZM alloy powders were sintered at 2000°C for 10 minutes. The microstructures of the sintered pellets, obtained as orientation maps using Electron Back-Scattered Diffraction (EBSD), are shown in Fig.7. The role of the complex carbides in restricting the grain growth in TZM alloy is obtained from the fact that the grain size of Mo is 8.12μm and that of TZM is only 3.36μm. The carbides also shift the recrystallization temperature to higher temperatures and improve the creep behaviour.

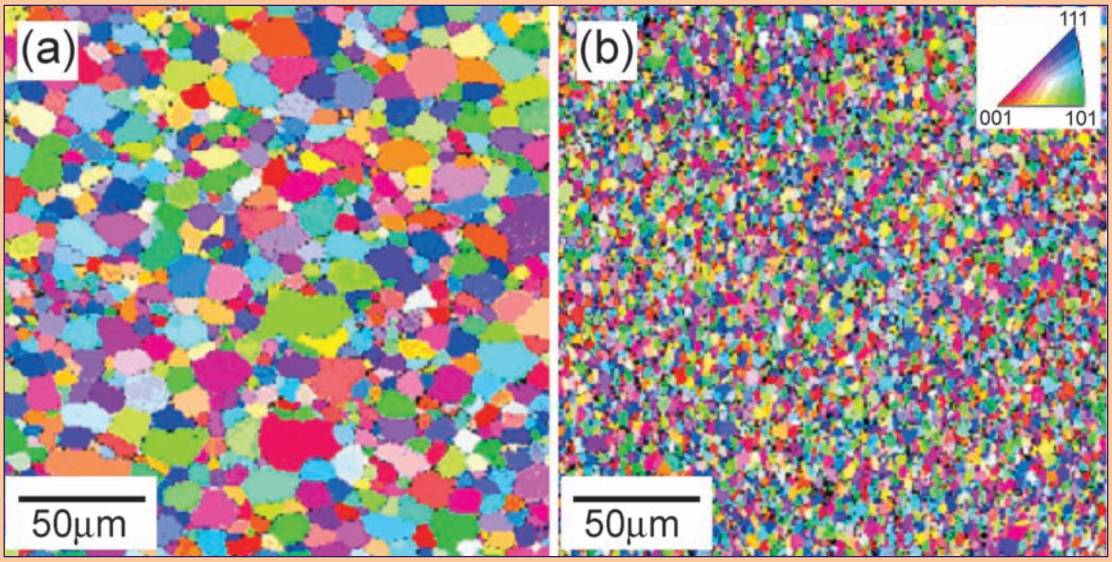

Fig. 7: Microstructures of (a) Mo and (b) TZM compacts sintered at 2000°C for 10 minutes. Inset in (b) is an inverse pole figure; the color codes indicate the orientation of the grains along different crystallographic directions.

5. Hot Isostatic Pressing

Techniques best suited for achieving near theoretical density of powders are: Hot Isostatic Pressing (HIP), spark plasma sintering, explosive compaction, pressure-less sintering, explosive compaction and hot pressing. Of these, HIP is the most promising for producing uniformly dense fine grained material. In this study, TZM alloy powder was consolidated using Cold Isostatic Pressing (CIP) into green compacts of 15mm diameter and about 20mm length. The compacts were then pre-sintered at 950°C for 2 hours under hydrogen flow for removing traces of oxygen and vacuum encapsulated in thin stainless steel tubes. The capsules were then placed inside a HIP chamber and isostatically compacted at varying argon gas pressures of up to 350 bar at 1250°C for 4hours. It was found that density better than 99.9% of the theoretical value (10.16 g/cc) was achieved by HIP. TEM analysis of the HIPped material, Fig.8, shows uniform dispersion second phase precipitates of 40 to 100 nm size, dispersed in the matrix of equiaxed grains of 1 to 1.5 μm. The ring diffraction patterns obtained from selected areas show the formation of the hexagonal $(Mo_{0.54}Ti_{0.46})C$, and the orthorhombic $(Mo_{0.72}\,Ti_{0.28})C$ complex molybdenum-titanium carbides. The high pressure and temperature resulted in dense materials free of pores.

6. Shape fabrication

Based on the study of powder consolidation and sintering, an attempt was made to prepare TZM alloy tubes. The green tubes were produced from the mechanically alloyed TZM powder by CIP at an optimized compaction pressure of 250 MPa. A specially designed cylindrical mould with matching end plugs having the provision to hold a polished SS tapered rod 25mm diameter was specially designed. The SS rod was polished and tapered for easy removal of compacted green tubes. A mechanical vibrator was used to fill the powder around the SS rod within the rubber mould. Multistage sintering of the green tubes was done in a resistance type graphite-heating furnace. The green tubes were initially heated slowly to about

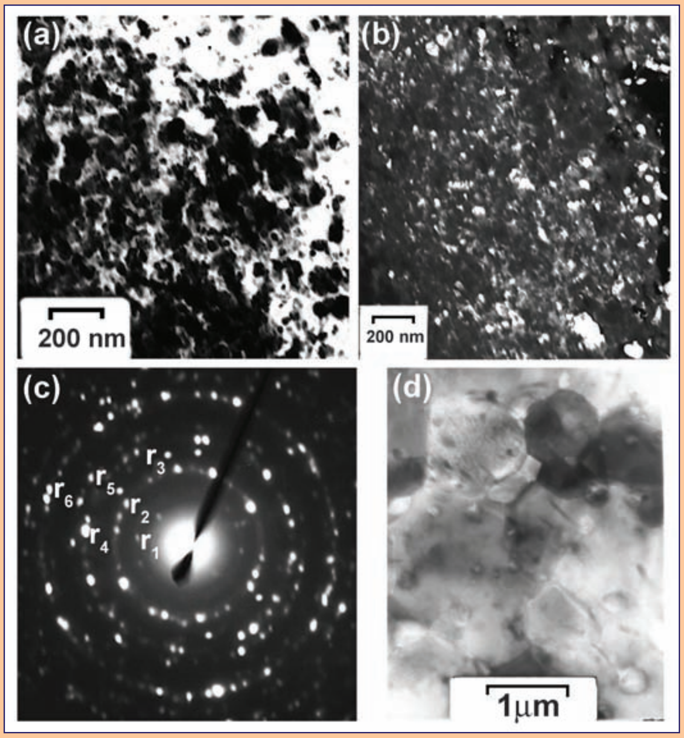

Fig. 8: TEM images of HIP alloy (a) bright-field image showing carbides; (b) dark bright-field image of carbides; (c) selected area diffraction pattern showing rings: the inner ring r_1 and r_3 for (002) and (101) of $(Mo_{0.54}Ti_{0.46})C$, r_2 and r_5 for (040) and (171) of $(Mo_{0.72}Ti_{0.28})C$ and r_4 and r_6 for (110) and (200) of Mo matrix; and (d) dark-field image showing fine grains with precipitates.

1000°C under hydrogen atmosphere to remove any absorbed or adsorbed oxygen from previous processing stages. The final stage of sintering was conducted at 1800°C for 2 hours at a vacuum level of 10^{-5} mbar obtaining a density of about 0.97 of theoretical value. Finally, TZM alloy tubes of 50 mm length, 22 mm ID and 27 mm OD were prepared from the sintered pre-forms by conventional single-point machining. Fig. 9 shows the green compact, the sintered pre-form and the machined tube produced from mechanically alloyed TZM powders. The detailed flow sheet of the process is presented in Fig.10.

Based on results of a study on the hot deformation of TZM alloys, it is envisaged that extrusion of sintered tubes at 1300-1400°C would be suitable for making tubes of larger dimensions. Finally, it should be mentioned here that a halide activated pack cementation technique has also been successfully developed, for incorporating a silicide based coating on the inner or outer surfaces of these TZM tubes, for improved high temperature oxidation resistance.

Acknowledgements

The authors are thankful to Prof. Indradev Samajdar of IIT, Bombay for his support in carrying out the XRD, SEM, TEM and EBSD studies required in this work. The authors are also grateful to WIP, BARC for helping them with HIPping of sintered TZM pre-forms.

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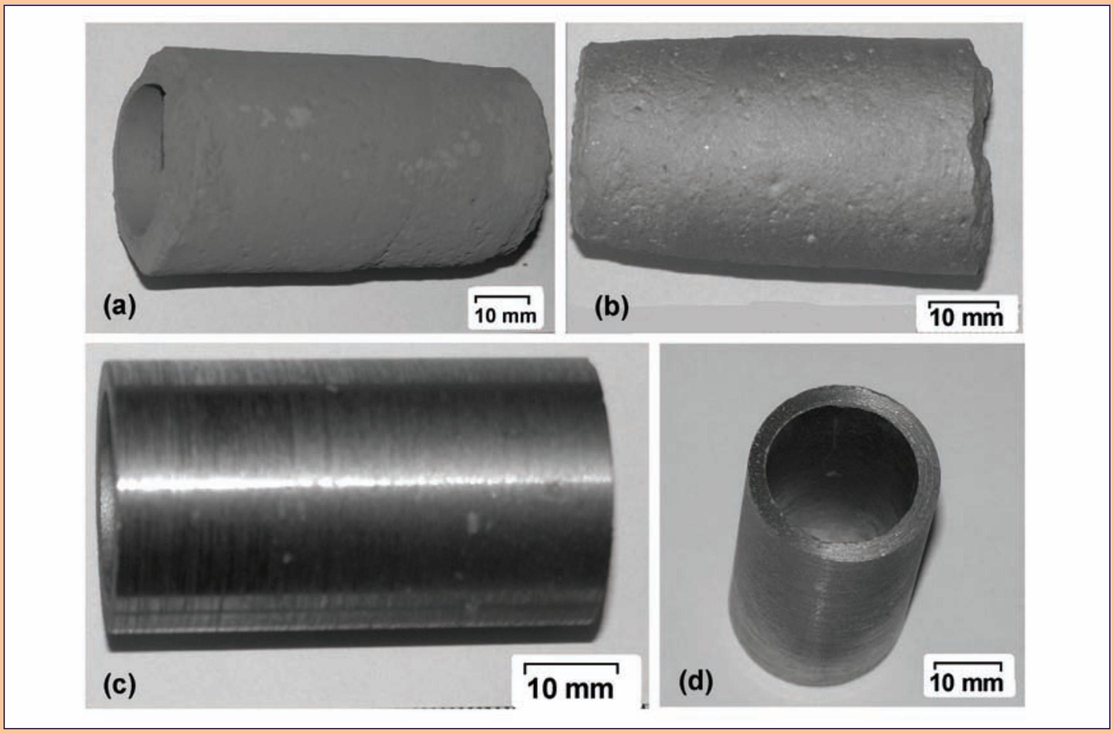

Fig. 9: TZM tube produced by mechanical alloying followed by CIP and sintering: (a) Green, (b) Sintered and (c) & (d) Machined

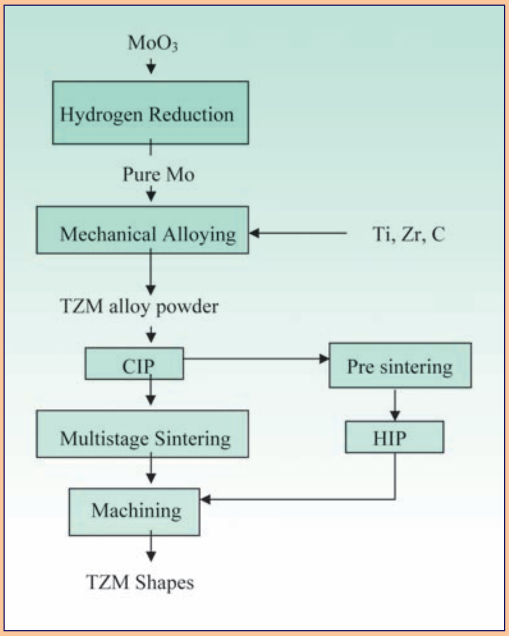

Fig. 10: Flowsheet for the preparation of TZM shapes

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Magnetocaloric effect and magnetic cooling

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Materials showing large Magnetocaloric Effect (MCE), i.e., a large change in temperature of a material upon a moderate change of an external magnetic field under adiabatic condition, have attracted a lot of attention in recent years, due to their practical application in magnetic refrigeration [1]. The magnetic refrigeration technology can be considered as an alternative to the conventional gas compression technology. Modern refrigerators and coolers (based on gas compression technology) may not be using ozone depleting gases but they still use greenhouse gases that cause the warming of the planet. Also a high cost of electricity is involved to operate their compressors. On the other hand, the magnetic refrigeration technology is an environment friendly cooling technology, as it does not use any ozone depleting/greenhouse gases or hazardous chemicals. Besides, one can eliminate the high capital cost of the conventional gas compressor and a high consumption of electricity.

Magnetocaloric effect was first observed by the German physicist Emil Warburg in 1880. The fundamental principle of the magnetocaloric effect was suggested by Peter Debye (1926) and W. F. Giauque (1927), independently. Later in 1933, this technique, most commonly known as adiabatic demagnetization, was first demonstrated experimentally by Giauque and his colleague D. P. MacDougall when they achieved a lowest temperature of 0.25 K. The lowest temperature achieved till that time was 0.8K (by Heike Kamerlingh-Onnes in 1910) by pumping away the vapour of liquid helium and causing it to evaporate under reduced pressure (the Joule-Thomson effect).

Fig. 1 shows a typical magnetic refrigeration cycle. When a magnetic material is exposed to a static magnetic field, spins align and the magnetic entropy

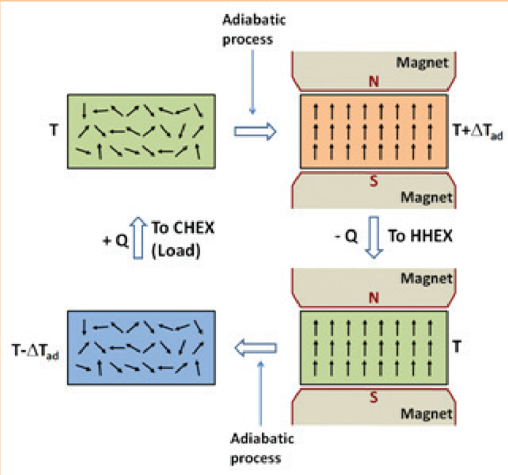

Fig. 1: A schematic diagram of a magnetic refrigeration cycle

of the system reduces. If this process is performed adiabatically, the reduction in the magnetic entropy is compensated by an increase in the lattice entropy (adiabatic temperature change, DT_{ad}) of the material. This added heat can then be removed by connecting the system with the Hot Heat EXchanger (HHEX). Now, if the applied magnetic field is removed under an adiabatic condition, the spins tend to reorient randomly by agitating action of the thermal energy, causing the magnetic entropy to increase and consequently, the temperature of the magnetic material drops as the magnetic spin system absorbs the thermal energy to perform its reorientation. The cooling of the magnetic material can then be utilized to cool a Cold Heat EXchanger (CHEX).

It took a long time to develop the first prototype magnetic refrigerator to achieve cooling near room cooling down temperature after its first demonstration to 0.25 K in 1933. Brown first applied the magnetic refrigeration near room-temperature

$Gd_{0.74}Tb_{0.26}$, in 1976. By employing Gadolinium (Gd) as the working substance, he attained a 47 K no-load temperature difference with a magnetic field change of 7 T. However, the first proof-of-concept magnetic refrigerator was developed by Astronautics Corporation of America and Ames Laboratory under the supervision of Carl Zimm. Spherical powder of Gadolinium was used as magnetic refrigerant and water was used as the heat transfer fluid. With the magnetic field change of 5 T, a temperature span of 10 K (between the hot and cold heat exchangers) was achieved. The maximum values obtained from this unit include a cooling power of 600 Watts, Coefficients Of Performance (COP) near 10, and approximately 60% of Carnot efficiency [2]. Later, they could achieve the temperature difference (between the hot and cold heat exchangers) of 38 K, for the same field change, but, the cooling power was reduced to 100W.

The modern magnetic refrigeration technology has shown a sign of a good start and many prototype magnetic refrigerators have been built and tested worldwide. However, there are a few challenges, such as, finding materials with large MCE, generation of a high magnetic field using permanent magnets, *etc*. which need to be accomplished before magnetic refrigeration could give the conventional vapour-based technology a run for its money. The last decade has seen various designs of rare earth-based permanent magnets (giving a magnetic field as high as ~ 1.5 T, between the centre of the air gap of the C-shaped magnet) which can be used in magnetic refrigerators. Applying the magnetic field beyond 2 T without using superconducting magnet is improbable. Now, more research is being done to search for a material with a large MCE over a wide temperature range with ΔH 2 T, which will ensure the success of magnetic refrigeration as a viable energy-saving and environmentally safe technology in the coming years. Fig. 2 shows the number of articles published since it was first expounded in 1933. It is evident from this figure that the search for materials with large MCE has gained a large momentum in last decade.

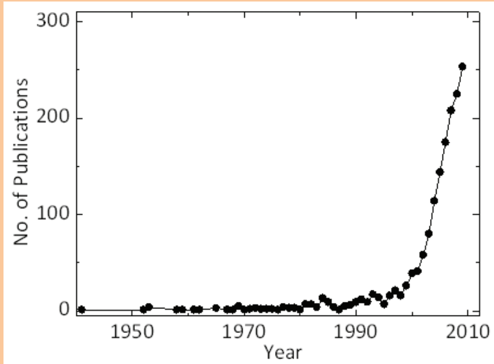

Fig. 2: The number of papers published on MCE (searched using SCOPUS (www.scopus.com) with a string "Magnetocaloric Effect" in the "Title, Abstract and Keywords" fields).

The magnetocaloric effect is particularly pronounced close to the temperatures and fields corresponding to magnetic phase transitions. The magnitude of this effect is strongly dependent on the magnetic order process. It is small for spin-glasses, antiferromagnets, moderate for ferrimagnets and, higher for ferromagnets. Among ferromagnetic materials, it is largest for materials showing first order magnetic phase transitions as compared to those showing second order phase transitions. The giant magnetocaloric material should also satisfy the following main criteria before it finds an application as magnetic refrigerant near room temperature: (i) a small lattice entropy (i.e. high Debye temperature), (ii) a small specific heat and large thermal conductivity (ensures remarkable adiabatic temperature change and rapid heat exchange), (iii) Curie temperature in the vicinity of room temperature, (iv) a wide operating temperature range, and (v) negligible thermal and field hystereses.

Gadolinium, which undergoes a paramagnetic to a ferromagnetic phase transition at 292 K, is commonly used in many of the prototype magnetic refrigerators. Its alloys are also promising due to their large MCEs. The Gadolinium alloys, used in magnetic refrigerators. As reported in literature, the transition temperature of Gd_5Si_4 can be tuned to room temperature, by substituting Ge for Si. The MCE is significantly stronger in $Gd_5(Si_2Ge_2)$ alloy, about twice as large as gadolinium alone. Apart from giant MCE, an absence of thermal and field hystereses is desirable from the application point of view. There are reports which show that efforts have been made to reduce the field hysteresis by substituting suitable element in the so-called giant MCE materials. One good example is the substitution of Fe at Ge site in $Gd_4Ge_2Si_2$, where 90% reduction in the field hysteresis was reported without any significant reduction in the magnetic entropy change for $Gd_4Ge_{1.9}Si_2Fe_{0.1}$.

Under the sub-project, "*25 R&D N 33.10: R&D on Magnetic Materials for Energy Systems*" of BARC Apex project "*25 R&D N 33: Energy Conversion*", we have been investigating MCE in a variety of magnetic systems, such as, Heusler alloys, half Heusler alloys, rare-earth intermetallics, perovskites, and molecular magnets [3-7]. Our aim is to first understand the physical principles that are responsible for their large magnetocaloric behaviour and then to tune their physical properties for achieving better MCE materials, which can be used to build an efficient magnetic refrigerator.

The MCE can be understood in terms of the magnetic entropy change and/or the adiabatic temperature change. The magnetic entropy of a system can be expressed as $S_M(T,H) = \partial F_M/\partial T$, where F_M is the magnetic free energy consisting of the exchange energy, magnetostatic energy, anisotropy energy and Zeeman energy. The magnetic entropy change $\Delta S_M(T)$, therefore, arises due to the coupling of the atomic magnetic moments with the external magnetic field. The temperature and field dependence of ΔS_M can be written using the following expression:

$$\Delta S_M(T,\Delta H) = S_M(T,H) - S_M(T,0) \quad (1)$$

$$= \int_{H_1}^{H_2} \left(\frac{\partial M(T,H)}{\partial T}\right)_H dH \quad (2)$$

The magnetic entropy change can also be written in terms of heat capacity of the material as

$$\Delta S_M(T,\Delta H) = \int_0^T \frac{C_p(T,H) - C_p(T,0)}{T} dT, \quad (3)$$

where, $C_p(T,H)$ and $C_p(T,0)$ are the values of the heat capacity at constant pressure measured in a field H and zero field, respectively. The adiabatic temperature change DT_{ad} can be given as

$$\Delta T_{ad} = -\int_{H_1}^{H_2} \frac{T}{C_{p,H}} \left(\frac{\partial M}{\partial T}\right)_H dH \quad (4)$$

From Eq. (2) and (4), it can be seen that for a large MCE i.e. large ΔS_M and ΔT_{ad}, one needs to have large $(\partial M/\partial T)_H$ and small value of $C_p(T,H)$. For the $M(H)$ data recorded at very close temperature intervals, Eq. (2) can be simplified as

$$\Delta S_M(T,H) = \sum_i \frac{M(T_{i+1},H_{i+1}) - M(T_i,H_i)}{(T_{i+1} - T_i)} \Delta H \quad (5)$$

Eq. (5) gives good and quick estimate of magnetocaloric effect for materials showing a second order magnetic phase transition as well as for a majority of materials showing weak first order phase transitions. However, for a truly discontinuous first order phase transition, Eq. (5) fails to describe MCE near its phase transition temperature and one has to directly measure the adiabatic temperature change.

From our recent study [3-7], we show in Fig. 3 the temperature dependence of ΔS_M for $La_{0.67}Ca_{0.33}Mn_{0.9}Fe_{0.1}O_3$ perovskite [3] and $TbCo_{2-x}Fe_x$ alloys [6]. For $La_{0.67}Ca_{0.33}Mn_{0.9}Fe_{0.1}O_3$, the maximum value of $-\Delta S_M$ for ΔH=3 T has been found to be 1.18 J kg^{-1} K^{-1} at 113 K with a relative cooling power of ~ 87 J kg^{-1} and a quite broad operative temperature range 65–160 K [3]. The operating temperature range corresponds to the temperature-range over which the magnetic entropy change lies above half of its maximum value and, a relative

cooling power is the area under the -ΔS_M vs T curve over the operating temperature range. For $TbCo_2$ and $TbCo_{1.9}Fe_{0.1}$ alloys, the values of maximum magnetic entropy change are found to be ~ 5.6 and 2.5 J kg^{-1} K^{-1}, respectively, for a 3 T field change [6]. The neutron diffraction experiments have also been carried out (using the facilities at the Dhruva research reactor) to investigate the magnetostructural coupling which is important to gain a microscopic understanding of the observed high MCE in these rare earth- and transition metal-based alloys [6]. We have also been studying the magnetocaloric properties of Heusler alloys $Ni_{2+x}Mn_{1-x}Sn$ and $Ni_{2+x}Mn_{1-x}Sb$ [7]. The parent compounds Ni_2MnSn and Ni_2MnSb show a paramagnetic to ferromagnetic transition below ~ 340 and 350 K, respectively. It is found that by substituting Ni at Mn site, the magnetic phase transition temperature can be tuned towards room temperature.

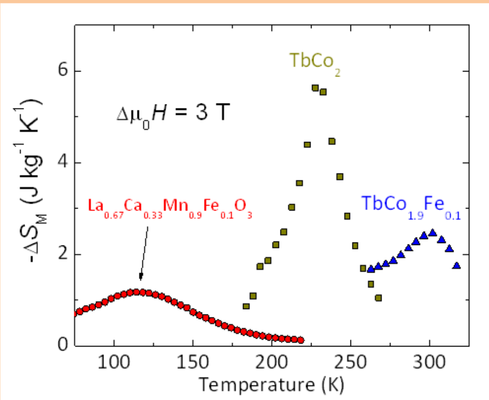

Fig. 3: The magnetic entropy change -ΔS_M (corresponds to a magnetic cooling) as a function of temperature for $La_{0.67}Ca_{0.33}Mn_{0.9}Fe_{0.1}O_3$ perovskite and $TbCo_{2-x}Fe_x$ (x = 0 and 0.1) alloys.

The operating temperature range is often quite narrow for any given magnetocaloric material. Finding an MCE material with a large magnetic entropy change over a broad temperature range is a challenge. By using multiple magnetocaloric materials, with overlapping operating temperature range, in a cascaded manner, a cooling over a broad temperature range can be achieved. Fig. 4 shows desired -ΔS_M vs T curves from magnetocaloric materials for application in a cascaded system.

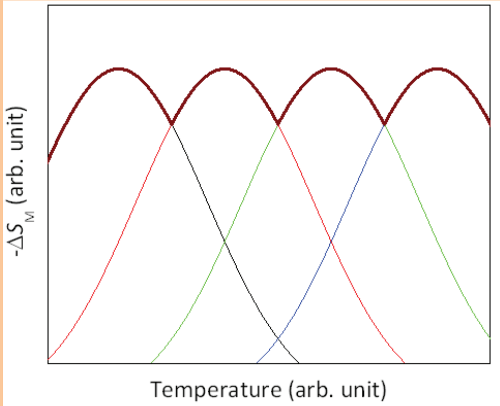

Fig. 4: Desired -DS_M vs T curves for a cascade system comprising of magnetocaloric materials with overlapping operating temperature range to achieve cooling over a broad temperature range.

The magnatic refrigeration technology is matured in terms of its application in the low temperature regime. The article brings out challenges and scope of further research work for commercialization of magnetic refrigeration.

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Investigations on Reinforced Concrete Structures

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1. Introduction

Reinforced Concrete (RC) has been the most popular construction material used worldwide in the past century. It has proven to be a wonderful construction material that possesses almost all of the desirable properties such as excellent insulation from environment, durability, low cost, ease of construction, ability to mould in any given shape to name a few. Even from structural aspects, reinforced concrete construction serves its intended purpose extremely well, if properly designed and constructed. However, the performance of reinforced concrete structures during past earthquakes has forced researchers to evaluate the suitability of the material to resist seismic excitations.

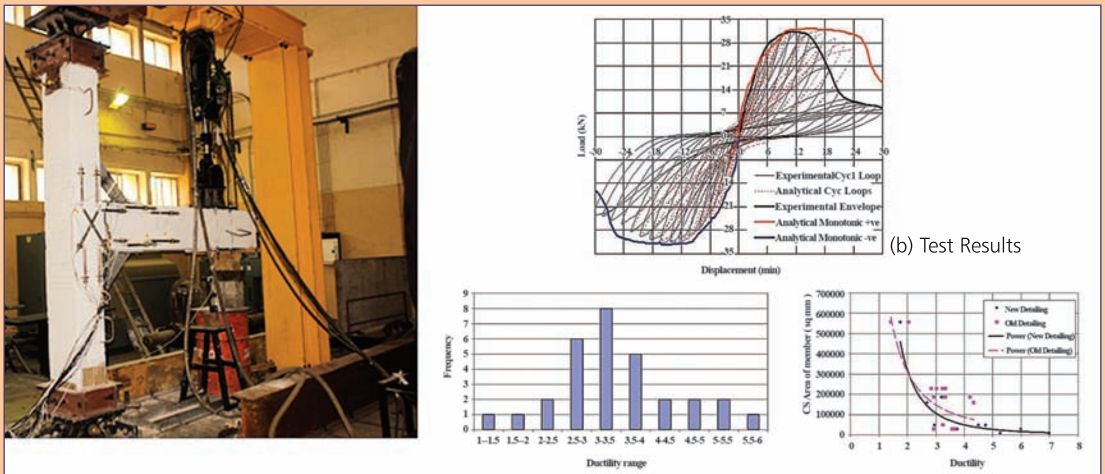
In order to evaluate the performance of the old and new RCC structures, a three-phase program has been formulated. The first phase includes evaluation of ductility and energy dissipation characteristics of RCC beam column joints with and without retrofitting; the second phase includes the evaluation of the behavior of structures under lateral monotonic loads, and the third phase includes the evaluation of the behavior of structures under dynamic (shake table) loading. Large number of tests has been carried out and are still running on beam-column joints and structures.

In addition to above, to reduce the cost and simultaneously ensuring the seismic safety retrofitting methods including base isolation techniques need to be developed. Significant progress is also made in this area.

2. Investigations on beam-column joints

It has been recognized world over that, in reinforced concrete structures subjected to earthquake type excitation, beam-column junction is an important structural element (Pauley and Priestley 1992). The joint consists mainly of three components, beam (along with the slab, if any), column, and the joint core. The characteristics and behavior of the joint therefore depends on the behavior of these three components. Out of the above, the joint failure is the most dangerous since a joint always fails in a brittle manner. Under reversing dynamic earthquake loads the joint core is subjected to tremendous shear forces, which leads to joint failure if not properly designed for. Various standard codes (ACI, EuroCode, NZS, IS) now give guidelines to design joint provide additional reinforcement in the joint core, which can prevent the joint shear failure. However, still a majority of structures worldwide are the ones designed and constructed much before such guidelines were put in force. Also, the new seismic guidelines may not always ensure the safety of the structures. Past earthquakes have exposed the vulnerability of such joints under seismic events. The two major failure modes for the failure of joints are (a) joint shear failure and (b) end anchorage failure. Thus, it can be said that deficiencies of joints are mainly caused by inadequate transverse reinforcement and insufficient anchorage capacity in the joint (Liu, Pampanin and Dhakal, 2006).

In order to evaluate the performance of beam-column joints during earthquakes, till now 35 joints



(a) Test setup

(b) Test Results

(c) Ductility variation of joints

Fig. 1: Experiments on beam-column joints

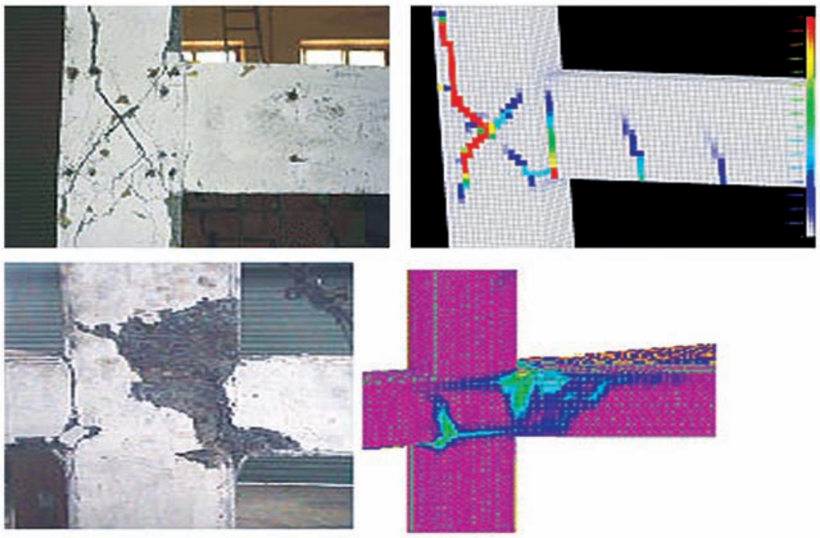


Fig. 2: Comparison of experiments and analysis for beam-column joints

increases, the ductility (in general) reduces and also the difference in ductility of old and new type detailing is not significant. The outcome of this investigation calls for a relook into the existing design provisions and such an attempt has been made. Fig. 2 shows a comparison of analytical damage prediction with experimental results.

with different reinforcement details, sizes, reinforcement ratios etc. have been tested under monotonic and quasi-cyclic loads. The performance of different retrofit solutions to improve the behaviour of the joint was also verified. Fig 1 shows (a) tests on beam-column joints, (b) Experimental and analytical results for a typical joint and (c) the ductility range obtained from experiments for all the tests. It was found that as the size of the joints

Retrofitting of beam-column joints of existing RC structures may be required if the capacity is less than the demand. Retrofitting solutions were developed based on haunch elements and using Carbon Fiber Reinforced Polymers (CFRP). Both the schemes gave highly encouraging results by improving the behavior of the joints significantly. Fig 3 shows the comparison of performance of as-built (control) and retrofitted specimens.

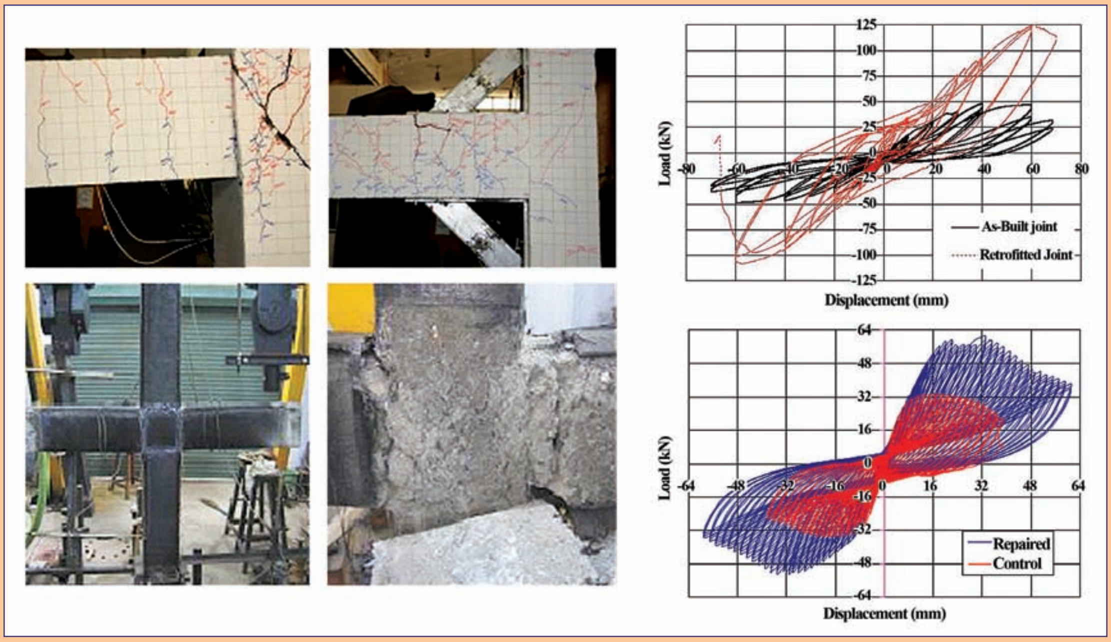


Fig. 3 : Investigations on Retrofitted Beam-Column Joints

3. Investigations on RC structures under monotonic pushover type loads

The second phase of the program includes experimentation of RC structures under monotonic pushover type loading. Pushover technique for RC structures subjected to earthquake loading is a very useful technique to know its performance states such as initial cracking, yielding of bars, ultimate state and failure state. However, higher mode effects and damping effects are considered conservatively and hence requires experimental verification. The very first and basic requirement of a correct pushover analysis is correct prediction of the base shear v/s roof displacement curve known as pushover curve or capacity curve. The correctness of such a curve depends largely on various modeling parameters such as material models for concrete and reinforcement, joint modeling, consideration for effects of axial forces, shear and torsion along with bending etc. To understand the effects of various modeling parameters and resolve the issues in appropriate modeling of the structures to perform nonlinear static analysis, one scaled down model structure and one full-scale prototype structure were tested. Since pushover analysis is a tool recommended and generally used for analyzing the old (non-seismically detailed) structures to verify their performance and assessment of the requirement for retrofitting (ATC-40), both the structures were detailed in accordance with non-seismic codes, with features such as no stirrups in the joints. The experiments on these structures were carried out under gradually increasing monotonic pushover loading up to failure.

The small scaled structure had section dimensions as 150mm x 200mm for both beams and columns, with beam center to center distance (bay width) as 1.2 m and column center to center distance (storey height) as 1.8 m. The structure was a 3-storeyed RC framed structure (Total height = 5.4 m) having two bays in both axes. Fig 4 shows the test setup, failure and pushover curve for the small-scale structure. In this case, beams and joints suffered much less damage. The full-scale prototype

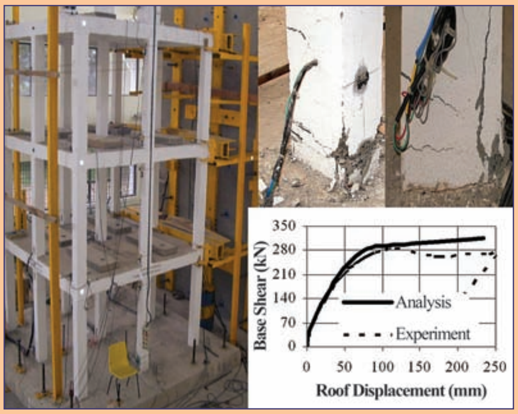


Fig. 4: Pushover test on small-scale structure

Fig. 5: Pushover test on full-scale structure

structure had section dimensions of the order of 350mm x 900mm for columns and 230mm x 1000mm for beams, with beam center to center distance (bay width) as 5.0 m and column center to center distance (storey height) as 4.0 m. The structure was a 4-storeyed RC framed structure (Total height of 17.0 m) having single bay in both axes. Fig 5 shows the test setup, typical failure and pushover curves for full-scale structure. The experiment was carried out as round-robin exercise in which, thirteen institutes participated and presented their pre-test-analysis results. Large variation in the predictions was found and the participants were requested to modify the analytical models based on experimental results. The post-test analysis of the full-scale structure is being carried out.

Fig. 6: Shake table tests on 3D RC structure

4. Investigations on RC structures under dynamic shake table loads

The third phase of the program includes experimentation of RC structures under dynamic shake table loading. Under this programme, three shake table tests on 3D RCC structures are planned. One such test is already conducted on a 3-storeyed structure with section dimensions as 75mm x 100mm. Fig 6 shows test specimen and typical failures observed. Further tests will be carried on structures having different configurations. One specimen will be exactly same as that shown in Fig 4, which was tested under monotonic pushover loads. This exercise will help in bringing out and resolve the deficiencies of pushover tests and analysis as compared to dynamic tests and analysis.

Another shake table test already conducted was performed on a 3D RCC structure with similar dimensions as the above-mentioned structure. The model was used to study the effectiveness of CFRP based retrofit scheme. The control specimen started yielding at 0.4g Peak Ground Acceleration (PGA). The strengthened model yielded at 1.0 g PGA. Fig 7 and 8 show un-retrofitted and retrofitted model.

4.1 Future works- Shake table Tests on Shear walls

Shear walls are commonly used in structures of nuclear facilities. Some examples are calandria vaults, spent fuel storage vaults, process cells of waste management facilities etc. The shear walls must posses the ability to dissipate energy imparted

Fig. 7: Structure without FRP retrofit

Fig. 8: FRP Retrofitted Structure

to it by earthquake by means of hysteretic behavior. It is known that accurate estimates of moment/ shear capacity of walls under cyclic loading with axial load are extremely difficult to make. This necessitates experimental testing for accurate assessment of shear response and capacity of the shear walls. The aim of the testing is to identify the exact mode of failure of the shear wall, failure load of the wall and to obtain the energy dissipating ability of the shear wall. The shear wall is designed and analyzed to predict the failure load. Test matrix and setup are planned.

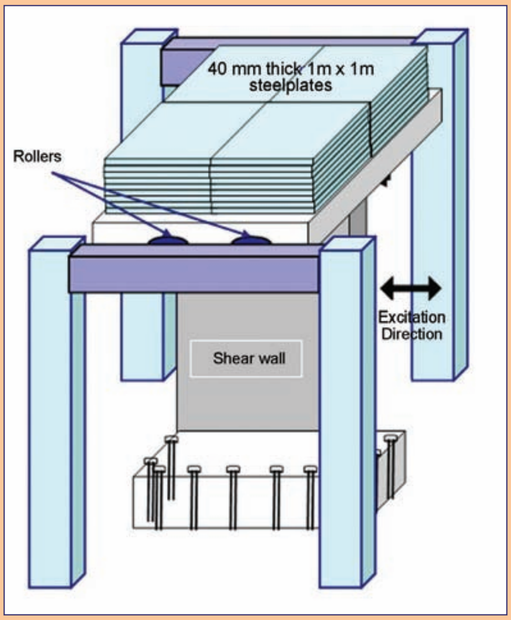


Fig. 9: Schematic for Shear wall tests

Fig. 10: Instrumented Buildings at IIT Guwahati

5. Base Isolation studies on full-scale structure

To reduce the earthquake loads on RC structures base isolation concept is very effective and to verify the concept and to develop the confidence in the utility two numbers of three storey buildings, one on base isolation and other on conventional foundation made at IIT, Guwahati campus . These

experimental buildings are experiencing four to five earthquakes every year and data being collected regularly. The base isolation is proved to be very useful for reducing seismic response as acceleration at top of isolated buildings was found to be less than $1/5^{th}$ of conventional building.

Concluding Remarks

To understand the behaviour of RC structure under earthquakes, tests are being performed regularly at component as well as structural level. It is found that the beam-column joints are crucial zones in RC structures especially of old structures and they generally perform very poorly during earthquakes. Retrofitting concepts using haunch elements and CFRP were developed and tested. It was found that this concept provides a practical solution to safeguard the old structures that invariably fail due to joint shear failures. Research on structures provided good insight on their behaviour under earthquakes. Further research work is being carried out to resolve the outstanding issues in the field of nonlinear static and dynamic analysis of RCC structures.

Acknowledgements

The support and encouragement received from Sri K.K. Vaze, Head, Reactor Structures Section, Dr. A.K. Ghosh, Head, Reactor Safety Division and Sri H.S.Kushwaha, Director, Health, Safety and Environment Group is acknowledged. Authors also highly acknowledge the support from Mechanical Metallurgical Section, BARC; Centre for Design and Manufacture, BARC; Arch & Civil Engineering Division, BARC; Central Power Research Institute Bangalore, Structural Engineering Research Centre Chennai and IIT Bombay for helping in successfully conducting the tests.

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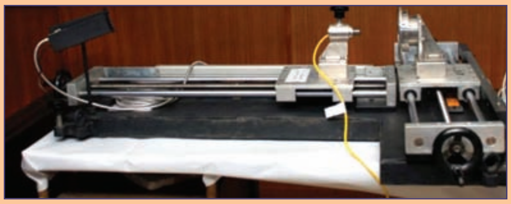
Design, Development and Supply of UMAC system to NPCIL

Tool for holding Sensor



Sensor calibration manipulator

Axial creep monitoring of the coolant channels is required to be done, during every bi-annual shutdown in Pressurized Heavy Water Reactors. Previously the Refuelling Technology Division had developed a PC based Creep Measuring System called "Technique for Measuring Axial Creep (TMAC)" which is in use in all operating PHWRs. TMAC is the remote measurement system and it uses Fuelling Machines to monitor the creep. Existing Z motion potentiometers of fuelling machine are used as sensors for the system. The system completes creep measurement in approximately two shifts of operation without any significant man-rem expenditure.

Based on request from NPCIL, a new technique called "Ultrasonic Measurement of Axial Creep (UMAC)"

Data acquisition system

Ultrasonic Sensor with controller unit

has been developed at the Refuelling Technology Division. The system generates creep data in tabular as well as graphical formats. Existing Fuelling Machines are used to carry the sensors to the reactor face. The fuelling machines do not contact the channel. UMAC measures the creep of all coolant channels within 4 hours. Man- rem consumption is almost nil.

UMAC has been successfully tried in operating reactor. UMAC comprises of non contact ultrasonic sensor to measure the distance between fuelling machine and channel, a fuelling machine compatible sensor mounting tool to take the sensor in front of the reactor face and a two-axis sensor calibration facility. The sensor signal is processed using indigenouly developed microcontroller-based data acquisition system, which converts sensor output in digital format and communicates to a Personal Computer via RS232 port for further processing of data. A window based graphical user interface was developed to acquire, display and process measurement data for generating report instantly in the desired format.

After successfully testing UMAC system at ITF, Engg.Hall-7, the system was satisfactorily used on experimental basis in some of the operating PHWRs. A MoU was signed with NPCIL to supply nine sets of system one each for RAPS-1&2, MAPS-1&2,

UMAC-Operator Interface Programme

Fig 4: UMAC handing over to NPCIL (Seen in photograph from left to right), Mr. S.Bhattacharya, RTD, BARC , Mr. R.J.Patel, Head FHD&D Section, RTD,BARC, Mr. S. Vijaykumar,CE(CCD),NPCIL, Mr. K.B.Dixit, Director (Engg), NPCIL , Mr. Nageswara Rao, Director (Operation), NPCIL, Mr. R.G.Agrawal, Head, RTD,BARC, Mr. R. K. Sinha, Director, RD&DG and DMAG BARC and Mr. Rites Ranjon, RTD, BARC.

NAPS-1&2, KAPS-1&2, KGS-1&2, RAPS-3&4, KGS-3&4, RAPS-5&6 and TAPS-3&4. The systems were made ready. A four day training and certification programme (10-13th November, 2009) was organized for operating plant personnel at Hall-7. The system was handed over to NPCIL on 13th November, 2009.

Brief Report on Two-Day BARC-ANDRA Theme Meeting on Deep Geological Repositories (TMDGR)

A two-day Indo-French Theme Meeting on Deep Geological Repositories (TMDGR) was organized during 19-20th October 2009, in Mod Lab C block auditorium. The meeting sponsored by BRNS, involved a series of invited talks by experts from the French National Agency for Radioactive Waste Management (ANDRA) and Indian experts from Nuclear Recycle Group, BARC. Besides experts from Central Mining Research Institute (CMRI) Roorkee, National Geophysical Research Institute(NGRI), Hyderabad, Indian Institute of Technology (IIT), Mumbai also delivered invited talks related to various field and laboratory-based studies being carried out under the Indian Geological Repository Programme. The meeting was inaugurated by Dr Anjan Chaki, Director AMDER Hyderabad, who delivered a key note address on the evolution of geological disposal concept for high level radioactive wastes in the last couple of decades. He emphasized on the better suitability of granites as host rocks for waste disposal in the Indian context in view of larger occurrences, massive and homogeneous rock-mass with good mechanical and geochemical properties.

Dr. Gerold Ouzouinian, Director, International Division of ANDRA made a detailed presentation on radioactive waste management practices in France. He elaborated on various types of wastes and their disposal routes being followed in France including studies towards setting up deep geological repository and their earlier work on granites and current URL based experimentation in Argillite rocks at Bure URL. He also outlined regulatory requirements for geological repository and future plans for development of geological repository as laid down under the French Law. In his second talk, he explained safety related practices in French waste management activities. Mr. S.D. Misra Director, NRG, BARC gave a detailed overview of radioactive waste management activities in India covering developments in vitirification technology, Interim storage facilities and ongoing activities in the field of geological disposal of radioactive wastes. Mr. P.K. Narayan, Head , RPS, BETDD, gave an overview of Indian Deep Geological Repository Programme covering salient aspects of Indian Thermo-Rock-Mechanical Experiment in Kolar Gold Mine, site selection activities for geological repository and ongoing URL development programme.

Dr. R.K. Bajpai, Convener of the theme meeting, presented details of site selection methodology, its application in granitic regions of India, associated laboratory based studies on micro crack developments, fracture permeability measurements, textural studies and determination of other rock mass parameters. He further elaborated on the ongoing geo-structural and hydro-geological investigations at URL site at Karnataka and gave details of the Buffer-Container experiment being planned in URL including its phasing and modelling. Mr. A.K. Rai, Regional Director, Southern Region, AMDER Bengaluru presented the geology and structure of Gogi URL Site and emphasized on the availability of good granites in deeper portion of this site. Dr SB Singh Emeritus Scientist, National Geophysical Research Institute Hyderabad, gave a very detailed account of various geophysical methods deployed in one of the promising sites in Rajasthan, to detect weak zones in granites up to a depth of one kilometre.

Dr. Patric Laindias, Scientific Director ANDRA gave a talk on various experiments being carried out at Bure, France. He explained various experiments

Dr. Anjan Chaki, Director, AMDER Hyderabad, Mr. S.D. Misra, Director NRG and Mr. P.K. Narayan, Head RPS, BETDD during the inaugural address delivered by Dr. Chaki.

Invitees and Delegates from BARC and other national institutes and laboratories

related to measurement of groundwater chemistry, pore water pressures and compositions, thermal degradation of clays, suction, re-saturation and other aspect of clays. He gave further details of instrumentation, excavation methods, monitoring systems being used in URL. The details of modelling for prediction of evolution of pore water pressures, moisture content, and porosity, permeability under the combined effect of thermal and mechanical stresses were also presented. Dr V.V.R. Prasad, Scientist In charge, Central Mining Research Institute Roorkee gave presentation on conceptual design and analysis of granite based deep geological repository. Prof TN Singh, Dept. of Earth Sciences, Indian Institute of Technology Mumbai, presented results of his studies on impact of the shape of disposal tunnel on their stability using site specific data and FLAC 3D Code. Dr. R.R. Rakesh made a presentation of radionuclide modelling related to Safety Assessment of Near Surface Disposal Facilities and associated *In-situ* experiments. A panel discussion was held at the end of the meeting and possible areas of cooperation and collaboration between ANDRA and BARC were worked out.

Inauguration of the 15th batch of the One-Year Health Physics Stipendiary Training Course

The One Year Health Physics Stipendiary Training Course being conducted by the Health Physics Division since 1989 has been largely meeting the requirements of professionally trained Health Physicists at BARC, NPCIL, IGCAR and AERB. The Training Programme for the 15th batch of Health Physics trainees was formally inaugurated by Mr. N.D. Sharma, Controller, BARC at HPD Auditorium, Radiation Protection Training & Information Centre on November 24, 2009. Mr. H.S. Kushwaha, Director, Health Safety & Environmental Group and Dr. P. K. Sarkar, Head, Health Physics Division were also present.

The inaugural function commenced with a welcome address by Dr. P. K. Sarkar. He stressed on the relevance of a specialized professional course in Health Physics discipline as the wide range of subjects relevant to the profession are not offered in the curriculum of any of the Indian Universities. He recollected the recent discussions with Chairman, UGC regarding the necessity of starting a full fledged course in Radiation Physics at graduate level in the Indian Universities to cater to the needs of our expanding nuclear power programme and the increasing use of radioactive sources in the country. Considering all the aspects, UGC also had expressed interest to initiate such courses in the near future. Dr. Sarkar expressed satisfaction that the scientists who had passed out through the previous training batches were doing well in their career and are holding important posts in different units of our department.

In his presidential address, Mr. H. S. Kushwaha observed that over the past few years, there was a rapid growth in the activities of the Department of Atomic Energy–not only in volume, but also in the variety of jobs involving radiation and radioactive systems. The Health, Safety & Environment Group had been making efforts to provide an efficient team of professional Health Physicists at each Unit of Nuclear Fuel Cycle Facilities. They are persons, technically competent and experienced to handle safety related problems with confidence and could suggest corrective actions wherever necessary. Simultaneously, efforts are being made to strengthen the R&D activities and theoretical studies to update our technology to international standards.

To meet the manpower needs, it was felt necessary to induct science graduates and impart them training in a well-structured Health Physics professional course, so that on successful completion of the course and with a few years of experience, they could take up responsibility at supervisory levels. Thus, the one-year Health Physics training course being conducted by the Health Physics Division since 1989 at HP Lab Tarapur and BARC Mumbai had been largely meeting the requirement of trained man power at the Scientific Assistant level.

The objective of this training programme essentially is to prepare the candidates to adopt a scientific approach in their job, to inculcate an analytical attitude in solving problems and to develop innovative methods in their field of work. With this objective in view, during the training, emphasis is given on familiarizing the basics of nuclear engineering, nuclear fuel cycle facilities, reactor physics, engineered safety features and safe operating procedures in nuclear facilities in addition to conventional topics relevant to operational Health Physics. Also, care has been taken to include new computer codes and programmes for safety

Mr. H.S. Kushwaha, addressing the gathering

evaluation, shielding calculations, atmospheric diffusion modeling, management and response to radiological emergencies etc. The course also includes general familiarization with the entire nuclear fuel cycle operations and regulatory aspects. Basic information on electronics and computer applications has also been introduced. Emphasis is given on making the trainees familiar with the systems and their safety aspects. Over the years, the Health Physics training programme has undergone significant upgrades with respect to the syllabus, structure of the training programme, training methodology, assessment procedures etc. Under the guidance of the 'Apex Committee for Health Physics Training Programmes', the syllabus, training material and the structure of the training programme are periodically upgraded so as to bring up this training to international standards.

Mr. Kushwaha observed that during these years, the department had undertaken a variety of operation and maintenance activities involving radiation sources which were accomplished successfully. Similarly the uses of radioisotopes in medical and industrial fields had grown manifold in recent years. An appreciable feature of all these activities was the record of safety that was maintained – both in conventional safety and radiological safety. In the above achievements, the silent contributions of teams of dedicated Health Physicists needed to be appreciated. Also, it was binding on everyone of us to ensure that the nuclear power generation and other activities of the department should have no adverse impact on the environment. It was important to develop a safety culture among the staff at every facility and every employee should be properly trained in radiological safety so as to make him capable of observing safety regulations as a built in habit. The overall safety should be focused on the safety of the plant, plant personnel, general public and the environment.

He appreciated the efforts of the course coordinators and the faculty for sparing time to share their knowledge and experience with the new entrants and helping the department in building up a young generation of scientific professionals.

He also acknowledged the assistance received from different facilities of BARC and NPCIL who had been extending cooperation for providing the facilities for "On the Job Training".

In his inaugural address, Mr. N. D. Sharma, Controller BARC noted that radiation was part of human life because of the presence of natural radioactivity everywhere on the surface of the earth.

Mr. Sharma appreciated the efforts of HS&EG in providing professionally qualified Health Physicists to various units of the department. He appreciated the syllabus and expressed satisfaction that the course was properly designed and was relevant to the challenges of our expanding nuclear power programme. Also, he observed that the course consisted of a wide range of subjects and is an example of a smooth merger of different disciplines, breaking the imaginary barriers of different branches of science and technology. He reminded the trainees of the necessity of developing a safety culture among the workers and building confidence in general public on nuclear power as a clean and safe source of energy. He concluded his address by congratulating the trainees for opting to join the Department of Atomic Energy and wished each one of them a successful career.

The inaugural function was concluded with a vote of thanks proposed by Mr. K. Narayanan Kutty, Officer In Charge, Training Group. He expressed gratitude to a large number of agencies for their valuable contributions in the successful completion of the training programme.

DAE-BRNS Theme Meeting on Quantum Structures (TMQS) : a Report

The Theme Meeting on Quantum Structures (TMQS) was jointly organized by the Bhabha Atomic Research Centre, Mumbai and Indian Association for the Cultivation of Science, Kolkata at the Multipurpose Hall, BARC Guest House, Anushaktinagar, Mumbai. This meeting was sponsored by the Board of Research in Nuclear Sciences (BRNS), Department of Atomic Energy. Prof. B. N. Dev, Prof. G. P. Das, and Dr. S. M. Yusuf were conveners for this theme meeting.

Quantum structures with man-made superlattices were launched almost four decades ago with compound semiconductor heterostructures and epitaxial growth. Later the field of quantum devices, from quantum wells to quantum dots and ultimately to nanoelectronics, took wings. In order to meet the ever increasing demand on high-performance materials and devices, the need for focused experimental-cum-theoretical research programmes on quantum structures and devices was felt. Accordingly, a Theme Meeting on "Quantum Structures" was organized in BARC during November 2-3, 2009, which coincided with the Homi Bhabha Centenary Year. The Meeting was organized to discuss and review the status of this emerging field of quantum structures, and pave the way for further developmental work and action plan in this very important area. On one hand, the deliberations are expected to help the young researchers with adequate exposure on the state-of-the-art tools such as MBE, STM, SQUID, MOKE, SAM, SEMPA, SPLEEM and various transport and optical measurement techniques. On the other hand, this meeting has helped consolidate our expertise and capabilities in utilizing these techniques in understanding various physical properties of advanced materials. Following the deliberations and discussions in this Theme Meeting, a road map for future activities in the area of quantum structures is being prepared.

Dr. S. Banerjee, Director, BARC gave the key-note address, elucidating the importance and relevance of quantum structure research in our country. In the inaugural session of the Theme Meeting on Quantum Structures (TMQS), Dr. J.V. Yakhmi, Associate Director, Physics Group, BARC gave the welcome address, Profs. B.N. Dev and G.P. Das of IACS, Kolkata gave an introduction and genesis of the Theme Meeting. Dr. S.M. Yusuf, BARC proposed a vote of thanks.

R. Muraleedharan and S. K. Ray delivered a talk on the growth of III-V and IV-IV semiconductor quantum well and quantum dot structures using Molecular Beam Epitaxy (MBE). D. Goswami talked about manifestation of quantum capacitance in single electron tunneling phenomena. Sandip Ghosh discussed about probing semiconductor quantum structures with polarized light. B.N. Dev's presentation addressed various aspects of growth and electronic properties of quantum dot and quantum wire structures.

S.M. Yusuf talked on probing quantum structures using magnetic techniques. Ferrites and other nanostructures were discussed by N. Venkatramani and D. Bahadur. Magnetization switching in ferromagnetic resonant tunneling diodes was the topic of presentation of Swaroop Ganguly. Indranil Das talked on spin polarized transport in low dimensional systems.

A group photograph of the participants of the Theme Meeting on Quantum Structures held during November 2-3, 2009

On the computational aspects, G.P. Das talked on simulation and design of quantum nanostructures. M. Deshmukh addressed the issue of breakdown of quantum Hall effect in graphene. D.G. Kanhere discussed about the nature of metal-insulator transition from graphene to graphane. Vijay Singh talked on scaling laws for semiconductor nanostructures.

In addition, various fabrication and characterization methods were presented by G.K. Dey, Ajay Gupta, V. Ganesan, P.V. Satyam, S. Dhamodaran, P. Chakraborty and D.C. Kothari. These methods include ion beam methods including Focused Ion beam (FIB), MOKE, SPM, TEM and SIMS.

There was a session of open forum and discussions coordinated by B.N. Dev. At the end of the meeting, a decision was taken to chalk out a road map on quantum structure research. Following this, G.P. Das gave the concluding remarks at the valedictory function.

Workshop on "Special Lubricants and Hydraulic Fluids for High temperature nuclear applications"

At the Inuagural function : (from right to left) : Mr. R.G. Agarwal, Head, RTD, Mr. P.K. Limaye, SO/G, RTD, Dr. R.T. Mookken, DGM I/c. (PD-GISM), IOC, R&D, Mr. R. Suresh, DGM I/c. (Technical Services), IOC (Marketing)

The Fluid Power & Tribology Section, Refuelling Technology Division (RTD) in co-ordination with Indian Oil Corporation Ltd (IOCL) and Tribology Society of India – Mumbai Chapter (TSI) organized a one-day interaction for development of "Special Lubricants and Hydraulic Fluids for High temperature nuclear applications". The workshop was attended by around 60-70 participants from DAE and 8 participants from IOCL. IOCL team was headed by Dr. R.T.Mookken, Dy. General Manager, IOCL-R&D Centre, Faridabad. Mr. R.G. Agrawal, Head RTD, inaugurated the workshop and briefed about the requirement of high temperature hydraulic fluids and radiation resistant lubricants for various applications. After the inauguration, Dr. R.T.Mookken, proceeded with his talk on "High temperature base fluids for nuclear plant applications" where he emphasized on the importance of selection of base oil type for various applications.

The Second session started with presen-tation by Dr. N.K. Pokhriyal, Senior Research officer, IOCL. His topic was" Advances in Greases". He spoke on selection of various base oils and additives for various application and their importance in performance enhancement for various applications. During his talk, he explained the basic steps involved in selection of grease for a particular application and various testing methods used for qualifying the grease. His lecture was followed by Dr. R.T.Mookken's lecture on "Conventional power plant lubricants and hydraulic fluids". The talk focused on selection of Hydraulic fluids and lubricants for a conventional power plant and where it could have a similar application in a nuclear power plant. The Third talk in the session was by Mr. Ajay Kumar, R&D IOCL, Faridabad on "Tribotesting of Lubricants". He gave a detailed presentation on various aspects of tribology and the testing reqirements for qualifying the product.

After tea, an interactive session was held where various requirements were raised by the participants. IOCL suggested that a joint project could be taken up to develop indigenous products which are radiation resistant and are suitable for high temperature applications. R&D Centre IOCL has the capability to develop such products on demand basis. Following was concluded from the session:

1. Nuclear power plants are generally use existing lubricants with frequent change overs. However, they could use high performance long life lubricants. BARC requested for data on existing high temperature lubricants from IOC such as Servo system HLP Oils, Servo synco E-68, high temperature grease with synthetic oils etc.

2. BARC will evaluate the performance of these oils including gamma radiation environment and recommend theirapplications in nuclear power plants. BARC / nuclear power plants can give their requirement with respect to service life expectations of lubricants for different application areas.

3. Neutron exposure testing can be held only at BARC which can be arranged on request from IOCL. BARC may send the list of lubricants which at present are being used in Nuclear Power Plants.

4. BARC requested IOC to give different types of base oils available in the market with respect to high temperature capabilities. IOC R&D will send this information to BARC.

5. BARC also agreed to share the specifications of the products which at present are being imported for nuclear power applications.

The Workshop concluded by a vote of thanks presented by Mr. N.L.Soni, Chairman, Tribology Society Of India, Mumbai & Pune Chapter and Head Fluid power & Tribology Section, RTD.

BARC Scientists Honoured

Name of the Scientist : **Dr. R.K. Vatsa, Chemistry Division, BARC**
Award : "Eminent Mass Spectroscopist" Award-2009
Awarded by : Indian Society for Mass Spectrometry (ISMAS).

Name of the Scientists : **Dr. Vinod J. Dhole & Dr. K.S. Reddy, Nuclear Agriculture and Biotechnology Division, BARC**
Title of the Poster : "Gamma ray induced moisture stress tolerant long root mutant in mungbean (Vigna radiata L Wilczek)"
Presented at : INS seminar on "Nuclear Technology for Sustainable Development" (NTSD09), Thapar University, Patiala (Punjab) held during 10-11 October, 2009.
Award : Poster Award in 'Scientist Category'.

Name of the Scientist : **Dr. A.K. Tyagi, Solid State Chemistry Section, Chemistry Division, BARC**
Award : Prof. R.D. Desai 80th Birthday Commemoration Award of the Indian Chemical Society.
Awarded at the : 46th Annual Convention of Chemists at Vellore, in Dec. 2009.

Name of the Scientist : **Dr. M. Roy, Chemistry Division, BARC**
Honour : Elected as a Young Associate of Maharashtra Academy of Sciences in the year 2009
Awarded by : Maharashtra Academy of Sciences for his significant contributions in the field of Chemical Sciences.

Name of the Scientists : **B.N. Pandey, Amit Kumar, Manjoor Ali and K.P Mishra, Radiation Biology and Health Sciences Division, BARC**
Title of the Poster : "Role of Oxidative Stress and Apototic Death in Radiation Induced Bystander Effect in Human Normal and Tumour Cells with Implications to Improvement in Cancer Radiotherapy"
Presented at : 2nd Asian Congress of Radiation Research held at Seoul, Korea during May, 17-20, 2009.
Award : Best Poster Award.

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