IGC Newsletter

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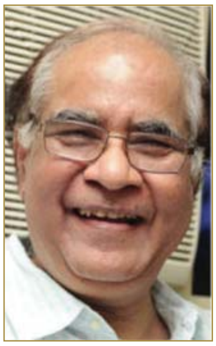
Inside

From the Director's Desk



New Year Message

I would like to wish you and your families happy, healthy and blissful New Year 2011. As the years roll by, each year brings fresh challenges, new opportunities and motivation to achieve greater heights.

The vast possibilities of our great future will become realities only if we make ourselves responsible for that future

Gifford Pinchot

I feel happy that we could sustain the momentum and keep our vision clear and focussed in realizing many notable achievements in the year 2010. Fast Breeder Test Reactor (FBTR), the flagship of our Centre, has completed twenty five years of operation in October, this year. It is one of the six fast reactors operating in the world, BOR-60 and BN-600 in Russia, Joyo and Monju in Japan and CEFR in China, being the other fast neutron reactors. It is really heartening to note that life extension studies have confirmed that FBTR can safely be operated for ten more effective full power years. So far, more than 1000 pins of the carbide fuel have reached a burn-up of 155 GWd/t without any breach of the clad, which is an international benchmark for carbide fuel. One subassembly has reached a burn-up of 165 GWd/t without any clad failure. Plutonium recovered after reprocessing of the spent fuel discharged from FBTR has been fabricated into fresh fuel pins and loaded back into the FBTR and thus, closing the fuel cycle. Like CIRUS was the test bed for the PHWR programme, same way FBTR is the foundation for our Fast Reactor programme.

Radiometallurgy laboratory (RML) has also completed twenty five successful years of operation, making many noteworthy contributions to the Centre both in providing post-irradiation examination (PIE) assessment of fuel pins, fuel subassemblies, wrappers, control rods etc. It has also made remarkable contributions to non-destructive evaluation, robotics and failure analysis. The inputs provided by the post-irradiation examination have provided crucial inputs to obtain safety clearances from regulatory authorities for taking the high plutonium content mixed carbide fuel to benchmark burn-ups. My joy is enhanced when I look back and recollect my association with both these programmes and feel satisfied that I got ample opportunities to contribute significantly for the growth and success of these programmes. I congratulate the colleagues, both present and past, whose contributions have been phenomenal for the success of these major achievements of the Centre. I have motivated the colleagues to document the experiences gained during the progress made by FBTR and RML and I am happy to observe that both the books have come out well, recording the history and growth, and would serve as reference material for the younger generation joining the Department. A function was organised on October 10, 2010, to commemorate the silver jubilee event. The then Honourable Minister of State for Science and Technology, Shri Prithiviraj Chavan graced the occasion as the Chief Guest. It was a happy occasion with several of the former colleagues who have contributed to the success of these programmes being present to share the joy and success.

It is heartening to know that many important regulatory clearances have been obtained towards the construction of Prototype Fast Breeder Reactor (PFBR) and BHAVINI is going ahead with this nationally important mission with commitment and dedication. On our part, having fulfilled the task of providing R&D inputs to PFBR, we are moving ahead with the design of advanced fast reactors with higher burn-ups, advanced fuels and structural materials, which will ensure enhanced performance with robust safety with improved economy etc. We continue to focus on structural mechanics, thermal hydraulics, metallic fuels, martensitic/ferritic and oxide-dispersion strengthened steels, advanced sodium pumps, separation of actinides, robust fuel cycle methodologies etc. The achievements in science are diverse in spectrum; estimating the performance of fuel, experimental performance assessment of the unique high burn-up mixed carbide fuel, studies on structural materials, which have the scope of improving the safety and economics of the fuel in future, basic research on tunable thermal properties of nanofluids, super-hydrophobic engineering surfaces, ultra-low friction engineering surfaces, architecturing of nano coatings for unique performance, computational modeling, high sensitivity characterization linked to performance, ab-initio design and development of unique sensors and instrumentation, room temperature ionic liquids, supercritical fluid separations, actinide separations etc. Engineering analysis of optimum plant layout, establishing thermal stripping limits, novel design of reactor components are some examples where innovative R&D is being carried out. The technology of reprocessing of the mixed carbide fuel, innovative design of sensors and development of processes for production of enriched boron and fabrication of boron carbide material for control rod applications for Fast Breeder Reactors are some of the significant developments the Centre has mastered after putting in considerable effort. The establishment of Mini Sodium Fire Experimental (MINA) facility to carry out experiments to understand the science and engineering of sodium fires is yet another milestone of significance.

We firmly believe in pyramid structure of management consisting of science, engineering and technology, each seamlessly making the base for transforming one to another to meet the mission-mode objectives of the Centre. We had conducted 400^{th} IGCSC meeting during April 2010 taking stock of our progress in various fields of science, engineering and technology. It emerged clearly that the Centre has grown in strength, achievements and contributions towards Fast Reactors and associated Fuel Cycle Science and Technology. It is indeed noteworthy that many young scientists and engineers had also presented their vision for the future of the Centre during the event. One of the areas that was highlighted pertained to harnessing of human resources both within the Centre and outside. In my view, this approach has been paying rich dividends to the mission mode programmes of the Centre and needs further strengthening. Other areas of focus were the environment, safety, infrastructure development, township improvement, medical facilities and school education.

You don't just stumble into the future
You create your own future

Roger Smith

We have been giving high priority to our national and international collaborations with eminent institutions. Special mention can be made about our creative and productive collaboration with Commissariat à l'énergie atomique et aux énergies alternatives (CEA), France. The collaboration is getting robust and relevant with many implementing agreements in the areas of basic sciences and safety. Many foreign and national dignitaries have visited our laboratories and the campus. Our earlier foresight in harnessing human resources for the R&D programmes of the Centre and the DAE is paying rich dividends. It is gratifying to note that the Training School at IGCAR has successfully completed its fourth year with many young scientists and engineers putting in their best brains to solve the complex problems of the Department. Same way, the research students of Homi Bhahba National Institute (HBNI) have enriched our campus by providing a truly academic environment. We have hundred forty students working at the Centre under aegis of HBNI, DST, CSIR and UGC. The upcoming Kalpakkam node of University Grants Commission- Department of Atomic Energy Consortium for Scientific Research, will have an important and complementary role in formalizing and synergizing many of these collaborations in the areas of physical, chemical and engineering sciences.

The future belongs to those who believe in the beauty of their dreams

Eleanor Roosevelt

Our townships have become greener and environmentally friendly due to dedicated efforts of our colleagues in the General Services Organization (GSO), Kendriya Vidyalayas and DAE schools. We are continuously improving with impressive academic and co-curricular achievements in schools. The hospital environment has improved remarkably with holistic medical care being imparted by dedicated medical doctors and the staff.

I see immense challenges and opportunities to ensure targeted performance of Prototype Fast Breeder Reactor, completing the design and development of FBRs-1 and 2, closing of the Fuel Cycle for Fast Reactors with benchmark specifications with respect to name plate capacity with plant life of 40 years and a small fraction of losses of fissile isotopes in the reprocessing and emerging development of metal fuels with closed fuel cycles etc. in the coming three years. The leadership in mission technologies would flow from excellence in science, innovations, close working of multidisciplinary teams, translation of research to technologies and ensuring attraction of a large number of bright young minds who can be nurtured to deliver excellence with relevance in close co-operation with best of academia, research and industry in the country and abroad. We have to continue to improve on successes through holistic approaches integrating science and technology missions, townships, neighbourhood, environment, ethics and equity.

Finally let me quote Mahatma Gandhi, "Be the change that you want to see in the world". All we need to do to change the world, is to transform ourselves in terms of our attitude, ethics, dedication and hard work in every aspect of our lives.

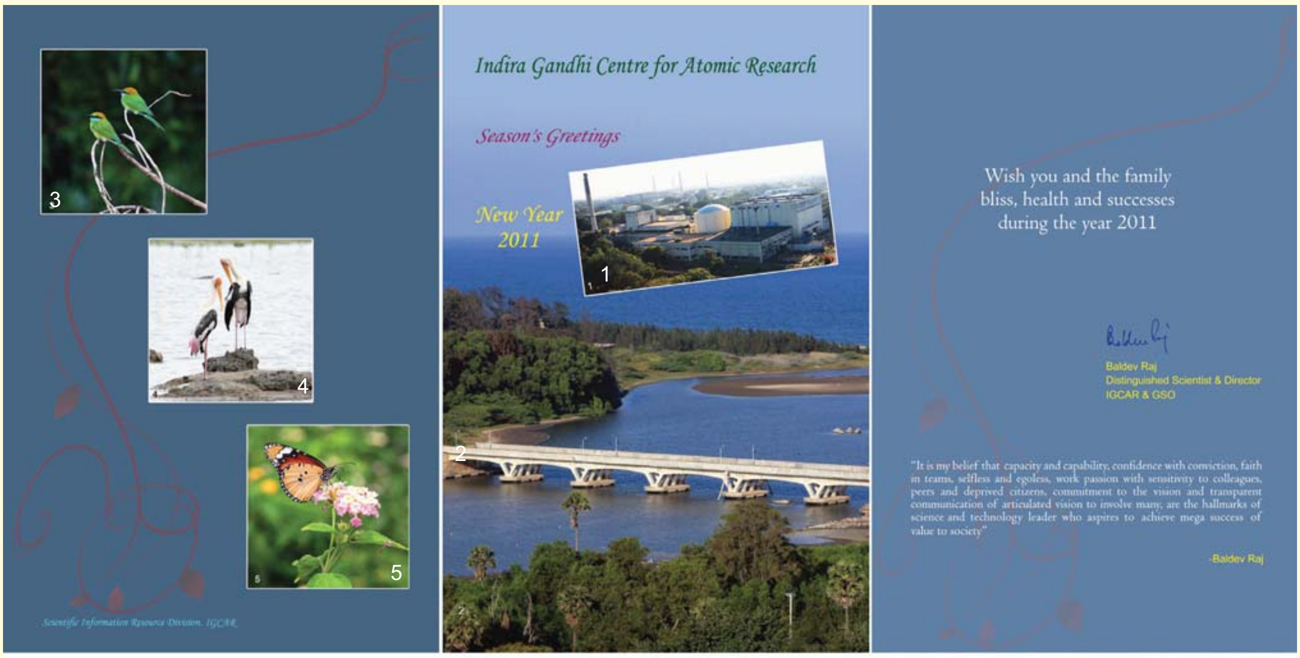
I would like to wish you and your families health, bliss, and continued successes.

With my best wishes and personal regards

(Baldev Raj)

Director,

Indira Gandhi Centre for Atomic Research &
General Services Organisation



1. Fast Breeder Test Reactor 2. Edaiyur Bridge
3. Small Bee-eater 4. Painted Stork 5. Butterfly (Plain Tiger)
Photographs captured at Kalpakkam campus

Inner Vessel - A Challenge for the Pool Type Sodium Cooled Fast Reactor

In the pool type sodium cooled fast reactor (SFR), the entire radioactive primary sodium circuit is housed within the main vessel. The sodium pool is contained by the inner vessel. The inner vessel is supported on the grid plate, which supports the core sub assemblies. The portion of the sodium pool housed within the inner vessel is termed as 'hot pool'. The remaining sodium surrounding the vessel is called 'cold pool'. The cold sodium is pumped into grid plate, from which the sodium is distributed to various subassemblies to remove the nuclear heat. Sodium jets, after getting heated up, mix with the hot pool. The hot sodium transfers its heat to the secondary sodium in the intermediate heat exchangers (IHXs), which penetrate the inner vessel at the appropriate locations. The primary sodium after passing through the IHXs gets collected back in the cold pool. To guide the sodium to flow through the IHX without any significant bypass, standpipes with seals are incorporated in the inner vessel. The control plug, positioned above the core to house the absorber rod drive mechanisms, thermocouples, sodium sampling sleeves, etc., also facilitates thorough mixing of hot pool.

Figure 1 shows the sketch of inner vessel positioned in the sodium pool. The inner vessel is constituted by lower cylindrical shell, upper cylindrical shell and conical shell connecting the upper and lower cylindrical shells, called 'redan'. These apart, it has six stand pipes in the redan portion for providing passages for four IHX and two primary pumps.

Implications of Inner Vessel on the Design

Though the inner vessel physically separates the sodium pool, there exists thermal continuity always, due to the high thermal conductivity across the thin metal wall. An important implication of this phenomenon is thermal stratification. In the pool type concept, both hot sodium pool, which is about 820 K and cold pool at about 670 K, co-exist and impose high ΔT (150 K) in sodium. The flow pattern and temperature profiles established with the presence of inner vessel causes narrow transition regions of hot and cold streams in the hot sodium pool. Such a phenomenon is called 'stratification' and is more pronounced in case of liquid metals such as sodium that has high thermal diffusivity compared to momentum diffusivity. The stratified layers generally oscillate steadily at lower frequencies ($<$ 1 Hz), which is one of the sources of high cycle thermal fatigue damage for the metal wall (Figure 2). The inner vessel significantly influences the decay heat removal condition, especially under post accident heat removal condition. The flow paths available in the sodium pool is very much limited for removing the decay heat generated in the core debris, settled on the core catcher after core disruptive accident. The inner vessel poses high challenge on the in-service inspection of reactor internals, particularly the cold pool components that ultimately supports the grid plate and core sub assemblies. The inner vessel thus challenges the choice of pool type concept for sodium cooled fast reactors.

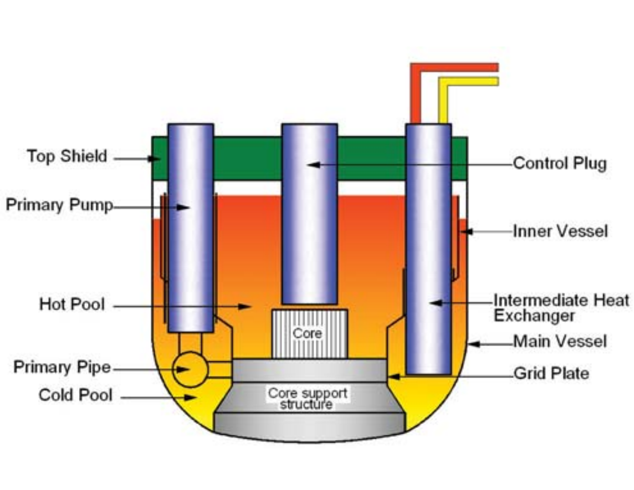


Figure1: Location of inner vessel in the pool type sodium cooled fast reactor

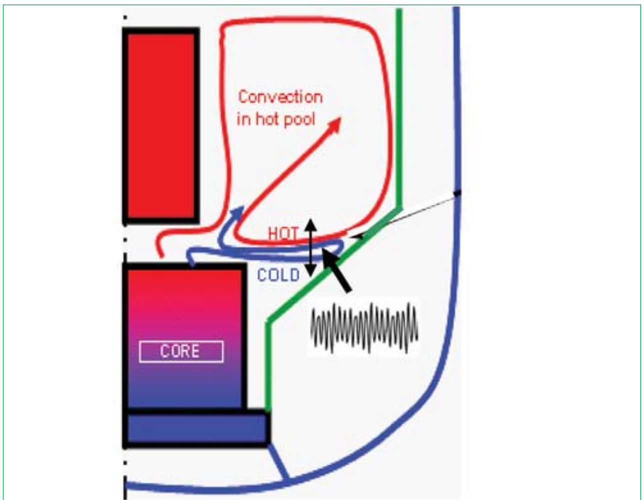


Figure 2: Development of stratification

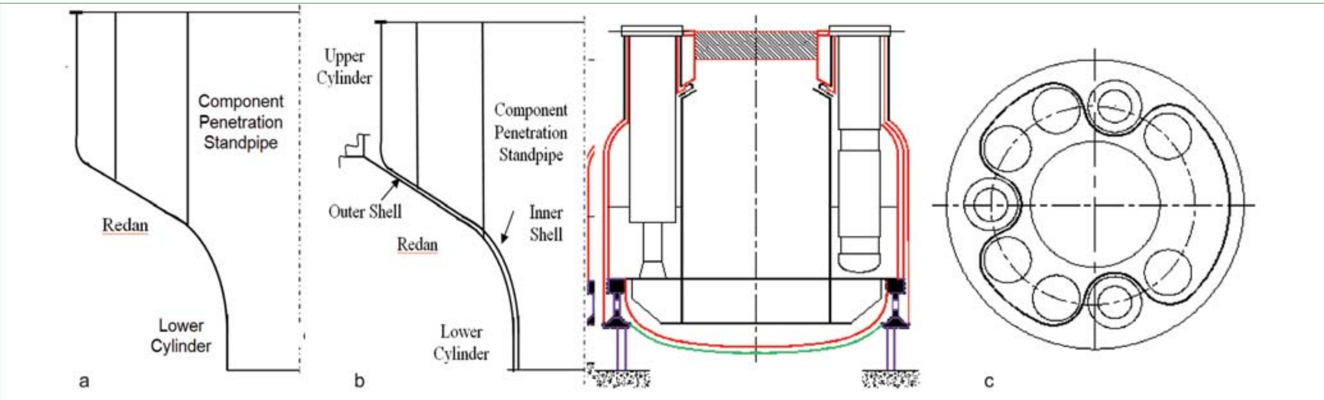


Figure 3: Typical inner vessel concepts employed in international sodium cooled fast reactors, a. Single wall concept, b. Double wall concept, c. Lobe type concept in BN type sodium cooled fast reactors

Inner Vessel Concepts

The inner vessel is generally a self-supporting structure, supported at its base on the grid plate. A single wall concept is preferred in most of the reactors including PFBR (Figure 3a). On the contrary, a double wall concept adopted for SPX (1200 MWe French SFR) is shown in Figure 3b, where the inner vessels in contact with hot pool, absorbs thermal gradients in view of its flexibility and the outer vessel is in contact with cold pool, carries the mechanical load due to the sodium pressure head and self weight including stand pipe. In BN series of reactors in Russia, the pumps are kept outside the inner vessel, which is feasible for bottom support designs and accordingly, the inner vessel shape gets complicated with the lobes (Figure 3c).

Proper choice of sealing system for the inner vessel is to be provided at the IHX stand pipes to minimize the leakage of hot sodium to cold sodium. In Phenix and SPX1, an innovative system using argon pocket is employed. Though it has many advantages in terms of good leak tightedness, construction simplicity and ease of disassembly and assembly of IHX for maintenance, gradual loss of argon due to diffusion into the hot liquid sodium and consequent fear of argon entry into the core has discouraged the use this option for future reactors. Alternatively, mechanical seals are preferred, which can be designed to minimize the sodium leakage to insignificant level. Figure 4 shows argon and mechanical seal arrangements. Mechanical seals are employed in BN 600 and PFBR.

Design Loadings and Failure Modes

The self weight of inner vessel along with the weights of stand pipes and pressure head equals the differential head between the sodium free surface levels in the hot and the cold pools. The self weight also constitutes the mechanical loads acting under operating condition. Under seismic loading condition, the vessel is subjected to high dynamic pressure loadings. These apart, in case of pump over-speeds, the normal sodium level difference across the inner vessel can further increase. In case of PFBR, the level difference is 1.5 meters under normal operating condition to maintain the primary sodium flow overcoming the pressure drop in the IHX. This increases to 4 meter when the pump over-speeds. The total force due to weight of standpipes (WIHX & PSP) is equal to about 50 tonnes and a Safe Shutdown Earthquake can enhance this force by about 10 %. The distributions of mechanical loads are shown

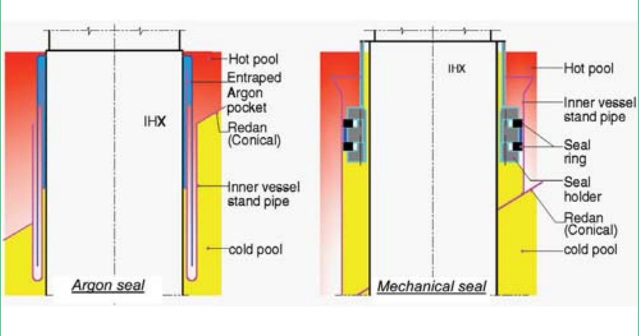


Figure 4: Concepts adopted for the seals in the inner vessels

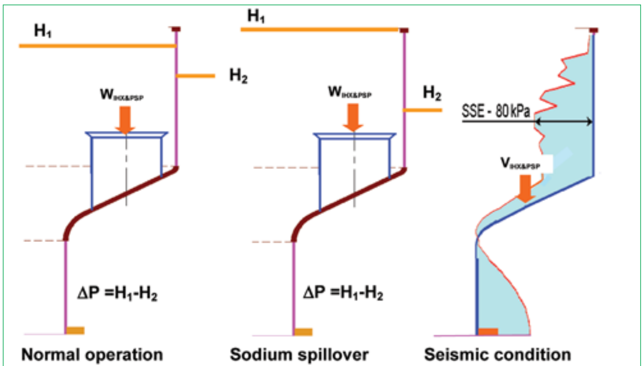


Figure 5: Mechanical forces considered for the design of inner vessel

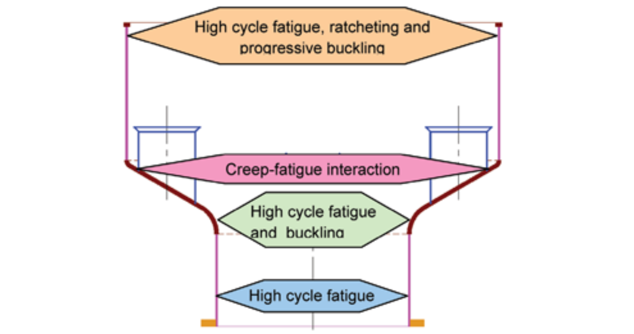


Figure 6: Mechanical forces considered for the design of inner vessel

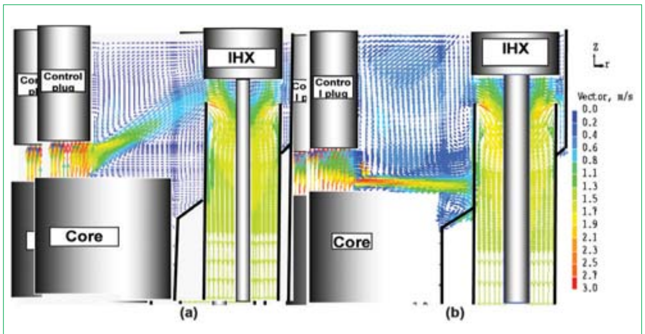


Figure 7: a) Stratified flow in hot pool
b) Stratification eliminated by skirt

in Figure 5. These loads decide the thickness of the vessel to prevent the buckling.

The inner vessel would be in an isothermal condition during reactor shutdown. During subsequent normal operating conditions, the surface of the vessel in contact with the hot pool is subjected to high temperature and the other surface facing the cold sodium pool is relatively at low temperature. These temperatures vary from lower elevation to higher elevation, thus imposing variations in both mean temperature and through-wall-temperature gradients, and the temperature gradients change during every reactor scram. The through-wall-temperature gradient (ΔT) reverses across the wall thickness. In case of PFBR, the inner vessel is at 473 K during reactor shutdown condition. The maximum ΔT under normal operating condition is 120K, which reverses to -60K at a particular instant during a reactor scram. Thus, the inner vessel is subjected to cyclic temperature gradients in view of change of operating states of the reactor, viz. shutdown, normal operation and reactor scram conditions, which in conjunction with mechanical loads, would cause creep, fatigue and creep-fatigue damages that decide the permissible life of the component.

The sodium free level oscillates continuously at low frequencies (< 1 Hz) during steady state operating condition itself, causing temperature fluctuations in the vicinity of sodium free level on the inner surface of upper cylindrical portion. Temperature fluctuations also occur on the vessel portion immersed in sodium pools, where thermal stratifications are possible. These temperature fluctuations cause high cycle fatigue damage on the adjoining structural wall. The free sodium level also varies when the hot pool temperature changes during reactor startup, shutdown and decay heat removal conditions. Under such conditions, the upper cylindrical shell is subjected to special kind of thermo-mechanical failure modes, viz. 'thermal ratcheting' and its consequent effect called 'progressive buckling'. Figure 6 depicts the above mentioned kinds of failure modes comprehensively. The investigation of such failure modes call for advanced numerical and experimental techniques.

Highlights of Advanced Numerical and Experimental Investigations

The inner vessel design is finalized based on advanced thermal hydraulics and structural mechanical analyses. Thermal hydraulic analysis carried out ensures that maximum stresses caused by mechanical and thermal loads are separated sufficiently so that their interaction effects are minimum and also the thermal stratification is minimum and acceptable. Structural mechanical analysis has been completed to: (i) optimize the shape and thickness of the redan portion from buckling considerations, (ii) estimate creep-fatigue damage, (iii) assess thermal ratcheting in the vicinity of near sodium free level and (iv) progressive buckling of the vessel near top edge that decide the stiffener dimensions. A few important results are highlighted in the following paragraphs.

CFD Simulation of Thermal Stratification

Towards predicting the stratification in the hot pool numerically, detailed fluid dynamic computations using appropriate turbulence model were carried out and it is found that strong stratification exists in the vicinity of redan (Figure 7a). To mitigate the thermal stratification, a porous cylindrical skirt is provided just below the control plug. The effect of this skirt is to increase the sodium velocity entering into the hot pool and thereby promoting good mixing and avoiding stratification as shown in Figure 7b. However, the provision of this skirt increases the pressure below the control plug bottom, in turn increasing the flow to the control plug through the annular passages in the absorber rod mechanisms. Large flow in the control plug is of concern from transient temperature (cold shock) seen by the control plug parts during a reactor

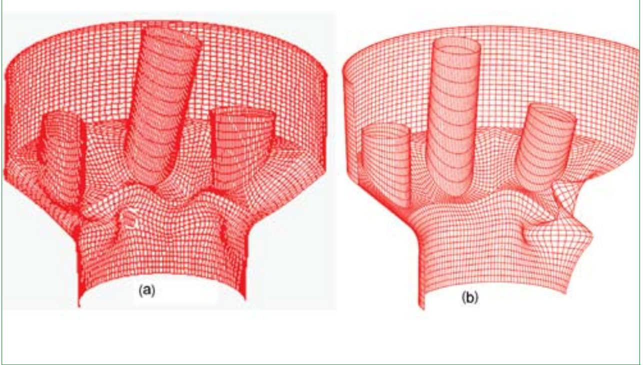


Figure 8: Buckling mode shapes under a) Normal condition
b) Safe shutdown earthquake condition

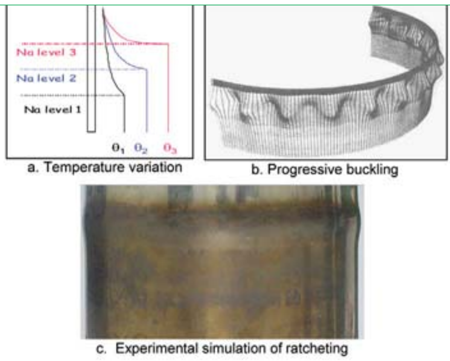


Figure 9: Mechanical behaviour of vessel near sodium free level under moving temperature gradient

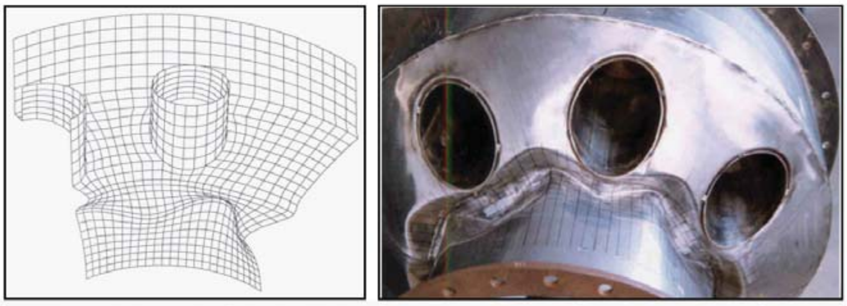
scram. Hence, a proper combination of annular clearances is chosen between the shroud tubes, respective absorber rod drive mechanisms and the perforations in the shroud tubes, to achieve the design goal.

Buckling Analysis

The thin walled shell structures are prone to buckle. In particular, the seismic events impose major forces by developing high dynamic pressures on the inner vessel. The redan portion buckles under combined mechanical and thermal loading conditions under normal as well as seismic loading conditions. Seismic forces are computed by elastoplastic buckling analysis, taking into account the effects of geometrical imperfections. Figure 8a and 8b depict the buckling mode shapes under normal as well as seismic loading conditions respectively. Among the vessels of reactor assembly, the inner vessel is found to be the most critical component, which buckles under seismic forces induced by a safe shutdown earthquake with a load multiplier of 1.52, which is higher than the minimum factor of safety of 1.3, required as per the design code RCC-MR (2002) for service level D conditions.

Thermal Ratcheting and Progressive buckling Analysis

When the axial temperature gradient is moving up and down along the upper cylindrical shell, there is a progressive development of strains symmetrically in the vessel in the vicinity of sodium free level, which stabilises after a few number of cycles (~20). This phenomenon is called ratcheting. Upon cyclic variation of axial temperature gradients, the amplitude of wrinkles (initial imperfection resulting from manufacturing) grows progressively as number of thermal cycles increase. After application of a certain number of load cycles, there is a rapid increase of the amplitude, indicating the initiation of 'progressive buckling'. Both ratcheting and progressive buckling have been visualised experimentally as well as predicted numerically using CAST3M computer code



Loading	Tolerance - mm	Test	FEM	Test/ FEM
Pressure P- MPa	-2.7 to 1.7	0.9	0.95	0.95
Axial force F- t	-2.9 to 2.5	1.61	1.40	1.15
P (MPa) & F (t)	-1.8 to 1.4	0.175 &1.180	0.151 & 1.180	1.16

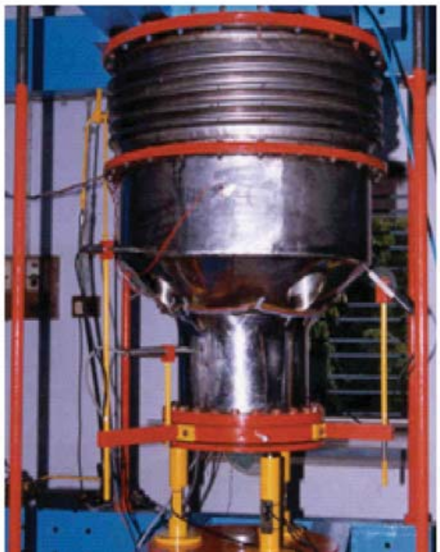


Figure 10: Experimental validation of buckling analysis for inner vessel

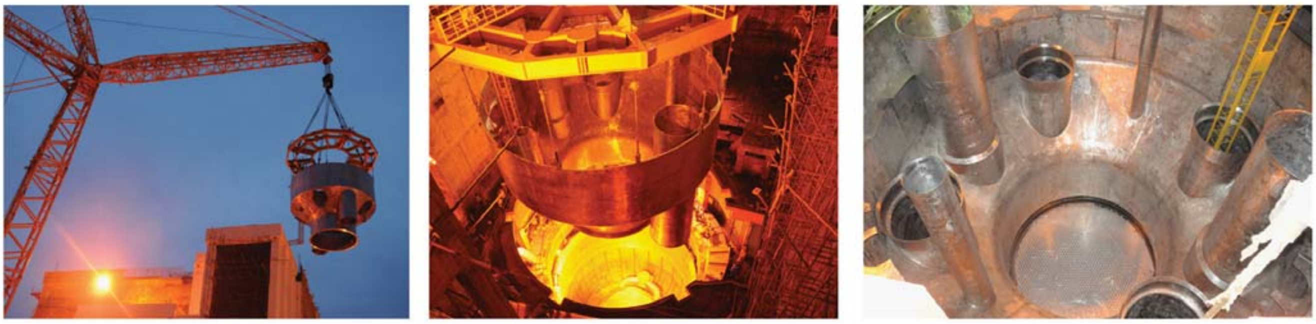


Figure 11: Erection sequence of inner vessel on the grid plate within main vessel

(Figure 9). From these investigations, it is concluded that there exists sufficient factor of safety to prevent the ratcheting as well as progressive buckling.

Buckling Design Validation

The buckling of inner vessel under internal pressure and loads through stand pipes has been simulated on 1/13th scaled models. Six tests were conducted and it is observed that the vessel buckles at the torus portion. The results demonstrate that the CAST3M can predict the critical buckling loads under various combinations of pressure and concentrated forces transmitted through the stand pipes conservatively with less than 16 % deviations. The buckled mode shape predicted by CAST3M is compared with numerical prediction as shown in Figure 10, which demonstrates clearly the capability of CAST3M code in predicting complicated buckling mode shape.

Construction Challenges

In view of its complex geometrical features with many penetrations, slenderness (15-20 mm thickness) and stringent tolerances specified for smooth insertion of pumps and intermediate heat exchangers through roof slab penetrations, the manufacturing called for sophisticated process, which is achieved by many mock-up trials. The tolerances achieved finally are very much satisfactory: form tolerances of 12 mm in the redan portion, verticality of standpipes less than 0.5 mm over the height of 4 meters. The inner vessel was manufactured by M/s BHEL, Trichy and is mounted on the grid plate, which was manufactured by M/s MTAR, Hyderabad. Hence, meticulous planning and dedicated efforts were made by the task force (responsible for manufacture and erection of reactor assembly components) along with BHAVINI and Industries, to achieve accurate interface dimensions, such of oval hole and pitch circle diameter. A simple and robust handling system without calling for any welding and heavy spiders was designed and tested. It has been also ensured that the assembly and disassembly of the handling system can be done at relatively shorter time span. With these milestones, the inner vessel was erected, within a time span of about 6 hours including the transport time from site assembly shop to the reactor location. Figure 11 depicts the sequence of erection.

Design Option for Future Fast Breeder Reactors

Beyond Prototype Fast Breeder Reactor, three twin units, each 2x500 MWe pool type Sodium Cooled Fast Reactors, similar to Prototype Fast Breeder Reactor but with improved economy and enhanced safety, are being designed. Significant changes are incorporated for reactor assembly components. With regard to inner vessel, the in-vessel transfer port, incorporated on the grid plate to accommodate the fresh fuel subassembly before handling by in-vessel transfer machine to insert into its respective sleeve in the grid plate, will now be integral part of the inner vessel. The in-vessel transfer port is also employed for positioning the spent fuel subassembly before handled by inclined fuel transfer machine to take it out of the reactor assembly. This calls for a geometrical modification of inner vessel, i.e. a toroidal redan of large single radius, instead of a conical shell connected with the adjacent cylindrical portion through a small radius toroidal sector. Further, a few openings (thermal valves) that open only during the post accident heat removal conditions, as alternative sodium flow paths for removing the decay heat from the core debris settled on the core catcher, are proposed to be incorporated. To amplify the opening area, options using shape memory alloys or link mechanism are being studied and the validated one would be incorporated in the final design.

(Reported by P. Chellapandi and colleagues, Nuclear & Safety Engineering Group)

Full Scope Replica Operator Training Simulator for Prototype Fast Breeder Reactor

Plant safety is of primary concern in any Nuclear Power Plant and it depends highly upon the knowledge possessed by the operators. High fidelity full scope operator training simulators play a significant role in imparting such plant related knowledge to the operating personnel in an effective way. It provides a platform for training the operators on normal and emergency conditions including all types of scenarios related to steady state and transient conditions of the reference plant.

Development of an operator training simulator is in progress. The main objective is to provide a computer based real time operator training tool for training the operators in advance, even before the actual plant could be commissioned. As per the Atomic Energy Regulatory Board guidelines, it is mandatory to have the operator training simulator in place, in order to train and qualify the operators before getting deployed for the main plant operation.

Hardware Architecture

The simulator hardware comprises of simulation computers, control panels, operator information consoles, input/output systems, instructor station, simulation network, power supply and distribution system as shown in the Figure 1. Operator consoles cater to overall monitoring of the plant using the most important and frequently used signals and controls. Normally, reactor startup, power raising, normal steady state power operation and shutdown operations are carried from the operator console. Instructor station facilitates control and monitoring of simulator operations. Figure 2 shows the newly installed simulator development facility at the annexe building of computer division which also provides a platform for R&D on improved human machine interface for the future FBRs.

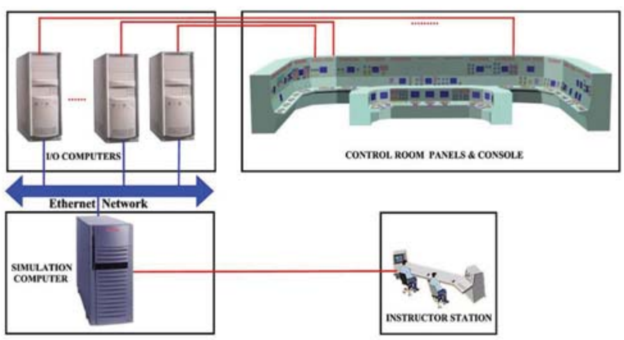


Figure 1: Hardware Architecture

Figure 2: Simulator development platform

Development of PFBR simulator includes modeling of various reactor subsystems as shown in Figure 3.

Simulated Plant conditions

The various plant operating conditions that are considered for modeling and simulation include shut down state of reactor, start up of reactor, reactor criticality (cold shut down and first criticality), power raise operation, steady state operation at full power and partial power, fuel handling operation, power setback, reactor trip etc.

Design and Development of Process Models

The process models are developed based on technical details collected from design documents, operation notes and plant safety analysis reports pertaining to each system. The system requirement specification document and modeling document are prepared for each system based on the above study. System flow sheets, approved panels drawings and logic diagrams are also collected for deriving data for designing the components.

Figure 3: Systems to be simulated

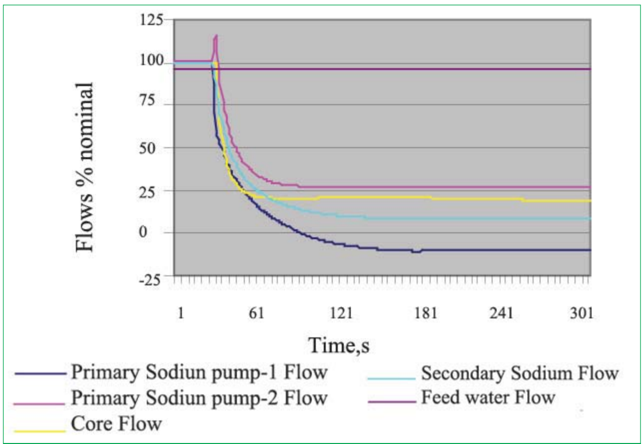


Figure 4: One PSP trip - Sodium, feed water flow

First, the conceptual model using basic components are made and then a detailed model is developed.

The basic functional modules of the simulator include process model, logic model and virtual panel model. The interface between the process, logic and the virtual panel are established by passing the input /output / feedback signal across the modules.

Further, the process models are classified into two main categories i.e. internal models and external models. The internal models include steam water system and electrical system simulation and are developed using the in-built components and devices provided by the simulation tool. The external models are developed in-house using system transfer functions considering the dynamic behavior of the plant under various transient conditions and include neutronics model, primary and secondary heat transport system, decay heat removal system, and core temperature monitoring system, fuel handling system etc.

The external models are developed using C and FORTRAN languages and integrated with the system and migrated to the simulator environment. The interface allows the external models to communicate with the other internal models developed using simulation tools. The other external models developed in-house include Alarm Generation, Log Message Generation, Reactor Startup Authorization, Fuel Handling Startup Authorization and

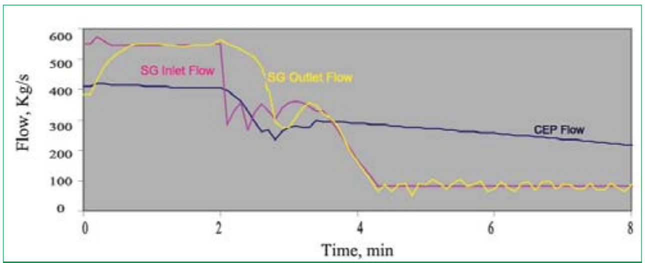


Figure 5: One BFP trip with standby not taking over-Flow

SG Pressure Control Model.

Integration and Performance Testing

Integration and performance testing is the most important phase of development of operator training simulator. Integration and testing is carried out to check and verify the communication between various processes, cycle time of each process, logical conditions of various components, display of associated alarms and system parameters, correct functioning of process, logics, control models etc.

The performance testing is carried out to verify the models developed, the design philosophy and the accuracy of the model with respect to system design.

Simulation of Plant Dynamics

Dynamic behavior of the plant is simulated for a set of benchmark transients identified to qualify the simulator for training programme. The list of benchmarks transients include, inadvertent withdrawal of one control rod, one primary pump trip or seizure, slowing down or speeding up of one or two primary pumps, one secondary sodium pump trip or seizure, sudden closure of sodium isolation valves, trip of main boiler feed water pump and standby, malfunction of water steam side isolation valves, failure of vacuum in condenser, tripping of condensate extraction pump, turbine load throw off etc. The system malfunctions include component failures like valve facing to close/open, stuck open /close, instrument and control channel failures etc.

One PSP trip

The flow profiles for one PSP and one BFP trip events are shown in Figure 4 and 5.

Turbine Trip Event

The simulated flow sheet shows the reactor at power setback condition after the occurrence of turbine trip event. The profiles indicating the steam generator pressure surge occurring due to sudden closure of steam isolation valve and governor valves, subsequent opening of atmospheric safety discharge valve, turbine by pass valve are captured and shown in Figure 6.

Analysis of Simulated Parameters

A hard copy of the profiles is taken with respect to time for simulated steady state and transient conditions and analyzed based on event analysis report. A comparison table is prepared for evaluating the performance testing. The percentage error

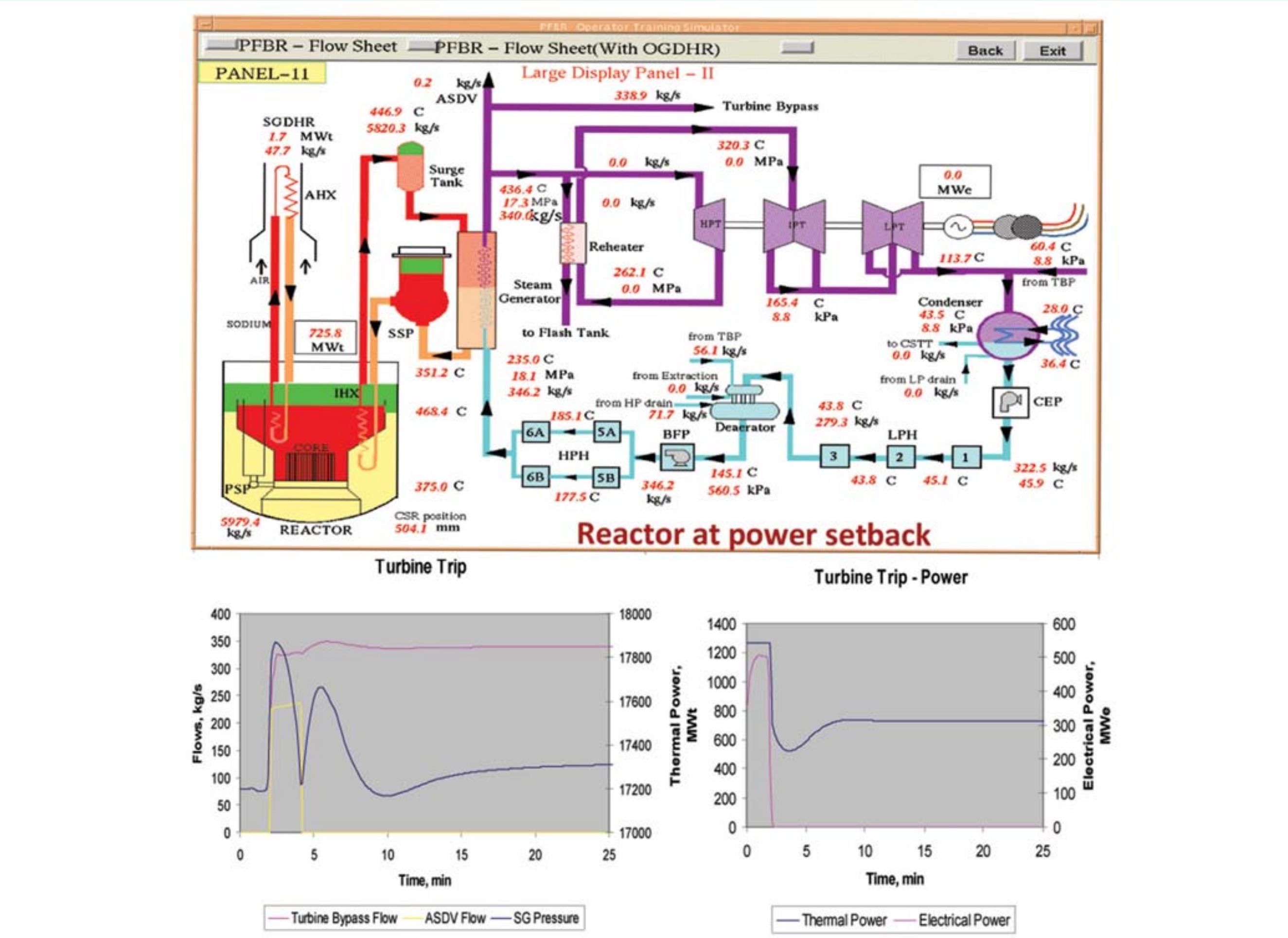


Figure 6: Turbine trip event

indicates the closeness of process simulation with the reference unit. Lower the error, higher is the closeness to the successful integration of the models.

Discussion with Design Experts

All the developed process models are demonstrated to design experts for validating the process models. The models are validated by observing the steady state and transient performance, configuration data of process models and scrutinizing the reports submitted on the simulated test results. The expert's comments are recorded and implemented into the system towards perfecting the model. The process models are passed on to verification and validation committee only after the validation by the design experts from Reactor Engineering Group.

Verification and Validation Testing of Process Models

A committee of experts from various units, NPCIL, BARC and IGCAR with specialization in design analysis and experience in similar field participate in verification and validation of process models. The process models developed are simulated and demonstrated to the team of experts of the verification and validation committee. Subsequently the verification and validation reports are made ready for the systems that are accepted for implementation.

Commissioning of BHAVINI Training Simulator

The commissioning of BHAVINI Training Simulator with version-1 of simulated process models is nearing completion.

The latest versions of developed software modules consisting of neutronics system, primary and secondary sodium systems, core temperature monitoring system, safety grade decay heat removal system, steam and water system are ported to BHAVINI training simulator and successfully tested. A migration procedure is also established based on the experience gained on porting of developed models to simulator development platform. The large display panel and the display stations are configured and tested for satisfactory performance. Integration and testing of steady state and transient conditions are also completed. The performance of the system is found to be satisfactory. The test report preparation is in progress.

(Reported by T. Jayanthi and colleagues, Computer Division, Electronics & Instrumentation Group)

Young Officer's FORUM

Non-Destructive Microstructural Characterisation using Nonlinear Ultrasonic Technique

Shri A. Viswanath obtained his Bachelor of Engineering degree in Metallurgical and Materials Engineering discipline from National Institute of Technology, Warangal in 2005. He is from 49th batch of BARC Training School and joined Non-Destructive Evaluation Division, IGCAR as Scientific Officer (C) In September 2006.

It is well known that changes in elastic properties of metallic materials are usually associated with one or a combination of variations in dislocation density, formation of dislocation dipole structures, precipitate-matrix coherency strains and formation of micro-cracks or voids. Thus, when a finite amplitude ultrasonic tone burst wave of a particular frequency is made to propagate through a material undergoing various structural changes or degradation, nonlinear interaction (distortion) of ultrasonic wave occurs with the above mentioned microstructural features and results in generation of harmonics. The amplitude of higher order harmonics can be measured and used to characterise microstructures during heat treatment and to assess material degradation, even at very early stages.

The amplitudes of fundamental (A_1) and second harmonics (A_2) are measured and the nonlinear ultrasonic parameter called, β given by equation (1) is determined and used.

$$\beta = \frac{8}{K^2 a}\left(\frac{A_2}{A_1^{\,2}}\right) \qquad (1)$$

where *K* is the material propagation constant and a is thickness of the material through which the ultrasonic waves propagate. As shown in Figure 1, piezoelectric ultrasonic transmitter and receiver are placed on opposite sides of a specimen to measure the fundamental and second harmonic amplitudes. Working on these lines, non-linear ultrasonic technique has come into existence and is being widely used as a nondestructive evaluation tool for characterisation of fatigue, creep, thermal degradation, micro cracks, voids, coherency strains due to precipitates and bonding strength of adhesive joints etc.

Experimental setup has been established for non-linear ultrasonic studies and Figure 2 shows the schematic of the setup which consists of high power *rf* tone burst generating system, digital storage oscilloscope, narrow band transmitting transducer (5 MHz), broad band receiver (4.7 to 13.8 MHz), low-pass & high-pass filters and data acquisition module interfaced to a personal computer. In general, the amplitude of second harmonic i.e. A_2 is less than 1% of the fundamental A_1 and is difficult to determine precisely from the amplitude spectrum of the received signals. Hence, a new technique called pulse inversion technique has been implemented to measure this feeble A_2. This technique involves superimposition of two transmitted waves (refer Figure 3a) with an incident phase angle difference of 180° which results in cancellation of all odd harmonics and in turn, amplification of the second harmonic amplitude significantly. The amplitude spectrum of either of the transmitted waves (0° or 180°) can be used to measure A_1, while A_2 is measured from the amplitude spectrum of the superimposed signal (Figure 3b). In order to determine β parameter, A_1 and A_2 are measured for

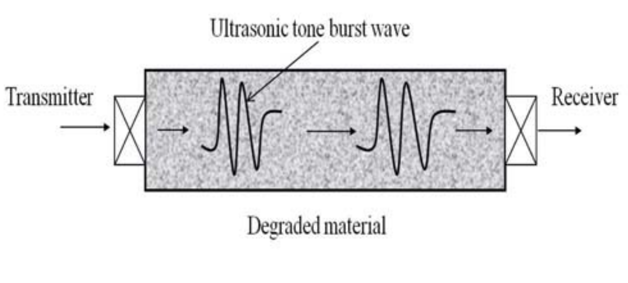


Figure 1: Schematic showing distortion of intially sinusoidal ultrasonic tone burst wave probpagating through material

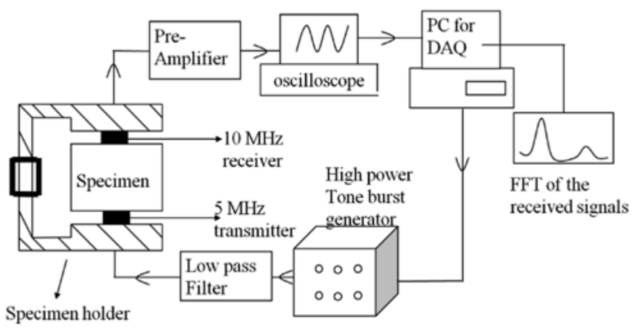


Figure 2: Schematic of the experimental setup used for Non linear ultrasonic measurements

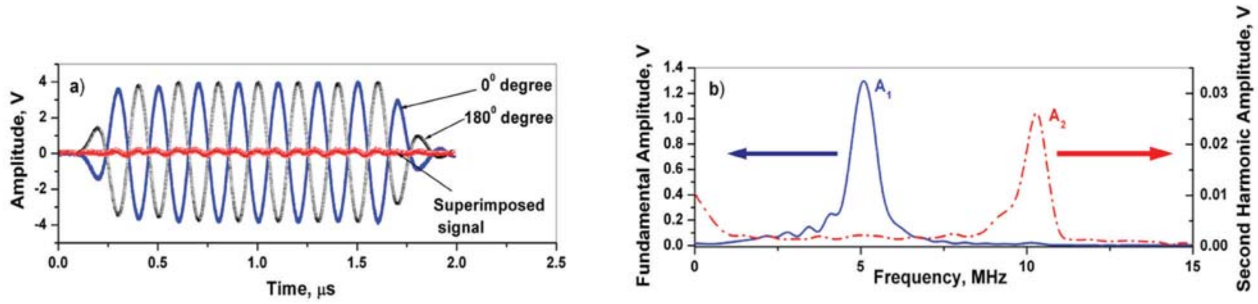


Figure 3:(a) Time domain 0°, 180° and superimposed ultrasonic tone burst wave forms for solution annealed specimen
(b) Amplitude spectrum of the 0° and superimposed wave forms

a given specimen at different power levels in the range of 300 to 700 V and a plot is made between A_2 and A_1, slope of which gives the β (equation 1) under constant experimental conditions. For examining the relative changes in the non-linear behavior of a degraded or heat treated material with respect to initial or solution annealed condition, relative β parameter defined by equation (2) is used

$$\text{Relative } \beta \text{ Parameter} = \frac{\beta_{degraded}}{\beta_{initial}} \quad (2)$$

where $\beta_{degraded}$ is the β parameter of degraded material and $\beta_{initial}$ is the β parameter of initial or solution annealed material. non-linear ultrasonic technique has been successfully applied to study heat treatment, plastic deformation and ageing behavior in steels as detailed in the following sections.

Study on microstructural changes in heat treated 0.4% carbon steel

Non-linear ultrasonic technique has been used for studying the microstructural changes in the 0.4% carbon steel subjected to solutionising at 1143 K for two hours followed by cooling at different cooling rates as given in Table I. The variation of relative β parameter as a function of hardness for furnace cooled, air cooled and water quenched specimens is shown in Figure 4. The micrographs corresponding to heat treated specimens are also shown in Figure 4. The furnace cooled specimen consists of coarse ferrite and pearlite mixture which results in lower hardness, while the air cooled specimens consist of fine ferrite and pearlite mixture which result in higher hardness. In the case of water quenched specimens, presence of martensitic structure results in very high hardness. As can be seen from the Figure 4, the normalized relative β parameter increases with increase in cooling rate of the specimens. Relative β parameter of water quenched specimens is attributed to the formation of martensitic structure with high dislocation density. These studies bring out that non-linear ultrasonic technique can be used for characterization of microstructural changes and for nondestructive estimation of hardness in the heat treated medium carbon steels.

Table 1: Details of carbon steel specimens

S.NO	Heat treatment	Rockwell hardness	Relative β Parameter
1	Furnace cooled	67	1
2	Air cooled	80	1.105
3	Water quenched	98	1.26

Studies on deformation behavior in cold worked AISI type 304 stainless steel

Non-linear ultrasonic technique has been used to study the deformation behavior in cold worked AISI type 304 stainless steel. The stainless steel specimens are cold rolled at room temperature to achieve 10, 19, 29, 38 and 47% reduction in

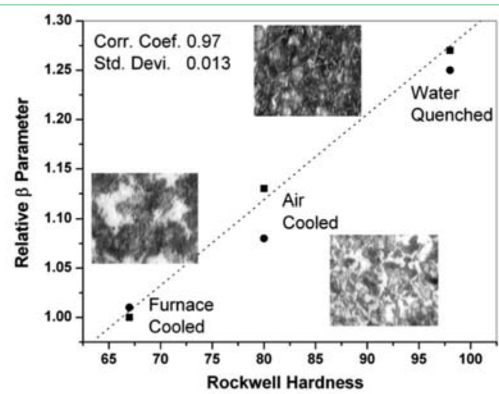


Figure 4:Variation of relative β parameter as function of hardness for furnace cooled air cooled and water quenched specimens

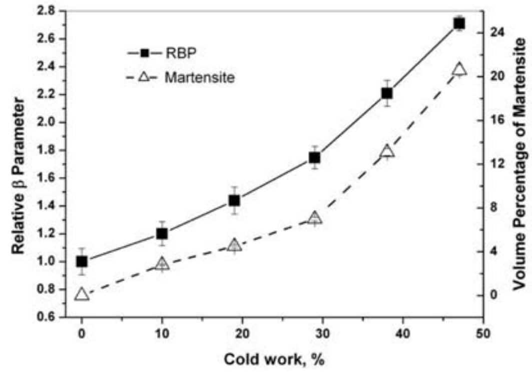


Figure 5: Variation of relative β parameter and volume percentage of martensite with % cold work in AISI type 304 stainless steel

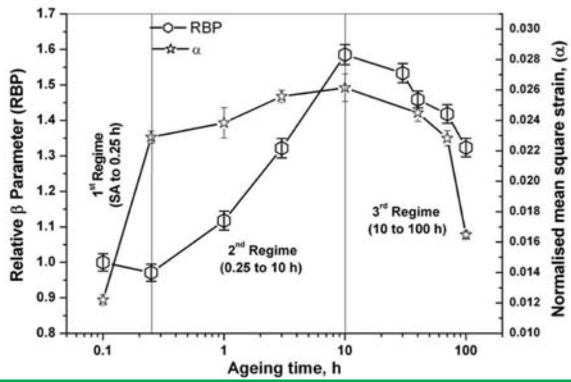


Figure 6: Variation of relative β parameter and α with ageing time

thickness. During cold work, the metastable austenitic stainless steel will undergo various microstructural changes, viz. i) increase in dislocation density ii) dislocation substructural changes and iii) formation of strain-induced α'-martensite and all these are expected to cause perturbation to the propagation of ultrasonic waves.

The volume percentage of α'-martensite is estimated using XRD technique. Figure 5 shows the variation of relative β parameter and volume fraction of α'-martensite with cold work. As can be seen, the β parameter increases with cold work with an overall increase of 170% for a cold work of 47%. The increase in β parameter with cold work is attributed to the increase in dislocation density, dislocation sub-structural changes and increase in volume percentage of α'-martensite.

Study of ageing behavior of M250 grade Maraging steel

Non-linear ultrasonic technique has been used for characterization of ageing behavior of M250 grade Maraging steel subjected to isothermal ageing at 755 K for varying durations of 0.25, 1, 3, 10, 40, 70 and 100 hours. X-ray diffraction (XRD) measurements are carried out in the angular range of 36 - 122° with a step size of 0.02° and dwell time of 4s with Cu Kα radiation for all the age hardened samples. The modified Williamson–Hall approach has been used to estimate the normalized mean square strain.

Figure 6 shows the variation of relative β parameter and normalized mean square strain (α) measured by XRD technique as a function of ageing time. The changes in relative β parameter with ageing time can be classified into three regimes as depicted in Figure 6. In the first regime, relative β parameter decreases by 2.9% for 0.25 hours aged condition as compared to the SA condition. This is attributed to the opposing effect of i) decrease in dislocation density will decreases in nonlinearity of the material and ii) increase in coherency strain due to precipitation of very fine coherent Ni_3Ti intermetallic precipitates which increase the nonlinearity. During second regime, 0.25 to ten hours of ageing, β parameter is found to increase by 60% with ageing time reaching a peak at 10 hours of ageing which is optimal and technologically important (without formation of any reverted austenite). This increase in β parameter is attributed to continued precipitation and growth of coherent Ni_3Ti and Fe_2Mo intermetallic precipitates. Upon prolonged ageing to the third regime, β parameter is found to decrease due to the combined effect of coarsening of precipitates and austenite reversion which reduce material nonlinearity. The studies have revealed that non-linear ultrasonic β parameter is sensitive to microstructural changes that occur during ageing of M250 grade Maraging steel and can be used for studying the ageing behaviour of precipitation hardened steels.

The studies carried out in different materials using the non-linear ultrasonic technique supported by microscopy clearly reveal the potential of the non-linear ultrasonic technique and its usefulness for comprehensive understanding and nondestructive characterization of microstructures in widely varying materials subjected to heat treatment, plastic deformation and ageing. Currently studies are in progress to detect early fatigue damage in modified 9Cr-1Mo steel and precipitation behavior in 17-4 PH steel using the non-linear ultrasonic technique. Efforts are also underway to modify the non-linear ultrasonic technique with transmitter and receiver probes on the same side so that on-component assessment of material degradation in operating components becomes a possibility.

(Reported by A. Viswanath, Non Destructive Evaluation Division, Metallurgy and Materials Group)

Young Researcher's FORUM

Shri Ch. Jagadeeswara Rao obtained his M.Sc., (Organic Chemistry) from Andhra University, Visakhapatnam. He joined IGCAR as a Junior Research Fellow in February 2006 and is pursuing his Ph.D on the applications of room temperature ionic liquids in nuclear fuel cycle under the guidance of Dr. K. Nagarajan, Fuel Chemistry Division, Chemistry Group. He has seven peer reviewed journal publications and one Indian patent to his credit. He has attended international conference EUCHEM 2010 held at Germany.

Potential Applications of Room Temperature Ionic Liquids in Nuclear Fuel Cycle

Room temperature ionic liquids (RTILs), as the name implies, are novel fluids comprising entirely of ions and are molten at temperatures lower than 373 K. They have several fascinating properties suitable for industrial exploitation, such as negligible vapour pressure, good solubility for organic and inorganic compounds, high thermal conductivity, wide electrochemical window etc. In the recent years, room temperature ionic liquids have been extensively studied for the applications in various stages of nuclear fuel cycle. In this perspective, studies were carried out to explore the feasibility of using room temperature ionic liquids for fuel cycle applications in the areas such as (i) non-aqueous reprocessing (ii) dissolution behaviour of uranium oxides and (iii) waste management.

Non-aqueous Reprocessing Applications

Pyrochemical processes are among the non-aqueous reprocessing methods. Of the several pyrochemical processes that are known, the following are currently under development: (a) the oxide electrowinning process, developed by Research Institute of Atomic Reactors, Russia suitable for reprocessing of oxide fuel, (b) the electrorefining process, developed by Argonne National Laboratory, USA, suitable for reprocessing of metallic fuels and (c) the fluoride volatility process developed by Russia and USA, suitable for the oxide as well as molten salt reactor fuels.

Although pyrochemical processes has several advantages over the aqueous reprocessing methods, they also have some disadvantages such as lower separation factors for fission products, need for sophisticated equipment and high purity inert atmosphere to handle hygroscopic salts and reactive metals, high temperature operation, etc. Thus, the employment of room temperature ionic liquids, in the place of the traditional high temperature inorganic molten salts in non-aqueous reprocessing would enable the operation of entire process at ambient conditions. In addition, the management of spent electrolyte can be simplified by tuning these organic electrolytes to incinerable form.

Electrodeposition of lanthanides and actinides

A new procedure was developed for the dissolution of oxides of lanthanides and actinides in room temperature ionic liquids followed by electrodeposition of them in metallic form (Figure 1). For this purpose, we have synthesized several ionic liquids that offer wide electrochemical window and extended cathodic stability. Among them, N-butyl-N-methylpyrrolidinium bis(trifluoromethylsulfonyl)imide ($BMPyNTf_2$) and N-methyl-N-propylpiperidinium bis (trifluoromethylsulfonyl)imide($MPPiNTf_2$) were selected for the study since they offered an electrochemical window more than 5 V and extended cathodic stability, adequate for the electrodeposition of trivalent lanthanides and actinides in metallic form. Europium oxide and uranium oxide were chosen as representative lanthanide and actinide elements in the present study.

Europium or uranium oxides were dissolved in required quantity of $HNTf_2$ in aqueous medium. The triflamides formed $M_x(NTf_2)_n$ (M = Eu(III) or U(IV) and x =2, 0 and n =3 or 4) were dried

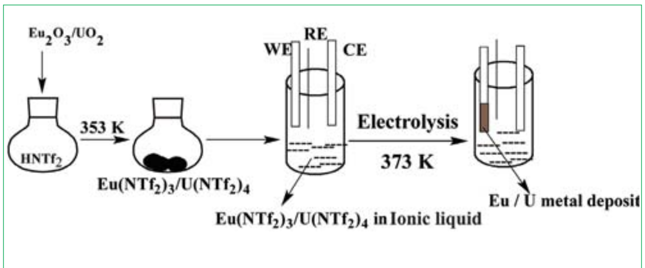


Figure 1: Electrodeposition of europium and uranium using room temperature ionic liquids

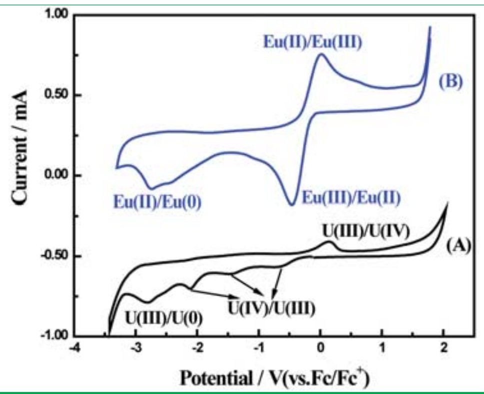


Figure 2: Cyclic voltammograms of (A) U (IV) in $MPPiNTf_2$ and (B) Eu(III) in $BMPyNTf_2$ at glassy carbon electrode at 373 K

using a rotary evaporator at 353 K and were diluted with ionic liquids. In order to confirm the feasibility of using these ionic liquids for electrodeposition, the electrochemical behavior of Eu(III) and U(IV) in room temperature ionic liquids was studied by various transient electrochemical techniques.

The cyclic voltammogram of Eu(III) in $BMPyNTf_2$ recorded at glassy carbon working electrode at 373 K shown in Figure 2. The onset of cathodic wave occurring at a potential of -0.09V (vs. Fc/Fc^+) which culminates in a peak at -0.45 V was attributed to the reduction of Eu(III) to Eu(II). This is accompanied by an anodic wave at -0.07 V during the scan reversal. The cyclic voltammogram of Eu(III) is also accompanied by an irreversible cathodic wave occurring at -2.79 V (vs. Fc/Fc^+) due to the reduction of Eu(II) to metallic europium. The EDXRF and XRD patterns (Figure 3A) of the deposited product obtained by the electrolysis of Eu(III) in $BMPyNTf_2$ at -2.9 V confirmed the presence of metallic europium.

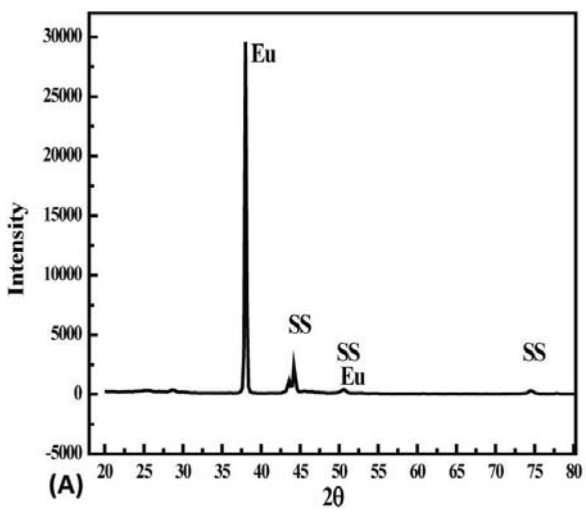
Similarly, uranium tetrakis[bis(trifluoromethanesulfonyl)imide], $U(NTf_2)_4$, was synthesized and the electrochemical behavior of U(IV) in $MPPiNTf_2$ was investigated at 373 K at glassy carbon working electrode. The cyclic voltammogram of U(IV) in $MPPiNTf_2$, as shown in Figure 2, shows four cathodic peaks at a peak potentials of -0.64, -1.45, -2.10 and -2.77 V (vs. Fc/Fc^+). The first three cathodic peaks were attributed to the reduction of U(IV) to U(III) and the peak at -2.77 V was attributed to the reduction of U(III) to metallic uranium.

The electrolysis of U(IV) in $MPPiNTf_2$ at -2.8 V resulted in the deposition of metallic uranium, which was confirmed by XRD and the surface morphology of the deposit given in Figure 3B. The studies demonstrated the feasibility of dissolving Eu_2O_3 and UO_2, in $HNTf_2$ and subsequent recovery as metals by electrolysis from RTIL medium.

Dissolution behaviour of uranium oxides

Dissolution of various uranium oxides were studied and a new procedure has been developed for the separation of the three uranium oxides namely, UO_3, UO_2 and U_3O_8 from a mixture of oxides by varying the temperature of the dissolution in a task-specific ionic liquid, Betaine bis(trifluoromethanesulfonyl)imide ($HbetNTf_2$).

Dissolution of UO_3 in $HbetNTf_2$ was very rapid and nearly 25 minutes were required for completely dissolve 1 wt.% uranium from UO_3, while 45 minutes were required for 5 wt.% uranium from UO_3 at 373 K. The UV-VIS absorption spectrum of a solution of UO_3 in $HbetNTf_2$ indicates the presence of U(VI)



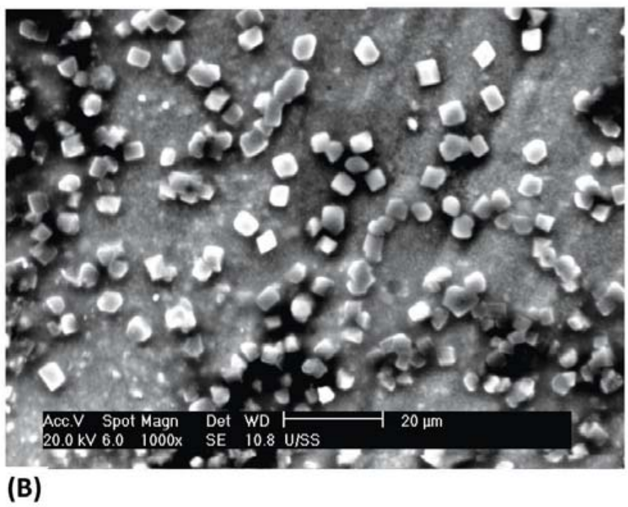


Figure 3: (A) XRD of the europium metal deposit on stainless steel (B) SEM image of the uranium metal deposit

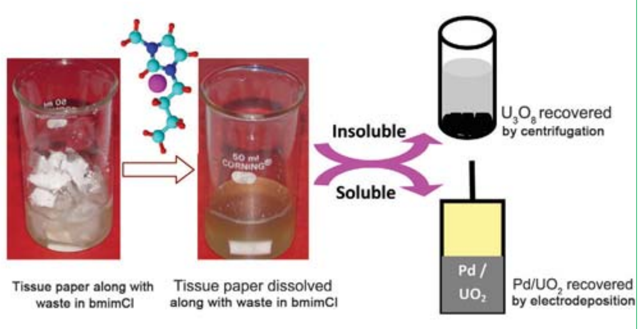


Figure 4: Treatment of tissue paper waste using room temperature ionic liquid

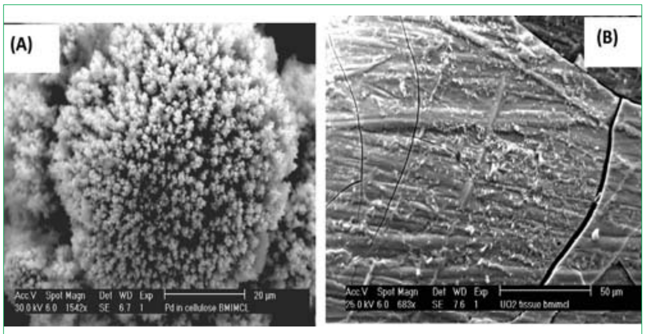


Figure 5: SEM images of the palladium metal deposit obtained by the electrolysis of (A) $PdCl_2$ containing tissue paper solution in bmimCl and (B) UO_2 deposit obtained from uranyl nitrate containing tissue paper solution in bmimCl

(UO_2^{2+}) in ionic liquid.

The possible mechanism of the dissolution of UO_3 in $HbetNTf_2$ may be represented by the reaction shown in equation 1.

$$2\,HbetNTf_2 + UO_3 \leftrightarrow UO_2(betNTf_2)_2 + H_2O \qquad (1)$$

As per this reaction, the stoichiometric solubility of uranium in $HbetNTf_2$ is 22.5 wt%. However the solubility limit of UO_3 in $HbetNTf_2$ was found to be only 14-15 wt.% in U, which is an indication that steric factors may be playing some role in deciding the solubility.

Unlike UO_3, UO_2 was insoluble in $HbetNTf_2$ when the temperature was less than 453 K. However, when the temperature of the reaction was increased above 453 K, gradual dissolution of UO_2 was observed leading to a yellow solution. The absorption spectrum of UO_2 dissolved in task-specific ionic liquid indicates that UO_2 dissolution might have been facilitated by prior oxidation of U(IV) to U(VI) in the presence of air. U_3O_8 was insoluble in $HbetNTf_2$ below 453 K, and very slow dissolution was observed when the temperature was increased to 473 K. Unlike UO_3 and UO_2, dissolution of 5 wt.% U_3O_8 in $HbetNTf_2$ was incomplete even after 25 hours and only 10-15% of the total uranium taken for the study was found to have dissolved in ionic liquid phase. Based on these results, a procedure was developed for the separation of the three oxides of uranium, namely, UO_3, UO_2 and U_3O_8 from a mixture of them using the differences among the solubilities in the task-specific ionic liquid. At the end of the process, the uranium present in ionic liquid could be stripped into nitric acid phase.

Waste management applications

The operations in nuclear facilities and the associated R&D units produce large volume of tissue paper waste (cellulosic waste) which generally contains radioactive fission products, lanthanides and actinides which add up to significant quantities. They are usually discarded as waste at the generation site. Currently, tissue paper waste contaminated with innocuous metals is normally dumped into environment for bio-degradation. The same treatment cannot be used for tissue paper waste contaminated with strategic and hazardous metals. Some industries adopt incineration at site for the treatment. This method generates large volume of secondary wastes and the off-gases released during combustion pollute the surroundings.

Treatment of tissue paper waste

Studies on the dissolution of tissue paper waste containing valuable nuclear materials were carried out in the ionic liquid, 1-butyl-3-methylimidazolium chloride (bmimCl). Recovery of strategic and potentially useful fission product contaminants from such waste was demonstrated by exploiting the unique properties of the room temperature ionic liquid. Cellulose pulp was regenerated by adding surplus water, after recovery, which could be recycled if the contamination is within the permissible levels. Based on our studies, a new procedure has been developed for the treatment of radioactive tissue paper waste using bmimCl (Figure 4). Uranyl nitrate and palladium chloride dissolve in bmimCl along with tissue paper. They are recovered by electrolysis of the solution by exploiting the wide electrochemical window of bmimCl. The electrochemical behavior of UO_2^{2+} and Pd^{2+} in bmimCl along with tissue paper was studied at glassy carbon electrode at 373 K with and without the addition of the co-solvent, dimethyl sulphoxide.

UO_2^{2+} and Pd^{2+} ions in bmimCl-tissue paper solution undergo irreversible, single step, two electron reduction reactions at glassy carbon electrode to give UO_2 and metallic palladium,

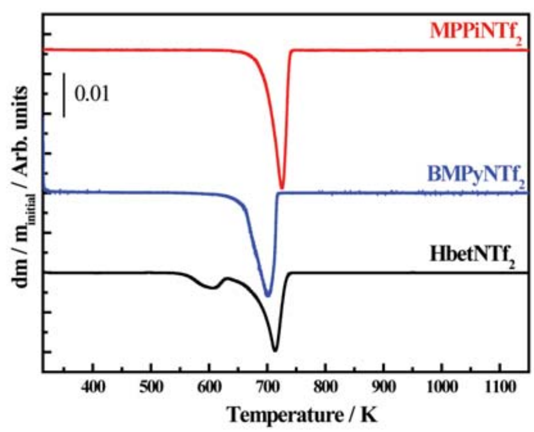


Figure 6: The derivative thermogravimetric patterns of $HbetNTf_2$, $BMPyNTf_2$ and $MPPiNTf_2$

respectively. The diffusion coefficients of UO_2^{2+} and Pd^{2+} were of the order of ~10^{-8} cm^2 s^{-1} at 373 K. The morphology of UO_2 and palladium deposits (Figure 5) was influenced remarkably by the presence of cellulose and dimethyl sulphoxide, which seem to complex with UO_2^{2+} and Pd^{2+} ions in solution and also behave as templates during electrodeposition leading to peculiar structures in the deposit. The extent of recovery of palladium and uranium were around 60 and 40%, respectively.

The separation of insolubles from tissue paper matrix using bmimCl was also studied. After dissolution of the tissue paper with insoluble waste in bmimCl, dimethyl sulphoxide was added and the insolubles were recovered by simple centrifugation. A procedure for the recovery of U_3O_8, boron, boron carbide or metallic palladium from contaminated tissue paper and regeneration of cellulose pulp and recycling of reagents was developed. The insoluble U_3O_8 was recovered quantitatively.

Radiochemical and thermal stabilities of ionic liquids

Room temperature ionic liquids should have adequate thermal and radiation stability for use in aqueous and non-aqueous reprocessing applications. Thermal stabilities of the ionic liquids were studied using DSC and TG techniques.

The ionic liquids, $MPPiNTf_2$ and $BMPyNTf_2$, were thermally stable up to 650 K, whereas $HbetNTf_2$ was stable only up to 560 K (Figure 6). Heat capacity measurements on $HbetNTf_2$ were carried out in the temperature range 340 – 470 K, whereas that of $MPPiNTf_2$ and $BMPyNTf_2$ were carried out from 298 – 520 K, using DSC. The observed heat capacity data of $HbetNTf_2$ (585-617 J K^{-1} mol^{-1}) were much lower than that of $MPPiNTf_2$ and $BMPyNTf_2$ as the total number of bonds in $HbetNTf_2$ are lower. The heat capacity of $MPPiNTf_2$ (606-756 J K^{-1} mol^{-1}) and $BMPyNTf_2$ (606-776 J K^{-1} mol^{-1}) are very close (±2%), as these are isomers. The present measurements provide the first data on the heat capacity of $HbetNTf_2$, $MPPiNTf_2$ and $BMPyNTf_2$. Based on the heat capacity values, the thermodynamic functions, H^0_T-H^0_{298} and S^0_T-S^0_{298} were determined.

Studies on the radiolytic degradation of $HbetNTf_2$, $MPPiNTf_2$, $BMPyNTf_2$, bmimCl, 1-hexyl-3-methylimidazolium chloride (hmimCl) and tri-n-octylmethylammonium chloride (Aliquat-336) were carried out using gamma irradiation at different absorbed doses. After the irradiation of the ionic liquids upto a maximum dose of 700 kGy, physical properties such as refractive index, density, color change, absorbance, viscosity and electrochemical windows were measured. Significant change in the colour of the room temperature ionic liquids was observed upon irradiation. However, the densities and refractive indices were unaltered. Presence of radiolytic products in room temperature ionic liquids increased the viscosity of these Newtonian fluids. When the viscosity of a liquid is independent of shear rate and the relation between shear rate and shear stress is linear, then the liquid is known as Newtonian fluid. In the present study, the ionic liquids were found to preserve the newtonian behaviour even after irradiation. The electrochemical window of most of the room temperature ionic liquids reduced to half by the absorption of 700 kGy gamma dose. Nevertheless, these ionic liquids were sufficiently stable, when irradiated up to 100 kGy, which is typically encountered during nuclear fuel cycle applications.

Conclusions

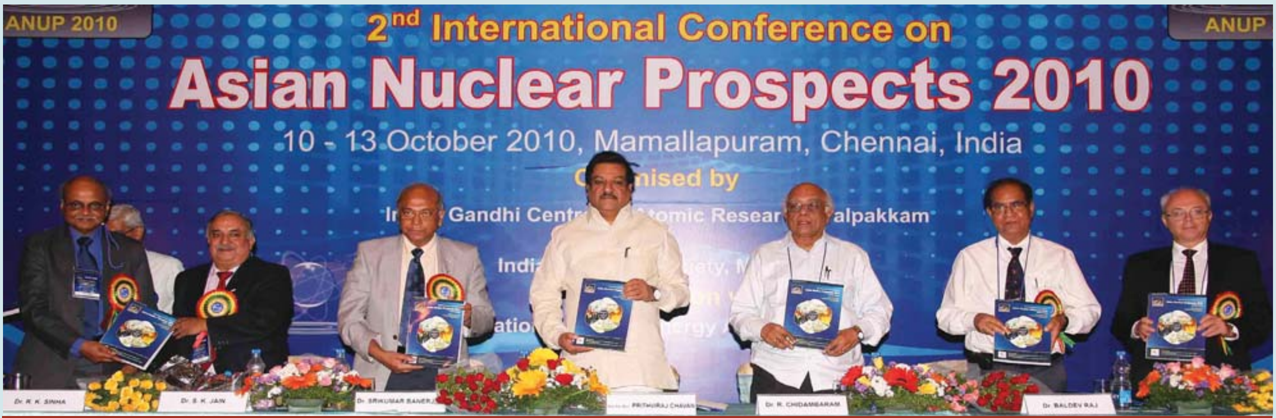
Our studies on the ionic liquids confirmed their potential applications in several areas of nuclear fuel cycle. From non-aqueous reprocessing point of view, ionic liquids are suitable candidates for dissolving Eu_2O_3 and UO_2, and perhaps other oxides of actinides in $HNTf_2$ medium followed by electrochemical recovery in metallic form. The task specific property of $HbetNTf_2$ can be exploited for the separation of the three uranium oxides namely, UO_3, UO_2 and U_3O_8 from a mixture of the oxides by varying the experimental conditions. Moreover, our studies indicate the possibility of using bmimCl for the treatment of cellulose based waste and quantitative recovery of valuables from them.

(Reported by Ch. Jagadeeswara Rao, Fuel Chemistry Division, Chemistry Group)

Conference/Meeting Highlights

Second International Conference on Asian Nuclear Prospects 2010 (ANUP 2010)

October 10- 13, 2010



Dr. R. K. Sinha, Vice President INS & Director, BARC, Dr. S. K. Jain, CMD, NPCIL & BHAVINI Dr. Srikumar.Banerjee, Chairman, AEC and Secretary, DAE, Shri Prithviraj Chavan, the then Honourable Minister of State for Science & Technology and Earth Sciences, Government of India Dr. R. Chidambaram, Principal Scientific Advisor to Government of India, Dr. Baldev Raj, Chairman, Organizing Committee and Director, IGCAR, Dr. Y. Sokolov, Deputy Director General, IAEA while releasing the souvenir during the inauguration

The Second International Conference on Asian Nuclear Prospects 2010 (ANUP 2010) was organized by the Indira Gandhi Centre for Atomic Research and the Indian Nuclear Society, in co-operation with the International Atomic Energy Agency (IAEA) during October 10-13, 2010, at Radisson Resort Temple Bay, Mamallapuram. The aim of the Conference was to bring about increased interaction between Asian countries which are having nuclear energy programmes and the developed countries of the world where nuclear energy has reached a level of maturity. The scope of ANUP 2010 included all aspects of nuclear energy and related technology. The format of the Conference included invited talks by eminent experts, poster presentation by participants (contributed papers), and a few oral presentations by young researchers.

The Conference evoked excellent response from the international nuclear community. Three hundred and thirty delegates from different parts of the world including about sixty from overseas, and about fifty from the industry attended ANUP 2010. There were nine plenary talks, forty one invited talks and one hundred thirteen contributed papers among which eight were young researcher oral presentations. Twenty seven speakers were from foreign countries. Among the contributed papers, twenty were from abroad, and the rest from Indian atomic energy units, national laboratories, universities and industry.

The Conference was inaugurated in the evening of October 10, 2010, by Dr Srikumar Banerjee, Chairman, Atomic Energy Commission of India. The function was presided over by Shri Prithviraj Chavan, the then Honourable Minister of State for Science & Technology and Earth Sciences, Government of India. Dr. Baldev Raj, Chairman, Organizing Committee and Director, IGCAR welcomed the gathering, Dr. R.K. Sinha, Vice President INS & Director, BARC and Dr. Y.Sokolov, Deputy Director General, IAEA addressed the gathering, and Dr. S.K.Jain, CMD, NPCIL & BHAVINI released the Souvenir and inaugurated the Exhibition. Dr. P. R. Vasudeva Rao, Director, CG, delivered the vote of thanks.

Three days were devoted to intensive technical discussions in three plenary sessions, and six technical sessions in parallel. The topics ranged from atomic minerals exploration to nuclear waste disposal, materials development and associated technologies. Eight young researchers gave short oral presentations on their R&D work in an impressive session chaired by Dr. Anil Kakodkar, Member, AEC and former Chairman, AEC. There was also an industrial forum, chaired by Dr. R. Chidambaram, Principal Scientific Advisor to Government of India, in which several leaders of the nuclear and related industries from India and abroad (AREVA India, Cameco India, Nuvia India, Westinghouse, BHEL and L&T) presented their perspectives on sustainable growth of nuclear energy in Asia and the rest of the world. There was an exhibition with ten pavilions showcasing the strengths and achievements of several industries allied to nuclear energy and was kept for all three days of the meeting. The Conference ended in the evening of October 13, 2010 with a panel discussion on the topic, “Engines of robust and sustainable nuclear energy growth” chaired by Dr. Anil Kakodkar. The panel consisted of senior nuclear programme leaders from almost all countries with major nuclear energy projects. At the end of the Conference, the feedback received from delegates and other observers uniformly referred to the high technical content and professional conduct of the event.

(Reported by U. Kamachi Mudali)

Conference/Meeting Highlights

Workshop on Structure and Thermodynamics of Emerging Materials (STEM-2010)

November 25-26, 2010

Dr. Baldev Raj, Director, IGCAR addressing the gathering, Dr. M. Vijayalakshmi Head, Physical Metallurgy Division Dr. T. Jayakumar, Director, Metallurgy and Materials Group, Professor R. K. Ray, Visiting Scientist, Tata Steel, and Dr. Saroja Saibaba, Head, Nuclear Materials Microscopy Section, Physical Metallurgy Division and Convener, STEM 2010 during the inaugural function

The BRNS sponsored two-day workshop STEM-2010 on the theme “Advanced Methods in Characterisation of Texture and Microtexture of Materials” was organized jointly by Indira Gandhi Centre for Atomic Research and The Indian Institute of Metals – Kalpakkam Chapter during November 25-26, 2010 at Convention Centre, Anupuram. Dr. T. Jayakumar, Director, MMG welcomed the participants and emphasized the role of crystallographic texture in the development of various nuclear materials. Dr. M. Vijayalakshmi, Head, Physical Metallurgy Division briefed upon the genesis of STEM annual meetings on a focused theme to foster professional knowledge, the recent advancements in texture characterisation and its potential for improving material performance. Dr. Baldev Raj, Director, IGCAR inaugurated the meeting, and stressed the importance of research collaborations and modeling studies for tackling various challenging problems in materials at a shorter time. The plenary lecture “Crystallographic texture in understanding material behavior” by Professor R.K. Ray, Visiting Scientist, Tata Steel, provided an excellent overview of the theme of the workshop. He provided a historical glimpse on texture studies, different representations of texture data and the role of texture in improving material properties through illustrative examples. Dr. Saroja Saibaba, Head, Nuclear Materials Microscopy Section and Convener, STEM-2010 delivered the vote of thanks.

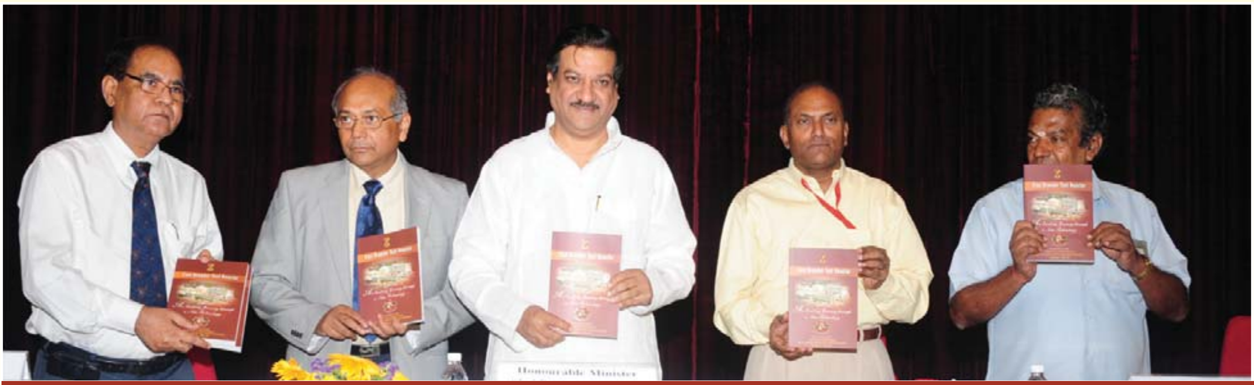
Invited lectures were delivered by eminent scientists from leading national R&D institutions and academia covering aspects of texture characterization techniques (electron back scattered diffraction, X-ray diffraction, transmission electron microscopy), mechanisms of texture formation and evolution, grain boundary engineering, texture-property correlations in nuclear and automotive industries and the recent developments. About one hundred and ten delegates from various institutes such as Indian Institute of Science, IITs, DMRL, NIT, IMMT, IPR, and other engineering/science colleges, and from DAE units of BARC, NFC and IGCAR participated in the two-day deliberations. Young research scholars presented their work as posters. The technical program was appreciated by the participants, and valuable inputs for futher discussions were provided during the feedback session at the end of two day workshop.

(Reported by Saroja Saibaba, Convenor, STEM-2010)

News & Events

Silver Jubilee Commemoration of Fast Breeder Test Reactor and Radiometallurgy Laboratory

October 10, 2010



Dr. Baldev Raj, Director, IGCAR, Dr. S. Banerjee, Chairman, AEC and Secretary, DAE, Shri M. S. Ramanujan, Postmaster General, Chennai City Region, Chennai and Shri G. Srinivasan, Director, Reactor Operations and Maintenance Group with the then Honourable Minister for Science & Technology, Shri Prithiviraj Chavan, during the release of commemorative volume on FBTR as a part of the silver jubilee celebrations

Fast Breeder Test Reactor, the flagship of the Centre, has performed exceedingly well without any major incidents. Every passing year has seen a new milestone being achieved for FBTR, in terms of reactor power, sodium temperature, fuel burn-up and so on. The unique high plutonium carbide fuel has seen a burn-up of 165 GWd/t without any clad failure. Radiometallurgy laboratory (RML), was designed primarily to be a robust companion of FBTR, as a Post-Irradiation Examination Laboratory. Development of robust and innovative Non-Destructive Evaluation Methodologies and Robotics have made a significant impact on the success of Fast Reactor programme. A glittering ceremony was organized on October 10, 2010 to commemorate 25 years of the successful operation of Fast Breeder Test Reactor and the commencement of Radiometallurgy Laboratory at the Centre. The programme commenced with a power point presentation on the history and growth of Fast Breeder Test Reactor and the Radiometallurgy Laboratory, indicating significant milestones. Dr.Baldev Raj, Director, IGCAR and one of the pioneers involved in commissioning of the Radiometallurgy Laboratory, welcomed the gathering. Dr.S.Banerjee, Chairman, Atomic Energy Commission and Secretary, Department of Atomic Energy delivered a very inspirational address. The then Honorable Minister for State for Science and Technology, Earth Sciences, Personnel, Public Grievances, Pensions and Parliamentary Affairs, Shri Prithiviraj Chavan, in his address, elaborated on the achievements of Department of Atomic Energy. On this memorable occasion, commemorative volumes on the history, growth and achievements of Fast Breeder Test Reactor and Radiometallurgy Laboratory were brought out. Indian Nuclear Society brought out a special issue on “Fast Breeder Test Reactor”. One book in Hindi on the history of IGCAR and two books on the environmental studies carried out in the campus were also released on this occasion. A special postal cover was released by Shri M.S.Ramanujan, Postmaster General, Chennai City Region to mark the occasion. Dr. M. R. Srinivasan, Member and former Chairman, AEC, Dr. R. Chidambaram, Scientific Advisor to Government of India and former Chairman, AEC, Dr. P. K. Iyengar, former Chairman, AEC, Dr. Frank Carre, CEA, France and Dr. Yuri Sokolov, Deputy Director General, IAEA presented their experiences with FBTR and felicitations on the occasion. The programme concluded with a vote of thanks by Shri G.Srinivasan, Director, Reactor Operations and Maintenance Group.

(Reported by M.Sai Baba)

Visit of Dignitaries

Dr. Baldev Raj, Director, IGCAR, Dr. S. Banerjee, Chairman, AEC and Secretary, DAE, the then Honorable Minister of State for Science and Technology, Shri Prithiviraj Chavan and Shri G. Srinivasan, Director, Reactor Operations and Maintenance Group during visit to Fast Breeder Test Reactor

Honourable Minister for Science & Technology, Minister of Earth Sciences, Minister of Personnel, Public Grievances and Pensions, Minister of Parliamentary Affairs, Shri Prithiviraj Chavan, visited the Centre on October 10, 2010 to participate in the silver jubilee commemoration of the Fast Breeder Test Reactor, the flagship of the Centre. The dignitaries later visited the Fast Breeder Reactor and Radiometallurgy Laboratory.

Honourable Minister of Power and Energy, Government of Sri Lanka, Shri Patali Champika Ranawaka with Dr. S. Banerjee, Chairman, AEC and Secretary, DAE and Dr. Baldev Raj, Director, IGCAR

Honourable Minister of Power and Energy, Government of Sri Lanka, Shri Patali Champika Ranawaka, Shri Vidya Dilruk Amarapala, Chairman, Ceylon Electricity Board, Shri Merrille Godfery Abeywickrama Goonetilleke, Director (Technical), Minister of Power and Energy, Shri V. Krishnamoorthy, Deputy High Commissioner for Sri Lanka in Southern India and Shri M. K. Pathmanaathan, Minister Counsellor & Head of Chancery, Deputy High Commission of Sri Lanka in Southern India visited the Centre on October 30, 2010. After meeting Dr. Baldev Raj, Director, IGCAR, Dr. S. Banerjee, Chairman, AEC and Secretary, DAE and other senior colleagues of the Centre the team visited the Fast Breeder Test Reactor, Hot Cells, Non-Destructive Evaluation Division, Madras Atomic Power Station, Nuclear Desalination Development Plant and construction site of Prototype Fast Breeder Reactor.

Visit of Dignitaries

Delegation from CEA with Dr. Baldev Raj, Director, IGCAR and other senior colleagues of the Department

A Delegation from CEA led by Mr. Christophe Behar, Director for Nuclear Energy which included Mr. Frederic Mondoloni, Director for International Affairs, CEA, Mr. Philippe Delaune, Deputy Director for International Affairs, International Affairs Division, Mr.Dominique Ochem, Special Adviser to the Director for International Cooperation, Directorate of Nuclear Energy and Mr. Alain Porrachia, Director for Innovation and Nuclear Support at the Directorate for Nuclear Energy visited the Centre during December 6-7, 2010. The delegation met Dr.Baldev Raj, Director, IGCAR and other senior colleagues of the Centre and visited Fast Breeder Test Reactor, Hot Cells, Laboratories in Non-Destructive Evaluation Division, Laboratories in Nuclear and Safety Engineering Group, Materials Science Group and Chemistry Group. The team also visited the construction site of Prototype Fast Breeder Reactor.

Prof. R. K. Ray, Visiting Scientist TATA STEEL R&D, Jamshedpur, addressing the students during the interactive session

Prof. R. K. Ray, Visiting Scientist, TATA STEEL R&D, Jamshedpur and Dr. Satyam Suwas, Associate Professor, Indian Institute of Science, Bengaluru visited the Centre on November 26, 2010. Prof. R. K. Ray and Dr. Satyam Suwas gave an inspirational address and interacted with the Trainee Scientific Officers and Research Scholars in the Centre.

Forthcoming Meeting / Conference

16th International Workshop on Electromagnetic Nondestructive Evaluation (ENDE- 2011)

March 10-12, 2011

The workshop is being jointly organized by Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam, India and Indian Institute of Technology, Chennai, India

Topics covered

As in previous ENDE workshops, the programme will comprise of invited lectures by prominent, academic& industrial experts and contributed oral presentations on:

- Analytical & numerical modeling of ENDE
- New developments and innovative applications in ENDE
- Signal and image processing methods and inversion
- Material characterization (microstructures, stresses and defects)
- Advanced sensors and their novel applications including Biomedical

CONFERENCE VENUE:

The workshop will be held in the IC&SR auditorium (http://www.iitm.ac.in/icsr), IIT Madras, Chennai. The campus is spread over 250 hectares of lush green forest, which is nearly midway (15 km) between the Chennai Airport and Central Railway station.

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Web: http://www.igcar.gov.in/seminars/

Gold Award for IGCAR Quality Circles in the International Convention

Quality Circle is a participatory management technique that enlists the help of employees in solving problems related to their own jobs. Circles are formed of employees working together in an operation who meet at intervals to discuss problems of quality and to devise solutions for improvements. Employees who participate in quality circles usually receive training in formal problem solving methods such as brain storming, pareto analysis, cause and effect diagrams etc. Then, they are encouraged to apply these methods either to specific or general company problems.

Three QC teams of IGCAR (named EXCEL, STAR & MOON) have participated in the International Convention on Quality Concept Circle (ICQCC-2010) held at Hyderabad during October 12-15, 2010. All the three QC teams secured “GOLD AWARD” and brought laurel to IGCAR. This is evident that our teams reached such a high level in QC presentation & skills among international QC teams.

Shri S. Suresh, Shri Joby Joseph, Shri V. Nanda Kumar, Shri R. R. Shridharan, Shri R. Kannan, Shri D. Alagar and Shri G. Mohanakrishnan from EXCEL QC, Chemical Technology and Vibration Diagnostic Division, FRTG
Shri T. V. Maran, Shri K. Mohanraj, Shri A. T. Loganathan, Shri A. Ramamurthy, Shri D. Kuppuswamy, Shri A. Anthuvan Clement from MOON QC, Zonal Workshop, FRTG
Shri M. Krishnamoorthy, Shri C. Subramanian, Shri G. Narendra Reddy, Shri K. M. Natarajan, Shri A. Padmanaban, Shri V. Kodiarasan from STAR QC, Central Workshop, ESG

Best Paper and Poster Awards

Several of our colleagues, research scholars and students, who present their research work at conferences and seminars, are recognized for their contribution in the form of "Best Paper/Poster Awards". In this issue the honours received from October - December 2010 are given.

1. Effect of heat treatment on the microstructure and microchemistry of explosive welded joints of Ti-5Ta-1.8Nb and 304L SS
   Ms. C. Sudha, Ms. T. N. Prasanthi, Dr. Saroja Saibaba and Dr. M. Vijayalakshmi, Physical Metallurgy Division, MMG
   Proceedings of National Welding Seminar, December 10-12, 2009, Kolkata
   First Best Research Paper- I.T Mirchandani Memorial Research Award-2010

2. A study on flow behaviour and microstructural evolution in 316LN austenitic stainless steel during hot forging
   Shri Sumantra Mandal, Ms. Dipti Samantaray, Dr. C.Phaniraj and Dr. A.K.Bhaduri, Materials Technology Division, MMG
   64th Annual Technical Meeting of Indian Institute of Metals, Bengaluru, November 14-17, 2010.
   2nd Best Oral Presentation Award (Material Processing)

3. Thermo-responsive Nanogel Crystals: Structure, Disorder and Dynamics
   Shri Rajendra Ganapathi Joshi, Condensed Matter Physics Division, MSG
   JSPS-DST Asian Academic Seminar 2010, held at Saha Institute of Nuclear Physics, Kolkata during November 29 -December 4, 2010.
   Out Standing Poster Award

4. Laser welding of Precision Engineering Components
   Shri K. A. Gopal, Dr. S. Murugan, Dr. S. Venugopal, and Shri K. V. Kasiviswanathan,
   Group for Remote Handling and Robotics, MMG
   National Welding Seminar, 2009-10, Kolkata
   Sharp Tool Award - 2010

5. Development of Brazed Joints using Induction Heating System for High temperature Nuclear Application
   Shri P. K. Chaurasia, Dr S. Murugan, Dr. S. Venugopal and Shri K. V. Kasiviswanathan,
   Group for Remote Handling and Robotics, MMG
   National Welding Seminar, 2009-10, Kolkata
   Weldman Award – 2010

6. In-situ weld repair of cracked shrouds of turbine and characterization of the weld joint
   Ms. M.Divya, Shri C.R.Das, Shri S.K.Albert, Shri V. Ramasubbu, Dr. A.K.Bhaduri, and Shri P. Sivaraman,
   Materials Technology Division, MMG
   National Welding Seminar 2009-10, Kolkata
   ESAB India Award – 2010, from Indian Institute of Welding, for Best Paper (All Categories)

7. Phase stability and phase transformation studies on grade 92 steel using differential scanning calorimetry
   Shri G.Nivashini, Shri S.Raju, Shri B.Jeya Ganesh, Shri S.K.Albert and Dr. A.K.Bhaduri,
   Materials Technology Division, MMG
   International Symposium for Research Scholars on Metallurgy, Materials Science and Engineering, IIT-Madras, Chennai during December 20-22, 2010
   Best Presentation Award

DAE Awards

Department of Atomic Energy has instituted annual awards for excellence in Science, Engineering and Technology in order to identify best performers in the area of Research, Technology Development and Engineering in the constituent units (other than Public Sector Undertakings and Aided Institutions). The Young Scientist, Young Engineer, Young Technologist, Homi Bhabha Science and Technology Award and Scientific and Technical Excellence Award fall under this category. Group Achievement awards for recognition of major achievements by groups have also been instituted. Life time Achievement Award is awarded to one who has made significant impact on the DAE's programme. They are the i-cons for young scientists and engineers to emulate. The awards consist of a memento, citation and cash prize. The recipients of the Group Achievement Awards from IGCAR for the year 2009 are:

Homi Bhabha Science & Technology Award	:	Dr. K. Ananthasivan, CG
Young Applied Scientist & Technologist Award	:	Shri Sudheer Patri, FRTG
Scientific & Technical Excellence Award	:	Dr. Shaju K.Albert, MMG, Smt. R. Vijayashree, N&SEG, Dr. B. Prabhakara Reddy, CG, Dr. Anil Kumar Sharma, N&SEG Shri S. Raju, MMG
Meritorius Award	:	Shri S. K. Goverdhan, ESG, Shri T. D. Sundarakshan, Dir. Office Shri P. V. Sellaperumal, N&SEG, Shri M. Arumugam, MMG
Special Achievement Award	:	Shri P. Ramakrishnan, CAO

Group Achievement Awards

Design, manufacture and deployment of radiation and corrosion resistant compact custom designed motor for centrifugal extractors

Shri R. Natarajan, RpG, Group Leader
Shri A. Sriramamurthy, Shri P. Vijayasekaran, Shri S. Sundaramurthy, Shri Felix Lawrence, Shri A. Palanivel, from RpG and Shri P. Perachi Selvam, from ESG

Design, Development and Commissioning of Unique Engineering Facility for Sodium Fire Studies

Shri E.H.V.M. Rao, SED, N&SEG, Group Leader
Shri Sanjay Kumar Das, Shri S. S. Ramesh, Shri P. Mangarjuna Rao, Shri S. S. Murthy, Shri M. Kumaresan, Smt G. Lydia, Shri C. Lobomissier, Shri S. Srinivasan, Shri K. E. Jebakumar, Shri D. Ponraju, Smt B. Malarvizhi, Shri Ramakrishnan, Shri J. Harvey, Shri B. K. Nashine, from SED, Shri Siva Kumar, Shri Raghavendran from N&SEG, Shri K. Velusamy, Ms. R. Thilakavathy, Shri T. Johnson, Shri M. Sundar, Shri Trinathvas Gopi, Shri Rahul, from ESG, Shri S. Balagurunathan, Shri S. Nagbhushanam, Shri N. Ramkumar, from ESD, Shri M. Nagamani, from ACVSD, Shri G. Kempulraj, Shri S. George, from CWD, Shri C. Muniyandi, Shri P. Narayana rao, Ms. M. Menaka, Shri Elumalai, Shri Hensan Raj, from QAD, Shri Kandasamy, Shri N. Ramesh from E&ISD

Design, Construction, Commissioning & Operation of SADHANA Loop for Demonstration of Natural Convection in SGDHR Circuit of PFBR

Shri K. K. Rajan, STG, FRTG, Group Leader
Shri G. Padmakumar, Shri G. Madhusoodanan, Shri P. L. Valliappan, Shri V. Vinod, Shri K. Jayagopi, Shri Vivek Nema, Shri Gautam Kumar Pandey, Shri P. Mohanraj, Shri A. Rajan, Shri A. Chandran, Shri R. Rajendran, Shri Rafiq Basha, Shri J. Prem, Shri K. Palani from SE&HD, Shri C. Meikandamurthy, Shri V. Ramakrishnan, Shri R.K. Mourya,

DAE Awards

Shri P. Vijayamohana Rao, Shri P. Madan Kumar, Shri M. Anubuchelian, Shri A. Kolanjiappan, Shri R. Ramalingam, Shri P. Bakthavachalam from C&IDD, Shri S. Chandramouli, Shri R. Rajendra Prasad, Shri S. Krishnakumar, Shri R. Punniyamoorthy, Shri D.Laxman, Shri D.Muralidhar, Shri S.Ravishankar, Shri S.Alexander Xavier, Shri C.Rajappan, Shri R.Iyyappan, Shri L.Eagambaram, Shri N.Sreenivas, Shri G.Anandan, Shri K.Karunakaran, Shri P. R. Ashokkumar, Shri V.Kumaraswamy, Shri M.Karthikeyan, Shri K.Ganesh, Shri Ashish Tiwari, Shri G.Vijayakumar, Shri J.Prabhu, from DD&RSD, Shri M.Shanmugasundaram, Shri P. Rajasundaram, Smt.Sundari Madasamy, Shri T.Chandran, Shri J.Vincent, Shri S.Nagajothi, Shri Vijay Tirkey, Shri S.Rangasamy, from STG

Selection and Development of Hardfacing Technology for PFBR

Dr. Arun Kumar Bhaduri, MTD, MMG, Group Leader
Dr. Shaju K. Albert, Shri Chitta Ranjan Das, Shri Harish Chandra Dey, Shri Hemant Kumar, Shri V. Ramasubbu from MTD, Shri S. Mahadevan, Shri Govind Kumar Sharma, from NDED, Shri R. Sritharan, Shri P. Puthiya Vinayagam, Shri V. Rajan Babu, from RCD, Shri V. Balasubramaniyan, from HTSD, Shri S. Ragupathy, Smt. R. Vijayashree, Shri Jose Varghese, from CH&MD, Shri C. Meikandamurthy, Shri V. Ramakrishnan, from C&IDD, Shri S. Parivallal, from CWD, Shri P. Jaganathan, from QAD

SQUID based measurement of biomagnetic fields

Shri M.P. Janawadkar, CMPD, MSG, Group Leader
Dr. K. Gireesan, Smt. C. Parasakthi, Shri S. Sengottuvel, Shri Rajesh Patel, Shri N. Mariyappa from CMPD, MSG

Design & Development of Small & Large Rotatable Plugs

Dr. P. Chellapandi, N&SEG, Group Leader
Shri Sriramachandra Aithal, Shri P. Puthiya Vinayagam, Shri V. Rajan Babu, Shri P. V. Sellaperumal, Shri S.Saravanan, Ms. P. Swetha from RCD, Shri V. Balasubramaniyan from HTSD, Shri S. Raghupathy, from CH&MD, Shri N. Vijayan Varier, Shri Vimal Kumar from TC&QCD, Dr. K. Velusamy, Shri S. Jalaldeen, Shri T. Selvaraj, Shri S. D. Sajish, Shri Juby Abraham, Shri Ramkumar Maity, Shri A. Sivakumar, Shri C. Raghavendran, Shri Gagan Gupta, Shri S. K. Rajesh, Shri M. Babu Rao, Shri R. Manu, Shri G. Venkataiah from MHD, Dr. S. Venugopal from RIRD, Shri R. Veerasamy, Shri R. Dhanasekaran, Shri S. Suresh Kumar, Shri J. Saravanan, Shri A. Gururajan from C&IDD, Shri A. Babu from RMD, Shri A. Venkatesan, Shri N. Subramanian from PPCD, Shri N. K. Sinha from IDEAS, Shri S. Chandramouli, Shri R. Puniamoorthy from DD&RSD, Shri Utpal Borah, Shri R. Nagarajan from MTD Shri A. Govindarajan from SE&HD , Shri M. Venkatesan from CH&MD

Development of DSR Drop Time Measurement System Using Acoustic Technique

Shri V. Prakash, CT&VDD, FRTG, Group Leader
Shri R. Veerasamy, Shri S. C. S. P. Kumar Krovvidi, Shri T. Logaiyan, from C&IDD, Smt. R. Vijayashree from CH&MD, Shri M. Thirumalai, Shri M. Anandaraj, Shri Ranga Ramakrishna, Shri P. Anup Kumar, Shri P. Adithan, Shri K. Tamilselvan, Shri A. Kanagaraj, Shri J. Jaikanth from CT&VDD, Shri C. Asokane, Ms. P. Anitha, Shri M. R. Jeyan from DD&RSD

Awards & Honours

Dr. Baldev Raj, Director, IGCAR has been elected President, Indian National Academy of Engineering (INAE). He will take over as President, INAE from January 1, 2011.

He has been awarded Betz - Dearborn - Professor C.N.R. Rao Medal and Chemcon Distinguished Speaker Award, Indian Institute of Chemical Engineers (2010)

He has been awarded the IIM Platinum Medal, Indian Institute of Metals (2010) – Highest award by Indian Institute of Metals for contribution in metallurgy.

Dr. A. K. Bhaduri, MTD, MMG has been awarded Sir LP Mishra Memorial Lecture Award – 2010 from Indian Institute of Welding.

Dr. Rani P. George, CS&TD, MMG has been awarded the Corrosion Awareness Award 2009-10 from NACE INTERNATIONAL Gateway India Section on September 24, 2010 at CORCON2010, in Goa.

Ms. Dipti Samantaray, MTD, MMG has received Best M.Tech. Thesis-INA Innovative Student Project Award - 2010

Study of Strain Induced Martensite formation in a Ti Modified 316 Stainless Steel Bellow by Transmission Electron Microscopy
Dr. R. Mythili, Dr. Saroja Saibaba and Dr. M. Vijayalakshmi, PMD, MMG
Appeared in Transactions of the Indian Institute of Metals, 62 (2009) 573-579, received the Indian Institute of Metals-SAIL Gold Medal 2010 during 48th National Metallurgist Day (NMD) and the 64th Annual Technical Meeting of Indian Institute of Metals, November 14-17, 2010, Indian Institute of Science, Bengaluru

Ms. J. Brijitta, CMPD, MSG has received the Best Thesis Award for her thesis titled "Phase Behaviour of Thermo Responsive Nanogel Dispersion: A Light Scattering and Confocal Microscopic Study" during the DAE-BRNS-National Laser Symposium (NLS-19) held at Raja Ramanna Centre for Advanced Technology, Indore during December, 2010.

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