IGC Newsletter

ISSN 0972-5741 Volume 85 July 2010

Inside

From the Director's Desk

Our Environment

"The earth, the air, the land and the water are not an inheritance from our fore fathers but on loan from our children. So we have to handover to them atleast as it was handed over to us"

Mahatma Gandhi

The issues engaging intellectuals, politicians and even the common man during the last one decade are environment and lack of ethics and paradigm changes to find solutions to the existing and emerging problems related to the social structure and material balance (C,N,P etc.) of the planet. The environmental challenges are mostly man-made and need our urgent attention. Be it rise in temperature or sea level, degradation of forest and forest cover, air pollution, loss of biodiversity, shrinkage of glaciers etc., all are interrelated to environmental problems which need a broader outlook and time bound solution. I strongly feel that the Mother Nature needs a climate bailout on a war footing basis so that our future generations will have the opportunity to experience the full spectrum of nature's enigma and lead good quality of life.

Even though there appears to be genuine concern about environmental issues, these are too complicated to be addressed in one giant step. India with 16% of world's population, and 1.8 % of the global forest cover, would do well to take the lead in environmental protection. The tendency to separate development from environment should be dismissed from our actions once for all. India aims to achieve a per capita electricity consumption at least equal to the present world average (2200 kWh/a) by 2020 from the current value of 660 kWh/a. This needs gigantic efforts to generate about 550 GWe by 2020, assuming population stabilization at 1.5 billion. In this endeavor, our Department has to play a key role in meeting a significant part of the energy demands of our country. To meet this sustainable energy growth, equal commitment has also to be devoted towards ecology and environment. Our capability to comprehensively study, monitor and predict possible impact on ecosystem should have momentum and quality. I would like to highlight the efforts being pursued at our Centre.

"Mismanagement of nature leads to consequent environmental damage"

Rachel Carson in Silent Spring

A panoramic view around Edaiyur bridge

The Beginning

Dr. A.K. Ganguly, who spearheaded the health and environmental research at BARC, Trombay, chose his colleague Dr. D.V. Gopinath to initiate the program at our Centre. Though, radiological research connected to environment picked up strength and is being pursued with vigor, the classical environmental research did not take off at the required pace. The campus at Kalpakkam is a breathtakingly beautiful natural site (~2500 acre campus) having intense interactions among land, sea and atmosphere. Keeping the green tradition created by Dr. Homi Bhabha, our Centre has steadily enhanced the steps to study ecological diversity, since 2007, and has embarked upon a robust and sustainable programme on Environment. The activity lead by Dr.K.K.Satpathy, has extensive R&D programs on aquatic and terrestrial ecology, terrestrial floral and faunal diversity, wetland biodiversity and hydrography of coastal milieu. The environmental research picked up momentum with one/two scientists and a few research scholars joining during 2005. Today when I experience the success and the expansion on their horizon, it gives me a sense of satisfaction and confidence that the programme is in the desired direction and adequate pace. I must say that for environmental scientists' eureka moments are rare. Moreover, it is a field science and progress is made by painstakingly putting together evidences from precise and patient observations. It takes a long time to make significant impact with tangible benefits. I am of the firm conviction that environment programme is important not only to meet the guidelines set by 'National Environmental Policy' but also in our self interest as an enlightened research and technology organization. In addition, the happiness in experiencing the biodiversity of Kalpakkam adds a new dimension to our success in science and technology.

Cruise troupe

Nutrients and Trace Metals in the Coastal Waters

"Seawater which accounts for 97% of world's surface water spread, should be regarded as a social resource needing scientific approach for the sustainable use"

Mahatma Gandhi

The productivity potential of coastal waters depends on the amount of nutrients (nitrite, nitrate, phosphate, total phosphate, ammonia, silicate and total nitrogen). The concentration of these nutrients varies depending on various environmental factors. It is imperative to keep a watch on the coastal water quality, especially on the nutrient dynamics and its seasonal and annual variation. The efforts in the recent past towards this end are scientifically significant and rewarding. Studies have indicated that although, nutrient concentration in this coastal milieu has


Triceratium broeckii


Brachysomophis cirrochelos


Pterios russelli


Natica lineate


Trichodesmium bloom patch


Torquigener brevipinnis


Penilia avirostris


Sea anemone

substantially gone up during post-Tsunami period, turbidity, the most single dominating factor, has adversely affected the productivity. These monitoring programmes are important to differentiate the changes in water quality due to natural and anthropogenic activity and take appropriate preventive actions. Moreover, the observations and their qualification would act as benchmark data for future impact assessment of the environment. I am happy that, efforts are underway to study the diurnal variation of physicochemical parameters and their influence on floral and faunal composition.

It is known that sediments are important carriers of trace metals in the hydrological cycle and reflect the quality of an aquatic system. Coastal and estuarine regions are important sinks for many persistent pollutants that get accumulated in the sediment at the bottom. Geo-chemical characteristics of these sediments are used to infer the weathering trends, source of pollution and for improving management strategies. The study undertaken to characterize the sediment with respect to textural quality and trace metals content is significant and would create a baseline data for future impact evaluation. Results from extensive studies have indicated the influence of Buckingham canal as an anthropogenic source on the sediment characteristics of the coast.

Marine Flora and Fauna

A systemic study is being pursued on phytoplankton, the microscopic (tiny) plants of aquatic ecosystem, which constitutes the most vital component of the biological community as primary producers in marine ecosystem. Their abundance and diversity is a reflection of the fishery potential of this coast. Baseline data on phytoplankton assemblage, which is of importance to evaluate future impact assessment, has also been integrated into the programme. The study indicated that, Kalpakkam is highly diversified and rich in phytoplankton species. About three hundred phytoplankton species have been catalogued, a remarkable indication of the sound health of Kalpakkam coastal waters. Two of our young researchers well trained in phytoplankton and zooplankton taxonomy, are pursuing their research in this important discipline of high relevance to the scientific world.

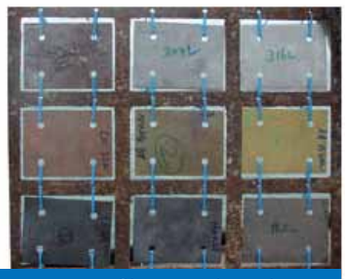
Unusual occurrence of large bloom of *Trichodesmium erythraeum* has been observed at this coast, for the first time. Its appearance exhibits visible alteration in the physico-chemical properties and phytoplankton dynamics of the coastal waters. Trichodesmium bloom is toxic and can deplete dissolved oxygen to the extent that fish population can be affected significantly crippling the livelihood of fisher-folks. This observation necessitates the need for continuous monitoring of the coastal waters for better understanding of the triggering mechanism behind such events. Efforts are being made to study the nanoplankton present in the coastal waters.

Enumeration of zooplankton, precious denizens in the marine environment is significant both ecologically and economically and thus has been taken up for studies. The composition, size, distribution, seasonal and annual variations of the species and their relation to physical and chemical characteristics are also being investigated. The study led to documenting the observation of one hundred and forty species reflecting the rich diversity of coastal waters of Kalpakkam.

Information on ecology and stocks of commercially important fish is of importance for both fisher folks and scientists to maintain sustainable level of harvesting. As a part of coastal biodiversity monitoring programme, an important initiative was undertaken to study the diversity of fishes along the Kalpakkam coast. Two hundred and fifty species have been catalogued during the last three years out of which two hundred and ten species have been identified. *Brachysomophis cirrocheilos* (Bleeker, 1857) and *Torquigener brevipinnis* (Regan, 1903), two varieties of fishes, native to Indonesia, have been found for the first time in the Indian coastal waters. It is important to mention that out of about eight hundred species reported

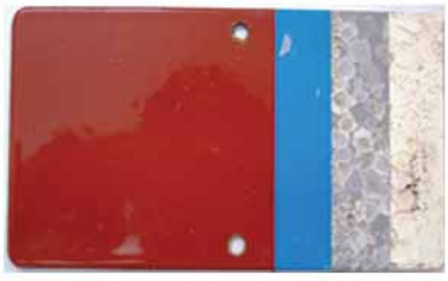
Fouled trash rack

Fouled metal panels



Clean metal panels

Sigma Glide after 151 days



After removal

Silt deposition on PSWHX

from the east coast of India, two hundred and fifty species have been observed in a small stretch of ten kilometers in a study spanning for a period of three years. This reflects the diversity and pollution free pristine environment of the Kalpakkam coast. The study also proves that location of nuclear power plant near the coast has not affected the fish diversity.

Among several invertebrate phyla of the animal kingdom, Mollusca forms one of the major and important phylum. The majority of mollusc species live in marine environments, and many of them are found inter-tidally, in the shallow sub-tidal and on the continental shelf. These are known to be excellent indicators of various pollutants and hence are monitored to assess the health of the coastal ecosystem. They are also potential source of various marine natural products having pharmaceutical and industrial applications. The study to catalogue the diversity and taxonomy of this elegant phylum (marine molluscs) is unique and the first of its kind for Kalpakkam coast. So far about one hundred and thirty species of molluscs have been collected out of which about eighty species have been identified. Results from these studies form a benchmark data for future investigations and impact assessment.

Biofouling and Monitoring of Coastal Ecosystems

Sedentary organisms, most of which are filter feeders, play an important role in the coastal ecosystems for the biogeochemical cycling of elements by siphoning out the decaying organic matter from the water column. Generally these species colonize on submerged surfaces and cause severe problems to man-made submerged structures. This phenomenon is called biofouling and the settlement intensity indicates the water quality of the region. Generally, polluted water does not favour gregarious growth and vice-versa and due to their sedentary nature, are also indicators of metal and organic pollution. As part of the studies on the biofouling and its control, a systematic collection, preservation, identification and photography of these organisms is in progress for this coastal belt. About one hundred species of these organisms have been identified so far. A visible shift in the peak settlement period of green mussel (the dominant as well as climax species) from April-August to September–October has been observed. Studies are also underway to assess the biofouling on different metal surfaces (mild steel, SS304, SS316, titanium, monel, cupronickel, copper, admiralty brass and aluminium brass) which would have direct commercial application not only for our Department but also for other agencies such as Navy, Railways and Ports. To provide solution for biofouling problem in Prototype Fast Breeder Reactor tunnel, proprietary antifouling paints have been studied and based on the results, an antifouling paint Sigma Glide has been chosen. Similarly, to overcome biofouling problem in process sea water heat exchangers (PSWHX) of PFBR, the commissioning of a dynamic loop is a significant step. Results of these experiments, would be useful for mitigating the biofouling of process seawater heat exchangers of present and future Fast Breeder Reactors.

A micro-sensor based magnetic reed relay has been designed and developed to monitor valve movement of the mussels. This study would pave the way for a refined regime called pulsed chlorination. The present practice of low dose continuous chlorination for biofouling control in the cooling water system of Madras Atomic Power Station as well as that to be adopted for Prototype Fast Breeder Reactor is generic and not specific. If the movement of the mussel (main culprit) to valves could be monitored, a significant reduction in inventory of chlorine could be achieved and that would reduce operational cost and reduce

Flora and fauna in the campus

environmental burden.

Terrestial and wetland biodiversity

Kokkilamedu Lake, a tiny brackish water lake, situated on the northeastern side of our campus covering an area of 0.5 square kilometre provides conducive environment for the wadersm, other aquatic and terrestrial fauna that inhabits the rich flora in and around the lake. This fresh water lake changed into a saltwater lake due to inundation and siltation during Tsunami. Considering its importance to the local ecology, physicochemical properties and biological diversity of the lake are being studied. This study would establish the limnology of the lake and help us to take appropriate measures to improve the biodiversity. Desilting work to improve the depth and the water spread area shall restore the lake back to its original status. Plantation of appropriate floral species around the lake, is being implemented to achieve sustenance and improvement of the avian population and their diversity.

One of the easiest ways to maintain good climate, ecological balance, conserve and enhance biodiversity at any site is to increase the green coverage significantly. Our Department has a rich tradition of maintaining ecological balance by planting trees in and around the establishments. IGCAR is no exception to this legacy of Dr.Homi Bhabha. The entire campus has been surveyed and a total of about eight hundred species of plants have been planted which includes a good number of medicinal plants. I visualize to see a medicinal plants park inside the site to grow into a gene pool of significance.

> *"Preserving medicinal plants is not only important for human health but also for surrounding ecosystem. New generation of treatments for some of the most serious diseases affecting mankind could soon be lost in a wave of animal and plant extinction"*
>
> Dr. Allan Hamilton, in the report on extinction of plants and animals

To improve greenery further, about thirty thousand saplings belonging to twenty three species have been planted (both at the site and township) during the last two years. The ambitious plan of planting about fifty thousand saplings per year so as to create a microclimate for comfortable environment, humidity, rainfall and ground water level for the benefits of population in and around Kalpakkam is a challenging and daunting task for the team. I have also challenged Dr. Satpathy and his team to create a record close to what Wangari Maathai, Nobel laureate from South Africa, has created in tree plantation. It is worth mentioning about our effort to grow a crop named Salicornia in the sea shore in collaboration with Gujarat Science Ashram, Vadodara. The team involved in this programme should accelerate the pace to enthuse coastal villages to replicate the success stories of Kalpakkam campus.

We are well aware that biodiversity is declining and changing. Every year additional set of species are added to the red list. We are at the brink of losing some of the precious plant and animal species. Biodiversity conservation and management in

Birds at Edaiyur Lake

the institutional campuses is essential, rewarding and fulfilling. A field of growing interest worldwide, 'urban biodiversity', seeks to understand how biodiversity promotes and maintains landscape health and human wellbeing through the provision of ecosystem services. This provides a challenge for scientists, planners, governments and communities throughout the globe.

Presence of three hundred and eight species of animals in a small campus like Kalpakkam indicates the magnitude of biodiversity. The presence of Civet and Porcupine (that are diminishing from wild) at Kalpakkam is due to less human intervention. Among others, birds (one hundred and fifty two species) and butterflies (sixty species) are remarkable elements of our beautiful environment. The presence of large diversity of butterflies in the campus indicates the abundant availability of flowering plants and as pollinators creating a benign ecosystem. A pictorial monograph being brought out on terrestrial faunal diversity of our campus would enthuse public and create awareness on the environment particularly among young students. Conservation, enhancement and eco-restorative measures to enhance the biodiversity further are under progress.

Wetland Conservation

"Wetland conservation should take livelihood dimensions into account rather than a purely technical approach"

Prof. M. S. Swaminathan on the issue of wetland conservation

Wetland constitutes a transitional zone between terrestrial and aquatic habitats. These are some of the most threatened habitats of the world. Fortunately, our campus is blessed with three water bodies (Kunnathur marsh- northwest, Kokkilamedu lake- northeast and marsh at western side). Together they nurture about one hundred aquatic birds, an indication of rich diversity. By creating conducive milieu at Kunnathur marsh, painted storks, that were generally seasonal visitors, have started nesting, at Kalpakkam. Prof. M. S. Swaminathan has been a continued source of inspiration for our campus. He and his colleagues are collaborators, par excellence, over the last two decades in this effort.

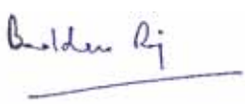
Monitoring of Air Quality

"Man has lost the capacity to foresee and to forstall. He will end up by destroying the Earth"

Albert Schweitzer

India has witnessed a phenomenal increase of industries and vehicles in the last decade along with the mushrooming of thickly populated human habitats. As a consequence, there has been a dramatic deterioration in the quality of air in most of the regions of our country. We lack an effective air quality management system and pollution control mechanisms. As a first step, it is essential that any establishment with industrial component should monitor the air quality in order to create benchmark data for future impact assessments and for taking preventive measures. We have launched, an initiative to assess the air quality at different locations of our campus. Various parameters such as oxygen, CO, CO_2, volatile organic compounds, temperature, relative humidity and sound levels are being monitored. The task of environment studies group in this campus will be completed only when we achieve 100% recycling of water, realise full potential of rainwater harvesting and provide clean and safe drinking water to the inhabitants of township and neighbouring villages.

I have love for nature and have a robust partnership with Dr. K. K. Satpathy and his colleagues in their pursuit of R&D in environmental sciences. Earth is a womb of mankind. It is important from ethical perspective that the womb is pristine and robust from sustainability considerations. Kalpakkam can be an outstanding example.



(Baldev Raj)
Director, IGCAR

IGCAR's Contribution towards Titanium Sponge Production

India is endowed with large deposits of titanium ore mainly in the form of ilmenite ($FeTiO_3$) along the sea coast near Kerala, Tamil Nadu, Andhra Pradesh and Orissa. Hitherto, the titanium industry in the country has been confined to beneficiation and export of the ilmenite or more significantly, in the production of titanium tetrachloride intermediate, purification and conversion back to pure titanium dioxide pigment for paints. Facilities exist in the country for melting of titanium sponge and down stream processing to finished products. The deposits of titanium ore in the country are equivalent to about 140 million tonnes of titanium.

The technology for extraction of titanium metal from the intermediate titanium tetrachloride has now been established in a batch size of about 3000 Kgs at Defence Metallurgical Research Labratory, Hyderabad (DMRL). The technology has been developed in collaboration and co-operation with our Centre and Nuclear Fuel Complex, Hyderabad. This technology is currently being transferred for large scale production with installed capacity of 500 tonnes per annum of titanium sponge to start with, at the M/s. Kerala Mineral and Metals Ltd. (KMML), Sankaramangalam, Kerala, with complete funding by Vikram Sarabhai Space Centre, Department of Space.

M/s. KMML is responsible for the construction and operation of the plant based on technology transferred by DMRL. DMRL is also responsible for training of O&M personnel of M/s. KMML. Providing the mechanical design, resolving of manufacturing issues during manufacture of the retorts and associated high temperature piping, and quality assurance of the retorts is the responsibility of IGCAR.

Process Requirement for Design

The conversion of titanium tetrachloride to virgin titanium called titanium sponge is achieved through a reduction process using liquid magnesium at a temperature of about 1120 K and subsequent purification of the sponge is done through pyro-vacuum distillation at a temperature of about 1250 K to remove magnesium and magnesium chloride locked up in its pores. The reactor is made out of explosively cladded SS430 with SS304 as base material (Figure 1). The reactor is designed based on mechanical strength of SS304 and the inside is cladded with SS430 to prevent contact of SS304 with the reactant liquid magnesium, as nickel bearing SS304 is not compatible with magnesium.

The reactor operates under continuously controlled positive pressure of argon during reduction and under vacuum during vacuum distillation. The positive pressure of cover gas within the retort during reduction reaction is maximum 0.25 kg/cm^2. The maximum internal pressure applied during periodic pressure transfer of $MgCl_2$ from the reactor is about 0.85 kg/cm^2. During the vacuum distillation stage for purification of the sponge, the absolute pressure within the reactor is 0.014 millimeter of water column.

Design Challenges

The combined process unit developed at DMRL comprises of two stations, furnace and condenser, in each of which an identical reactor is housed, which are connected together with an inter-connecting pipe. The reactor measures approximately

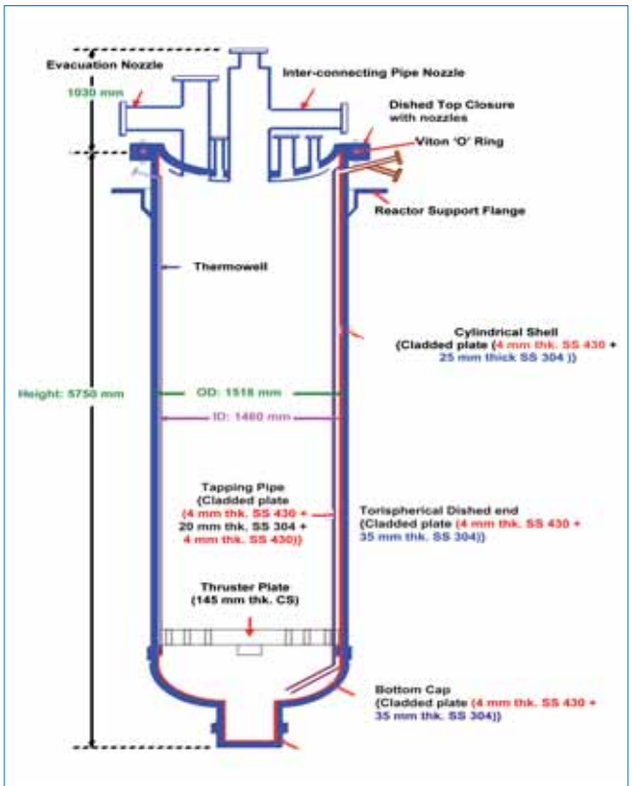


Figure1: Schematic of the Clad SS 304 / SS 430 Reactor (assembled) for KMML's 500 tonnes per annum titanium sponge

Figure 2: Cladded Reactor for Titanium Sponge Production

1.5 meters in diameter and is about five meters in height with a wall thickness of approximately 30 millimeter. The reduction reaction is carried out in the reactor kept in the furnace station and during the next stage of distillation, the magnesium and magnesium chloride from the titanium sponge pass through the inter connecting pipe and get collected in the reactor externally cooled with water kept in the condenser station. The reactor in the condenser station has to be mounted on trolleys for mobility to allow thermal expansion of the inter-connecting pipe conveying magnesium and magnesium chloride vapours from one reactor to the other at 1170 K, the reactor in the furnace being stationary.

A dual flange design has been developed for the reactor. A flexible flange, welded below the top of the reactor, serves to support the reactor on the flange of a eight zone, 480 kW pit type furnace, ensuring leak tightedness of the furnace, for maintaining the vacuum in the furnace, when the retort is under vacuum during distillation, so as to minimize the differential pressure. These flanges are water cooled for safety of the vacuum seals and have to withstand the stress due to internal heat radiation and also allow radial expansion at high temperature.

A 450 millimeter nozzle at the bottom of the reactor has been designed with a capped closure, amenable for de-welding of the cap after every batch run to enable ejection of sponge cake from the top of the reactor, using a ram operating through this nozzle, vertically with a hydraulic press. The cap has to be welded with high reliability to the nozzle before restart of every batch operation, as any failure of this weld can be of safety concern due to leakage of molten magnesium and air ingress causing metal fire. The procedure for qualification of this important weld has been developed by IGCAR.

A perforated carbon steel plate, 150 millimeter thick located within the reactor near the bottom of the reactor, completely immersed in liquid Magnesium/Magnesium chloride, is designed to retain and support the 3000 kilograms sponge cake produced during the process.

Quality Assurance during Fabrication

The reactors are fabricated conforming to ASME Section VIII Division 1 with special requirements, in terms of improved chemical composition of stainless steel plates and welding consumables and tighter manufacturing tolerances. The complete quality assurance including stage inspection was carried out by the quality assurance team of IGCAR and NFC, Hyderabad for the experimental reactors used for technology development at DMRL. The quality assurance team of IGCAR is now carrying out the quality assurance and complete stage inspection for the sixteen numbers of reactors being manufactured for the production plant at Kerala Mineral and Metals Ltd. The reactors are being manufactured by Larsen & Toubro, Ranoli and the first reactor has been successfully manufactured and dispatched to Kerala Mineral and Metals Ltd. The reactor undergoing final hydro test is shown in Figure 2.

(Reported by S.C. Chetal and colleagues, REG)

Process Modeling of In-situ Electrochemical Partitioning of Uranium and Plutonium in PUREX Process

In the PUREX process of nuclear fuel reprocessing, uranium and plutonium are co-extracted from aqueous nitrate solution into organic (TBP) phase as U(VI) and Pu(IV) nitrates to achieve separation from fission products. Further, it is necessary to separate uranium and plutonium from each other and also purify them separately for the end use. Stripping of plutonium from metal rich organic phase is accomplished by selectively reducing the plutonium to poorly extractable trivalent species [Pu(III)] by means of a reducing agent (such as ferrous sulphamate, hydroxylamine nitrate or uranous nitrate) or by in-situ electrochemical reduction. The extent to which separation of plutonium from uranium is achieved depends upon the distribution coefficients of the species involved under the prevailing conditions of partitioning cycle.

In PHWR spent fuel reprocessing plants, externally generated uranous [U(IV)] is the commonly used reducing agent for U/Pu partitioning to achieve effective separation between uranium and plutonium. In these flow sheets, requirement of uranous is generally 6-10 times the stoichiometric requirement. Due to high content of plutonium in FBR fuels (about 25-30% Pu), addition of large excess of uranous is not a feasible option as it involves recycle of large quantities of uranium. The other suitable option is to employ electrochemical in-situ reduction as there is no external chemical addition for reduction purpose.

PUREX solvent extraction flow sheet has been greatly facilitated by the development of computer codes to do the complex stage-by-stage equilibrium calculations involving multi solutes. It is a valuable tool for simulating various conditions and to arrive at optimum flow sheet conditions. In majority of the cases it helps in cutting down the experimental runs required. Some of the important computer codes developed in the past for simulating PUREX solvent extraction systems are SEPHIS and its modifications, PUBG, PUMA, SOLVEX, etc, and all of them designed for mixer-settler contactors. Except for PUMA, all these codes provide transient response of a contactor from specified initial conditions to the steady-state conditions. Each of these codes address a specific case and none of them are capable of handling in-situ electrochemical separation of uranium and plutonium in the partitioning cycle of PUREX process.

A computer program PUSEP has been developed to predict the concentration profiles under electrolytic conditions. The basis of model equations development involves countercurrent multi-component extraction with coupled chemical and electrochemical redox reactions (Figure 1). The model is specific to mixer-settler contactors and is limited to mass transfer equilibrium.

Complete mixing in mixer compartment of mixer-settler unit and mass transfer due to extraction occurs in this compartment leading to equilibrium between the phases. It is also assumed that stage residence times are sufficiently long so that diffusional resistances can be ignored.

The developed code generates transient concentration profiles

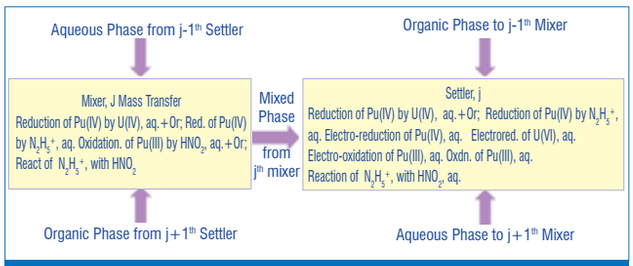


Figure 1: Basis for Process model for one mixer-settler stage

from the initial conditions to steady-state conditions and it provides important information about the variation of solute concentration with time in the contactor bank. Transient calculations can only provide the information about unsafe accumulation of solute if any. Simulation of almost all the published experimental results concerning to electrolytic partitioning of Pu/U were carried out in order to test the validity of the model equations and associated computer program.

Basis of Mathematical Model

To simulate partitioning process, detailed models of the distribution equilibria for the species involved, the mass transfer kinetics and the redox reactions are needed. Material balance equations based on an idealized model for mixer-settlers incorporating distribution coefficients of the species involved and redox reactions are solved numerically in order to obtain concentration profiles of the species in stages of mixer-settler bank. The equations are:

Mass balance equation for mixer

$$\frac{dX_{mj}}{dt} = \frac{1}{(h_a + h_o D_j)}\left[A(X_{j-1} - X_{mj}) + O(Y_{j+1} - Y_{mj}) + h_a \Sigma r_{amj} + h_o \Sigma r_{omj}\right]$$

Mass balance equation for settler

$$\frac{dX_j}{dt} = \frac{A}{H_a}\left(X_{mj} - X_j\right) + \Sigma r_{aj} + \Sigma r_{\theta} \qquad \frac{dY_j}{dt} = \frac{O}{H_o}\left(Y_{mj} - Y_j\right) + \Sigma r_{oj}$$

Electrochemical In-situ Reduction Process

The plutonium is chemically and electrochemically reduced to lower the valence state and is back-extracted into the aqueous phase. Within an electro-reduction mixer-settler Pu (IV) reduction results from the reactions: electrochemical Pu(IV) reduction,

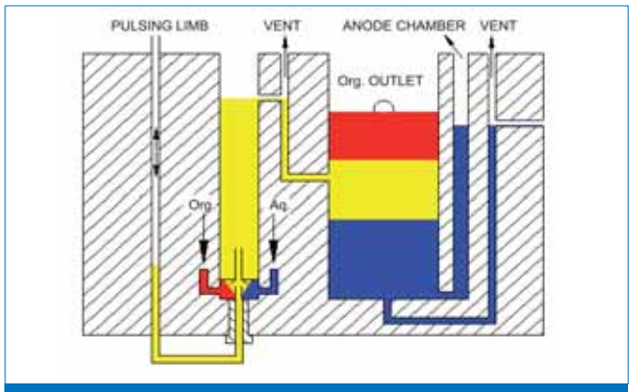


Figure 2: Schematic of one stage of mixer-settler bank

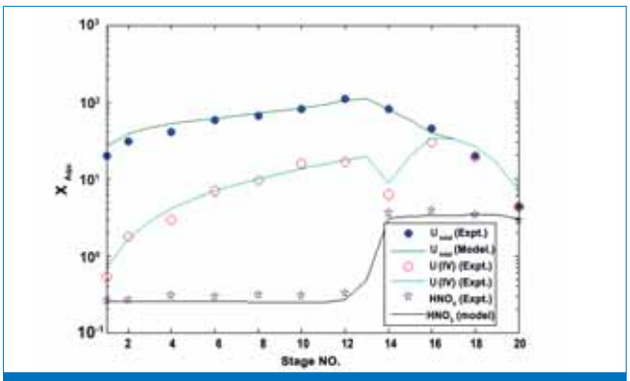


Figure 3: Comparison of calculated and experimental data on uranium reduction in a 20-stage electrolytic mixer settler

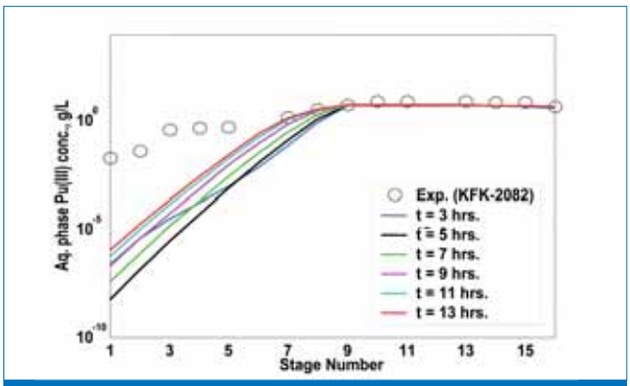


Figure 4: Comparison of experimental and calculated profile of Pu(III) in 16-stage 1B contactor (KFK-2999)

indirect Pu(IV) reduction by U(IV) [electrochemically formed] and reduction of Pu(IV) by hydrazine.

The major fraction of Pu(IV) reduction is caused by U(IV) formed electrochemically within the extractor. Hydrazine reduces Pu(IV) much more slowly than does U(IV). It is common to add hydrazine as a holding reductant to prevent Pu(III) re-oxidation by nitrous acid, which is produced during electrolysis as well during dissolution step.

Electro-reduction Extractors

Pulsed column and mixer-settlers are used for electrochemical separation of uranium and plutonium. But mixer-settler offers more flexibility in operating conditions in comparison with column with regard to phase separation and accessibility for sampling. The extraction section of the mixer-settler bank is equipped with the electrodes. The cathode made of titanium is placed in the settling chamber; the anode made of platinum or platinized titanium, tantalum is placed in an anodic space provided in the settling chamber of mixer-settler. Due to selective placing of the anode in the settling chamber, electrolysis takes place preferentially in the aqueous phase of the settler compartment. A prototype twenty-stage electrolytic ejector mixer-settler operating without diaphragm has been designed and developed at RpG, IGCAR and the schematic of one stage of mixer-settler bank is shown in Figure 2. In this bank, stages one to thirteen are equipped with electrodes, Several experimental runs with uranium reductions have been carried out with this bank. Figure 3 gives the comparison of the predicted profile with the experimental run. In this experiment aqueous feed is at 14^{th} stage and the concentrations are: U: 67.4g/litre and HNO_3: 4.35M. The organic scrub is 30% TBP in NPH.The strip solution concentrations are HNO_3:0.26M and $N_2H_5^+$:0.35M.The respective flow rates are: 6 ml/min, 6 ml/min and 4 ml/min respectively for feed, scrub and strip.

Simulation of almost all the published experimental results concerning to electrolytic partitioning of Pu/U have also been done to validate the code. Two typical examples of comparison between experimental data and predicted results are described in Figures 3 & 4. Figure 4 gives an example of the comparison between the experimental data and the predicted profile. Experimental data [KFK-2082] is based on 20%TBP in n-dodecane.The organic feed stream is at 10^{th} stage and the concentrations are U: 49.6 g/litre and Pu: 2.33 g/litre .The organic scrub is 20% in n-dodecane.The strip solution concentrations are: HNO_3:0.4M and $N_2H_5^+$:0.26M.The respective flow rates for feed, organic scrub and strip are 0.75, 0.156 and 0.12 litre per hour. The deviations in the plutonium profile in the low concentration are probably due to slow strip rate of Pu-HDBP complex and uncertainty in the estimation of distribution coefficient in low concentration region.

Factors Affecting the Performance

- U-Pu ratio, HNO_3 concentration in aqueous, strip solution flow ratios and residence time. The most significant influence on the separation was found to be residence time. All other parameters have less importance when varied within reasonable limits.
- Increasing nitric acid concentration lowers uranium and plutonium re-extraction from the organic phase. In addition less U(VI) is available for electrolytic reduction which takes place in the aqueous phase only. Lower U(IV) concentrations reduces Pu(IV) reduction and thus separation.
- Increased plutonium feed concentration obviously requires a larger supply in reductants for compensation. But it also increases the salting-out effects by the higher Pu(III) concentration, therefore reducing the re-extraction and separation.
- A rise in temperature increases reaction rates but may have complicated effects on fluid-dynamics, extractability and re-oxidation rate.
- Hydrazine may be necessary to prevent re-oxidation, but it also acts as a salting-out agent and therefore reduces separation.
- The ratio of area of cathode to anode is to be chosen as large as possible to reduce anodic oxidation of Pu(III).

Conclusion

Model equations have been validated by carrying out several experimental runs with different flow sheet condition for uranium reduction in a twenty-stage electrolytic mixer-settler and literature data on U/Pu reduction. The theoretical predictions agree well with the experimental data. The salient feature of the developed code is that it is applicable to extraction and stripping cycles of PUREX process also.

(Reported by N.K. Pandey and colleagues, Reprocessing Research & Development Division, RPG)

Young Officer's FORUM

Design of Steam Generators for future FBRs

Shri R. Nanda Kumar did his B.E. degree in Mechanical Engineering from N.N. College of Engineering under University of Madras in 2001. He is from 2nd batch of Training school at IGCAR and joined in IGCAR as Scientific Officer in September 2008 and is working in Heat Transport Systems Division, REG.

Introduction

A series of 500 MWe fast breeder reactors (FBRs) are planned beyond PFBR. The present design of PFBR is being reassessed based on the manufacturing experiences gained with a focus on improved economics and enhanced safety.

From worldwide operating experiences of FBRs it is seen that reliable performance of steam generators, wherein sodium and high pressure water/steam are separated by a thin wall boundary, is very crucial from plant availability considerations. The experience also has highlighted the importance of adopting state-of-the-art design features (e.g. raised spigot butt weld joint between tube and tube-sheet, incorporation of provision for in service inspection of tubes etc.) and providing adequate redundancy of steam generator modules in each of the secondary sodium loops.

Based on the design, development and reassuring of manufacturing experience with steam generator for PFBR, the concept of integral once through steam generator with modified 9Cr-1Mo as principle material of construction is retained for future FBRs (Figure 1). It is a counter current heat exchanger with sodium on shell side and water/steam in tubes. The tubes with optimized dimensions (Inner diameter & wall thickness) are arranged in triangular pitch with a bend to accommodate differential thermal expansions and are welded to top/bottom tube sheets at their either ends.

Tube wall thickness

The tube wall thickness of 2.4 mm is estimated for the future FBR steam generators, taking into account design temperature, pressure and the allowances for corrosion, chemical cleaning, wall thinning at the weld joint, tube end machining and fretting wear allowances over a design life of sixty years.

Tube length selection

Owing to the constraints in the manufacture of the tube, the PFBR steam generator was designed with a tube length of 23 meter. However, for future FBR, a longer length of tubes is preferred in order to reduce number of tube to tube-sheet joints for minimizing possibility of sodium-water reaction throughout the design life. Further, it is observed that manufacturing schedule of steam generator is largely influenced by the number of tube to tube-sheet joints and hence, it is preferable to reduce their number. The tube length as a function of heat transfer area, related to number of tube to tube-sheets joints, and joint failure rate are presented in Figures 2 & 3 respectively. A tube length of 30 meter is judged to be the best taking into consideration economics over 23 meter length, tube manufacturing and transportation aspects and hence, the same is chosen.

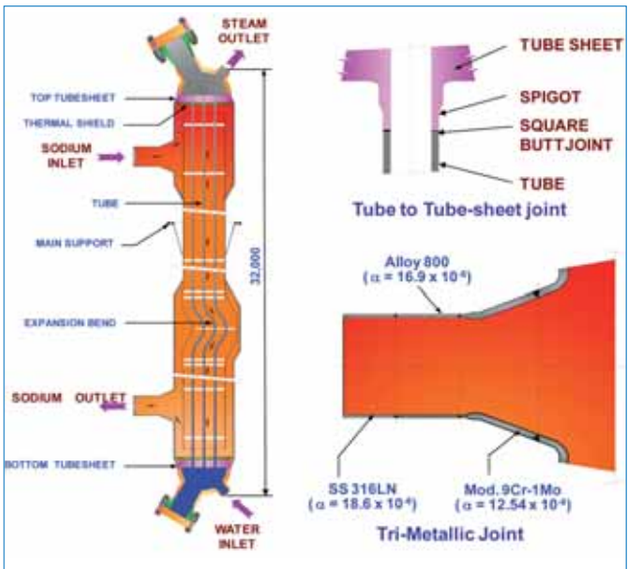


Figure 1: Integral once through steam generator for future FBRs

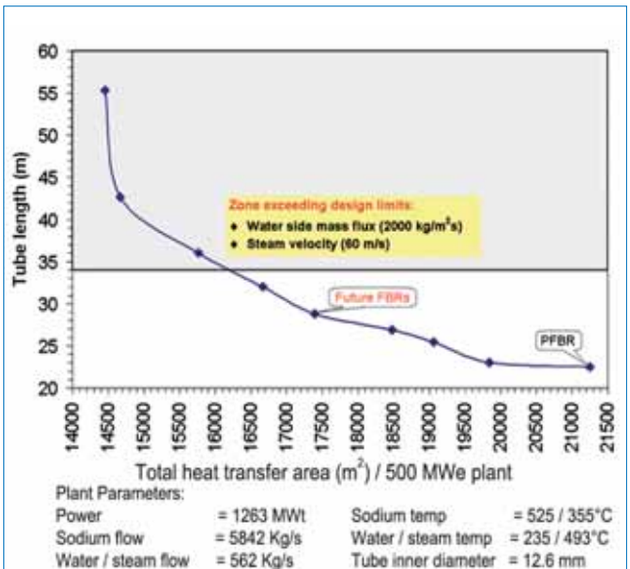


Figure 2: Variation of total heat transfer as a function of tube length

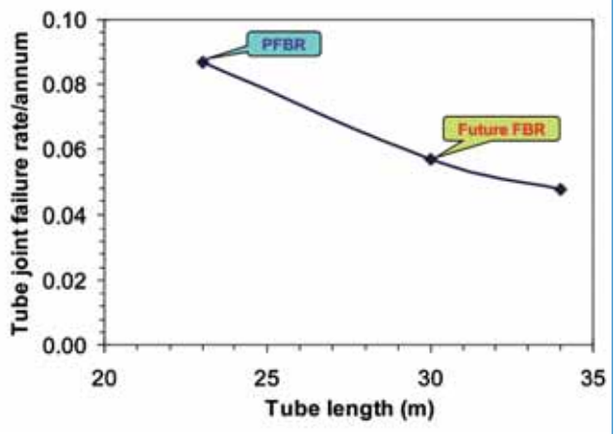


Figure 3: Variation of tube joint failure as a function of tube length

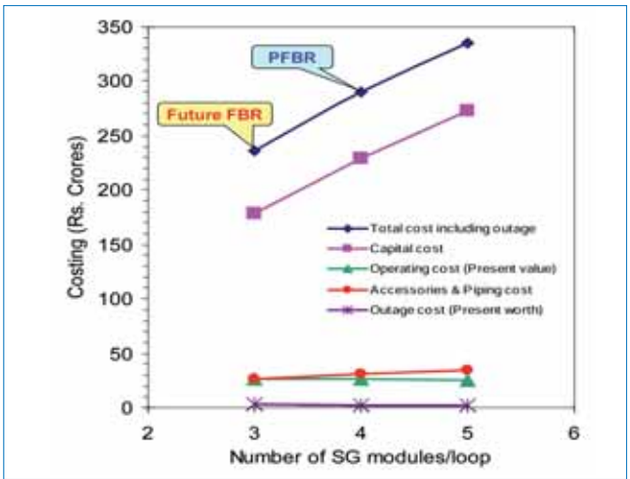


Figure 4: Variation of cost as function of total number of steam generators

Detailed optimization studies, taking into consideration the overall effect of capital cost, outage cost and construction schedule, have indicated that a design with three modules / loop each having four hundred thirty three tubes / module (ID / OD: 12.6 / 17.4 mm) are optimal leading to 40% lesser tube to tube-sheet joints and tube joint failure rate / annum thereby, improving the safety and economy as shown in Figures 3 & 4. With the above steam generator design, the total number of steam generator modules for the twin units of future Fast Breeder Reactor is 6 x 2 +1 (spare).

The reduction in number of steam generator modules (from 4 steam generators/loop in PFBR to three steam generators/loop for future FBR) also leads to corresponding reduction in length of sodium and water/steam piping, number of rupture discs and isolation valves, number of hydrogen in-sodium detection systems, instrumentation and heating arrangement leading to associated cost savings (Figure 4), reduced outages and compact layout.

Process design of Steam Generator

The process design of steam generator is evolved with the plant parameters, respecting limits on water side mass flux (2000 kg/m^2s) based on rippled magnetite formation, maximum steam velocity (60 m/s) based on erosion consideration, maximum heat flux (725 kW/m^2) to reduce risk of water side corrosion effects and avoiding unstable flow regimes throughout the range of operation of steam generator. A literature survey indicates that these limits are applicable to 2¼ Cr-1Mo steels and choice of the same for modified 9Cr-1Mo steel is conservative.

Detailed thermal sizing calculations are carried out for steam generator (three steam generator/loop configurations) and the results are presented in comparison with PFBR steam generator (Table 1)

Figure 5 indicates the different phase regimes and associated temperature distribution in the tube along the length of steam generator.

Though the literature indicates the critical heat flux limit for the evaporator region in a conventional steam generator, in once-through design as in our case the peak heat flux tends to occur in the super-heater region wherein it is observed that the specified limit is marginally exceeded. However this is acceptable as the corrosion rate in the peak heat flux region is expected to be lesser than in the critical heat flux region, which is also reflected

Table 1: Results of Process design of steam generators for future FBR's

Description of steam generator	Future FBR	PFBR
Thermal power per steam generator (MW)	210.5	157.9
No. of steam generator/plant	6	8
Design life (Years) / Cap. factor	60 / 85%	40 / 75%
No. of tubes	433	547
Tube length (m)	30	23
Tube size (inner diameter / thickness) (mm)	12.6/2.4	12.6/2.3
Pitch (mm)	32.4	32.2
Shell inner diameter (mm)	736	831
Heat transfer area (m^2)	710	652
Water inlet velocity (m/s)	2.09	1.24
Steam outlet velocity (m/s)	29.8	17.8
Water mass flux (kg/m^2s)	1735	1030
Sodium velocity (m/s)	3.67	2.08
Shell side pressure drop (bars)	1.4	0.8
Tube side pressure drop (bars)	7.20	2.80
Max. Δ(ΔT), K	16.6	20.2
Critical quality	0.25	0.30
Critical heat flux based on tube inner diameter (kW/m^2)	566	579
Peak heat flux based on tube inner diameter (kW/m^2)	836	694

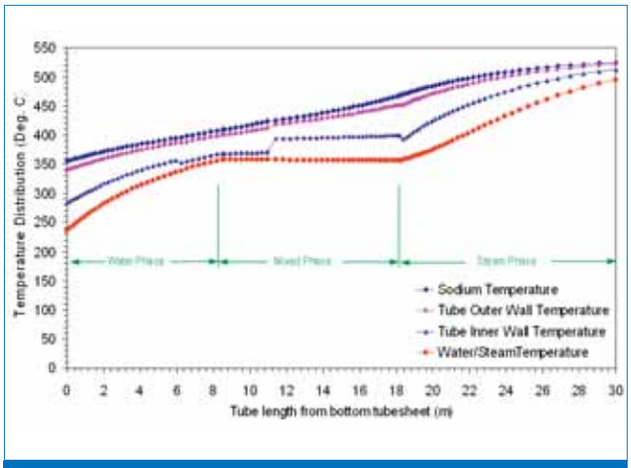


Figure 5: Temperature distribution with variation of tube length

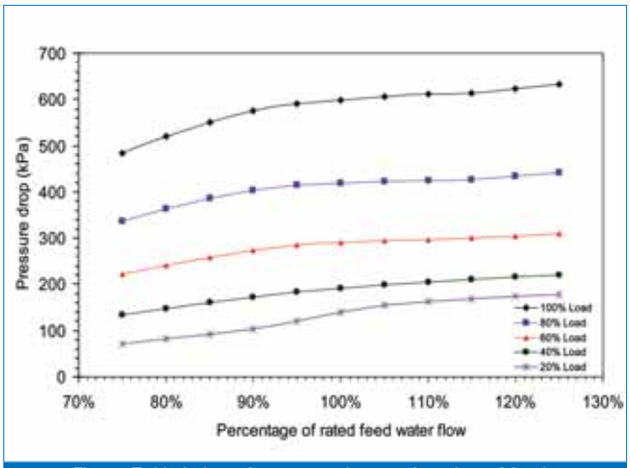


Figure 7: Variation of pressure drop as function of feed water flow rate

in the results of the experiments reported in literature. Figure 6 shows the heat flux distribution (based on inner diameter of tube) along the tube length and the critical and peak heat flux junctions.

Stability characteristics of the steam generator module is also verified at part load operations. With the incorporation of a predetermined orifice arrangement at the water inlet of each tube, it is seen that the steam generator can be stably operated from 20% part load to 100% load comfortably. Variation of pressure drop with change in feed water flow rate for different loading conditions are presented in Figure 7.

The results show that there is no flow reversal at any location along the length, which ensures the static stability.

Tie-rod selection

Tie-rods are provided to support the steam generator tube bundle supports that are provided periodically along the tube length. If the steam generator tubes and tie-rods, that are of same material, are chosen with similar dimensions the same would lead to difficulties in differentiating them during manufacture as they appear very similar outwardly.

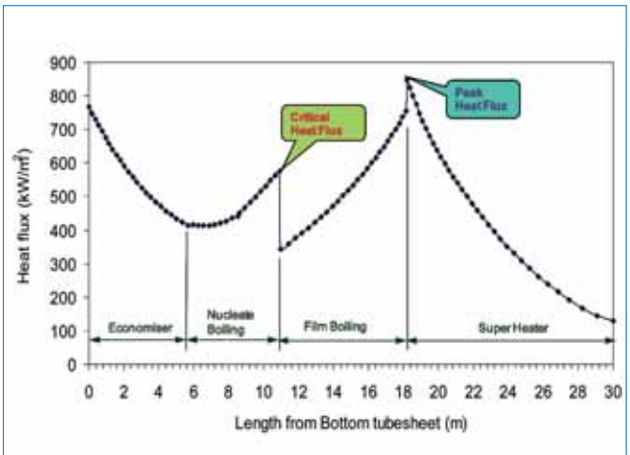


Figure 6: Variation of heat flux along the tube length

With this in the background, detailed calculations has revealed that twelve numbers of ∅12mm tie-rods arranged circumferentially are found to be adequate towards meeting its structural and flow induced vibration criteria and the specification requirements of Tubular Exchanger Manufacturers Association (TEMA) conservatively.

Conclusion

Based on the above studies, the optimized steam generator with 30 meter long tubes leads to:

- Reduction in number of tube to tube-sheet joints by about 40% for the plant on account of increased tube length, which enhances the overall reliability of steam generator units and hence the availability of the plants.
- Saving of about 27% on material of construction for all steam generator units (including spare) together with considerable reduction in number of tube to tube sheet weld joints leads to direct savings in manufacturing time and costs that contribute to overall economy of future FBRs.
- Further, reduction in the number of modules results in compact layout and leads to reduction in overall manufacturing schedule.
- The choice also results in reduction in associated piping, number of rupture discs and isolation valves, hydrogen in-sodium detection systems, instrumentation and heating arrangement leading to associated cost savings.

Therefore, a steam generator with four hundred thirty three numbers of 30 meter long tubes with three modules per loop concept is being conceived for future FBRs.

(Reported by R. Nanda Kumar,
Heat Transport Systems Division, REG)

Young Researcher's FORUM

Studies on the Recovery of Man-made Noble Metals from Spent Nuclear Fuel

Shri M. Jayakumar, completed his M.Sc. and M.Phil from University of Madras. He joined as a Research Fellow in Fuel Chemistry Division, IGCAR in January 2006 and is pursuing Ph.D. under the guidance of Dr. T. G. Srinivasan. He is working on the electrochemical recovery of platinoids from waste solutions using room temperature ionic liquids as medium. He has seven international publications and a chapter in a book. He has published five papers in national proceedings and participated in 3rd International congress on ionic liquids, Australia.

Introduction

There is a huge demand for the platinoids such as ruthenium, rhodium and palladium in various industries owing to their unique physical and chemical properties. The abundance of platinoids in the earth crust is very low and is geographically limited to few countries. The cost of production and purification is likely to increase the prices of platinoids further due to scarce resources being available. In this context, spent nuclear fuel is an alternate source of the platinoids.

Significant quantities of platinum group metals (ruthenium, rhodium, palladium) are produced as by-products of fission in nuclear reactor. Most of the isotopes of fission platinoids are stable, except ^{103}Ru, ^{105}Ru, ^{106}Ru and ^{107}Pd isotopes. However, if the spent nuclear fuel is cooled for more than ten years, most of the radioactivity associated with ruthenium and rhodium becomes negligible. The only radioactive isotope, which can sustain for long time is ^{107}Pd. However, the intrinsic radioactivity of ^{107}Pd (soft β-emitter with E_{max} of 35 keV) is very weak and can be tolerated for several industrial applications.

The spent nuclear fuel is conventionally reprocessed by industrially well-established PUREX process for the recovery of plutonium and depleted uranium. Since platinoid fission products are inextractable during PUREX, nearly 70% is routed to high level liquid waste in the form of nitrate and nitrosyl complexes along with other fission products. The remaining 30% of fission platinoids along with technicium and molybdenum remain as insoluble residue during dissolution. In addition, non-aqueous pyrochemical method is also under development for reprocessing of spent nuclear fuel in several countries due to inherent advantages of inorganic molten salt media. Traditionally, the electrolytic medium comprises of a eutectic of alkali or alkaline earth chlorides, molten at temperatures above 800 K. In the recent past, room temperature ionic liquids have been extensively investigated for possible applications in various stages of nuclear fuel cycle. Room temperature ionic liquids 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. Encouraging results obtained from those studies induced investigations on other challenges encountered in the recovery of fission platinoids from high level liquid waste and spent nuclear fuel. In this context, the present work deals with the feasibility of employing room temperature ionic liquids as medium for the recovery of fission platinoids. The properties of room temperature ionic liquids such as ion exchange behavior and wide electrochemical window were exploited to develop technically viable method for the recovery of platinoids. The electrochemical behavior of platinoids present in nitric acid and ionic liquid medium was studied to evaluate the technical suitability of room temperature ionic liquids and compare

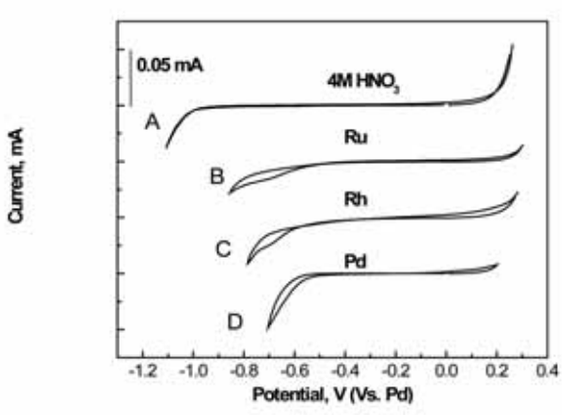


Figure 1: Comparison of cyclic voltammogram of 4 M nitric acid and Ru(III), Rh(III), Pd (II) in 4 M HNO_3 recorded at stainless steel working electrode. Counter electrode: platinum, Quasi-reference electrode: palladium wire. Scan rate: 0.01 Vs^{-1} T:298 K

with direct electrochemical methods. The effect of various parameters on the electrochemical behavior of platinoids was investigated by various transient electrochemical techniques. Electrodeposition of platinoids and the factors influencing the surface morphology of the deposits were studied.

Direct electrochemical recovery of platinoids from nitric acid medium

The electrochemical behavior of platinoids in nitric acid medium and simulated high level liquid waste was studied as a prelude to understand the technical feasibility of recovering fission platinoids from high level liquid waste by direct electrodeposition. The cyclic voltammograms of nitric acid and platinoids in 4M nitric acid are displayed in Figure 1. The electrochemical window of nitric acid is ~1.2 V ranging between –0.9 to +0.2 V (Vs Pd) (trace A). A cathodic wave occurring at –0.7 V in case of Ru(III) (trace B) and Rh(III) (trace C) and –0.4 V in the case of Pd(II) (trace D) are due to their reduction to metallic forms.

Electrodeposition of platinoids from 4M nitric acid medium was studied at various overpotentials for about eight hours. The potentials were varied from –0.5 V and –0.95 V (Vs. Pd). The experiments involved electrolysis of platinoid nitrates in nitric acid medium at stainless steel electrode as cathode. The potentials were optimized to be -0.5 V, -0.75 V and -0.95 V (Vs. Pd) for palladium, rhodium and ruthenium deposition, respectively. Table 1 shows the result of electrochemical recovery of platinoids from 4M nitric acid. Under these specified conditions, the recovery of palladium was quantitative. However, the recovery of ruthenium and rhodium was low and limited to 4% and 14%, respectively. The X-ray diffraction patterns of the deposited metals were comparable with standard JCPDS data. The surface morphology of the palladium deposit was dendritic in nature while rhodium and ruthenium deposits had spherical morphology (Figure 2).

The results discussed above dealt with the electrochemical and electrodeposition behavior of individual solutions (i.e.) either Ru(III) or Rh(III) or Pd(II) is present in nitric acid medium. However, the recovery of the platinoids from a ternary solution was quite different. Electrodeposition of platinoids from a ternary solution was studied at different cathodic potentials ranging from –0.5 V to –1.0 V (Vs .Pd). Quantitative recovery of palladium was achieved only at a potential of –0.9 V (Vs. Pd) in this case. The recoveries of ruthenium and rhodium were ~17% and ~4%, respectively. Moreover, the presence of palladium favored underpotential deposition of ruthenium and rhodium. Surface morphology of ternary deposits indicated spherical shapes with fibrous surface. In contrast to palladium and rhodium deposition, electrolysis of Ru(III) nitrate from nitric acid medium results in the evolution of gas at anode leading to the blackening of the electrode, perhaps, due to evolution of RuO_4. X-ray diffraction pattern of the deposit collected from the top of the glass surface in anodic compartment showed

Table 1. Electrolysis of platinoid nitrates in 4M nitric acid medium at various applied potentials at stainless steel electrode. Ru(III) added as $Ru(NO)(NO_3)_3$, Rh(III) as $Rh(NO_3)_3$, Pd(II) as $Pd(NO_3)_2$ Initial concentration of paltinoids= 20 mM

Metal	Applied potential (Vs. Pd) V	$[Metal]_{ini}$ g	Time *hrs*	Actual recovery obtained %	Faradaic efficiency %
Ru	< -0.95	0.060	8.5	<1	-
	-0.95	0.060	8.5	3.7	4.1
Rh	< -0.75	0.060	8.5	<1	-
	-0.75	0.060	8.5	14.1	5.5
Pd	-0.4	0.055	8.5	0	-
	-0.45	0.055	8.5	< 5	36.3
	-0.5	0.055	9.3	100	52.2
	-0.6	0.055	4.6	100	64.8

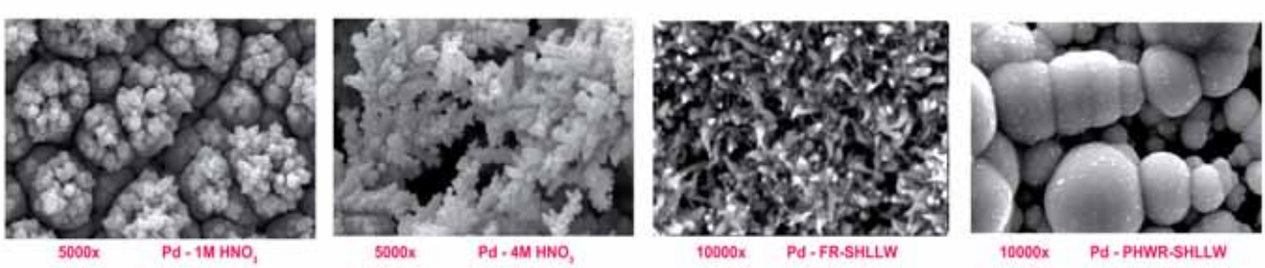


Figure 2: SEM images of palladium deposited from 1M and 4M nitric acid and Fast Reactor-Simulated High Level Liquid Waste and PHWR-Simulated High Level Liquid Waste solutions. Working electrode: stainless steel, counter electrode: platinum, quasi-reference electrode: Pd wire. T: 298 K. Duration of electrolysis: 8 hours. Applied cathodic potential: -0.5 V(Vs. Pd)

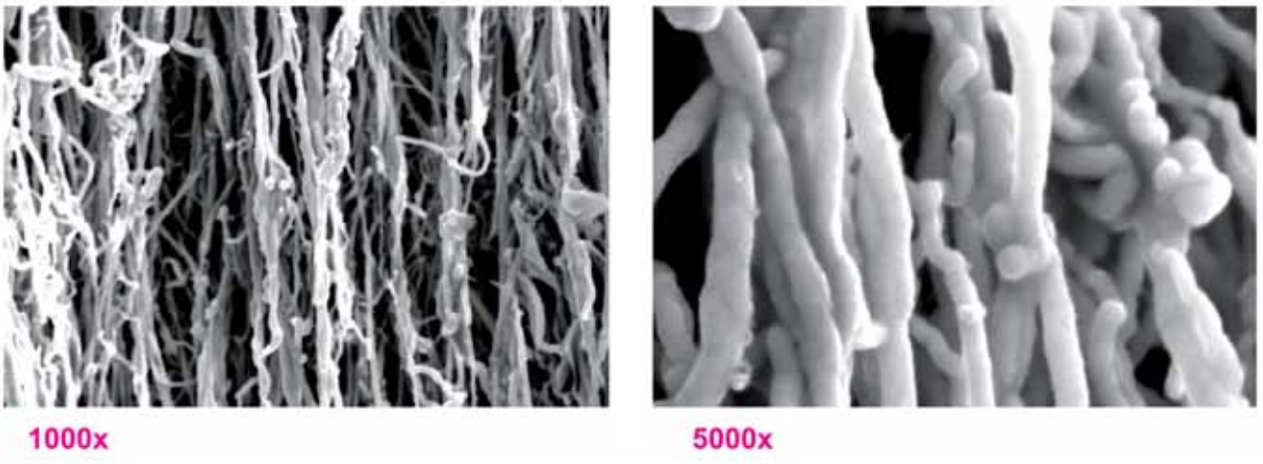


Figure 3: SEM images of palladium deposits obtained by Extraction-Electrodeposition from Fast Reactor-Simulated High level liquid waste

the presence of RuO_2 confirming the well-recognized fact that Ru(III) is oxidized to volatile RuO_4 (at anode) and deposited on the walls of the vessel as insoluble RuO_2.

Based on the above encouraging results, the electrodeposition of palladium from simulated high level liquid waste solution was carried out at stainless steel electrode at an optimized potential of –0.5 V (Vs. Pd). In contrast to the recovery obtained in 4M nitric acid medium, the recovery of palladium was limited to ~30% only in simulated high level liquid waste . It was found from several voltammetric investigations that prospective interfering ions present in high level liquid waste such as Ag(I), Fe(III) nitrate, U(VI), etc. underwent redox reactions in preference to palladium deposition and lower the recovery of palladium. It was concluded that the palladium deposit modifies the electrode surface and enhances the unwanted redox reactions resulting in poor recovery of palladium. The surface morphology showed fibrous and spherical morphologies for deposits obtained from Fast reactor-simulated high level liquid waste and PHWR–simulated high level liquid waste solutions, respectively (Figure 2).

Electrochemical recovery of palladium by Extraction-Electrodeposition (EX-EL)

Since, the major cause for incomplete recovery of palladium by direct electrolysis is due to interfering ions, separation of palladium(II) from the interferences appears to be the pre-requisite for electrodeposition. This has led to the development of a new approach, known as EXtraction-ELectrodeposition (EX-EL) method, for quantitative recovery of palladium from high level liquid waste. The process involves the use of room temperature ionic liquid, tri-n-octylmethylammonium nitrate (TOMAN), both as an extractant for the Pd(II) from simulated high level liquid waste and as an electrolytic medium for quantitative electrodeposition of palladium from organic phase.

Quantitative extraction of Pd(II) was achieved in five contacts. The electrochemical behavior of Pd(II) present in the organic phase was investigated at a stainless steel electrode by cyclic voltammetry to study the feasibility of recovering palladium by electrodeposition. A surge in cathodic current was observed at a potential of –0.5 V (Vs. Pd) due to palladium deposition. Nearly twenty and thirty five hours were required for the quantitative deposition of palladium from organic phase obtained after extraction of palladium from 4 M nitric acid and Fast reactor-simulated high level liquid waste. The organic phase could be recycled for more than five times without any change in the extraction or electrodeposition behavior. Surface morphology of the deposit showed long microfibres of palladium in all the cases (Figure 3). The process was demonstrated up to 500 mL (VAq=VOrg = 500 mL) scale using simulated high level liquid waste.

Utilization of the end product i.e. metallic palladium depends upon its purity and the degree of decontamination achieved from other fission products during extraction and electrodeposition. To examine this, the Fast reactor-simulated high level liquid waste was spiked with actual high level liquid waste (Burn-up 100,000 MWd/Te) and the decontamination achieved during extraction with 0.5 M TOMAN/$CHCl_3$ was measured. A decontamination factor of thirteen was achieved during extraction and one hundred was achieved during electrolysis.

Recovery of platinoids using ionic liquids from non-aqueous media

Ionic liquids are also widely investigated as possible substitutes to

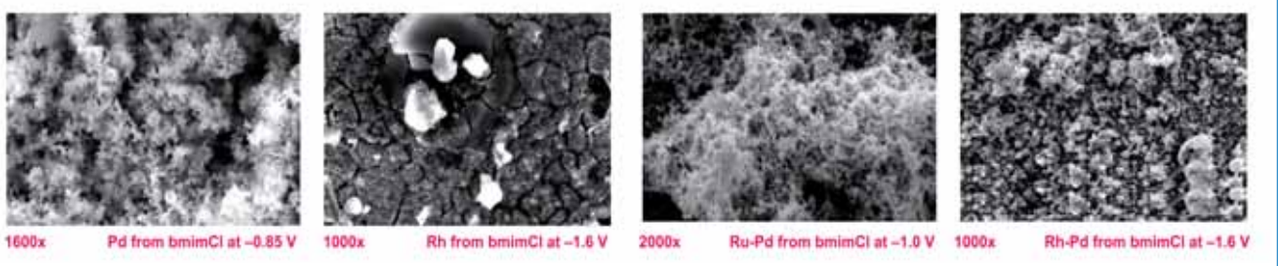


Figure 5: SEM images of platinum metals deposited from bmimCl medium. Working electrode: stainless steel, counter electrode: glassy carbon, quasi-reference electrode: palladium wire. T: 373 K.

high temperature molten salts in non-aqueous electrodeposition of metals. In this context, the electrochemical behavior of platinoids was investigated by cyclic voltammetry using glassy carbon as working electrode and palladium as quasi-reference electrode. The ionic liquid, 1-butyl-3-methylimidazolium chloride (bmimCl), was used as the electrolyte. All the three platinoids showed a complex redox behavior in bmimCl (Figure 4). Based on the reduction potentials obtained from cyclic voltammogram, electrodeposition of platinoids was carried out from bmimCl ionic liquid. While electrodeposition of palladium from bmimCl on stainless steel working electrode was achieved at –0.8 V (Vs. Pd), rhodium required –1.7 V (Vs. Pd) whereas ruthenium did not deposit even at the cathodic limit of bmimCl (-1.8 V) (Vs. Pd). However, ruthenium could be deposited from other ionic liquids such as bmimPF6 and bmimNTf2. Surface morphology of the palladium deposit was dendritic and these dendrites agglomerated with increase in applied cathodic potentials. Rhodium deposit was mostly uniform. Electrodeposition was also carried out from binary and ternary mixtures of platinoids in bmimCl. Co-deposition was observed in all the cases, except in Ru(III)-Rh(III) in bmimCl solution where no deposit

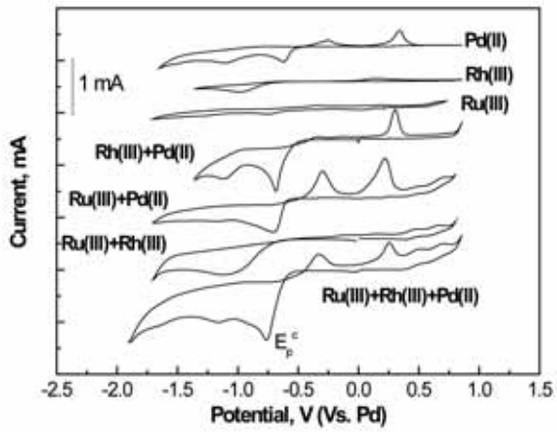


Figure 4: Cyclic voltammogram of 60mM each Ru(III), Rh(III), and Pd (II) in bmimcl and their equi-molar mixtures in bmimCl recorded at a glassy carbon working electrode. Counter electrode: glassy carbon, Quasi-reference palladium wire. T:373 K

was obtained. Ruthenium, which was not deposited in bmimCl, was found to co-deposit underpotentially at –0.8 V (Vs. Pd) in the presence of palladium. The X-ray diffraction patterns of the deposited metals were comparable with standard JCPDS data. The surface morphology of platinoid deposited from bmimCl ionic liquid is given in Figure 5.

The platinoids, Ru(III), Rh(III) and Pd(II) underwent an irreversible single step charge transfer, three-electron transfer in case of Ru(III) and Rh(III) and two-electron transfer in case of Pd(II) to their respective metallic forms at platinum and stainless steel electrode. The solution chemistry and electrochemical behavior of Ru(III) nitrate and Rh(III) in nitric acid medium were complex. Presence of palladium favored the underpotential deposition of ruthenium and rhodium. Copious evolution of RuO_4 was observed during the course of the electrolysis of Ru(III) nitrate solution and aggravated in the presence of palladium. Several complications aggravate in the presence of interfering metal ions such as silver, iron etc. that are likely to be present in high level liquid waste during electrolysis. As a consequence, a novel approach, extraction-electrodeposition method, was developed for the quantitative recovery of palladium from Simulated high level liquid waste using room temperature ionic liquid as medium. The study revealed that the extraction electrodeposition process offers rejection of fission products and near quantitative extraction and deposition of palladium from a host of elements.

For the first time, the electrochemical behavior of these three platinoids from a single ionic liquid, namely, bmimCl, has been investigated by various electroanalytical techniques. Electrodeposition of platinoids from individual and mixtures from bmimCl ionic liquid was carried out and all the deposits were characterized. The study established the feasibility of using ionic liquids as electrolytes for the recovery of fission platinoids by non-aqueous route.

(Reported by M. Jayakumar, Fuel Chemistry Division, CG)

News and Events

400th meeting of IGC Scientific Committee

April 12, 2010

Dr. Baldev Raj, Director, IGCAR & Chairman, IGCSC releasing the CD containing the compendium of minutes and presentations

The 400th IGC Scientific Committee meeting was held on April 12, 2010 at Sarabhai Auditorium. The special programme was aimed to reminisce the past performances and to look into the future. The programme was aptly named as I4V5 (IGCSC 400 & Vision for 500).

During the 395th IGCSC meeting Dr. Baldev Raj, Director, IGCAR and Chairman, IGCSC suggested that the 400th IGCSC can be conducted as a special event. A small team comprising Dr. T. Jayakumar, Shri S. A. V. Satya Murty, Shri A.S.L.K. Rao, Dr. M.D. Mathew, Shri K.V. Sureshkumar, Dr. M. Sai Baba and Shri R. G. Raghavan, was formed to plan and organise the event.

Dr. Baldev Raj, Distinguished Scientist, Director, IGCAR/GSO and Chairman, IGCSC, Dr. Prabhat Kumar, Project Director, BHAVINI, Shri K. Ramamurthy, Station Director, MAPS, all the Group Directors of IGCAR, Project Director, FRFCF, IGCSC members, Heads of Sections, Senior officers of IGCAR/GSO in the grade of SO/G and above, Officers from Administration and Accounts of IGCAR, Principals of the Schools of Kalpakkam and Commandant of CISF, Kalpakkam attended the meeting.

The first ever meeting of the Reactor Research Centre Scientific Committee (RSC) was conducted on May 9, 1972. The first RSC comprised of : Shri N. Srinivasan, Chairman, RSC, Shri K. Chakravarthi, Shri N.L. Char, Shri B. S. Iyengar, Shri S.R. Paranjpe, Shri A.R. Parthasarathy and Shri N. Swaminathan. RSC was renamed as IGCSC in January 1986. Currently, we have a total of sixty one members of the IGCSC and a Secretary.

The program started with Shri R. G. Raghavan, Secretary, IGCSC welcoming the gathering. Dr. Baldev Raj, Director, IGCAR and Chairman IGCSC gave the opening remarks and released the compendium of the minutes of the IGCSC meetings held so far i.e. upto 399. He also inaugurated the PFBR model kept on display at the entrance of the ground floor of Homi Bhabha Building.
Programme on this special occasion consisted of :

- Presentations by the Group Directors and Project Director, Fast Reactor Fuel Cycle Facility
- Presentations by the Young Officers of IGCAR - about their views on what is the vision for future of the domains of R&D in the Centre.

Presentations were also made on a wide range of topics which included:

- √ Collaborations, Human Resources Development, Publications and Citations
- √ Patents, Intellectual Property Rights and Technology Transfer
- √ Expertise of IGCAR extended to other organizations
- √ Overall budget – Growth and current scenario
- √ Township Amenities and Neighbourhood Development Programme
- √ Improvements in Administration and Accounts
- √ Civil & Electrical Maintenance including Horticulture
- √ Vision for meeting the growing medical needs
- √ Challenges in meeting the growing educational requirements
- √ Environment and Safety
- √ Industrial Security in current scenario

Dr. Baldev Raj, Director, IGCAR and Chairman, IGCSC gave the concluding remarks and Shri R. G. Raghavan, Secretary, IGCSC proposed the vote of thanks.

(Reported by R. G. Raghavan, Secretary, IGCSC)

News and Events

MoU with Shri Chandrasekarendra Saraswathi Viswa Maha Vidyalaya, Kanchipuram

June 1, 2010

Dr. Baldev Raj, Director, IGCAR, Prof.V.Shivkumar, Vice-Chancellor, Prof.V.S.Vishnu Potty, Dean, Sanskrit and Culture and Dr. A. Jayalakshmi, Registrar, Shri Chandrasekarendra Saraswathi Viswa Maha Vidyalaya, Kanchipuram and Dr. M. Sai Baba, Head, Strategic & Human Resources Planning Section during the signing of MoU

An MoU was signed between IGCAR and Shri Chandrasekarendra Saraswathi Viswa Maha Vidyalaya, Kanchipuram on June 1, 2010 for enhancing cooperation towards pursuing academic and neighbourhood development activities. Prof.V.Shivkumar, Vice-Chancellor, Shri Chandrasekarendra Saraswathi Viswa Maha Vidyalaya, Kanchipuram, Dr.A.Jayalakshmi, Registrar and Prof.V.S.Vishnu Potty, Dean, Sanskrit and Culture, participated on the occasion.

(Reported by M.Sai Baba, S&HRPS)

Conference/Meeting Highlights

Discussion Meeting on Emerging Technologies for Clean Water (May 21-22, 2010)

Dr. R. Chidambaram, Principal Scientific Advisor, Government of India, addressing the gathering during the inaugural session. Dr. Baldev Raj, Director, IGCAR, Prof. T. Pradeep, IIT-M, Dr. C. Anand Babu, Head, Separation Technology and Thermal Hydraulics Division, FRTG are seated on the dais

A two day discussion meeting on "Emerging Technologies for Clean Water" was organized at SRI Guest House, Anupuram, during May 21-22, 2010. About thirty six participants and experts from premier academic institutes, national laboratories and industries, actively involved in various aspects of research and product development in diverse areas related to clean water were invited to participate. This focussed meeting was organized under the auspices of the 'Office of the Principal Scientific Advisor, Government of India' and was supported by the Department of Science & Technology, New Delhi. Dr. R. Chidambaram, Principal Scientific Officer, Government of India in his inaugural address highlighted the tasks that have been completed, challenges ahead and the perspective and vision towards providing clean water solutions to the nation. Dr. Prasada Raju, Department of Science & Technology highlighted the importance of this activity in terms of various funding mechanisms for worthy research and product realization initiatives. On the first day, the delegates made brief presentations of their work and gave suggestions on specific areas of activity that could be undertaken towards achieving the objective of clean water for all. On the second day, three specialist/theme group meetings were conducted (i) nanostructured and related materials (ii) membranes, related materials and contaminants (iii) industries and product development for clean water. These specialist groups had intense discussions to arrive at specific recommendations. These recommendations were consolidated in the final session, under the chairmanship of Dr. Baldev Raj, Director, IGCAR to identify the thrust areas and a comprehensive roadmap for implementation by the National Water Mission, Government of India.

(Reported by C. Anand Babu, FRTG)

Conference/Meeting Highlights

Robust Instrumentation & Control Systems for FBR Program

(May 20, 2010)

Dr. P. Swaminathan, Director, EIG, Shri B. Krishnakumar, Head, Components and Instrument Development Division, FRTG, Shri S. Ilango Sambasivan, Head, Electronics and Instrumentation Division, EIG & Shri S. A. V. Satya Murty, Associate Director, EIG, during the inaugural session of the meeting

A theme meeting on 'Robust Instrumentation and Control Systems for FBR Program' was held on May 20, 2010, in Ramanna Auditorium, IGCAR, Kalpakkam, under the auspices of EIG. Shri B. Krishnakumar, Head, Components and Instrument Development Division, FRTG welcomed the participants and gave the genesis of the theme meeting. Dr. P. Swaminathan, Director, EIG, in his inaugural address, outlined the importance of Instrumentation and Control Systems in Nuclear Power Plants, regulatory requirements, design and development and qualification methodology currently adopted for Instrumentation and Control Systems of PFBR. He further stressed the need for security aspects also to be addressed in design and development of instrumentation and control systems, since future Instrumentation & Control Systems will be computer based. There were seven invited talks covering the areas of Quality Assurance in Design and Manufacturing phase, Quality Assurance in Operation & Maintenance phase, Information Security in Nuclear Facilities, Challenges in Neutronic Instrumentation, Operator Training Simulator and Gap areas for R&D. About sixty participants working in the areas of instrumentation and control systems of IGCAR and BHAVINI attended the meeting. Shri G. V. Kishore, Electronics and Instrumentation Division, EIG proposed the vote of thanks.

(Reported by B. Krishnakumar, FRTG)

Visit of Dignitaries

Prof. Arvind P. Kudchadker, Emeritus Professor, IIT-Bombay, Mumbai and Dr. Shanti Kudchadker along with the students of the Training School

Prof. Arvind P. Kudchadker, Emeritus Professor, IIT-Bombay, Mumbai visited the Centre along with his wife, Dr.Shanti Kudchadker and gave a special lecture to the students of Training School on April 5, 2010 at Ramanna Auditorium on the topic,"Research and innovation ecosystem" and interacted with the students.

Visit of Dignitaries

Shri Sriprakash Jaiswal, Hon'ble Minister of State for Coal, Government of India with Shri S. C. Chetal, Director, REG, along with other officials of the visiting team from the Ministry of Coal

Shri Sriprakash Jaiswal, Hon'ble Minister of State for Coal, Government of India visited the Centre on April 6, 2010. During the meeting with the DAC members of the Centre he was briefed about the Fast Reactor Programme in India by Shri S. C. Chetal, Director, REG and on the status of PFBR by Dr. Prabhat Kumar, PD, BHAVINI. Shri Sriprakash Jaiswal visited the Fast Breeder Test Reactor, Laboratories in the Non-Destructive Evaluation Division, Hot cells, Madras Atomic Power Station and the construction site of PFBR.

Prof. M. S. Swaminathan, Member of Parliament (Rajya Sabha), UNESCO Chair in Eco-technology, M. S. Swaminathan Research Foundation & former Chairman, National Commission on Farmers, Government of India delivering the eminent lecture

Prof. M. S. Swaminathan, Member of Parliament (Rajya Sabha), UNESCO Chair in Eco-technology, M. S. Swaminathan Research Foundation & former Chairman, National Commission on Farmers, Government of India visited the Centre on April 8, 2010 and delivered an Eminent Lecture on the topic, "Nuclear tools for agricultural transformation" as a part of the commemorative celebrations on the occasion of birth centenary of our founder father Dr.Homi J.Bhabha. During the visit, Prof.M.S.Swaminathan visited rice fields (salt tolerant varieties) being grown in the Centre, plantation site and restoration of lake at site which are being pursued by the Centre in collaboration with the M.S.Swaminathan Research Foundation.

Forthcoming Meeting / Conference

Recent Advances in PIE & Remote Technologies for Nuclear Fuel Cycle (RAPT-2010)

September 23-24, 2010

(http://www.igcar.gov.in/seminars/rapt2010.pdf)

A National Seminar on 'Recent Advances in PIE and Remote Technology for Nuclear Fuel Cycle' (RAPT-2010) is being organized by IGCAR, Kalpakkam during September 23-24, 2010 at Convention Centre, Anupuram. The objective of the seminar is to bring together, the engineers and scientists working in the complimentary areas of Post Irradiation Evaluation (PIE) and Remote Technology in various units of DAE, industries and academic institutions, to consolidate and disseminate the expertise gained over the years. RAPT-2010 will cover all aspects of remote fuel fabrication and inspection, PIE techniques, design of in cell equipments and development of various remote inspection technologies for operating nuclear power plants and reprocessing facilities. The seminar would have invited talks by eminent experts as well as contributed oral and poster presentations by field experts in the areas of specializations mentioned below.

Topics:

- Performance evaluation of nuclear fuel and structural materials
- Hot cell systems and remote handling equipments
- Remote techniques for fuel fabrication, reprocessing and waste management
- Remote chemical processing and techniques
- In-cell equipments for nuclear facilities
- Imaging techniques for radioactive materials/environments
- Remote non-destructive evaluation of components
- Remote maintenance of in-cell equipments/ Reactor components
- Remote ISI techniques for nuclear power plants and reprocessing facilities
- Robotics for integrated fuel cycle facilities

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2nd International Conference on ASIAN NUCLEAR PROSPECTS 2010 (ANUP 2010)

October 11-13, 2010

(http://www.anup2010.com)

Conference on Asian Nuclear Prospects 2010 (ANUP 2010) is being organized by IGCAR, Kalpakkam and Indian Nuclear Society. The meeting would provide scientists and engineers a forum to interact with and learn from world experts in nuclear technology. The venue of the meeting is Radisson Resort Temple Bay, Mamallapuram.

Professionals

Several technical sessions focussing on the nuclear energy and technologies with plenary and invited presentations by eminent professonals in the field are planned in addition to poster sessions and presentation by young authors. Support of TWAS, OECD, IAEA and Nuclear societies of other Asian countries has been solicited. Deadline for registration of participants for attending the Conference is September 30, 2010.

AIM/Scope of the conference:

- To create an interactive forum for multi-disciplinary discussion and to encourage interactions between scientists/engineers and personnel from industrial, research and academic organizations
- To identify new technologies and frontier areas of research in nuclear energy
- To deliberate on future trends relating to nuclear energy and technologies

- The following topics would be discussed:
  - Integration of nuclear with other energy sources
  - Social outreach of nuclear energy in Asian countries
  - Research and technology breakthroughs in nuclear energy
  - Spent fuel management both open and closed cycle
  - Modelling and simulation, including waste management
  - Human resource development and Knowledge management

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Best Paper/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". The "Best Paper/PosterAwards" would henceforth form a part of the IGC newsletter. In this issue the honours received from January - June 2010 are given.

1. Assessment of Fatigue Damage in Aircraft Landing Gears using Magnetic Barkhausen Emission Technique
T. Jayakumar, S. Mahadevan, S. Vaidyanathan, S. Arunkumar, G.K. Sharma, T. Saravanan, B.P.C. Rao and Baldev Raj, Non-Destructive Evaluation Division, MMG. 8th International Conference on Barkhausen Noise and Micromagnetic Testing (ICBM8) held at IGCAR, Kalpakkam during February 2010.
Best Paper Award

2. Exploration of Possible Novel Phases in Ge-Sn System using LHDAC
Y. A. Sorb*, N.R. Sanjay Kumar, N.V. Chandra Shekar, M. Sekar, T.R. Ravindran, N. Subramanian and P.Ch. Sahu, Condensed Matter Physics Division, MSG, 21st AGM of MRSI held at Sardar Patel University, Gujarat during February, 2010.
MRSI Prize for the Best Poster Paper

3. HRTEM Characterisation of Ceria - Zirconia Multilayers Prepared by Pulsed Laser Deposition
Chanchal Ghosh, G.Balakrishnan, Divakar Ramachandran, P.Kuppusami, E.Mohandas and D.Sastikumar, Physical Metallurgy Division, MMG. 21st AGM of MRSI held at Sardar Patel University, Gujarat during February, 2010.
MRSI Prize for Best Poster Paper

4. Synthesis and Imaging of Green and Red Lumininescent CdTe Nanocrystals Incorporated in Thermo-responsive Microgel Particles
J. Brijitta*, B.V.R. Tata, K.Saravanan, B.K. Panigrahi and T. Kaliyappan, Condensed Matter Physics Division, MSG
ICONSAT-2010 held at IIT-Bombay, Mumbai during February, 2010.
Best Poster Award

5. Phase Diagram and Thermochemical Studies on Pb-Fe-O System
Sulata Kumari Sahu*, C.V. Vishnu Vardhan, Rajesh Ganesan and T. Gnanasekaran, Liquid Metals and Solid State Chemistry Division, CG . 17th DAE-BRNS National Symposium on Thermal Analysis (THERMANS 2010) held at University of Kurukshetra, Haryana, during March, 2010.
Best Poster Award

6. Thermodynamic Functions of Pure and Nd-doped Barium Titanate Ceramics
R. Babu, R. Kandan, Hrudananda Jena, K.V.Govindan Kutty and K. Nagarajan, Chemistry Group,
17th DAE-BRNS National Symposium on Thermal Analysis (THERMANS 2010) held at University of Kurukshetra, Haryana, during March, 2010.
Best Poster Award (Third Prize)

7. Enthalpy Measurements on Ti-15at.%Nb alloy by Drop Calorimetry
Josephine Prabha*, S. Raju, B. Jeyaganesh*, Arun Kumar Rai and I. Johnson, Physical Metallurgy Division, MMG
17th DAE-BRNS National Symposium on Thermal Analysis (THERMANS 2010) held at University of Kurukshetra, Haryana, during March, 2010.
Best Oral Presentation Award

8. A Novel Conductometric Technique for Determination ff Rate Constant using Pulsating Sensor
Kuheli Das*, P. Sahoo, M. Sai Baba, N. Murali and P. Swaminathan, Real Time Systems Division, EIG
Electroanalytical Chemistry and Allied Topics (ELAC-2010) during 16-18 March, 2010 at Puri, Orissa,
Best Poster Award (2nd Prize)

9. Study of Beta to Alpha Phase Transformation on Continuous Cooling from the Beta Phase field in a Ti-5%Ta-1.8%Nb Alloy
Madhusmita Behera*, R. Mythili, S. Raju and S. Saroja, Physical Metallurgy Division, MMG
National symposium for Materials Research Scholars and Workshop on Advanced Characterisation Techniques (MR10) during May, 2010 at IIT-Bombay, Mumbai.
Best Oral Presentation Award

* Research Scholar

Awards & Honours

- Dr. Baldev Raj, Director, IGCAR has been
  Elected President, International Institute of Welding, which has a membership of fifty one countries.
  Elected Fellow of ASM International, USA

  Dr. Baldev Raj, Director, IGCAR has been awarded the INSA Prize for Materials Science, Indian National Science Academy (2010)

  Dr. Baldev Raj, Director, IGCAR has been invited to be:

  Member, DAE Science Research Council
  External Expert, Peer Review Committee for the Cluster – Chemical Sciences, Group I: Chemical Materials & Energy, Council of Scientific & Industrial Research, New Delhi (2010)
  Member, R&D Advisory Council of Bharat Heavy Electricals Ltd. to enhance performance multifold based on science based technologies
  Co-Chair, Editorial and Scientific Committee of International Journal of Nuclear Energy Science and Technology
  Member, Governing Body of J&K State Council for Science & Technology
  Member, Research Council, Institute of Minerals & Materials Technology, Bhubaneswar
  Member, Advisory Council, Great Lakes-Bauer Energy Executive MBA Programme
  Chairman, Research Advisory Board of PSG Institute of Advanced Studies, Coimbatore
  Member, Editorial Advisory Board, Bulletin of Materials Science

- Dr. P. Chellapandi, Director, SG, has received Distinguished Alumnus Award of IIT-Madras, 2010.

- Dr. P. Swaminathan, Director, EIG, was awarded INS 2009 Award in "High Technology Nuclear Related Areas" for his R&D contribution in development of strategic Instrumentation and Control system for FBR program.

- Dr. T. Gnanasekaran, Associate Director and Head, Liquid Metals and Solid State Chemistry Division, CG, has been awarded the MRSI medal and the Life time Achievement Award of the Thermal Analysis Society.

- Dr. M. Sai Baba, Head, Scientific Information Resource Division and Strategic & Human Resources Planning Section has been invited to be a member of the Editorial and Scientific Committee of the International Journal of Nuclear Knowledge Management published by the World Council of Nuclear Workers(WONUC).

- Shri J. Jayapandian, Shri K. Prabakar, Shri C.S. Deepak and Smt. Usharani Ravi from Surface and Nanoscience Division, MSG have received the 'Design Award' for 'Measuring micro displacements using CD's Optical pickup Head from Idea for Design pages of Electronic Design' in May 2010.

- MOON QC (Facilitator: Shri B. Krishnakumar, Head, Components & Instrumentation Division, FRTG) has bagged the PAR EXCELLENCE PRESENTATION Award (The Highest in Quality Circle Competitions) at National Convention for Quality Circle at AMC Engineering College.

Published by Scientific Information Resource Division, IGCAR, Kalpakkam - 603 102