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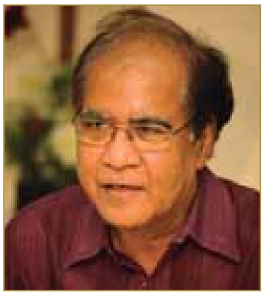
Inside

From the Director's Desk



Ethics in Management of Large Strategic Research Organisation

Leading a large organisation and giving direction to realise the goals is a challenge and an opportunity. The challenge is even greater if the organisation's focus is Research and Development and working in a mission mode. In the continued journey of achieving the goals, one should not loose sight towards functioning on ethical basis. I believed that the basis of successful management has been in enforcing ethical values. Establishing, nurturing, and sustaining this quest for excellence in the pursuit of science and technology calls for continuously raising the bars of achievement to high and higher levels; without losing track of the cardinal management principle that excellence must be sought within the precincts of ethics. This latter requirement is of paramount importance in harnessing the capacities and capabilities of all the organisational assets including the human resources in a harmonious manner with ethical and efficient management intertwined in a robust and judicious manner.

> **The first step of evolution of ethics is a sense of solidarity with other human beings**
>
> *– Albert Schweitzer*

The concepts of ethics are rather omnipresent. Ethics in business and entrepreneurship have been matters of intense debate and extensive studies in the past and current periods. However, the succinct crystallisation of the role of ethics in management of science and technology in a transparent manner is ever evolving. Interactive and synergistic collaborative environment needs research and study of practices and their outcomes. A systematic analysis of the permeation of ethics and its impact in S&T reveals that the management of front line, strategic and large research organisations has not been adequately addressed. Ethics in the management of strategic research institutions is an important and essential ingredient to achieve excellence with relevance. It is important to practice excellence, relevance and ethics in an effective new way to do ample justice to the confidence that common citizens repose in such organisations. The leader of such an organisation needs to deal with people with varying specialities and expertise that usually range from intellectual group consisting of scientists and engineers who have received highest academic degrees and peer recognitions in their chosen fields of expertise to highly skilled technicians and supporting personnel, besides employees involved in managing general administration and finance related issues. In some special and strategically oriented organizations, the leadership has to be sensitised to give honest perspectives and status to policy makers, media, common citizens and even international fora and individuals. In addressing all these multitasks, the leadership has to be constantly aware of the need to support the aspirations of scientists, engineers and in fact the entire cross section of organization, as mentioned above. The task of ethical management of a big and thriving R&D institute in a fulfilling manner is extremely challenging but rewarding to obtain management insights and deliver the desired results. In this article, I have articulated my perceptions of the issues in management ethics in strategic R&D organization. My efforts are propelled by the desire to share with you some of my personal management experiences in rendering my duty. Being a passionate and compulsive writer, I wish to enjoy narrating the story of my journey in transforming Indira Gandhi Centre for Atomic Research into a multi disciplinary research Centre of international stature, repute and excellence, while at the same time more than meeting the defined boundaries of the mandate given to the Centre.

I start the article with a short introduction of the Indian nuclear program as visualised by Homi Jehangir Bhabha and the vision and mission of IGCAR framed by the successive illustrious leadership of the atomic energy program. This portion of the article is written with the hope that those readers who are not familiar about the Department of Atomic Energy and IGCAR will get a precise perspective and the contextual basis of the ensuing discussions.

The Indian Nuclear Program

Realising the vision of transforming India into a technologically and economically advanced nation, necessitates a commensurate growth in energy generation. To sustain the anticipated growth rate of Gross Domestic Product to catalyse the required industrial growth, and to ensure improved standard of living, a nearly eight hundred percent increase in energy-generation is projected as essential in the next four decades. Considering the postulated energy demand by 2050 and taking stock of the availability of fuel resources in the country and internationally, it has been estimated by the Department of Atomic Energy that India would require an estimated contribution of at least 25% from nuclear energy. It is certainly desirable to have a larger share than twenty five percent contributions for energy security, environmental sustainability and to absorb some of the uncertainties in the newer forms of renewable energy options such as solar, wind, bio mass, fuel cells, etc. A substantial increase in the contribution of nuclear energy to power generation can only be achieved through maximum utilization of the limited uranium resources and the vast thorium reserves available in the country. Towards enabling this vision, successful development and commercialisation of fast breeder reactors (FBRs) are inevitable.

Figure 1: Dr.Homi Bhabha with Pandit Jawaharlal Nehru

Dr. Homi Bhabha, the founding father of Indian Atomic Energy programme, under the patronage and with the complete confidence of Pandit Jawaharlal Nehru, unfolded the vision of building a strong base in nuclear science and technology, which would provide comprehensive energy security to the country. He, along with his colleagues in the Department of Atomic Energy, formulated a three stage nuclear programme. The first stage consists of Pressurized Heavy Water Reactors (PHWRs), which are based on natural uranium resources and indigenously produced heavy water. The second stage is centered on Fast Breeder Reactors (FBRs), utilizing plutonium generated in PHWRs and recycled by closing the fuel cycle. The third stage would ensure energy security through advanced thorium based reactors (thermal and fast), which would exploit the large resources of thorium, available in India. The fissile material inputs to the third stage would come from plutonium and U^{233} produced in the PHWRs and fast breeder reactors respectively.

After a successful first stage programme in which India has mastered the technology of design and construction of Pressurised Heavy Water Reactors (PHWR) and built over 15 PHWRs of varying capacities, it has embarked on the second stage of Fast Breeder Reactors (FBR).The capabilities of India to add large amounts of electricity generation capacity on shorter horizon through water reactors have increased significantly after the recent civilian nuclear cooperation agreement. The possibility of ploughing plutonium from imported fuels in fast breeder reactors with closed fuel cycle opens up an unparallel opportunity of realising a large role for nuclear energy in the energy basket of India.

The Indian FBR programme started with the design and construction of the 40 MW(t) Fast Breeder Test Reactor (FBTR) at the Reactor Research Centre later renamed as Indira Gandhi Centre for Atomic Research Kalpakkam. Reactor Research Centre was born in 1971, with a clear mission of developing Fast Breeder Reactor Science & Technology in the country for commercial exploitation. The successful design, construction and criticality of FBTR in 1985 and its subsequent successful operation for the last 25 years without major incidences, have been an important milestone in demonstrating the technological viability of fast spectrum reactors. A burn-up of 1,65,000 MWd/tonne of the unique high plutonium based carbide fuel, successful reprocessing of this fuel, and mastering the sodium handling technology including extended continuous operation of the sodium pumps without maintenance, are just a few of the major technological highlights of Indian fast reactor programme. This success has paved the way for stepping into the commercial phase of the second stage of the nuclear power generation programme. Construction of a 500 MW(e) Prototype Fast Breeder Reactor (PFBR) project has commenced at Kalpakkam and will be commissioned in September 2011. The technology achievements have been possible based on developing rigorous science based technologies for the last forty years in all the relevant disciplines, through multi and interdisciplinary research, attracting and nurturing young men and women of high merit to pursue the cause of national mission with dedication and perseverance.

Indira Gandhi Centre for Atomic Research – A Brief Overview

Indira Gandhi Centre for Atomic Research is the second largest R&D establishment of the Department of Atomic Energy, next only to Bhabha Atomic Research Centre. Over the years, the Centre has established a comprehensive range of R&D facilities covering the entire spectrum of FBR technology related to sodium purification and monitoring, reactor engineering, structural mechanics, thermal hydraulics and flow induced vibration, component testing in high temperature sodium environment, hydraulic development of sodium pumps, reactor physics, metallurgy and materials, chemistry of fuels and materials, fuel reprocessing, reactor safety, control and instrumentation, computer applications etc. IGCAR has developed a strong base in a variety of disciplines related to these advanced technologies.

Apart from the thrust areas related to nuclear technology, the Centre has credentials to be among leaders of research in various frontier and topical subjects like quasicrystals, oxide superconductors, nano-structures, clusters, Super Conducting Quantum Interference Device (SQUID) fabrication and applications, exopolymers, theoretical and experimental studies of condensed matter, ionic crystals modelling, solvent extraction, colloids, etc. IGCAR has extended its expertise and facilities to other vital sectors such as defence, space and Indian industries to develop reliable solutions in specialized and unresolved challenging problems. It has nurtured strong and continuing collaborations with leading educational and R&D institutes like the Indian Institutes of Technology, Indian Institute of Science, National Research Laboratories, Public Sector Organisations, and select institutes from abroad. The history of evolution of various research and engineering programmes, groups and their achievements have been documented and published in peer reviewed journals,

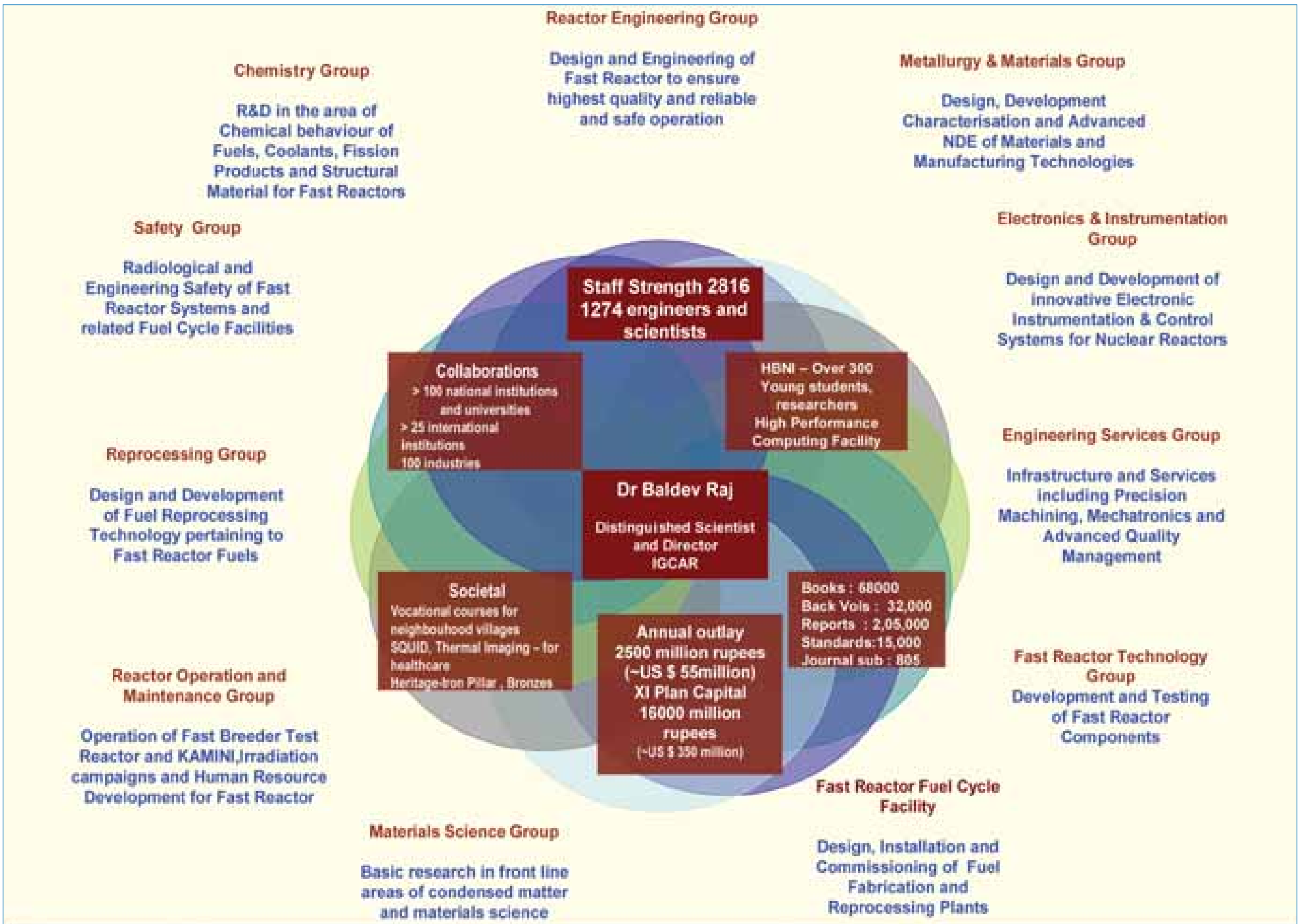
Mission of IGCAR

- To conduct a broad based multidisciplinary programme of scientific research and advanced engineering development, directed towards the establishment of the technology of Sodium Cooled Fast Breeder Reactors (FBR) and associated fuel cycle facilities in the Country.
- The mission includes the development and applications of new and improved materials, techniques, equipment and systems for FBRs.
- Pursue basic research to achieve breakthroughs in fast reactor technology.
- ISO 9001 certified laboratories and services.

Vision Statement

Indira Gandhi Centre for Atomic Research must provide robust R & D products, consultancies and enabling support to realise Prototype and commercial sodium cooled fast reactors being built by Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI) and Fast Reactor Fuel Cycle Facility (FRFCF) in time, in cost and with quality to the complete satisfaction of utilities

To be a global leader in sodium cooled fast breeder reactors and associated fuel cycle technologies by the year 2020 AD



IGCAR is a multi faceted and multidisciplinary organization with various groups as indicated above interfaced seamlessly and working with coherent synergism towards development of fast reactor technology and related fuel cycle facilities.Basic Sciences is considered as the cradle and assurance to achieve success. Basic sciences are innovatively intertwined with the mission, applications and spinoffs to industry, society and strategic sector.

Figure 2: Organisational Chart of IGCAR

books, encyclopaedia, patents, standards, annual reports of the Centre. The IGC newsletter published periodically chronicles the highlights of our achievements; which can be downloaded from the website http://www.igcar.gov.in. The organisational structure with some major parametric details such as number of personnel, budget levels, collaborations etc are shown in Figure 2.

> *Nurture your mind with great thoughts : to believe in the heroic makes heroes*
>
> *- Benjamin Disraeli*

During my engineering studies in metallurgy at Government college of Engineering & Technology, Raipur (then MP, now Chattisgarh), I learnt about the vision and eminence of Dr.Homi Jehangir Bhabha. I dreamt of working with Dr. Homi Bhabha. After getting the gold medal from Ravishankar University, for topping in all branches of engineering, I applied for job in only one organisation - the organisation that is now known as Bhabha Atomic Research Centre, named after Dr. Homi Bhabha after his untimely death in an air crash in 1966. My dream did not diminish or change with the untimely demise of Dr. Homi Bhabha, on the contrary, it got strengthened by the not so explainable logic that I have to play a role in realising the unfulfilled dream of Dr. Homi Bhabha. I never looked back on my dream and decision, in spite of many challenges in my career. The reality was sustainable due to interesting assignments and challenges in science and technology which I was addressing, indeed ever increasing, with every passing year.

> *The beginning is the most important part of the work.*
>
> *- Plato*

I joined the 13th batch of the training school of Bhabha Atomic Research Centre in the year 1969 and after a brief stay at Riso National Laboratory, Roskilde, Denmark for a year (1973-74) as a visiting scientist, I joined the then Reactor Research Centre and now Indira Gandhi Centre for Atomic Research, Kalpakkam. In the year 1974, I was entrusted with the responsibility of designing and developing a post-irradiation examination laboratory for fast reactor fuels and structural materials. While I continued with my engineering assignment of building up the hot cell facility (a world class facility today), I also realized that a reliable and safe fast reactor technology would demand availability of robust NDE (non destructive evaluation). In the 1980s, within the next ten years, I built a multi and interdisciplinary team consisting of physics, electronics, metallurgy (mechanical, physical and corrosion) and instrumentation, to pursue R&D in NDE, in addition to the assignment of post irradiation, examination and evaluation. Today, the NDE group at IGCAR is unique. A small group of dedicated personnel starting with about 10 scientists, engineers and technical staff has grown to about 100 in a span of three decades. The group has not only applied their unique expertise to various challenging problems in nuclear and strategic industries and for societal applications but has also nurtured the NDE science and technology in the country and world.

IGCAR has pioneered NDE science and technology. The group has more than 600 research publications in peer reviewed journals and international conferences and more than 15 books in the area of NDE science and technology, arguably the largest for any group worldwide.

In 1988, I became the Head of the Division for Post Irradiation Examination and Non-Destructive Testing and in 1992, I took over as Director of Metallurgy & Materials Group. In 2004, I was selected to lead the Centre as the Director. This Centre has more than 2480 scientific and technical personnel and a budget of over ~550 crores (~US $ 12 million) per annum. During the last six years, the Centre has been transformed from a mission oriented mindset to a Centre of Excellence by developing comprehensive expertise and core competence in various facets of engineering, technology and basic sciences with the enabling MANTRA of networking with national and international institutions in a symbiotic way. This has been possible by adopting innovative approaches in science management imbibed in me by my mentors, such as leading from the front, throwing challenges to bright young minds, daring them to dream and providing every support to them to expand their horizons. Apart from these, I have placed enhanced emphasis on building the IGCAR-Research-Academia linkages and mentoring young engineers and scientists, to motivate and nurture their visible and latent talent. The excellence and benchmarks were set through the mechanisms of peer reviews through expert committees. The committees had some of the most eminent professionals of the country and were chaired by Prof. S.K.Joshi, Prof. K. Kasturirangan and Prof. M.M. Sharma to peer review the activities in physical, engineering and chemical sciences respectively. This has led to consciously guard against complacence, a probable reason for down trends for any successful and eminent research group.

Only those who will risk going too far can possibly find out how far one can go

-T S Eliot

Looking back, not only in the area of science and technology but also in the areas of biodiversity for conversation and sustenance of ecology, primarily the environment and horticulture within Centre and at the township which accommodates the staff and families of scientists, engineers, doctors and service personnel, a sea-change has occurred during the last six years. All these things have given me immense satisfaction. As I take a look with a sense of pride and fulfilment in being able to contribute in a holistic way, I feel that if one has to identify the factor that has been responsible for the glorious transformation from a mission focussed Centre to a Centre for Excellence in forty years of its existence, it is the ability to harmoniously synthesize the multiple roles of operating in the "research mode" and the "mission mode" and integrating it with ethical and imaginative management practices with the foresight and vision of founding fathers of Department of Atomic Energy namely, Dr. Homi Bhabha and Dr. Vikram Sarabhai.

Ethics in Management of Research Organisations: My Perceptions and Experiences

Ethics, also known as moral philosophy is a branch of philosophy that addresses questions about morality—that is, concepts such as good and bad, noble and ignoble, right and wrong, justice and virtue. Major branches of ethics include:

Meta-ethics: About the theoretical meaning and reference of moral propositions and how their truth-values (if any) may be determined;

Normative ethics: About the practical means of determining a moral course of action;

Applied ethics: About how moral outcomes can be achieved in specific situations;

Moral psychology: About how moral capacity or moral agency develops and what its nature is;

Descriptive ethics: About what moral values people actually abide by.

Within each of these branches are many different schools of thought and still further sub-fields of study [Source: Wikipedia – http://en.wikipedia.org/wiki/Ethics].

Management for large strategic organization refers to getting people together to accomplish the designed and agreed goals and objectives. It comprises of planning, organizing, leading or directing and controlling an organization through various groups for the purpose of accomplishing and exceeding the goals. It is quite clear that ethics and management are interrelated in a not-so-visible way and in this modern world wherein we have intense global competitions, the concept of ethics is many a time modified by organisations to suit the **changing times or it seems out of place at times with hollow societal values and beliefs of unfounded definitions of success.**

Ethics has been a well debated subject matter for at least 2500 years since the time of Vedas, Socrates, Aristotle and Plato. Many ethicists consider emerging ethical beliefs to be the "current" legal matters i.e. what becomes an ethical guideline today is often translated to a law or regulation or rule in future. Values which guide how we ought to behave are considered as moral values e.g. values such as respect, honesty, fairness, responsibility etc. Statements around how these values are applied normally are referred to as moral or ethical principles. Ethics is thus the matter of values and associated behaviours.

Managing ethics in the workplace involves identifying and prioritizing values to guide behaviours in the organization and establishing associated policies, procedures and guidelines. There are a number of research and other articles on ethics in business, , and society, and at micro and macro levels. However, as mentioned earlier, ethics as the core of governance, as applied to management of science in large and strategic technology organizations has not been discussed adequately. In business or entrepreneurship,

Figure 3: Issues in Management Ethics in Large Strategic Research Organizations

An institution is akin to an icon such as the ancient temples of south India or the pyramids of Egypt. Building such institutions and nurturing it to glory requires many ingredients and building blocks. The base of this icon is a strong long term mission and research goals with adequate human resources and finances. The binding mortar is vision and ethics mixed with empowerment of faith in excellence and relevance. When the building blocks and binding mortars are par excellence with smart capabilities and have ability to withstand long term oscillations and stresses, the institution becomes iconic nationally and internationally and stands in good stead with time.

At a research organisation like IGCAR, with technological mandates set in a mission mode, differences in approach are due to

- *Varying deliverables ranging to research, development and deployment of fast reactors and associated fuel cycles, achieving breakthroughs in basic sciences and engineering for realizing enhanced safety and cost effectiveness*
- *Working with multi-disciplinary and multifaceted personnel*
- *Satisfying peers to ensure international and national recognition*
- *Satisfying national needs and aspirations of employees*
- *Pursuing basic science to levels of excellence*
- *Sustaining excellence and motivation of individuals for the life time to work in mission mode with self sacrifice, secondary importance to ego and faith in teams*

ethical guidance is an obligation to customers and also for enhancing the profits.

I have tried to identify some of the issues related to management ethics as applicable to IGCAR. These are depicted in Figure 3.

The crux is clarity of thoughts, capacity to involve colleagues in a transparent manner and capability coupled with credibility to take decisions as and when faced with ethical dilemmas.

The Centre must continue to have a vision, mission and the ability of daring to dream big. Most of the ethical dilemmas faced by me have turned out to be learning experiences and looking back, not so complex, as they appeared at the time of taking decision. I present below four different case studies:

Case – 1

In the long run, you hit only what you aim at. Therefore, though you may fall initially, you had better aim at something high.

– Henry David Thoreau

As institutions and research organisations grow, the pyramid like structure that one starts with at the inception slowly becomes inverted with the top (middle and senior management becoming heavy). When such a situation arise, apart from the issues arising due to perceptions among the seniors, the overall research output (publications, patents and deliverables) drops. This is likely to cause disillusionment and lack of interest in younger colleagues and also introduce lethargy and complacency among senior staff and associated personnel. The overall organisational stature starts shrinking. In such cases, it is the vision, core competence of the leader and that of senior management and the pursuit of imaginative ethical management strategies that sustain growth and excellence of individuals and the organisations. The ethical dilemma in such a challenge is to generate adequate leadership positions for younger colleagues within the permitted structure empowerment without hurting the sentiments of the middle and senior management personnel. An intertwined dilemma associated with this is the basis for the selection of a few such younger colleagues from among many, who may consider themselves as competent and fit for such a selection process. I could solve the challenge through collective decision making involving seniors. The selection is a difficult and time consuming process requiring a performance oriented (not just publications) and a transparent basis involving a combination of pro-activeness + scientific temperament + demonstrated management skills + core competence + acceptability within and outside + peer recognition + ability to act ethically.

The net result is that, we have today a management council synthesised and structured with a blend of wisdom and experience – "grey hairs" and "white hairs" with an average age of around 45 – 50 and a ethical and hierarchical structure in place not only for the present but which can sustain for the coming years and continue to create leaders when challenges for IGCAR shall increase multi-fold. We have clearly identified young leaders in age group of 30 to 40 years who are capable of shouldering challenges and responsibilities with accountability. The system is accepted and has become a common practice in the Centre.

Case – 2

A mission oriented centre has a unique mix of science, engineering and administration based groups in various proportions. These groups of excellences are networked at the top but can have simmering differences at lower levels due to a variety of reasons, some of which can be traditional (such as scientists versus engineers or technical versus administration) etc. These issues, if not addressed properly can affect the harmonious working, essential for meeting the mission, goals and excellence in science and technology. The ethical dilemma is to devise an understandable and implementable system without destroying the fundamental character or the fabric of the groups nurtured over the decades. The challenge is to enhance the productivity without disrespect to tradition and texture of work being done by these groups. I have realised that identification of challenging technological problems and imaginative integration of personnel starting from grass root scientists through multidisciplinary task force approaches is an effective way of overcoming this dilemma. The result of this approach is the cultivation of strong teamwork thus enhancing scientific productivity and engaging the minds with positive approach which was experienced by the Centre by way of achievements manifesting in results and appreciated by a diverse range of specialists and organisations. This approach has resulted in developing minds with a sense of mutual recognition and mutual appreciation of individual performances and creating a harmonious and integrated scientific, engineering, technology and administrative community. This approach also enabled to build a strong fabric and desired texture for working with fun and fulfilment without any suspicion or lack of respect to any activity or level of hierarchy. The mantra in respect of the skill sets of all disciplines, integrate the inputs of gifted individuals and work as a team with commitment to mission without concern that someone of merit would lose recognition of his/her individual contribution.

Case – 3

> *If you see things and say 'why?' But I dream things that never were and say 'why not?'*
>
> *-George Bernard Shaw*

In a mission oriented centre, there is always a feeling that activities need to be focused to a particular programme mission. However, research institutions always have a blend of scientific and engineering personnel some of whom would like to break away from traditional areas and do front line research on topics of immediate or futuristic relevance. A visionary leader can be placed in a serious ethical dilemma caught between the ideologies of these groups both of which are rational and correct in their own convictions. I have also been placed in such predicaments. Such a situation calls for a sensitive and imagination coupled approach. I have introduced the concept of peer review in IGCAR during the last six years by eminent professionals of high eminence and integrity. Apart from this approach, I have also started the practice of sending the IGC newsletter, Annual Report and other publications of IGC to eminent national and international specialists including former directors of the Centre. The encouraging response and the excellent comments have not only helped me to overcome the above mentioned dilemmas, but has also served to strengthen the frontiers of science and engineering research towards enhanced core competencies. Newer basic research initiatives of national relevance could also be started in the Centre with the full support of all the senior management personnel who earlier had shown total commitment to mission programme but scant inclination towards basic research. A few times, it was demonstrated in mission programme that basic scientists provided us with paradigm shift possibilities and novel enabling methodology and solutions in difficult to resolve circumstances. In this context we must remember that, from time immemorial, the world has benefited by overcoming prejudices, which are the real hindrances for new findings or getting a solution of complex problem.

Case - 4

> *The hindrances to new discoveries are prejudices not the knowledge*
>
> *-Francis Bacon*

With the growth of organization, the number of personnel increases and concomitantly the challenges and opportunities are also bound to increase. Differences of opinion between individuals are possible due to a variety of factors including concept leading to certain perception, career, socio-economic, cultural disparities etc. While these are common to all organisations, the more challenging one is the difference of opinion between younger colleagues and senior personnel or the second in line in the management. It is not uncommon that a leader would be placed with a severe ethical dilemma, especially when a difference of opinion originates from competent personnel. Such cases need to be handled with a great amount of sensitivity, fairness and transparency. It should be ensured that the there is no loss of expertise & compliance to the organisation. Indeed synergy between the top hierarchies is the solution to motivation and practising what you talk to your younger colleagues. My experience has indicated that combining sensitivity with humane values and also through intimate discussions, such situations can be addressed in a satisfactory manner. In some cases, I have successfully experimented lateral repositioning without affecting the dignity of the staff or hurting the sentiments of the concerned individuals. Such lateral repositioning has provided better leadership, and also additional benefit of the availability of complementary expertise which has spurred the multidisciplinary R&D activities in that group – a paradigm shift. It is important that lateral repositioning is done in a transparent way and the process of decision making is explained to all concerned.

There are a number of such situations which I can dwell upon. However, I have just presented some significant cases which give a glimpse of the broad canvas of ethical issues encountered in the management of research organisation. In all these cases, I have been primarily guided by the following seven core values: Respect, Integrity, Credibility, Excellence, Transparency, Enhancing Competence and Differentiation (Figure 4).

My Perspective of Gap Areas

Though it might appear that all the major management issues have been addressed, introspection reveals that there are indeed some gap areas that need to be addressed, but the present day mechanisms and individual limitations including those adapted so far make it difficult to address the challenges in a wholesome manner. Three such areas are identified below:

In this age of constant and rapid change, creativity is a must to sustain excellence consistent with ethics. Harnessing of creativity and innovation needs top priority. In any scientific institution excellence can be enhanced through open exchange and exploration of innovative/ radical ideas and constructive critical comments from the creative minds – young and old alike. However, sometimes, these ideas can appear to be contrasting and even conflicting with the mindsets of seniors by the way of touching their egos and pathos. Though the leader may be convinced of the merit of the idea, in the process

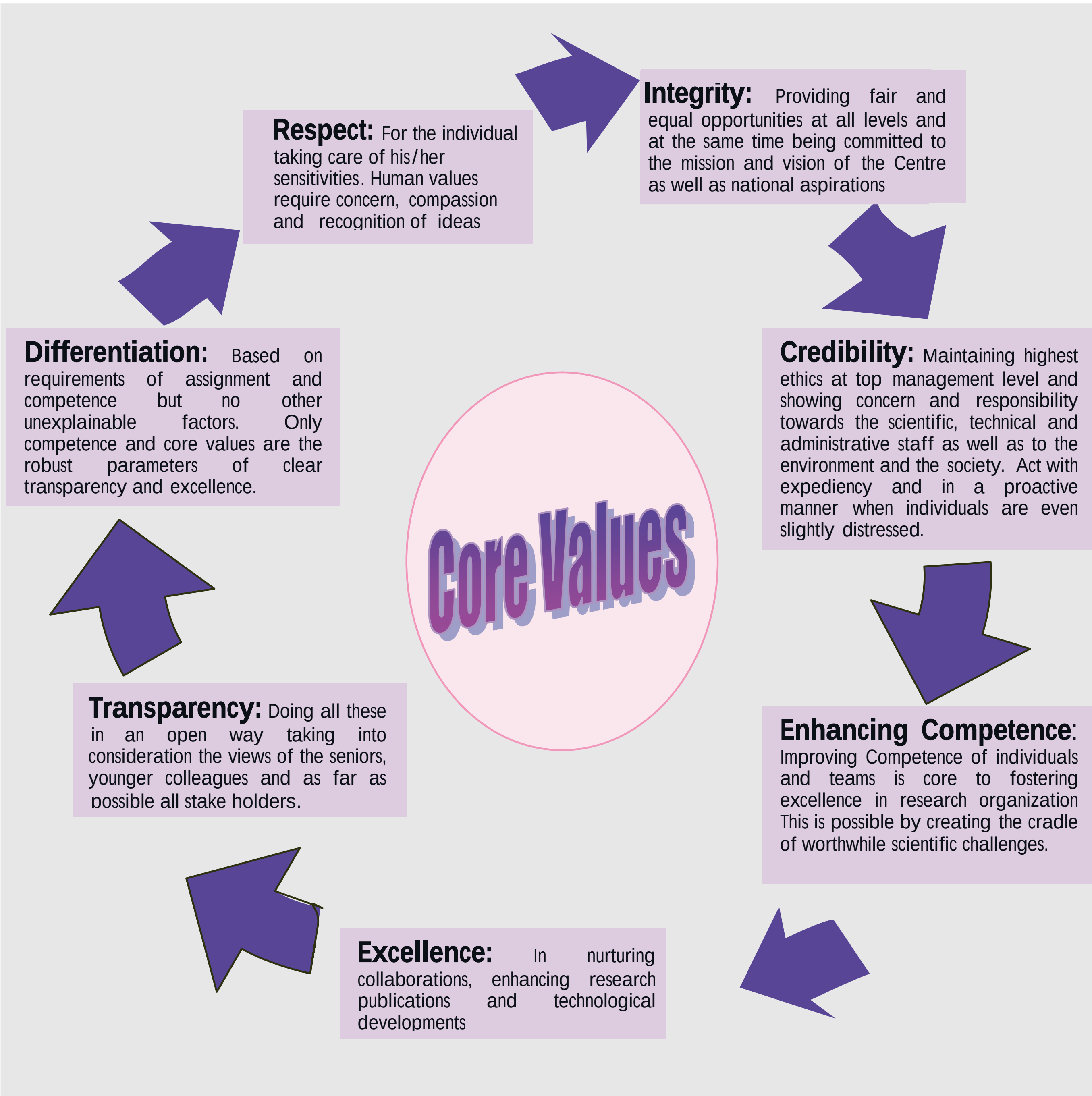


Figure 4: Core Values for Management of Research Organisations

of collective decision making, situations can arise resulting in the ideas being relegated to the background or not being considered. This could result in diminishing work outputs or deliverables from highly talented scientists. It could also result in their getting de-motivated resulting in withdrawal from the main stream of the organization or even leaving the organisation. Many such cases are not always noticed in a large organization, resulting into a major fall in excellence and delivery of products and even mission.

> *Teamwork is the ability to work together toward a common vision. The ability to direct individual accomplishment toward organizational objectives. It is the fuel that allows common people to attain uncommon results.*
>
> *- Andrew Carnegie*

In research organisations, it is always necessary for the mentors and research managers to create a bouquet of challenging problems and set international bench marks both for themselves and also to look for ways and means of surpassing the preset standards. This approach serves to motivate the younger colleagues and also push the horizons of excellence. In an institution with a multi disciplinary blend of senior management with diverse backgrounds and attitudinal dispositions, some of whom may be proactive, some being traditional, some having conservative outlook and some being technologically backward, it is difficult to expect all the management personnel to think cohesively in a chosen direction. This reality results in creation of localised bottlenecks. In both the cases mentioned above, though I have been able to address them on individual basis, in the broad organisational canvas, it continues to be a challenge for me.

> *At back of every noble life there are principles that have fashioned it.*
>
> *-George Horace Lorimer*

The third area is reverse mentoring. When we think of mentoring, we always remember the senior level personnel whom we consider as ideal mentors with long experience and look at the young scientists and engineers as a group needing advice and encouragement. This is far from truth. Young scientists and engineers carry with them knowledge and skills built on latest thinking in the specific field. These young minds can re-define the work content and pace. The culture of inching for quick access to information and desire to succeed at fast pace, are the inherent innovative capabilities of the young which make them ideal mentors for seniors in an effective symbiotic ecosystem of research and development. Reverse mentoring by such young specialists can be beneficial if these bright minds could get a chance to demonstrate their knowledge and skills and thus create outstanding breakthroughs in relevant and mission driven programs. On the other hand, senior scientists get the knowledge they require, which helps them to define new benchmarks and also to manage their portfolio backed by enhanced knowledge base. While I have been adopting this reverse mentoring personally by trying to spot young bright brains and defining to directly the challenging assignments, together directly requiring breakthroughs in a centre with over 2000 employees and annual intake of more than 100, it is a difficult task to implement this on a larger platform. It is here the willing participation of all senior and middle level management is needed for realisation of this practice. This approach has proven to be a challenge. The success requires a change in the mindset of individuals at all levels. We all know, change in the mindset is a biggest challenging and success realisation is extremely slow.

Quo Vadis

> *Change and growth take place when a person has risked himself and dares to become involved with experimenting with his own life.*
>
> *- Herbert Ooto*

Most of us think of ethics (or morals) as basically being guidelines for distinguishing between right and wrong or between acceptable and non-acceptable behaviour. We start learning the rudiments of ethics at home in our early days tutored by our parents and then at the school by our teachers and subsequently in our social settings by people at large. Although we acquire the sense of right and wrong during childhood (sometimes misplaced), moral development is a learning curve that occurs throughout our life as we pass through different stages of growth. The older we grow; we are supposed to be more mature, wiser and more ethical. Ethical norms are so omnipotent that one might be tempted to regard them as simple morality based commonsense. On the other hand, if morality were nothing more than commonsense, then why are there so many ethical disputes and issues in our society? One plausible explanation of these disagreements is that all of us recognize some common ethical norms, but differ in interpretation (which can be based on selfishness or societal cause) and application based on our own perception, values and life experiences.

It gives me immense satisfaction that over the span of forty one years of my working in DAE at various levels, the ethical management principles practised by me is indeed a blend of corporate ethics laced with innovations and imaginative thoughts in the realm of large strategic research organisation.

This approach has resulted in networking of scientists and engineers at all levels, nurturing extensive collaborations not only between groups but also among multi-institutional ones, resulting in a multi-faceted research and growth of science and technology. The impact of this approach can be judged from science and technology markers and more important tangible success in transforming a mission focussed centre to a place of excellence in basic and applied science and technology. The focus has not been found lacking in other endeavours such as management of townships and neighbouring villages etc. The path of encouraging creativity and innovation by placing greater emphasis on nurturing ethical values at all levels, younger generation to the top management in an endeavour to ensure a seamless route to excellence. This approach has paid rich dividends to the nation. I have gained immensely as the whole exercise is endowed with plenty of bliss with fun. I bestow the gratitude to my teachers, peers, colleagues, mother and the Guru. It has been a long pursuit of science and technology, with divine inspiration.

(Baldev Raj)
Director, IGCAR

The Fast Breeder Test Reactor (FBTR) at Indira Gandhi Centre for Atomic Research, Kalpakkam, is a fore-runner to the second stage of the Indian nuclear power programme. It is heartening to state that the fuel has achieved a peak burn-up of 165 GWd/t (about 18 atom %) without any pin failure. The operating experience of FBTR has provided valuable feed-back and immense confidence to launch the commercial phase of Fast Reactors in the country. FBTR has been a fountainhead for nurturing of competent personnel for the design, construction and operation of subsequent FBRs.

The facilities for Post-irradiation examination which are of paramount importance. These facilities were established along with the commissioning of the reactor. The successful operation of FBTR with a unique advanced fuel like mixed plutonium uranium carbide, relies heavily on the step wise Post-irradiation examination of the irradiated fuels and materials. Valuable feedback on the behaviour of fuel, control rod materials and structural materials have been obtained from Post-irradiation examination. These evaluation have enabled us to predict and estimate the residual life of the fuel, control rods and critical components of FBTR and to ensure its safe and optimal utilisation of the reactor. Robust Non-Destructive Evaluation methods were also developed simultaneously, which have aided both in selection and performance evaluation of materials over the years.

It is a momentous occasion for the Centre to commemorate the successful operation of Fast Breeder Test Reactor and the Radio metallurgy Laboratory for the last twenty five years. I shall write a more personal account of these milestones, in my next column as I would enjoy sharing this wonderful journey with all the readers.

It is gratifying to me that for a large part of my tenure in this Department, I had the opportunity to contribute towards the realisation of these important milestones in the history of our Centre.

I congratulate my colleagues, who have been involved with passion and dedication, in realising the mission programmes of the Centre and giving our country its place of pride in the international arena of nuclear energy.

(Baldev Raj)
Director, IGCAR

Novel Design and Construction Features of Main Vessel Cooling System for a Pool Type Sodium Cooled Fast Reactor

In a pool type sodium cooled fast reactor (SFR), the entire radioactive primary sodium circuit is housed in a single vessel, called 'main vessel'. The components supported by the vessel are core support structure (CSS), grid plate (GP), core subassemblies, primary sodium pipes, pump header and inner vessel (Figure 1). The grid plate is basically a box type structure, consisting of top and bottom plates, inter-connected by sleeves. These sleeves provide rigidity to the structure and guide the feet of the core subassemblies. For facilitating sodium flow to the fuel, blanket, storage and reflector subassemblies, holes are provided in the sleeves. The primary pipes and pump headers are the integral parts of the grid plate. The inner vessel, which separates the hot and cold sodium pools, is bolted to the grid plate and the grid plate in turn is bolted to the core support structure flange. The core support structure is finally welded to the bottom of the main vessel, so as to keep the welds in the support skirt under compression, thereby eliminating any possibility of crack opening. In view of its important safety functions, namely supporting the core and housing the coolant, the main vessel is the most critical component in SFR. Accordingly, it is designed and constructed respecting strictly the nuclear class 1 rules (e.g. RCC-MR). These apart, certain features are introduced to enhance its structural reliability, viz., choice of highly ductile construction material, austenitic stainless steel type SS 316 LN, maintaining relatively low operating temperatures so that there are no significant creep/carbide precipitation issues and performing periodic inspection during its service. The main vessel is constituted by a cylindrical shell of 12.9 meter diameter, ~10 meter height and 25 millimeter wall thickness with bottom dished head.

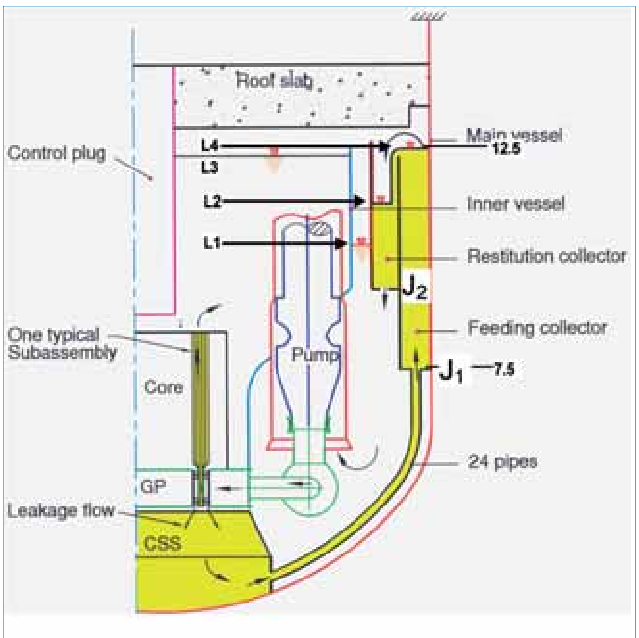


Figure1: Main vessel internals and cooling system

This article presents the design basis, design and construction features, highlights of thermal hydraulics and structural mechanics analyses and validation studies carried out to enhance the confidence on the functionality and structural integrity of main vessel cooling system for the 500 MWe Prototype Fast Breeder Reactor (PFBR). Figure 1 depicts the schematic sketch of the cooling system integrated with the associated components in the main vessel of PFBR.

Design Specifications

Process Requirements

The main vessel needs to be cooled in the cylindrical portion over a height of ~5 meter (7.5 to 12.5 meter from the bottom), which is facing the radial heat flux emanating from the hot pool (Figure 1). It is worth mentioning that, if this portion is not cooled, the straight portion of the main vessel would have attained the temperatures similar to that of inner vessel, i.e., 400°C to 550°C reflecting the hot pool temperatures. Hence, to maintain the main vessel within non-creep regime (430°C), in the creep cross over curve, recommended by RCC-MR, the net heat flux from the inner vessel to be removed is 33.3 kW/m^2 during normal operating condition.

Conceptual Design Features of Main Vessel Cooling System

To meet the process requirement described above an annular space is created by introducing a co-axial shell (outer thermal baffle) adjacent to main vessel, along which the required cold sodium is allowed to flow upward, thereby removing the heat flux emanating from the inner vessel. The outer thermal baffle is also called 'weir shell'. The sodium stream overflows from the weir shell at its top edge ('crest'), joining back to the cold pool. To accomplish this, another co-axial shell ('inner baffle') is introduced between weir shell and inner vessel. With the introduction of the inner and outer thermal baffles, the sodium plenum confined between the inner vessel and main vessel, is basically separated into three compartments: (1) cold plenum between the inner vessel and inner baffle merging with the cold pool, (2) restitution collector confined between the inner baffle and outer baffle and (3) feeding collector between the weir shell and main vessel. The required flow is fed to the feeding collector from the sodium plenum confined below core support structure, through discrete pipes and the core support structure plenum, in turn gets the flow from the pressurized plenum in the grid plate, through predetermined annular space between the grid plate sleeve and foot of the each fuel subassemblies. The cold sodium plenum below core support structure, feeding and restitution collectors, weir shell, inner baffle and pipes connecting the core support structure plenum and feeding collector constitute the main vessel cooling circuit. The system is designed and manufactured respecting nuclear safety class 2 requirements. However, the weld connecting the weir shell with main vessel shall meet the class-1 rules of RCC-MR.

Flow requirement

A leak tight cold sodium plenum is created within core support structure, which is fed by sodium from grid plate, pressurized to ~8 bar by two primary pumps. The sodium pumped to the grid plate (7 t/s) flows into the sleeves through the holes provided in them in the first stage. Subsequently 91 % of sodium flows inside the subassembly through the holes incorporated in the foot of each subassembly, ~3% leaks upward through the foot seating surface to flow through the inter-space between the wrappers and ~6% is allowed to leak downward to reach the plenum inside core support structure through the annular area between the grid plate sleeve and foot. The required pressure in the plenum is developed by dropping the pressure from 8 bar in the grid plate to the required value (~1.5 bar in the plenum) to maintain the sodium flow in the feeding collector, which is achieved by appropriate labyrinths machined on the foot of the subassembly. Figure 2 depicts the source of sodium flow to the cooling system.

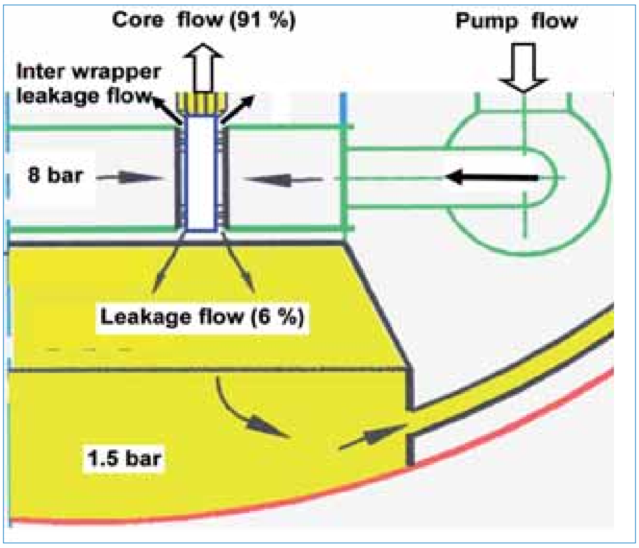


Figure 2: Source of sodium flow to cooling system

Design constraints

Elevation of Baffle Junctions

An annular plate is introduced to connect the bottom edge of outer baffle with the main vessel at an elevation (J_1 indicated in Figure 1), where the temperature is just equal to cold pool temperature (400°C) and above which, the temperature rises because of radial heat flux from the inner vessel. The sodium stream overflowing from the weir shell joins to the cold pool at the appropriate elevation (J_2 indicated in Figure 1) such that the temperature difference between the injected sodium and the sodium pool temperature at that location would be acceptable (~30°C) to avoid the risk of thermal striping. For PFBR, J_1 = 7.5 meter and J_2 = 8.7 meter from main vessel bottom.

Elevations of Free Levels

The free level differences between sodium in inner vessel (L3) and cold plenum (L1) should provide necessary pressure head (L3-L1) to facilitate the primary sodium flow through intermediate heat exchangers (IHX) overcoming the associated pressure drop (~1.5 meter head of sodium column). The sodium free level in the feeding collector (L4) should be ≥ the level in the inner vessel (L3) to ensure that the flowing sodium covers the entire region of the radial heat flux. The sodium level in the restitution collector (L2) should lie in-between the free levels of sodium in the feeding collector (L4) and cold plenum (L1). This choice is crucial and should be selected based on the following two considerations:

There should not be any risk of fluid elastic instability of outer baffle (weir shell) for which the free fall height of sodium should be shorter and should not lie in the unstable regime (critical fall height 'vs' flow rate over the weir shell). Based on the analysis, the fall height of 300 millimeter is fixed during normal operation by introducing appropriate friction loss coefficient in the exit holes drilled in the annular plate connecting the inner baffle with the weir shell.

There should not be any risk of dynamic buckling of thermal baffles under seismic loadings. Higher level difference between the feeding and restitution collectors impose higher external pressure on the weir shell, hence higher risk of buckling of weir shell. If shorter difference is apportioned to the weir shell, the inner baffle would be subjected to higher external pressure to respect the net pressure head of 1.5 meter.

Optimum Radial Gaps between Baffles

An optimum annular space is arrived at taking into account of various factors, viz., minimum manufacturing tolerances on radius that can be achieved, net effect on main vessel diameter, flow velocity restrictions from erosion point of view and access for welding and inspection of other associated structures, such as an annular plate to connect the main vessel and baffle, inlet coolant pipe nozzles and flow distributor plates to be introduced to achieve uniform axial flow over the circumference of the vessel. The annular radial gap between the inner baffle and outer baffle (the one adjacent to main vessel) is again dictated by the same considerations that governed the choice of gap between main vessel and outer baffle. For PFBR, the optimum radial gap arrived at is 90 millimeters for both feeding and restitution collector plenums.

Weir Shell Crest Profile

One of the sources of argon gas entrainment into primary sodium is the weir shell and hence sodium should not get separated from the weir shell surface. This also has another advantage that the terminal velocity of sodium on the restitution collector surface would be minimum due to the friction force developed on the surface. This is achieved by attaching a thick circular ring with a profile that can meet the above requirements. Detailed experimental investigations have been carried out on weir shell profile to assess flow separation, gas entrainment and liquid film thickness over weir shell. The full scale slab model of water-air system is based on Froude similarity, wherein the fall height and water flow rate have been varied as parameters. Variation of liquid film thickness over the outer thermal baffle has been measured by a special conductance cum position sensor (Figure 3). Measured film thickness and the subsequent numerical integration of the governing equations suggest that there is no flow separation in the chosen profile of weir-crest. It is found that gas bubbles entrain in the restitution plenum for all fall heights greater than ~100 millimeter irrespective of the flow rate. However, all the entrained air bubbles bubble out to free surface. They penetrate to a maximum depth of only 700 millimeter. This depth is only about ¼th the depth of sodium available in the restitution plenum and hence, it is established that there is no fear of gas entrainment in main vessel cooling system.

Number of coolant pipes

The sodium present in the core support structure plenum enters the feeding collector through dedicated pipes. If sufficient number of pipes is not selected, in case of any random failure (rupture) or blockage of one or two pipes, there could be a stagnant zone in the feeding collector, thereby causing unacceptable circumferential temperature

Figure 3: Weir – Crest testing full scale water model & water film thickness being measured by a special conductance probe connected to data acquisition system

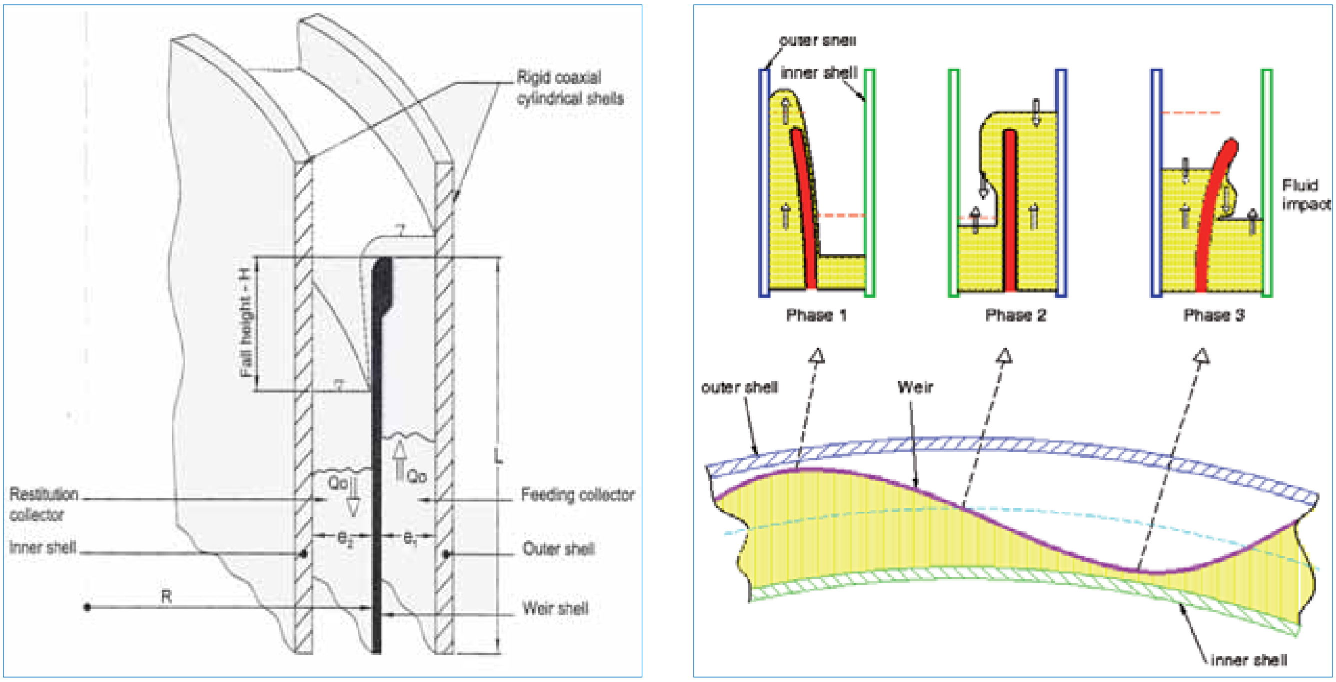


Figure 4: Schematic sketch of idealised cooling system and weir instability mechanism

gradients and the absolute temperatures can exceed the proposed limit of 430°C. Larger number of smaller pipes needs higher pressure head at the core support structure plenum and poses welding problems. Based on extensive parametric studies and hydraulic tests by postulating one pipe ruptures or one pipe blockage, 24 numbers of 83 millimeter diameter pipes were selected. The layout of the pipes has been finalized by respecting the structural integrity requirements for protecting against flow induced vibration, seismic stresses, fatigue damage and mechanical interactions with the adjoining main vessel surface.

Confirmation of Flow Rates under Various Operating Conditions

In the design conceived, the flow to the cooling pipes depends upon the pressure head developed by the pump. As per the operation strategy of PFBR, the core flow at 20 % power level is 50 % of nominal pump flow and corresponding hot pool temperature would be 475°C. 3D thermal hydraulics analysis of cooling system for one pipe rupture, one pump blockage and non-uniformity of the radial gaps (± 15 mm) both under 100 % and 20 % power levels have been carried out and confirmed that the highest main vessel under these condition do not exceed 410°C against the acceptable value of 430°C. Sufficient number of thermocouples are embedded in the main vessel outer surface to monitor the same. It is possible to adjust the flow by way of changing the shape and dimensions of the labyrinths machined on the subassembly foot.

Structural Integrity Assessment: Highlights of Results

The weir shell, inner baffle and pipes are analysed for flow induced vibrations and buckling, which are the critical failure modes. Creep-fatigue damage is estimated as per RCC-MR:2002 at the inlet and outlet nozzles, when the cooling pipes are subjected to thermal transients following the postulated failures of secondary and boiler feed water pumps. Based on these investigations, the structural integrity is assured with comfortable margins. Two advanced theoretical and experimental analyses carried out for the

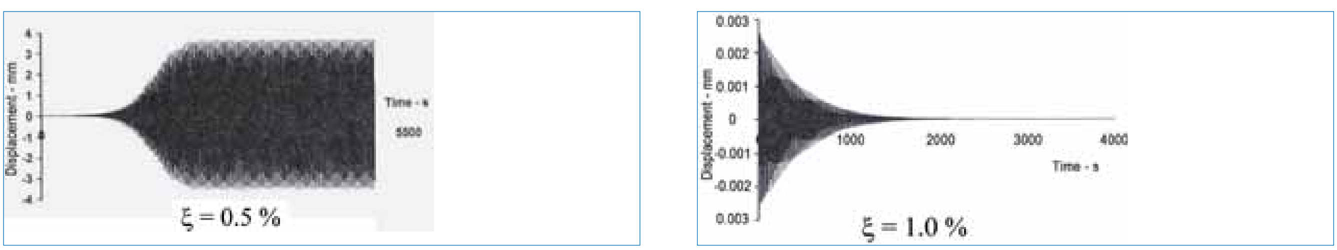


Figure 5: Displacement of PFBR weir shell during fuel handling condition

investigations of flow induced vibration and buckling under seismic loadings are highlighted below.

Fluid-elastic Instability of Weir Shell

When the sodium flows over the weir shell and falls back on the free level of restitution collector, dynamic fluid forces are developed on the free surfaces of feeding and restitution collectors due to sloshing of liquid surfaces under small perturbation of weir shell. These forces enhance the shell displacements, resulting in unstable vibration, termed as fluid elastic instability. This phenomenon is illustrated in Figure 4.

With the fundamental understanding, self induced fluid forces on the weir shell due to sloshing of liquid free levels are identified and analytical expressions are derived. Using the modal super position principles, the modal based non-linear dynamic equilibrium equations are written. Subsequently the equations are solved by direct integration technique using Newmark-β method using the natural frequencies and mode shapes computed numerically through CAST3M 2000 code. Evolution of weir displacements and wave heights are obtained for the experimental benchmark problem which simulates 1/5 scale model of DFBR, the Japanese fast breeder reactor. The fall time and dynamic responses are predicted satisfactorily even with a few available input data. Subsequently, PFBR weir shell was analysed and noted that the flow rate and associated fall height during fuel handling condition are critical. Further, the analysis also indicated that the weir shell vibrations are negligible for the damping value >1 % and for the damping of 0.5 %, the maximum amplitude is ~ 3.5 millimeter (Figure 5).

From the literature it is confirmed that the minimum damping of weir is >1 %. Hence, weir shell would be stable during fuel handling operations and thereby satisfying all the operating conditions. The computer code developed for this analysis has been used for understanding the phenomena and similarity principles, apart from using for analysis of weir shell response of thermal baffles of PFBR.

Hydraulic tests on the full scale sector water mockup were conducted to identify the instability zones and compared with the theoretical predictions. The study has shown excellent comparison on dynamic displacement of weir shell crest as well as the instability regimes (Figure 6).

Dynamic Buckling under Seismic Loads

The critical thin walled shell structures in the reactor assembly of SFR, in general, are the main vessel, inner vessel and thermal baffles. On these structures, the seismic events impose major forces by developing high dynamic pressures, thereby causing a great concern on structural integrity due to buckling. An integrated analysis for determining realistic forces and critical buckling loads at any instant during the seismic event has been carried out for the reactor assembly vessels of PFBR. The dynamic forces including pressure distributions generated on the vessel surfaces are determined by seismic analysis of reactor assembly with time history approach based on 3-D seismic analysis. Subsequently, elasto-plastic analysis is carried out at the critical time steps which are identified based on strain energies that are associated with the shear and compressive stresses developed at the portions of the vessels prone to buckle. The shear buckling modes of thermal baffles are found to be important. The design code RCC-MR (2002) specifies a requirement of minimum 1.3 factor of safety on the computed critical buckling load for the safe shutdown earthquake (SSE), categorized as level D loading. This means that the minimum critical buckling load

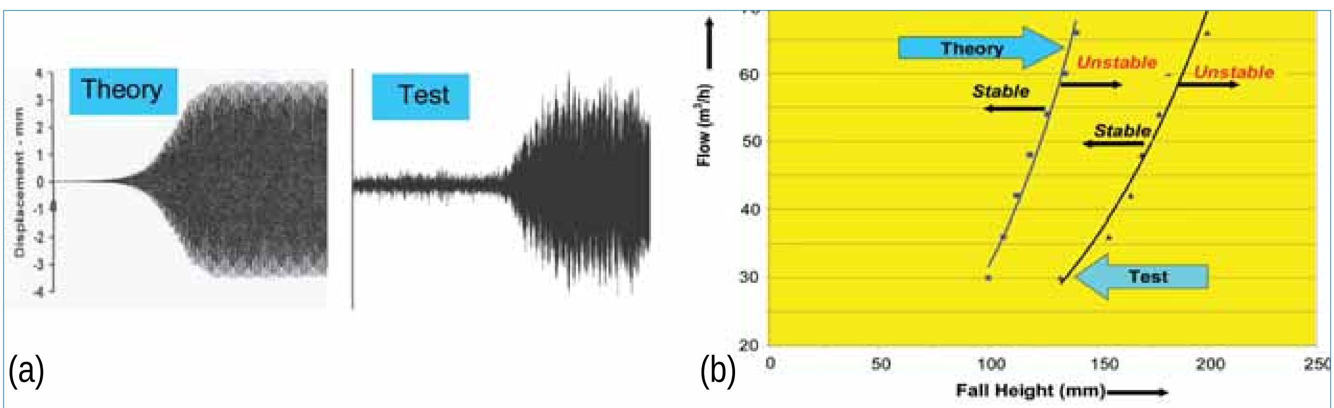


Figure 6: Theoretical and experimental simulation of weir instability
a) Dynamic displacement of crest of thermal baffle and b) Weir instability regimes

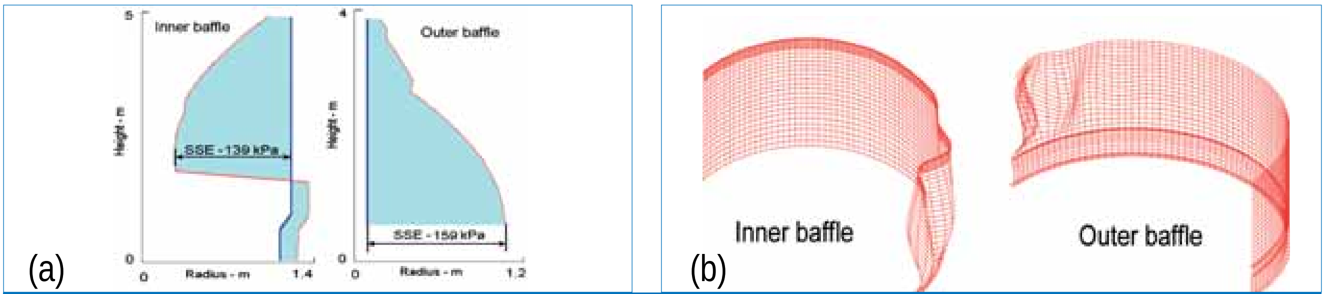


Figure 7: Results of dynamic buckling analysis (a) Peak dynamic presure distributions and (b) Critical buckling modes in shear

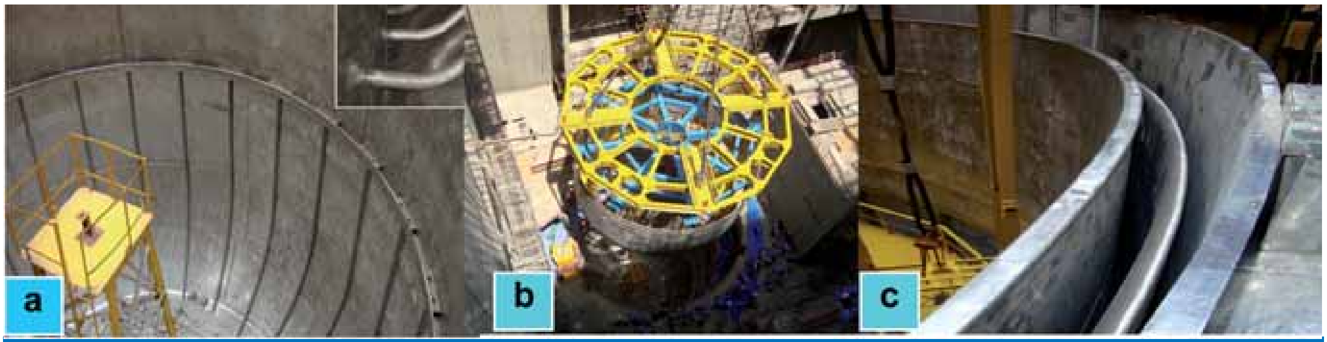


Figure 8: (a) Cooling pipes, (b) Thermal baffles and (c) Integration with main vessel

should be more than 1.3 times the imposed load under safe shutdown earthquake. The minimum load factor computed for inner and outer thermal baffles are 2.56 and 2.4. Thus, it is demonstrated that the thermal baffles respect the buckling design criteria of RCC-MR. Figure 7 shows the peak dynamic pressure distributions and also critical buckling modes of inner and outer thermal baffles.

Construction of Cooling System

The thermal baffles are basically thin shells of high slenderness ratio (Diameter/thickness = 12300/15 = 820), which have to be manufactured with stringent form tolerances, since they have high impact on the wall thickness required for protecting against vibration and buckling risks. Further, the main vessel diameter depends on the form tolerances of the thermal baffles. Since main vessel and cooling system are manufactured independently at two different industries, manufactu-ring tolerances at the interface have to be tight to respect the construction code requirements on weld mismatch, in particular. Further, the weir shell has to be welded to main vessel, which has to respect the class-1 weld inspection requirements, and hence weld sequences are to be selected carefully. These apart, the handling of thin shells of the cooling system should and also be carried out carefully without introducing any permanent deformations.

The challenges addressed above have been met and thermal baffle system has been satisfactorily manufactured by M/s. BHEL, Trichy. The structure was transported, erected and welded with the main vessel (manufactured by M/s. L&T) successfully, with the systematic planning by IGCAR and BHAVINI. Figure 8 depicts a few photographs taken during manufacturing and erection stages.

Conclusion

The cooling system of main vessel calls for introduction of novel design and construction features, which have been realized for PFBR. The advanced computer codes and analysis and experimental techniques that have been developed would be useful for the future Sodium-cooled Fast Reactors, being conceived nationally and internationally. It is worth putting efforts to eliminate the main vessel cooling to facilitate reduction in main vessel diameter and freedom from vibration of cooling system. Further, there is no requirement for sophisticated analysis, expensive testing and manufacturing technology. This could be achievable with the application of realistic high temperature design rules of RCC-MR:2007, state-of-art viscoplastic analysis computer codes developed at Nuclear Engineering Group, feedback of creep-fatigue and ratcheting tests conducted at Structural Mechanics Laboratory, development of advanced stainless steels including data generation at Metallurgy and Materials Group.

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

Development of Carbon Microspheres for Extinguishing Sodium Fire

Combustion of sodium depends on many factors such as temperature of sodium, percentage of oxygen, moisture content of atmosphere, velocity of air, surface area and depth of the sodium pool. The method of extinguishing sodium fire should enable effective isolation of the metallic surface from the ambient atmosphere. A good sodium fire extinguishment should be neither a combustible material nor a supporter of combustion and compatible with liquid sodium. It should be stable, non-hygroscopic, free flowing, inexpensive, freely available, easy to dispose and with density less than 0.8 g /cm^3 . It should rapidly cool the metal in order to reduce the possibility of re-ignition and the quantity of powder required per unit area of sodium fire should be small. Commonly used sodium fire extinguisher (sodium bicarbonate – DCP) neither dissolves in water nor does permit its easy removal after application over sodium fire, making disposal of residues a pain-staking job. A novel application of carbon was envisaged in extinguishing sodium fire. It can be directed on to sodium fire from an extinguisher with conventional nozzle. It extinguishes sodium fire first by covering the metal surface and thus separating the metal from an oxygen source and secondly by conducting heat away from the burning sodium. The excellent flow characteristics, high thermal conductivity, chemical inertness and non-smoking properties of these microspheres suggest an effective way to extinguish sodium fire. Once the fire is extinguished, the metal can be easily recovered since no actual reaction occurs between the carbon microspheres and the metal to produce undesirable contaminants. This article focusses on the successful development of carbon microspheres and their characterisation. A high temperature carbonization process yields carbon microspheres with high purity and uniform diameters. A stepwise carbonization process had been developed for the synthesis of carbon microsphere from sulphonated styrene-divinylbenzene resin. In order to prevent the oxidation of sulphonated styrene-divinylbenzene an autoclave made up of stainless steel was fabricated. The stainless steel vessel (Figure 1) should possess leak tightedness at high temperature (1123 K), hence knife edged flange with copper gasket was welded to the top of cylindrical stainless steel vessel. Argon inlet and outlet were provided in the stainless steel vessel for purging.

Figure 1: The stainless steel vessel with knife edged flange

The sulphonated styrene-divinylbenzene resin was washed with methanol and dried under Infra Red lamp. The dried sample was transferred into the leak tight stainless steel vessel and placed in a muffle furnace. Argon gas was purged into the vessel at a flow rate of 200 ml/minute. Heating was carried out at various temperature zones for given time intervals. In this process, elimination of water, sulphurdioxide and hydrogen will occur at three temperature zones. Sulphonated styrene-divinylbenzene was heated to 373 - 473 K for the elimination of water molecules, 573 – 773 K for the elimination of sulphurdioxide and 1023 – 1123 K for the elimination of hydrogen by condensation processes. The time of heating at each temperature zone was optimized.

The carbon product was further purified using sintering technique by heating in air at 1173 K. The partially carbonized carbon microspheres were oxidized leaving behind the pure carbon microspheres. The fine powder of carbon microsphere was analyzed for completion of carbonization, functional group evaluation, structural morphology, topography and thermal stability.

Fourier Transform Infra Red spectroscopic analysis of carbon microsphere indicated deformation of aromatic ring, presence of sulphone group (to a large extent) and aromatic C=C (double bond) in the compound Analysis of carbon microsphere using MSAL-XD2 X-Ray Diffractometer reveals the presence of two peaks at d = 3.7308 A^o and d = 2.0623 A^o which are reflection from

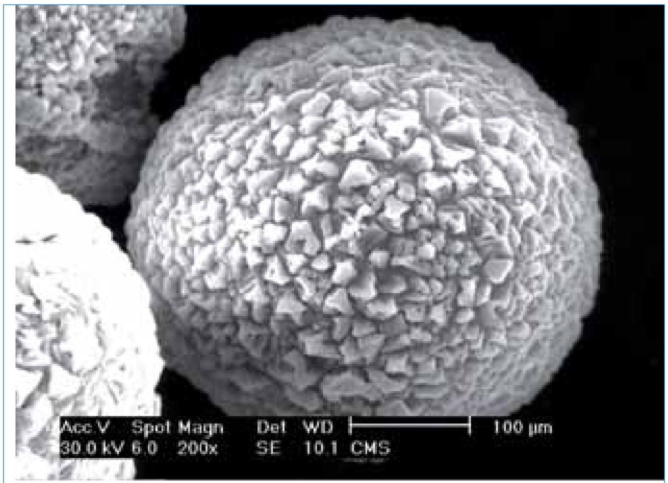


Figure 2 SEM image of carbon microsphere

(002) and (101) planes respectively. The peaks can be indexed to a hexagonal graphite lattice with cell constant a = 2.448 A° & c = 6.834 A°. The non-smooth pattern of the sample shows presence of both graphitized and non-graphitized carbon.

Raman spectrum of carbon microsphere has been recorded at ambient temperature. Two strong peaks at 1580 cm^{-1} as well as at 1360 cm^{-1} correspond to typical Raman peaks of carbon materials. The peak at 1580 cm^{-1} (G) corresponds to an E_{2g} mode of graphite layer. The peak at 1329.5 cm^{-1} (D) is associated with vibrations of carbon atoms with dangling bonds in plane terminations of disordered graphite. This carbon manifest intensity ratio of ID/IG=0.7 indicates amorphous carbon structure.

The Scanning Electron Microscope image of carbon microsphere showed spherical shape (400 μm dia) with rough surface (Figure 2).

Thermal stability of the carbon microspheres had been studied by Thermogravimetric analysis and the heat flow during heating was obtained from Differential Thermal Analysis curve. The gases evolved during heating of the substance was analysed by using on-line mass spectrometer. The carbon microsphere showed good thermal stability upto 1023 K and above which thermal decomposition occurs with the evolution of carbondioxide, sulphurdioxide and hydrogen. DTA analysis shows that evolution of water is endothermic and evolution of other gases such as carbondioxide, sulphurdioxide and hydrogen are exothermic.

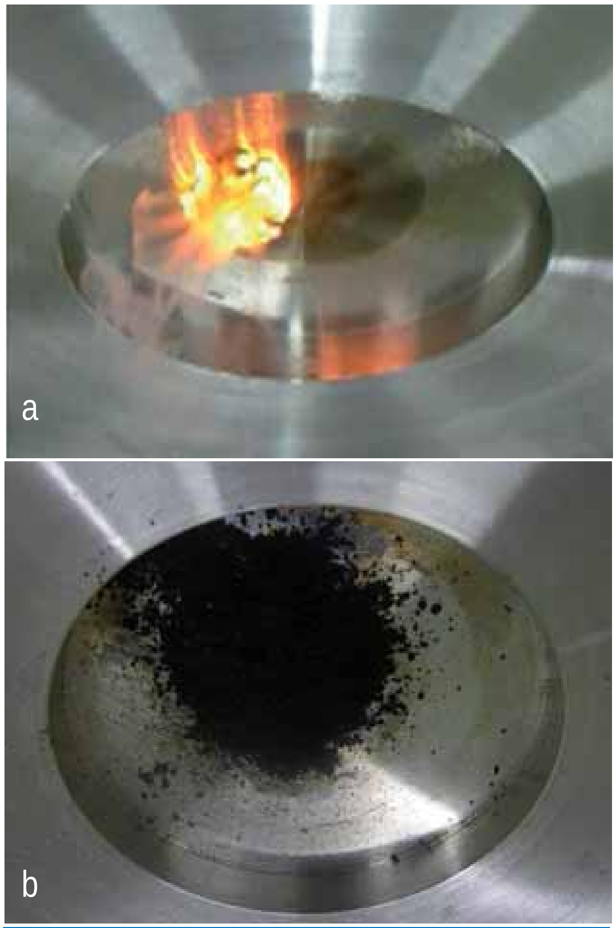


Figure 3: a) Small scale Sodium fire b) Sodium fire extinguished by carbon microsphere

The performance of the carbon microsphere in extinguishing the sodium fire was tested in small scale and it was observed that carbon microsphere formed a layer over the surface of burning sodium thereby extinguishing the sodium fire (Figures 3a and 3b). There was no secondary fire observed during this experiment. Qualifying the carbon microsphere as sodium fire extinguisher is in progress.

Having demonstrated the usefulness of carbon microspheres in extinguishing sodium fire, we are continuing our efforts to improve the properties of carbon microspheres. Density of carbon microsphere prepared in the above carbonization process is measured to be 1.56 g/cc. Efforts are being made to synthesise carbon microsphere with smooth surface and lower density. Carbon microsphere is more promising as sodium fire extinguisher due to their greater thermal stability and inertness.

(Reported by D. Ponraju and Colleagues,

Radiological Safety Division, SG)

Young Officer's FORUM

Plant design life for CFBR

Shri Kulbir Singh, obtained Bachelor of Technology (B.Tech.) degree in Mechanical Engineering from Guru Nanak Dev Engineering College, Ludhiana (Punjab) in 2005. After completing training from 2nd batch of BARC training school at IGCAR, Kalpakkam, joined Mechanics & Hydraulics Division, REG, IGCAR in September 2008.

Construction experiences of Sodium-cooled Fast Reactors (SFRs), have brought to focus the high cost of SFR as compared to Pressurized Water Reactors (PWRs) and have highlighted that considerable cost reductions are essential for their commercial deployment. Higher design life of a plant is one of the major cost reduction factors. The unit energy cost (UEC) is expressed as a function of design life and it is seen that, by increasing the design life from 40 years to 60 years, the unit energy cost is reduced by ~ 4 %. This has in fact got significant impact on economy, hence it is required to have plant with higher design life. As a follow-up to Prototype Fast Breeder Reactor (PFBR) with 40 years of design life (75 % load factor), it is planned to construct four more 500 MWe commercial fast breeder reactors (CFBRs), similar to PFBR with improved economy and safety and having 85 % load factor & 60 years design life.

Approach to Define Design Life

The life time of a component can be defined as the period during which the component can perform its intended functions safely, reliably, and economically. For future CFBRs life prediction, same plant as PFBR with corresponding operating temperature and a loading is taken. For defining the design life, all the major components are listed under two categories: permanent and replaceable. For permanent components design life of 60 years is considered. Since replacement of some replaceable components would be difficult & calls for long reactor shutdown, the design life of 60 years as that of permanent components is specified. For the other replaceable components, viz. core sub assemblies (SAs), control rods, inflatable seals in the roof slab, cold traps, etc, variable design lives are specified.

Major issues related to plant life of SFRs

Material degradation

1) Effects of sodium, 2) Thermal aging and 3) Neutron irradiation

Sodium is practically non-corrosive with controlled oxygen and carbon impurity, but exposure to flowing sodium produces changes in material properties due to carburization and decarburization. Thermal aging causes the reduction of ductility and fracture toughness in the material. Effect of thermal aging on SS-316 LN is low as compared to other austenitic steels because of low carbon contents. A neutron irradiation effect on grid plate which is critical component from dose level aspect has a value below the allowable limit. The deduction from the current data and experience reveals that material degradation issues are not influencing the design life of SFRs.

Structural mechanics aspects

The high temperature failure modes(Figure 1) could be the major life limiting factors for SFRs. Few high temperature failure modes mentioned below are very specific to SFRs

1. High cycle strain controlled fatigue damage

Sodium free level fluctuations in the vicinity of vessel, oscillation of stratified sodium layers and thermal striping are the special problems which cause strain controlled high cycle fatigue damage. Permissible temperature difference limits ΔT_p for SFRs are shown in Figure 2. At all locations of thermal striping and stratification ΔT metal is well below

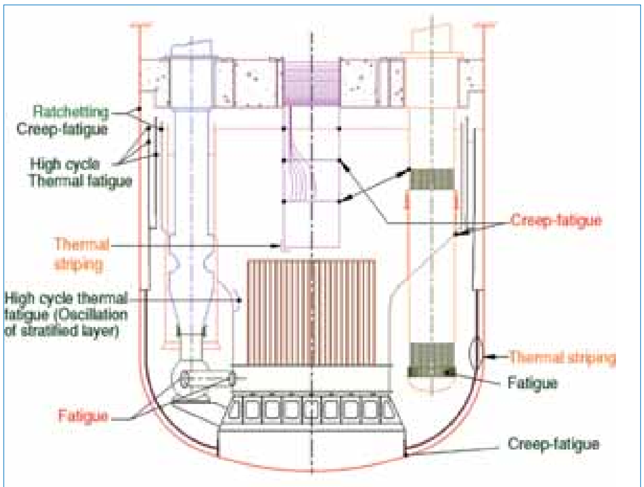


Figure 1: High temperature failure modes

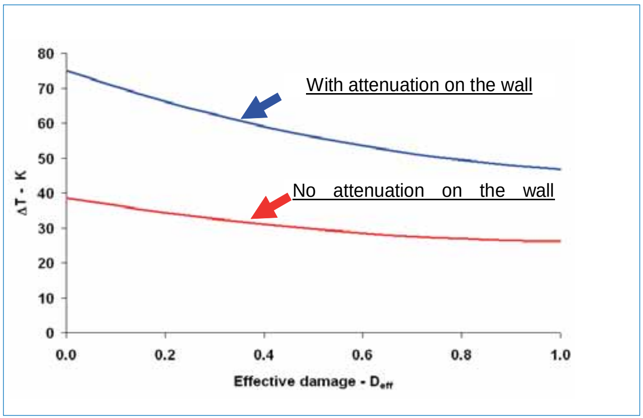


Figure 2: Permissible ΔT_p limits for the SFR structures, made of SS 316 LN

the permissible limit for corresponding creep-fatigue damage value. Hence the high cycle strain controlled fatigue damage is not the concern for 60 years of plant design life for future CFBRs.

2. Thermal ratcheting

The sodium free levels vary slowly following the changes in the hot and cold pool temperatures depending upon the operating condition. The level variations cause large temperature and stress variations which effects main vessel (MV) severely. The '23-Parameter Chaboche Viscoplastic Model' is used for predicting the ratcheting strain. Max deflection (~15 mm) due to ratcheting is less than MV thickness (25 mm), hence no risk of buckling. Maximum accumulated hoop strain after 60 years is ~ 0.3 % which is lower than acceptable value of 0.5 % for welds

3. Creep fatigue damage

The creep-fatigue damage is assessed for the high temperature components, viz. main vessel, control plug, inner vessel, intermediate heat exchanger (IHX) and steam generator (SG), as per RCC-MR code. Table I indicates that the governing component from creep fatigue damage point of view for the CFBR is IHX, which is having the effective damage (D_{eff}) of 0.686 for 60 years with permissible life of ~ 85 years. Hence design life of 60 years is comfortable for future CFBRs.

Table I: Creep Fatigue Damage (For 60 y of design life)

Component	Load cycle/ annum	Hold time/ cycle (h)	Creep Damage (D_c)	Fatigue Damage (D_f)	D_{eff}
Main Vessel	4SGDHR(*)	24	0.030	0.0105	0.054
Inner Vessel	19 Scrams	350	0.075	0.0225	0.128
Control Plug	19 Scrams	350	0.540	0.0075	0.558
IHX	22 Shutdowns	305	0.675	0.0045	0.686
SG	22 Shutdowns	305	0.450	0.0450	0.555

*Safety Grade Decay Heat Removal

Table II: Adequacy of tube wall thickness for SG

Location	Design Life	Minimum Thickness (mm)	Net allowance (mm)	Net Thickness Required (mm)
Tube	60	1.498	0.606	2.104
At weld	60	1.536	0.856	2.392
At belt (Support location)	60	1.498	0.954	2.452

4. Design of IHX and SG tubes with loss of tube wall thickness

Tube thickness for IHX with corrosion allowance and tolerance is adequate. Fretting wear at support is a concern for 60 years of design life. In view of pessimistic value of fretting wear rate and also as IHX is replaceable component, it is judged that IHX can have 60 years of design life.

Bend tubes of 17.4 millimeter OD and 2.4 millimeter nominal wall thickness would be used for SG of CFBR. The thickness requirements for steam generator at different locations are presented in Table-II. For 60 year design life steam generator tube thickness should be ~ 2.452 millimeter from fretting wear consideration at support location. This would be due to conservative analysis and higher factor of safety in calculating fretting wear rate. With provision of in service inspection (ISI) of steam generator tubes loss of thickness at support location can be monitored regularly, and hence it is judged that steam generator can have design life of 60 years.

Conclusion

- Based on technical and economical requirement, a design life of 60 years is acceptable for permanent components.
- For the replaceable components such as pumps,fuel handling components and secondary circuit components including Steam Generator (SG), considering the economics, 60 years design life is specified.
- The limiting factor for 60 years of design life for IHX is fretting wear rate which will be investigated, as present value is pessimistic.

(Reported by Kulbir Singh,
Mechanics & Hydraulics Division, REG)

Young Researcher's FORUM

Phase Behaviour of Thermo-Responsive Nano/Microgels

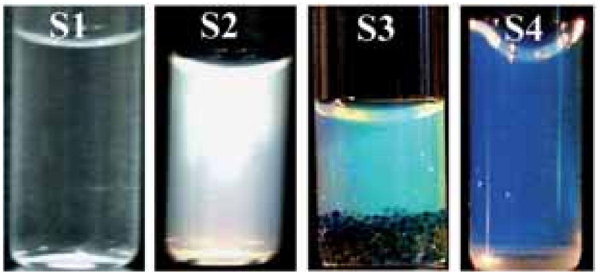
Ms. J. Brijitta obtained her M.Sc Degree from PSGR Krishnammal College for Women, Coimbatore and M.Phil. degree from St. Joseph's College, Trichy. She holds a university rank for M.Sc. and a gold medal in M. Phil degree. She is an UGC-DAE CSR scholar pursuing her doctoral degree under the guidance of Dr. T. Kaliyappan, Pondicherry University and Dr. B. V. R. Tata in the Condensed Matter Physics Division, Materials Science Group. Her expertise is on the synthesis, characterization and phase behaviour of thermo-responsive nano/microgel dispersions. She has published four international journal papers and five papers in national proceedings. She has attended ten national/international conferences and won two best paper awards in two international conferences.

Nanoparticle dispersions are studied with considerable interest not only because of their fundamental interest in understanding the co-operative phenomena such as structural ordering, crystallization and glass transition but also for their practical use in a wide range of disciplines including, photonics, optical devices, sensors, drug delivery and bio-separations. Some of these applications use ordered arrays of nanoparticles 'self-assembled' by sedimentation, centrifugation etc. The system of monodisperse nanoparticles can thus serve as super-atoms and exhibits structural ordering analogous to that observed in atomic/molecular systems. In the case of conventionally investigated nanoparticle dispersions such as, polystyrene, polymethylmethacrylate, silica etc, the particle size is fixed and temperature (T) is not a controllable parameter to investigate the phase behavior. However there exists a novel nanoparticle dispersion comprised of thermo-responsive nano/microgel particles of poly(N-isopropylacrylamide) (PNIPAM), wherein particle size is tunable by varying T and hence the volume fraction ϕ and the interparticle interactions. Thus it will be of interest to investigate the phase behavior of these nanogel dispersions by merely varying the temperature which is otherwise is not possible in conventional nanoparticle dispersions.

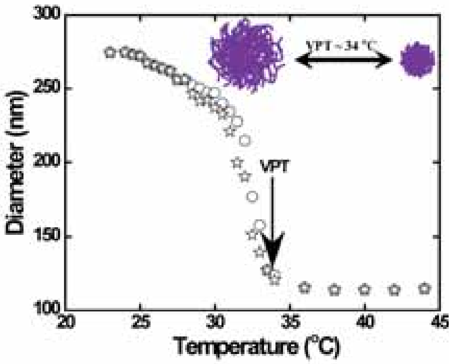
Structural Ordering and Phase Transitions in poly(N-isopropylacrylamide) Dispersions

In order to investigate the phase behaviour, aqueous dispersion of thermo-responsive poly(N-isopropylacrylamide) nanogel particles has been synthesized by free radical precipitation polymerization. Samples of varying number density, n_p, have been probed for their temperature dependant phase behavoiur using static and dynamic light scattering techniques (SLS/DLS) and real space structure using confocal laser scanning microscopy (CLSM). Effect of temperature on particle size is carried out on a dilute sample S1 (Figure 1) with $n_p = 4.36 \times 10^{11}$ cm^{-3} using dynamic light scattering technique. At 25°C the average hydrodynamic diameter of the nanogel particles is found to be 273 nm with size polydispersity < 1%. Upon increasing the T, the particle size decreased and at 32.4 °C the nanogel particles suddenly collapsed to 110 nm. This sudden transition in volume of the particles is identified as the volume phase transition (VPT). This transition is found to be reversible upon lowering the temperature.

Sample S2 with increased $n_p = 4.36 \times 10^{12}$ cm^{-3} appeared slightly turbid but did not exhibit iridescence even after repeated annealing. Static light scattering studies on this



(a)



(b)

Figure 1: (a) Photographs of samples S1, S2, S3 and S4 with varying n_p. (b) Dependence of Poly(N-isopropylacrylamide) (PNIPAM) particle size as function of T. Arrows indicates the volume phase transtiton temperature

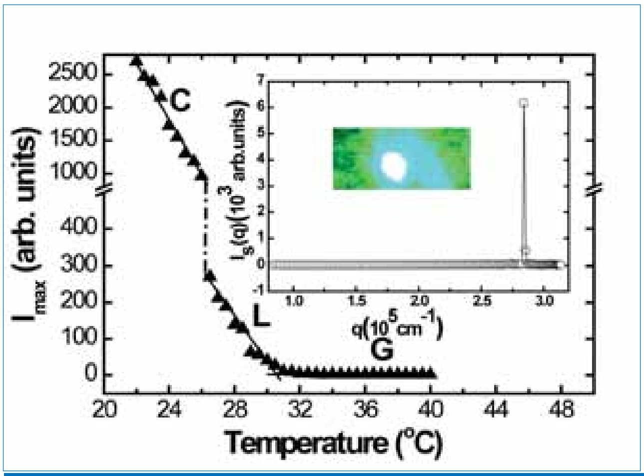


Figure 2: Bragg peak intensity $I_{max}(q)$ as a function of T for sample S3. C, L, and G represent the temperature region where sample S3 exhibits crystalline, liquid-like and gas-like disorder, respectively

sample revealed fluid (liquid-like) to fluid (gas-like) transition at ~ 31.5 ºC.

Crystalline, Melting and Fluid-Fluid Transition

Sample S3 which is ten times more concentrated than sample S2 with n_p = 8.71×10^{13} cm^{-3} showed iridescence upon repeated annealing above volume phase transition due to the Bragg diffraction of visible light. A sharp Bragg peak at q = 2.84 × 105 cm^{-1} (inset Figure 2) is observed by performing SLS measurements using a 488 nm Argon ion laser. The observation of iridescence and a sharp Bragg spot (inset in Figure 2) suggests that sample S3 is crystalline and has several single crystals. The melting transition of these poly(N-isopropylacrylamide) nanogel crystals is identified by monitoring the Bragg peak intensity I_{max} as function of T (Figure 2). The sudden drop in I_{max} at 26.2ºC is due to the melting of poly(N-isopropylacrylamide) nanogel crystals into a liquid-like order. Further, the Bragg peak position remained the same across the melting transition, which suggests no change in n_p across this transition. Upon increasing the temperature beyond the melting point of poly(N-isopropylacrylamide) nanogel crystals, the peak intensity decreased and showed a change in slope at 30.5ºC. Beyond 30.5ºC, the structural ordering in the suspension is found to be gas-like. Thus the change in slope observed at 30.5ºC is due to the occurrence of fluid to fluid transition similar to that observed in sample S2.

SLS/DLS studies on sample S4 have shown that the structural ordering is glass-like.

Random HCP and FCC Structures in PNIPAM Microgel Crystals

In order to study the real space structure of the PNIPAM crystals using CLSM, aqueous suspension of 520 nm poly(N-isopropylacrylamide) microgel particles have been synthesized. From this suspension two samples are crystallized by two different routes (1) as-prepared sample and (2) recrystallized sample. The real space structures of these two samples having ϕ=0.43 are determined using a CLSM. CLSM images of several regions of the microgel crystal are analyzed for determining the in-plane (2D) and 3D pair-correlation functions (g(r)) and the stacking sequence for both the crystals. The stacking disorder in the PNIPAM microgel crystals is quantified by analyzing the stacking sequence of the crystalline planes along the Z-direction. From the stacking sequence the stacking probability, α is determined. The consecutive three images in a region are assigned pseudo colours RGB (red, green and blue) for A, B, C planes and then merged these images. If the RGB colors are seen distinctly (inset Figure 3B) after merging, then it can

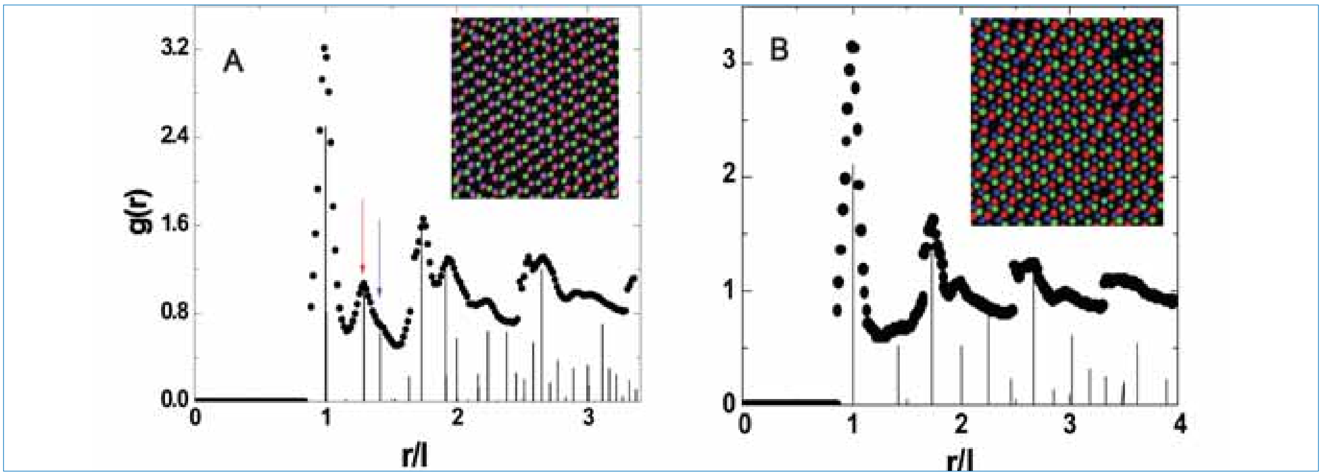


Figure 3: 3D g(r), for the PNIPAM microgel crystal in (A) the as-prepared sample; arrows indicate the positions of the peaks in the split second peak and (B) the re-crystallized sample. Insets: Merged image of the three layers in the PNIPAM microgel crystal revealing (A) hcp-type stacking and (B) fcc-type stacking.

be a fcc-type of stacking; whereas if two of the colors merge (inset Figure 3A) then it can be hcp-type of stacking.

The as-prepared sample had stacking disorder with an average stacking probability $\alpha \sim 0.42$ which along with the analysis of 3D g(r) (Fig. 3A) revealed the structure of microgel crystals in this sample to be random hexagonal close packing (rhcp). Further, for the first time a split second peak is observed in the 3D g(r) (arrows in Fig. 3A) of the as-prepared sample. A split second peak is usually observed in glasses. It is shown through simulations that the split second peak arises due to the displacement of 57% of the B-planes from the ideal hcp positions.

The as-prepared sample is melted by heating it above VPT and recrystallized it at a cooling rate of 0.15 °C/min. The recrystallized sample is subjected to CLSM studies similar to that mentioned above. Surprisingly, the split second peak disappeared and the peaks in the 3D g(r) (Fig. 3B) matched with that of the simulated ideal fcc structure. Further, the stacking probability α determined by analyzing the stacking sequences is found to be close to one. Thus it is concluded that the structure of the PNIPAM microgel crystals in the recrystallized sample is fcc. Present observations reveal that the PNIPAM microgel crystals prepared by two different routes lead to two different crystal structures of the same system.

PNIPAM-CdTe QDs Nanocomposites for Binary Imaging

The study of binary colloidal alloys in real space requires the identification of the individual colloidal particles for fluorescence imaging. So far the studies involving binary colloidal dispersions, the two different colloidal particles are distinguished from each other by labelling them using two different fluorescent probes such as organic dyes. However most of the organic dyes such as FITC, RITC are prone to photo-bleaching during the experimental run time itself. Moreover, the two dyes need to be excited using two different excitation wavelengths. These limitations can be overcome by making use of semiconductor quantum dots (QDs); QDs have size tunable emission colour, narrow emission profile and high photo-stability. Towards this aqueous suspension of cadmium telluride (CdTe) QDs capped with thiol groups having their characteristic emission at 529 nm (green luminescent) and 590 nm (red luminescent) have been synthesized. A novel method for preparing green and red luminescent PNIPAM-CdTe QDs nanocomposites have been achieved by incorporating the CdTe QDs into the PNIPAM particles of 730 nm by incubating them at 45°C for 48 hours. This resulted in the loading of the QDs into the PNIPAM particles due to the formation of effective hydrogen bonding between the amide groups of the PNIPAM and thiol capping on the CdTe QDs. The photoluminescence intensity of the red luminescent composites is matched with that of the green luminescent nanocomposites by loading more red luminescent QDs into the PNIPAM particles followed by incubating them for 60 hours. A 1:1 mixture of the green and red luminescent PNIPAM-CdTe nanocomposites is used for fluorescence imaging using CLSM. For the first time the binary dispersion of PNIPAM-CdTe QDs nanocomposites is imaged simultaneously using a single wavelength (488 nm) excitation. Figure 4 shows the true colour confocal fluorescence images of the binary dispersion of PNIPAM-CdTe QDs nanocomposites.

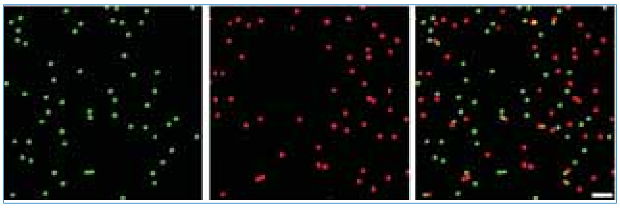


Figure 4: True colour confocal fluorescence micrographs of binary dispersion of PNIPAM-CdTe QDs nanocomposites (A) and (B) green and red fluorescence of the nanocomposites captured in two fluorescence channels and (C) overlay of (A) and (B). Scale bar, 3μm

The novel findings of the present study are (a) first report of fluid to fluid transition in PNIPAM nanogel dispersions which exhibited liquid like and crystalline order (ii) the structure of the PNIPAM microgel crystals depends on the way they are prepared (iii) first observation of a split second peak in the 3D g(r) of the as-prepared PNIPAM microgel crystal (iv) first report of real space imaging of a binary dispersion of PNIPAM particles incorporated with CdTe QDs using single wavelength excitation. The phase transitions reported here are useful for developing temperature sensors, optical switches, and drug delivery applications. The PNIPAM-CdTe QDs nanocomposites can be used as markers for biological labeling.

(Reported by J. Brijitta
Condensed Matter Physics Division, MSG)

News and Events

Report on BITS Practice School

May 24, 2010

BITS PS I Students with Shri S.C. Chetal , Director, REG during interaction session

Twenty five students from BITS Pilani (Pilani and Goa campuses) underwent BITS practice School for seven weeks at our Centre. Dr. P.R. Vasudeva Rao, Director, Chemistry group inaugurated the BITS practice School at IGCAR on May 24th 2010. The BITS practice school bridges the professional world with the educational world. The course aims at exposing the students to industrial and research environments, on how the organizations work, to follow and maintain work ethics, study the core subjects and their application in the organization, participate in some of the assignments given to them in the form of projects. The students were from various engineering disciplines like, Mechanical Engineering/Computer Science/ Electrical & Electronics/Electronics & Instrumentation and Electronics and Communication Engineering. Students carried out challenging projects at various divisions in line with their discipline. During their period of stay they visited various facilities at IGCAR, BHAVINI and MAPS. Group discussions, seminars, project work presentation and report writing formed the practice school curriculum. On completion of the practice school, Dr P. Chellapandi, Director Safety Group and AD, NEG, distributed certificates to the students during their valedictory function. Shri S.C.Chetal Director REG, had an interaction session with the students on one of the days during practice school.

(Reported by M. Sai Baba, Coordinator-BITS Practice School)

BITS PS I Students and guides with Dr P Chellapandi during Valedictory Function

News and Events

Graduation Function of Fourth Batch of Training School Officers

September 2, 2010

Dr. Baldev Raj, Director , IGCAR addressing the gathering while Dr. T. Ramasami, Secretary, Department of Science and Technology, Dr. S. Banerjee, Chairman, AEC and Secretary, DAE and Dr. M. Sai Baba, Head, BARC Training School at IGCAR are seated on the dais during the graduation function

The fourth batch of forty eight TSOs from the BARC Training School at IGCAR have successfully completed their training and were graduated in a special ceremony that took place on September 2,2010 at 10.30 hrs in the Sarabhai Auditorium, Homi Bhabha Building, IGCAR. Distinguished Academician, Dr.T.Ramasami, Secretary, Department of Science and Technology was the Chief Guest. Dr.S.Banerjee, Chairman, AEC and Secretary, DAE presided over the function. Dr. M. Sai Baba, Head, BARC Training School at IGCAR welcomed the gathering. Dr.Baldev Raj, Distinguished Scientist and Director, IGCAR gave an enlightening address to the gathering. Dr.S.Banerjee released the souvenir featuring the activities of training school programme in the previous academic year and Dr.T.Ramasami received the first copy. In his presidential address Dr. Banerjee gave a very inspiring and thought provoking lecture to the graduates passing out. Dr.T.Ramasami gave away the prestigious 'Homi Bhabha Prize' comprising of a medallion and books worth Rs.5000 to the meritorious toppers from all the disciplines. He also gave away the course completion certificates to all the graduate TSOs. A few of the Trainee Scientific officers shared their experience, gave a feedback on the academic programme and their stay at hostel. Dr.T.Ramasami gave a very inspiring and motivational lecture to the students. Dr. Vidya Sundararajan, S&HRPS proposed the vote of thanks.

(Reported by M.Sai Baba, BARC Training School at IGCAR)

Fourth Batch of Graduates of BARC Training School at IGCAR with Dr. T. Ramasami, Secretary, Department of Science and Technololgy (Chief Guest), Dr. S. Banerjee , Chairman, AEC & Secretary , Dr. Baldev Raj, Director, IGCAR and Senior colleagues of the Centre and members of S&HRPS

Conference/Meeting Highlights

Quality Circles Annual Meet (QCAM- 2010) at IGCAR

August 16-17, 2010

STAR QC team receiving Dr. Placid Rodriguez memorial Trophy (Mechanical and Manufacturing Category).

EXCEL QC team receiving Shri M.K. Ramamurthy memorial Trophy (Plant Operation & Services Category)

Quality Circles Annual Meet (QCAM) is being conducted every year by Apex Steering Committee on Quality Circles (ASCQC) at IGCAR. The aim of this convention is to provide a common platform for working group people to share the knowledge gained by them in applying new ideas to solve their work related problems. This year, QCAM was conducted during August 16-17, 2010. The programme was inaugurated by Shri S.C. Chetal, Director, REG. Dr. P.R. Nakkeeran, Director, Tamil Virtual Academy, Chennai delivered the key note address. Thirty-six Quality Circles (about 300 members) from IGCAR, GSO, MAPS and Schools at Kalpakkam had presented their QC case-studies under Mechanical & Manufacturing Category, Plant Operation & Services and Schools Category. A quiz programme on QC concepts, QC tools & techniques was conducted to propagate the QC concepts. Professionally qualified judges from Quality Circle Forum of India, Chennai chapter assessed the case-studies presented in parallel sessions at Sarabhai Auditorium and Ramanna Auditorium. The Valedictory address was given by Shri G.Srinivasan, Director, ROMG. He also gave away the Memorial Trophies to successful QC groups.

(Reported by G.Kempulraj & C. Anand Babu)

LOTUS QC team receiving Dr. Sarvepalli Radhakrishnan memorial Trophy (Schools Category)

Visit of Dignitaries

Delegates from United Kingdom with Dr.P.R.Vasudeva Rao, Director, CG and Dr.M. Sai Baba, Head, S&HRPS

A delegation from United Kingdom led by Dr.Richard Nicholas Buttrey, Second Secretary, Science and Innovation Network, British High Commission, Dr.Daniel Jonathan Rham, Incumbant Second Secretary, Dr.Christopher Fitzgerald, VVIP Programmes and Dr.Mathew Donald Kennedy Chalmers, Physics World visited the Centre during July 29-30, 2010. After a brief meeting with the Director, IGCAR and deliberations with collaborators of the projects, the team visited the Fast Breeder Test Reactor, Laboratories in Materials Science, Metallurgy & Materials and Chemistry Groups.

Delegates from CEA with Shri S.C.Chetal, Director, REG along with other participants of the CEA-DAE Review Meeting

A delegation from CEA comprising of Mr. Phillip Delaune, Deputy Director for International Cooperation, International Affairs Division, Mr.Dominique OChem, Special Advisor to the Director for International Cooperation, Nuclear Energy Division, Mr.Thierry Forgeron, Group for Innovation and Nuclear Support, Mr.Sunil Felix, Nuclear Energy Division and Mr.Hugues De Longevialle, Counsellor , Energy and New Technologies, French Embassy in India visited the Centre during July 8-9, 2010 for participating in the Mid-term Annual Review Meeting of CEA-DAE cooperation. After deliberations with participants from DAE, the team visited Fast Breeder Test Reactor, Hot Cells, Laboratories in Non-Destructive Evaluation Division, Fast Reactor Technology Group, Chemistry Group, Materials Science Group, Safety Group, Structural Mechanics Laboratory and the construction site of PFBR.

Visit of Dignitaries

Dr.A.U.Ramakrishnan, Honorary Homeopathic Physician to the President of India while delivering the talk along with Dr. Baldev Raj, Director, IGCAR

Dr. A.U. Ramakrishnan, Honorary Homeopathic Physician to the President of India visited the Centre on July 28, 2010 to deliver the "Vikram Sarabhai Memorial Lecture" at Sarabhai Auditorium on "Homeopathy-The Need of the Modern World". Earlier he has also visited the Fast Breeder Test Reactor and the Magnetoencephalography Facility at the Materials Science Group. Dr.Ramakrishnan was accompanied by his wife.

Forthcoming Meeting / Conference

MRSI Workshop on Materials Issues in Low Energy Nuclear Reaction Devices

February 12-13, 2011

(http://www.iscmns.org/iccf16/post_conf_workshop.htm)

A Satellite Workshop on the theme "Materials issues in Low Energy Nuclear Reaction Devices" is to be conducted at the Chariot Beach Resort Hotel in Mamallapuram during Feb 12-13, 2011 following the 16th International Conference on Condensed Matter Nuclear Science (ICCF16) being held in Chennai during Feb 6-11, 2011. The Workshop will provide an opportunity to Indian researchers interested in the Materials Science aspects of CMNS/LENR devices to interact with their peers from India and delegates from abroad. It will enable Indian researchers, especially those who have a good understanding of hydrogen in metals, to gain an appreciation for the unique challenges posed by deuterated/hydrogenated metals in enabling anomalous nuclear reactions to take place in metallic lattices, under certain special conditions which are not yet fully understood.

Topics covered:

The workshop is being organized by the Kalpakkam Chapter of the Materials Research Society of India. Dr.C.S.Sundar, Director, Materials Science group of IGCAR is the convener and Dr. Vittorio Violante of ENEA, Italy the co-convener. The programme would comprise of only invited talks followed by interaction.

Participation is limited to about 40 participants who are active in the area of Materials Science. There is no registration fee for this Workshop but interested participants must register in advance.

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Forthcoming Meeting / Conference

DAE-BRNS Theme Meeting on Chemistry in Back End of Fuel Cycle (CBFC-2010)

November 25-26, 2010

The Southern Regional Chapter of the Indian Association of Nuclear Chemists and Allied Scientists (IANCAS-SRC) will be organising a theme meeting on the role of chemistry in the back end of the fuel cycle during November 25-26, 2010 at the HASL lecture hall, IGCAR. The meeting would be funded by the Board for Research in Nuclear Sciences, Mumbai.

Nuclear Fuel Reprocessing, essentially an intimate mixture of chemistry and chemical engineering, presents unique challenges due to the intense radiation environment, the high level of separation and purity required as well as the large diversity of elements present in the process streams. Many of these challenges have been met and further improvements in the processes used are still being carried out. The classical aqueous solvent extraction processes serve as the workhorses but non-aqueous methods are of increasing interest. In addition, integration of the process to include waste management and environment issues are also taking place as a part of the holistic approach to back end of fuel cycle. Chemistry has a key role to play in these processes in a variety of ways.

The program would consist mainly of invited talks by experts which would focus on the current international and national scenario. Some of the areas of focus would be actinide and fission product separations, alternate extractants for reprocessing, computational chemistry and tailoring of ligands, analytical methods including non-destructive assay and on-line monitoring, corrosion chemistry as well as waste management and environmental issues.

Topics covered:

- Actinide and fission product separations
- Alternate extractants for reprocessing
- Computational chemistry and tailoring of ligands
- Analytical methods including non-destructive assay and on-line monitoring
- Corrosion chemistry as well as waste management
- Environmental issues

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Forthcoming Meeting / Conference

Structure & Thermodynamics of Emerging Materials (STEM-2010)

BRNS sponsored two days Workshop on
Advanced Methods in Characterisation of Texture and Microtexture of Materials

November 25-26, 2010

It is proposed to conduct the two days Structure & Thermodynamics of Engineering Materials - 2010 workshop, the third in STEM series on "Advanced Methods in Characterisation of Texture and Microtexture of Materials" during November 25-26, 2010 at Convention Centre, Anupuram. This workshop is sponsored by BRNS and is jointly organized by Indira Gandhi Centre for Atomic Research, Kalpakkam and the Indian Institute of Metals, Kalpakkam Chapter.

There has been a growing research interest in the field of 'Crystallographic Texture of Materials' across various research/academic institutions in the country. This is a very relevant area of study since development of components for the fast reactor fuel cycle poses several challenges with respect to texture and microtexture in Iron, Titanium and Zirconium based systems. This workshop seeks to provide a forum for the participants, to learn the fundamentals as well as current developments in 'Texture, Microtexture and Grain Boundary Analysis', from renowned experts. The aim of this workshop is to initiate and enhance through tutorial type lectures the current understanding on select topics that are at the core of physical metallurgy of advanced materials design and development.

Topics covered:

- Description of Texture data
- Texture measurements by X-ray Diffraction
- Electron Back Scattered Diffraction – Principle & Procedure
- Texture Mechanisms and Modeling
- Evaluation of Grain Boundary Nature using EBSD
- Role of Texture in Fabrication of Components for Nuclear Reactors
- Texture studies in different Material Systems
- Recent Developments in Texture
- Texture at High Resolutions

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Awards & Honours

- Shri R. Natarajan, Director, Reprocessing Group, has been elected, Fellow of the Indian National Academy of Engineering (INAE) in recognition of his contributions to "Engineering Sciences"

Best Paper/Poster Awards

- Shri Abhishek Mitra, Shri V. Rajan Babu, Shri P. Puthiyavinayagam, Shri N. Vijayan Varier, Shri Manas Ghosh, Shri Hemal Desai, Shri P. Raghavendra, Shri Anand Mistry, Dr. P. Chellapandi, Shri S.C. Chetal and Dr. Baldev Raj, were awarded the "Best Paper Award" for 'Technology Development of Thick Plate Narrow Gap Welding', during National Weld Meet - 2010, held at Puducherry on Aug 6, 2010.
- Smt. N. Sivai Bharasi, Dr. H. Shaikh and Dr. R. K. Dayal, were awarded "Best Paper Award" for "Effect of Applied Potential on the Stress Corrosion Cracking Behaviour of Weldments of AISI Type 316 Stainless Steel" during National Weld Meet - 2010, held at Puducherry on August 6, 2010.

- Six quality circles from IGCAR: MOON(FRTG), SAMURAI(ESG), EXCEL(FRTG), STAR(ESG), SAKTHI(GSO) and RAINBOW(FRTG) participated in the Quality Circle State Level Convention (CCQCC-2010) during September 4-5, 2010 at Meenakshi Sundararajan Engineering College, Chennai along with 135 other QC teams and bagged Gold (MOON and SAMURAI), Silver (EXCEL and STAR) and Bronze (SAKTHI and RAINBOW) medals.
- The Quality Circle annual meet held at Kalpakkam during August 16-17, 2010, the following teams received trophies as indicated.
  - Dr. Placid Rodriguez Memorial Trophy in the Mechanical and Manufacturing Category awarded to team from Civil Engineering, ESG (Leader: Shri S Satheesh Kumar, Facilitator: Shri M.Krishnamoorthy).
  - Shri M.K.Ramamurty Memorial Trophy in Plant Operation and Services Category awarded to team from Chemical Technology and Vibration Diagnostic Division, FRTG (Leader: Shri S.Suresh, Facilitator: Shri G. Mohanakrishnan).
  - Dr.Sarvepalli Radhakrishnan Memorial Trophy in Schools Category awarded to team from Atomic Energy Central School-No.2, Kalpakkam (Leader: Ms.S.R.Nandini, Facilitator: Ms.S.Jayasree)

Dr. M. Sai Baba, Convenor, **Editorial Committee Members: Shri Utpal Borah, Dr. K. Ananthasivan, Dr. K.K. Satpathy, Shri N. Desigan, Shri S. Varadharajan, Dr. Vidya Sundararajan, Shri C. Jayakumar and Shri J. Daniel Chellappa.**

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