



IGC newsletter



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Director's Message

- Republic Day Message of Director, IGCAR

IGCAR Lecture Series

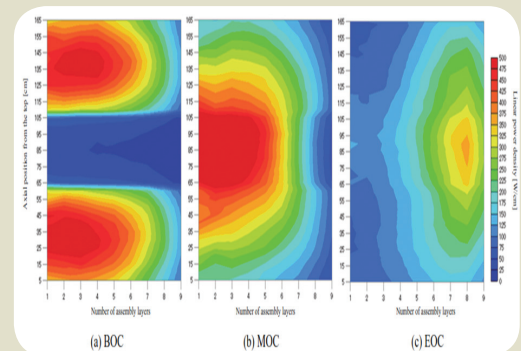
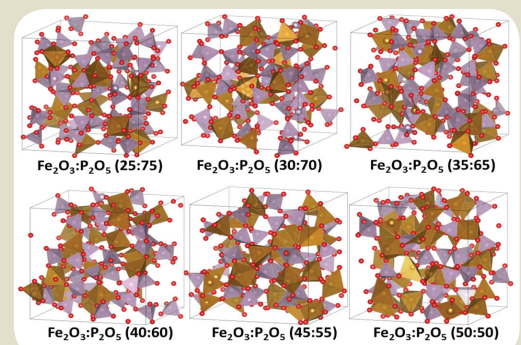
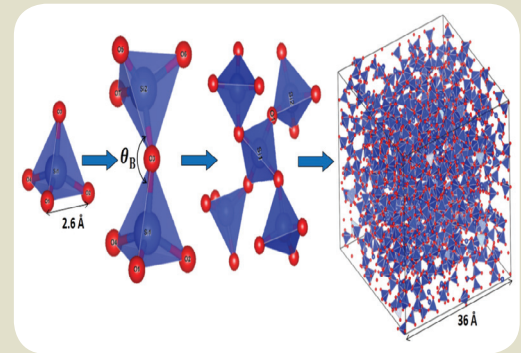
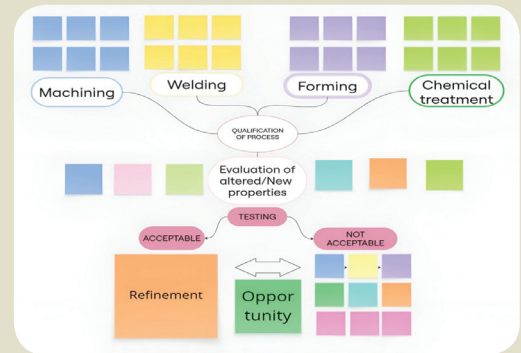
- Capital Projects & Budget Monitoring Mechanism
- Development of Separation Techniques for Molten Salt in Pyrochemical Reprocessing
- Quality Assurance: An Approach Beyond Standardization towards Problem Solving
- Civil Engineering Aspects in the Conceptual Design of PFBR Seawater Intake and Outfall Structures
- Atomistic Modelling of Iron Phosphate Glass Properties
- Hydrogen Production, Storage and Transportation: Pathways for Nuclear-Hydrogen Synergy
- Breed & Burn Travelling Wave Reactor: A Review
- Fatigue Crack Growth in Structural Materials: Implications for Nuclear Reactor Design

News and Events

- 12th Biennial DAE-BRNS Symposium on Separation Science and Technology (SESTEC-2026)
- Technology Transfer and Incubation Agreement Exchange
- Observance of Swachhata Pakhwada 2026 at IGCAR
- 9th National Conference URJAVARAN – 2025-26

Awards, Honours and Recognitions

Bio-diversity @ DAE Campus, Kalpakkam



EDITOR'S DESK

Dear Reader,

Greetings

It is my pleasant privilege to forward the latest issue of IGC Newsletter (Volume 147, April 2026, Issue 2). I thank my team for their timely inputs, cooperation, and support in bringing out this issue.

The IGCAR Lectures Series articles on “Capital Projects & Budget Monitoring Mechanism” by Shri S. Sridhar; “Development of Separation Techniques for Molten Salt in Pyrochemical Reprocessing” by Dr. D. Sujish; “Quality Assurance: An Approach Beyond Standardization towards Problem Solving” by Shri Shri Krishna Tripathi; “Civil Engineering aspects in the Conceptual Design of PFBR Seawater Intake and Outfall Structures” by Dr. R. Murugan; “Atomistic Modelling of Iron Phosphate Glass Properties” by Dr. Sharat Chandra; “Hydrogen Production, Storage and Transportation: Pathways for Nuclear–Hydrogen Synergy” by Dr. Arjun Pradeep; “Breed & Burn Travelling Wave Reactor: A Review” by Dr. Neethu Hanna Stephen and “Fatigue Crack Growth in Structural Materials: Implications for Nuclear Reactor Design” by Dr. Nani Babu Matcha are included in this Newsletter.

In the back cover, We have Black Drongo bird found in DAE campus, Kalpakkam.

The Editorial Committee would like to thank all the contributors. We look forward to receiving constructive suggestions from readers towards improving the IGC Newsletter content.

We express our deepest gratitude to Director IGCAR for his keen interest and guidance.

With best wishes and regards

Shri J. Rajan

Chairman, Editorial Committee, IGC Newsletter and

Head, Scientific Information & Networking Division, IGCAR

REPUBLIC DAY MESSAGE OF DIRECTOR, IGCAR



SHRI SREEKUMAR G. PILLAI
DIRECTOR, IGCAR

Dear Colleagues,

On this auspicious occasion of Republic Day, we gather to commemorate the adoption of our Constitution and to reaffirm our collective commitment to the ideals that define our Republic – duty, discipline, unity, and service to the nation. This day reminds us of our responsibilities as custodians of public trust and national institutions.

As India advances through the Amrit Kaal – a transformative journey towards the centenary of our Independence – the nation has articulated a clear vision of sustainable growth, technological self-reliance, and environmental responsibility. Energy security lies at the heart of this vision, and nuclear power continues to occupy a vital role in ensuring a clean, reliable, and resilient energy future for the country.

Nuclear energy provides dependable base-load power while supporting India's climate commitments and long-term developmental goals. The expansion of India's nuclear power programme is being pursued in a calibrated and responsible manner, guided by indigenous capability, advanced technology, and uncompromising safety standards. This balanced approach reflects our national resolve to harmonise growth with safety, sustainability, and public confidence.

In this context, the SHANTI Bill, which has been passed by Parliament, represents an important step towards strengthening the legislative and institutional framework governing nuclear safety, security, and accountability, and towards enhancing public confidence in the orderly expansion of nuclear energy during the Amrit Kaal.

Against this national backdrop, our Centre has continued to discharge its responsibilities with dedication and professionalism. Over the past year, despite operational and project-related challenges, we have made steady progress in maintaining safe and reliable operations, advancing critical projects, strengthening safety and quality

systems, fulfilling regulatory and statutory commitments, and enhancing institutional capabilities through continuous capacity building and skill development.

We continued to extend strong support to the Prototype Fast Breeder Reactor. The successful conception, commissioning, and operation of the direct fuel loading system enabled the first approach to criticality, with fuel loading progressing steadily. Advanced in-service inspection using the indigenously developed DISHA robotic system has further strengthened confidence in critical reactor components. Our focus remains on supporting integrated commissioning and progressive power operation of PFBR.

The Fast Breeder Test Reactor continued its safe and reliable operation at full power, contributing electricity to the grid while serving as a vital platform for irradiation experiments, fuel development, and technology demonstration. Significant progress was made in nuclear hydrogen production, isotope generation, and materials research. The fortieth anniversary of FBTR's first criticality was commemorated with the participation of distinguished former leaders and associates and marked by notable scientific achievements, including in-house radioisotope separation. The KAMINI reactor also continued its valuable role in neutron-based research, detector testing, and experimental studies.

A major milestone was achieved with the in-principle approval for FBTR-II, paving the way for large-scale development and testing of metallic fuel for future fast reactors, along with associated fabrication, post-irradiation examination, and pyro-processing facilities. This project will significantly strengthen India's fast reactor programme and contribute to long-term energy security.

Our reprocessing programme maintained steady momentum, with successful campaigns at CORAL and DFRP, recovery of strategic nuclear materials, and important advances in actinide separation. Parallel progress in pyro-processing and metal fuel irradiation further reinforced India's closed fuel cycle capabilities.

In fast reactor technology and allied areas, new sodium test facilities and advanced robotic inspection systems were commissioned, enhancing indigenous design, testing, and inspection capabilities. Significant achievements were also recorded in basic and directed research, including advanced materials, sensors, quantum communication, and the establishment of state-of-the-art experimental facilities of international standing.

In the areas of safety, environment, and health, new monitoring and emergency response systems were operationalised, detector performance was enhanced, and digital healthcare services were expanded. Green initiatives such as thermal energy storage systems and increased solar power capacity further demonstrated our commitment to sustainability and responsible operations.

Innovation and entrepreneurship were encouraged through the DAE Incubation Centre, while structured training programmes, lecture series, and national capacity-building initiatives strengthened human resources. Extensive outreach activities helped spread scientific awareness and inspired students, faculty, and the wider public.

These highlights represent only a part of the collective achievements of our organisation. On this 77th Republic Day, I place on record my deep appreciation for the dedication and service of all our serving employees, whose professionalism and commitment sustain our mission each day. I also extend our respectful gratitude to our retired colleagues, whose contributions laid the strong foundation on which we continue to build. Their legacy of discipline, integrity, and excellence remains a guiding inspiration.

I would also like to gratefully acknowledge the invaluable contributions of all personnel providing auxiliary and support services, whose dedicated efforts are integral to the success of our programmes. This includes our Administrative, Accounts, Medical, and Engineering Services, the CISF, Fire and Safety Services, the Transport Section, and many others who constitute one of the key strengths of this organisation. Our sincere appreciation is also extended to the personnel of the various service organisations across our campus and townships. I also place on record my special thanks to the Unions and Associations for their continued cooperation and constructive support.

As an organisation entrusted with a critical national mission, our responsibility extends beyond technical excellence. It lies equally in upholding integrity, safety, accountability, and public trust in every aspect of our work.

As we move forward in the Amrit Kaal, let us draw inspiration from the ideals of our Constitution and renew our pledge to serve the nation with integrity, pride in the Tiranga, and unwavering commitment to a strong, self-reliant, and prosperous India.

With these words, I once again extend my warm Republic Day greetings to all of you and your families.

Jai Hind.



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LECTURE
SERIES

CAPITAL PROJECTS & BUDGET MONITORING MECHANISM

INTRODUCTION

The fund required for operation & maintenance of various labs, plants and general infrastructure at IGCAR is allocated through revenue budget. The fund required for setting up of new facilities/laboratories/plants and other infrastructure development activities are allocated under capital budget through sanctioned capital projects. All the laboratories, facilities and other infrastructure that exist now are established through capital budget obtained through capital projects. Up to the year 2025, 275 capital projects have been executed with a capital expenditure of about Rs. 7723 Cr. (incl. FRFCF expenditure of Rs. 2770 Cr. up to March 2021). Hence, to get funding for R&D activities of IGCAR, the capital projects need to be formulated and approvals obtained.

CAPITAL PROJECT LIFE CYCLE

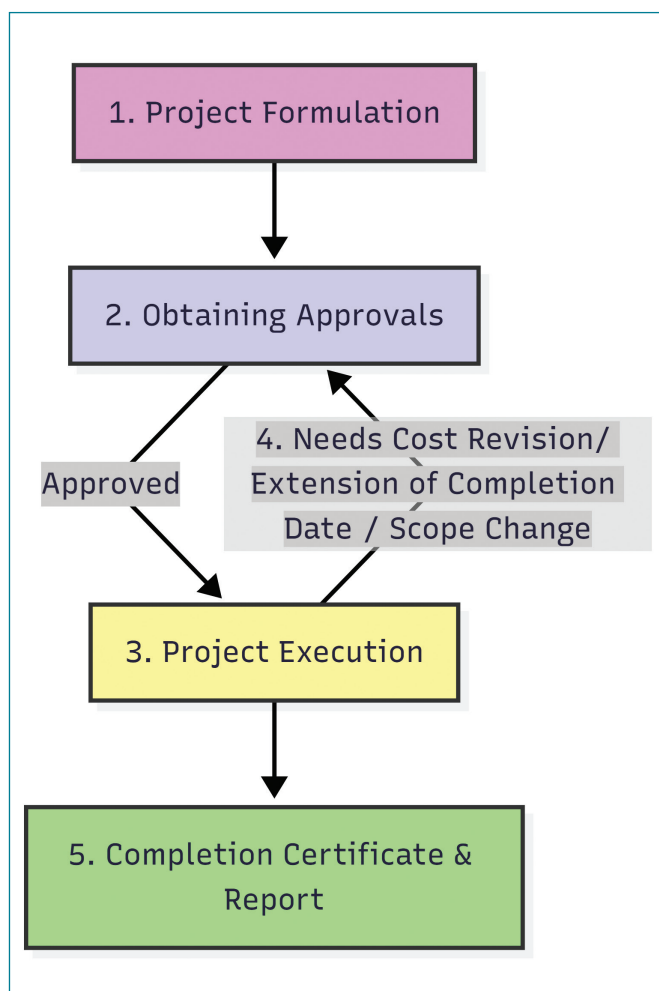
The capital project life cycle has five phases, namely:

1. Project Formulation
2. Obtaining Approvals
3. Project Execution
4. Revision of cost/Extension of completion date/Change of scope
5. Completion Certificate & Report

Each of the stage is explained briefly in the following section.

1. PROJECT FORMULATION

- a. The research & development activities are a continuous process.
- b. During the course of ongoing research work, new requirements/new areas for research are identified. These requirements are then compiled into a new project proposal.
- c. The objective, scope, outcome, societal benefits, milestones and technical features of the project must be well defined.



- d. The new project would require funds for procurement of equipments, works/collaborative projects to be carried out etc.
- e. Cost estimation is done through market survey/previous purchase orders/obtaining budgetary quotations etc.
- f. Additional amount (normally 5% p.a.) is considered to the cost estimates to take care of inflation/currency fluctuation etc.
- g. The project duration, object head wise break up & year wise phasing of expenditure are finalised.
- h. The Executive Summary for In-Principle Approval (IPA), DPR format, PES format are prepared.
- i. At this stage, the Apex project coordinator and an

alternate coordinator are identified and mentioned in the project reports. They are responsible for the project formulation, obtaining approvals, execution, reporting the periodic project progress and upon completion, submission of reports. They are also responsible for responding to any queries from Audit, Parliament questions and providing information sought under RTI Act.

2. OBTAINING APPROVALS

- a. Irrespective of the project cost, approval of Group Board (GB) and IGC Scientific Committee (IGCSC) are to be obtained.
- b. The Project Appraisal Committee (PAC) is the apex body in DAE to recommend the proposals to the Department. For each vision scheme, a sub-committee has been constituted under PAC to review the projects and recommend it to the apex PAC (Table 1).
- c. Also, there are 2 special committees called Major Works sub-committee and Electronics sub-committee, having specialists from the respective fields. PAC may refer the proposals to these committees if needed.
- d. With all necessary approvals (GB, IGCSC, PAC sub-committee & apex PAC), the proposals are sent to Atomic Energy Commission (AEC) for In-Principle Approval (IPA).
- e. After obtaining the IPA, the proposals are submitted to concerned section in DAE head quarter (R&D section for IGCAR, BARC etc.)
- f. Based on the project cost, the approval of competent authority is processed in the Department and clarification/additional information, if any, sought by DAE is to be provided (Table 2).
- g. Upon approval by the competent authority, the administrative & financial sanction order is issued.

3. PROJECT EXECUTION

- a. The projects are executed through carrying out the research & development works.
- b. The equipments/items required for the work are procured by following the purchase procedure (DPS/MRPU/LPC/GeM local orders).
- c. The collaborative/infrastructure (civil, electrical, mechanical) works are executed through works tenders (GeM).
- d. The Annual Budget required for the payments are secured through submission of budget proposal at appropriate stage (Budget Estimates/Revised Estimates/Final Requirement).

4. REVISION OF COST / EXTENSION OF COMPLETION DATE / CHANGE OF SCOPE

- a. During execution of the project, there are situations that may necessitate change in the scope of the project, which may lead to cost escalation or extension of completion date or both.
- b. The Revision of cost may be required due to inflation/delay/FE fluctuations etc.
- c. The delay in project execution (Procurements, works) may lead to extension of completion date (with or without revision of cost).
- d. The proposal for revision also require approval of competent authority in the department (all internal approvals, vision sub-committee & apex PAC are required).
- e. As the Revision is an exception, utmost care must be taken towards completion of the project within the sanctioned cost and time. (i.e. avoid seeking revision of cost or time or scope).

5. COMPLETION CERTIFICATE & REPORT

- a. The Completion Certificate for apex project and the Completion Report for sub projects are to be submitted as per formats prescribed by PAC.
- b. All the project related documents are considered permanent. Hence, they need to be preserved carefully (by the Group Office) and passed on to the successors for future reference and responding to the queries, if any.

PROJECTS & BUDGET MONITORING MECHANISM

Timely implementation of projects within the sanctioned cost of the project is very important. The purpose of project monitoring is to avoid cost escalation/extension of completion date of the project. Hence, monitoring of the progress is given utmost importance.

Two main parameters to measure the project progress are:

1. *Physical progress* – Physical progress refers to the amount of progress made towards achieving the major milestones envisaged in the project.
2. *Financial progress* – Financial progress refers to the amount of expenditure made as against the sanctioned cost of the project.

As part of the project monitoring mechanism, the progress is being reviewed & reported by the Project Coordinator at various periodicities to different committees/agencies.

1. Apex PAC monitors the progress on a monthly basis – The physical progress (in % terms) & financial progress (in Rs. Cr.) needs to be updated by the Apex Project

- Coordinator in the PAC – MON website <http://pac.anunet.in>.
2. The Physical & Financial progress and also the commitments (Rs. in Cr.) needs to be reported to DAE on a quarterly basis.
 3. The project status is also presented by the Coordinator to the Group Board, IGCS and Vision sub-committees.
 4. The Vision sub-committees review the project progress regularly and reports to apex PAC.
 5. The financial progress (overall at IGCAR) is also reported to the Parliament during its Budget Session, Monsoon Session and winter sessions.
 6. These mechanisms help various authorities to identify the bottleneck and help resolve the issues towards timely completion of the projects.

BUDGET MONITORING MECHANISM

- a. Out of the total project cost, certain amount sought by the project authorities are allocated by the Government through Annual Budget (called Budget Estimates), before commencement of the financial year (1st April).
- b. During the course of the financial year, chance is given to the project authorities to revise the budget allocation for the current financial year (called Revised Estimates), by August. At this stage itself, the funds required for the next financial year also needs to be projected to the Government.

- c. As per the FRBM act, the Monthly Expenditure Plan (MEP) for each project is to be submitted and the projected expenditure must be at least 67% of the BE for first 9 months (i.e. up to December) and a maximum of 33% can be spent during the last quarter of FY. Further a maximum of 15% (out of 33%) can be spent during March.

FACILITIES AVAILABLE TO THE PROJECT COORDINATOR

1. Expenditure reports (MRPU as well as IGCAR) are available under Plan/e-proc/Atoms.
2. The list of purchase order/work order is available in e-proc/Atoms.
3. Also the list of indents under various stages is also available in e-proc.
4. The final expenditure compiled with “Other unit bookings” is made available through Plan website and emails are sent to the project coordinators for updating the progress in PAC website.

FUTURE PLANS

Towards strengthening the project monitoring mechanism, especially towards achieving the milestones & deliverables, it is planned to implement a professional project monitoring software – to capture the timelines of each project activity and track the progress in a sustainable way. This may also aid calculating the physical progress of the project for reporting purposes.

Table 1: List of vision schemes

Vision Scheme	Description
VS-1	Power sector schemes in the first stage of Indian Nuclear Power Programme
VS-2	Rare metals, Exploration, Mining and Milling
VS-3	Fast Reactor and Back-End fuel cycle for the 2nd stage of Indian Nuclear Power Programme
VS-4	Healthcare (Cancer treatment)
VS-5	Food security – nuclear agriculture and food preservation
VS-6	Water and Waste water management – technologies for management of municipal waste and water purification
VS-7	Mega science schemes (INO, CERN, FAIR, LIGO, TMT, SKA, MACE etc.)
VS-8	Directed research and education
VS-9	Basic Research programmes (fundamental research)
VS-10	Societal outreach schemes
VS-11	Special schemes (strategic/national security)

Table 2: Financial limits for new project approval

Authority	Monetary Limit
Secretary, DAE	Upto Rs. 100 Crores
Secretary DAE (with committee)	Beyond Rs. 100 Crores Upto Rs. 200 Crores
Member (Finance)	Beyond Rs. 200 Crores Upto Rs. 500 Crores
Atomic Energy Commission	Beyond Rs. 500 Crores and Upto Rs. 1000 Crores
Cabinet/CCEA	Beyond Rs. 1000 Crores



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LECTURE
SERIES

DEVELOPMENT OF SEPARATION TECHNIQUES FOR MOLTEN SALT IN PYROCHEMICAL REPROCESSING

Pyrochemical reprocessing is a non-aqueous separation technique adopted for the reprocessing of spent metallic fuels. Separation of fission products from the useful actinides is achieved in a high temperature electrochemical cell (electrorefiner), wherein the anode is the chopped spent fuel, the cathode is a steel rod for electrodeposition and molten LiCl-KCl eutectic mixture with 2% UCl_3 is the electrolyte. Further to electrorefining, the dendritic uranium deposits are stripped off from the occluded salts and melted in a vacuum distillation and melting furnace also called as Automated Vacuum Distillation and Melting System (AVDMS). A schematic of the AVDMS is shown in Fig. 1. This vacuum furnace comprises of two parts. One is the stationary part comprising of the vacuum chamber mounted on a structure, the induction coil, ceramic insulation, susceptor and transition piece. The mobile part comprises of the graphite crucible with lid, radiation reflector plates, condenser, and salt collection vessel. This system will be housed in a hot cell and therefore remote operation of the system was one of the challenges. Also, since, Pu also will be consolidated in the actual system, it was important to develop a solid induction coil where water cannot be used for coil cooling. Development of a passively cooled induction heating coil capable of heating the charge

upto 1300 °C was taken up. Preliminary studies were carried out in a mock set up with a 40 kW induction generator. Various coolants like air and liquid nitrogen mixture were tried. It was finally concluded that an indirect heat sink for the vessel and cooling of the power feedthrough of the induction coil was mandatory to reach temperatures of 1300 °C. Copper melting at 1150 °C was first demonstrated using solid induction coil. Further uranium deposit containing occluded salt from the first campaign of electrorefining was subject to salt distillation at 10 torr pressure and temperature of 1100 °C. Uranium dendrites were then melted and consolidated at 1250 °C as shown in Fig. 2. This system was used further for 15 campaigns of salt/cadmium distillation and 4 campaigns of uranium melting.

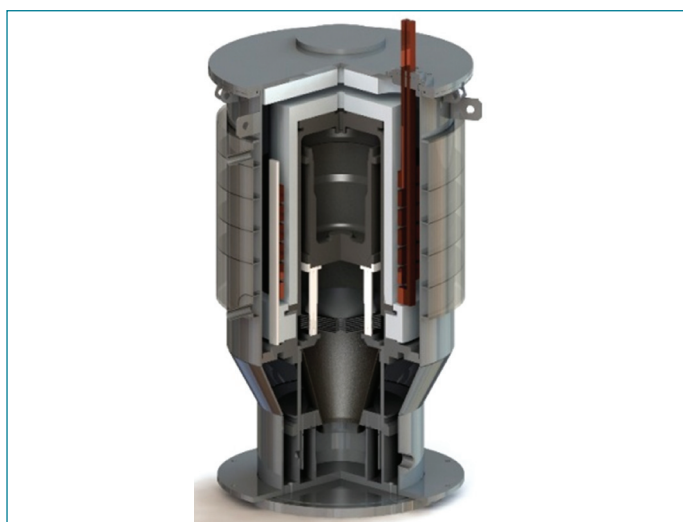
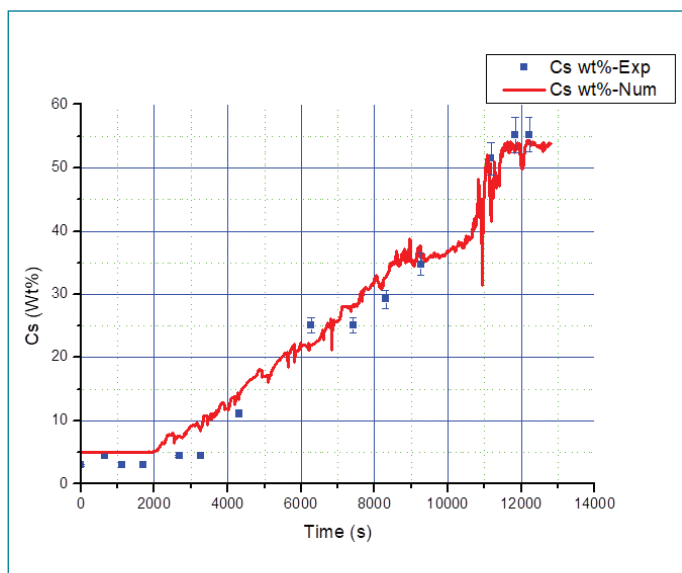


Fig. 1: Automated Vacuum Distillation and Melting System



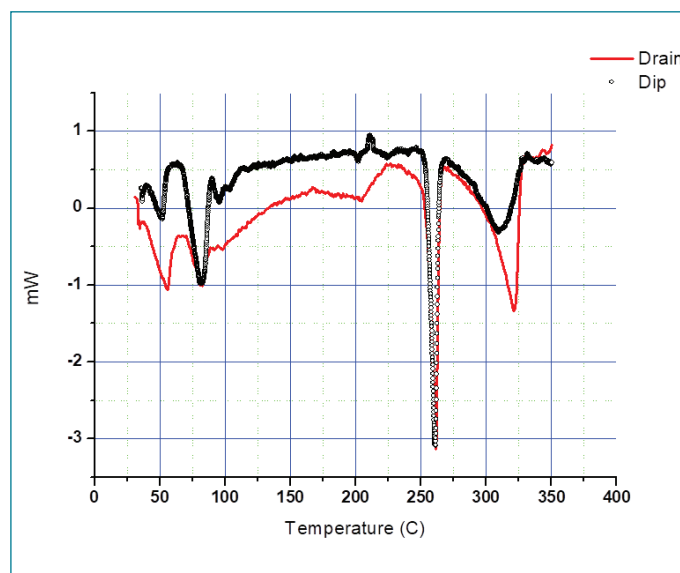
Fig. 2: Uranium dendrites and consolidated ingot

During electrorefining of spent metal fuel, fission products accumulate in the electrolyte. increasing the decay heat and activity levels in the salt. In order to ensure safe operation, a portion of the salt is removed from the electrorefiner to separate the fission products. ^{137}Cs is one of the major heat generating radionuclide in the spent salt. Also, ^{137}Cs forms a



Theoretical and experimental CsCl concentration profile at Crystallizer bottom

low melting ternary eutectic with LiCl-KCl at 260 °C, which is 95 °C less than the binary eutectic temperature of LiCl-KCl. The ternary eutectic composition being 57 wt% CsCl, 25 wt% LiCl and 18 wt% KCl. Also, CsCl solubility in liquid phase is much higher than that in the solid phase. This difference in solidus temperature and solubility could be utilized to enrich an impure salt mixture from 1 wt% to a maximum of 57 wt% CsCl by slow cooling. Melt crystallization of impure salt mixture was therefore pursued to purify the salt containing ^{137}Cs . Preliminary heat transfer modeling of molten sodium nitrate salt carried out using ANSYS-Fluent. The results on solidification time evaluated numerically and determined experimentally showed very good match. The model predictions were accurate with a mere 1.9% error on the solidification time. In the next step, combined heat and mass transfer modeling of CsCl was carried out. Effective separation is aided by both micro-segregation and macro-segregation of the solute at the solid-liquid interface during solidification. Also, the lower solutal expansion coefficient resulted in settling of CsCl to the bottom liquid phase of the crystallizer during solidification. Experiments were carried out with 6.6 kg of LiCl-KCl eutectic salt mixture with 1 to 5 wt% CsCl concentrations in a glove box. Changes in the solidification temperature, time, pattern and CsCl concentration distribution were observed with 5 wt% initial CsCl concentration. The variation



TG-DTA plot for salt sample collected by drain method and dip method

of temperature in the salt mixture with time was predicted with good accuracy and there was a very good match between the numerical and experimental transient temperature pattern. The maximum error in the prediction was only 4.7%. Salt samples collected by drain and dip methods in duplicates were analyzed by TGDTA. The endothermic peaks for the salt samples at 261 °C from TGDTA analysis indicate that CsCl concentration in ternary eutectic composition is about 57 wt%. The mechanism of solute transport predicted by the numerical model during solidification by diffusion is validated by the experimental results. The diffusivity of CsCl in molten LiCl-KCl reported in literature ($1.3\text{E}-09 \text{ m}^2/\text{s}$) matches with the model results. The molar flux of CsCl during solidification was evaluated to be $2.8\text{E}-03 \text{ moles}/\text{m}^2\text{s}$. The liquid phase mass transfer coefficient of CsCl in salt was found to be $9.42\text{E}-03 \text{ moles}/\text{m}^2\text{s}$. This can be scaled to multi-stage crystallization process using a crystallizer and buffer tanks arrangement. The processed salts after one stage of crystallization can be transferred and stored in buffer tank. In the second stage operation, the stored salt can be remelted, transferred and mixed with fresh feed in the same crystallizer. This process can be repeated until the desired purity and recovery is achieved. This process is therefore very much amenable for remote hot cell operation as there is no pumping machinery or high pressure or energy intense operations.



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LECTURE
SERIES

QUALITY ASSURANCE: AN APPROACH BEYOND STANDARDIZATION TOWARDS PROBLEM SOLVING

INTRODUCTION

In high-integrity nuclear systems, quality cannot remain a procedural obligation; it must operate as a strategic function with an independent engineering discipline. While regulatory frameworks provide structure through codified requirements in design, procurement, manufacturing, inspection, documentation, and audits, experience demonstrates that compliance alone does not guarantee performance certainty. Variability in processes, complex weld geometries, material deviations, limited inspection access, degradation behaviour, and lifecycle discontinuities introduce residual risks beyond prescriptive controls.

Within this complex technological ecosystem, the Quality Assurance Division (QAD) of IGCAR has progressively positioned itself as a strategic assurance partner—integrating engineering insight with regulatory rigor. By aligning verification activities with risk awareness, innovation maturity, and lifecycle continuity, QAD supports organizational objectives of safety, reliability, and long-term asset sustainability.

QAD—STRATEGICALLY BRIDGING THE GAPS

Technological advancement follows a non-linear trajectory: demand accelerates, implementation often lags, and knowledge matures progressively (Fig. 1). Over time, quality

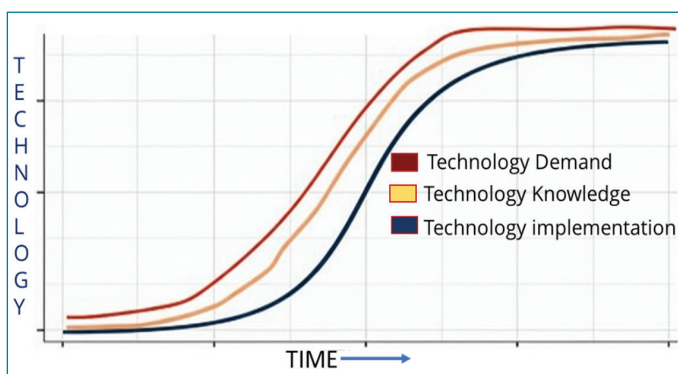


Fig. 1: Technology adoption S-curve highlights demand precedes implementation: Derived from Gompertz Growth Model: (Tjørve & Tjørve, 2017)

has evolved from strategies of final product inspection to statistical control, structured quality assurance (QA) systems, and now toward predictive, data-driven governance models integrating analytics and digital tools. Strategic assurance therefore demands continuity across requirements definition, design validation, procurement integrity, controlled fabrication, inspection discipline, commissioning verification, and operational feedback. The “Quality Factor” that serves as the institutional governance mechanism and bridges the gap between ambition and available capability, ensuring that technological complexity is matched by structured control, analytical depth and disciplined risk management.

Recognizing this systemic imperative, QAD transforms quality philosophy into executable engineering practice and insert the technical judgments through structured checkpoints, measurable acceptance criteria, independent validation systems, and early-stage technical interventions, uncertainty is converted into controlled performance margins (Fig. 2). Lifecycle integration is institutionalized by

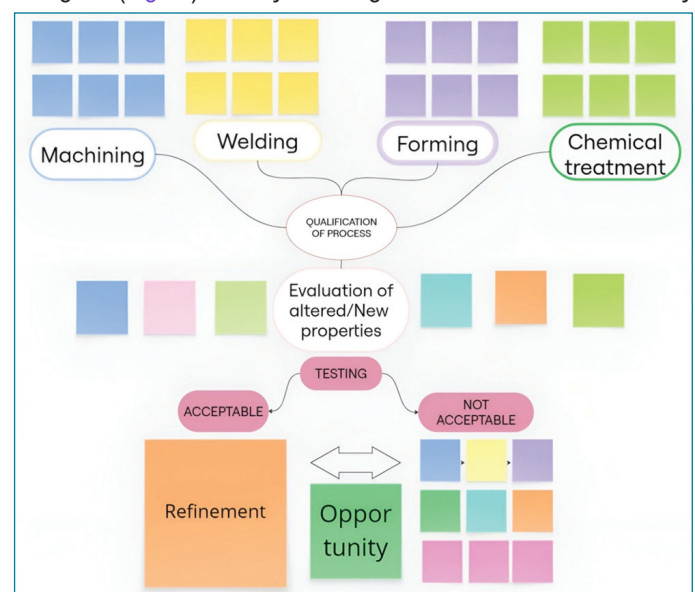


Fig. 2: Process flowchart showing the opportunities drawn from QAD at decision nodes for initiating research activities in a simple procedure qualification activity

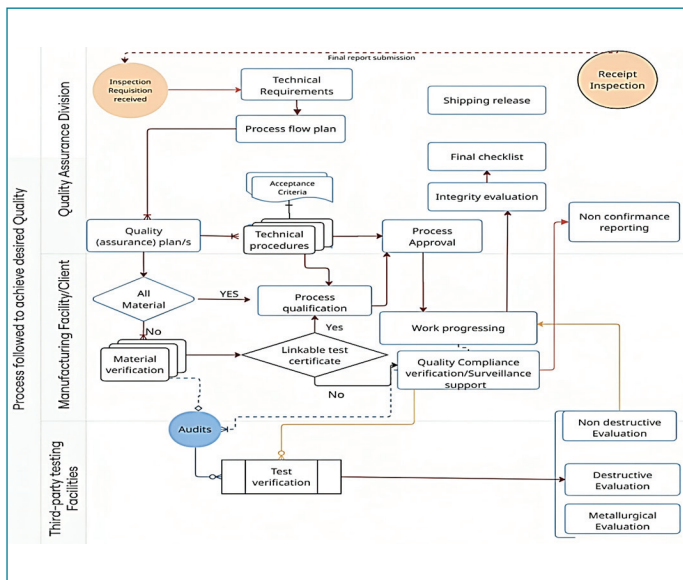


Fig. 3: Synergised multi-domain engagement of QAD for delivering the quality in various projects involving mechanical manufacturing

synchronizing material traceability, procedure qualification, personnel competence assurance, surveillance audits, non-conformance governance, and corrective action into a closed-loop framework (Fig. 3). By deploying advanced non-destructive evaluation (NDE) platforms, digital documentation consolidation, qualification analytics, and knowledge-based decision systems, QAD accelerates the organization’s transition from reactive defect correction to predictive assurance—strategically bridging the gaps between innovation and safety, execution and reliability, and aspiration and demonstrable performance.

NON-DESTRUCTIVE EVALUATION

The QAD has evolved into a strategic structural integrity platform supporting high-reliability nuclear systems, including the qualification of critical PFBR equipment/ instruments such as transducers of under sodium ultrasonic scanner (USUSS), intermediate heat exchanger (IHX), hydrogen in argon detector (HAD) etc. Diagnostic precision has been significantly enhanced through advanced ultrasonic techniques like phased-array examination and automated scanning, integrated with radiography, metallographic replication, and in-situ chemical verification to strengthen the requalification of thin tanks and piping for DFRP, FRFCF, FRTG, FBTR and RCL etc. Currently, QAD is advancing several NDE methodologies by transitioning from traditional testing to rigorous scientific frameworks. A key proposal involves leak-testing method developed from the vast data generated during FRFCF glovebox fabrication, that utilize temperature-corrected pressure for obtaining the observation time during testing. This analytics define precise, mathematically validated testing durations and addresses existing gaps in technical literature.

Collectively, such initiatives have shifted NDE from routine defect detection to predictive integrity assurance and data-driven decision-making for long-term system reliability of thin and thick structures.

SUPPLY CHAIN INTEGRITY AND STRATEGIC INTERVENTION

In a globally complex supply environment, exposure to counterfeit and non-genuine materials elevates authenticity from a procedural check to a strategic risk-control parameter. By embedding in-situ chemical verification, documentation scrutiny, certification validation, and independent material authentication into procurement workflows, QAD safeguards system integrity before installation and operation.

FROM SMALL CHANGES TO SERVICE PERFORMANCE

Targeted engineering interventions—including distortion-control methods, corrosion evaluation, and custom fixture design for fabrication activities, early internal weld inspections, 360° bore inspection tools, modern visual systems, and laser-based structural monitoring—have measurably reduced rework, downtime, and resource consumption. These initial improvements evolved to meet emerging inspection requirements across various projects, both within and outside the IGCAR campus.

QUALITY ASSURANCE IN SPECIALIZED WELDING

To address complex challenges, specialized welding qualification programs were developed. These programs ensure minimum leak paths and required functional strength in multi-material, multi-thickness joints. These joints are utilized in critical front- and back-end cycle components, such as large heat exchangers, flexible couplings, and dynamically balanced parts operating in corrosive environments—areas where standard volumetric or surface inspections are often difficult or impossible during fabrication and service. By carefully updating procedures, maintaining strict code discipline, validating macro- and micro-examinations, and tightly controlling heat inputs, the QAD successfully turned design specifications into real-world results. Ultimately, QAD transformed focused technical solutions into long-term system reliability and operational efficiency.

SUMMARY

The Quality Assurance Division of IGCAR has redefined the role of quality from a regulatory checkpoint to a strategic pillar of nuclear excellence. By systematically closing the gap between high-level technological ambition and real-world operational capability, QAD has evolved into a lifecycle integrity partner.



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LECTURE
SERIES

CIVIL ENGINEERING ASPECTS IN THE CONCEPTUAL DESIGN OF PFBR SEAWATER INTAKE AND OUTFALL STRUCTURES

The Prototype Fast Breeder Reactor (PFBR), a 500 MWe nuclear power plant at Kalpakkam, utilizes seawater as the ultimate heat sink for condenser and auxiliary cooling systems. The total seawater requirement for the Condenser Cooling Water (CCW) and Auxiliary Seawater (ASW) systems is approximately 29 m³/s. Given the abundant seawater availability, a once-through cooling system was adopted, discharging warmed water back to the sea through a dedicated outfall system.

A detailed techno-economic comparison of offshore and onshore alternatives led to the selection of an onshore-based scheme comprising an offshore intake structure, submarine tunnel with vertical shaft, onshore pump house (Fig. 1), and an outfall system consisting of an underground RCC tunnel, seal pit with sloped apron and outfall canal with guided bunds.

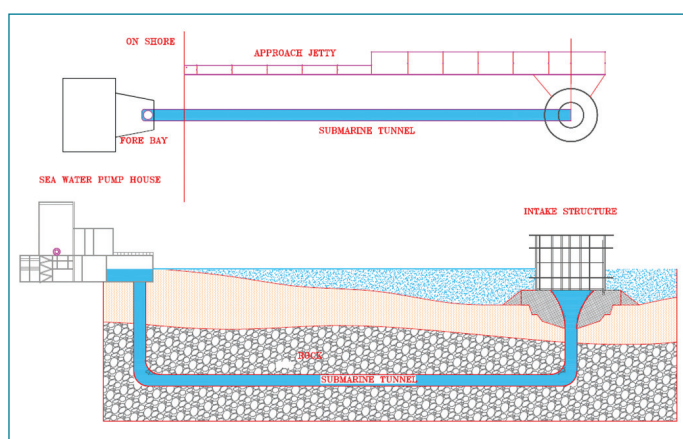


Fig. 1: Seawater intake system for PFBR

The intake system features a Reinforced Cement Concrete (RCC) Morning Glory type structure located 490 m offshore. The location was finalized based on adequate water depth and minimal littoral sand deposition. The intake velocity is limited to 0.5 m/s to protect marine life, and screens are provided to prevent debris ingress. Seawater is conveyed through a 3.6 m diameter horseshoe-shaped tunnel constructed 50 m below

the seabed in hard rock. The 565 m long tunnel, laid at a slope of 1:250, maintains a flow velocity of 2.5 m/s and is provided with concrete lining and antifouling coating. A 530 m long approach jetty ensures permanent access for construction and maintenance.

The warmed water is discharged through an RCC duct operating under siphon action to a seal pit, which maintains water seal and prevents air ingress (Fig. 2). The discharge then flows through a 1.2 km long outfall canal before entering the sea (Fig. 3). Extensive pre-engineering studies, including bathymetric, oceanographic, geotechnical, and model investigations, formed the basis of the conceptual design.

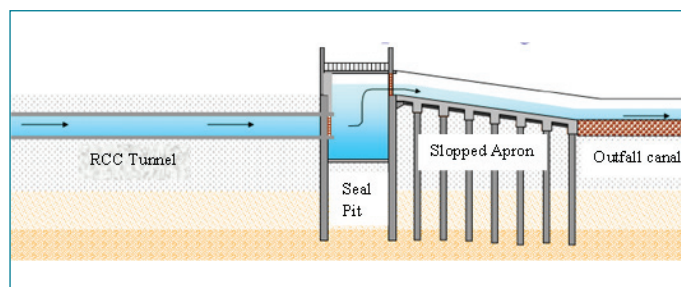


Fig. 2: Seawater seal pit and outfall structures for PFBR



Fig. 3: Seawater outfall canal with Guided bund for PFBR

This seminar paper presents the key civil engineering considerations, hydraulic design principles, structural configurations, marine construction challenges, and environmental safeguards incorporated in the conceptual design of the PFBR seawater intake and outfall systems.



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LECTURE
SERIES

ATOMISTIC MODELLING OF IRON PHOSPHATE GLASS PROPERTIES

Research on atomistic modelling of Iron Phosphate Glass (IPG) was started in MMS in 2016 with three scientists. Since then two persons have done their PhD and one JRF is currently working on studying the physical properties of IPG.

We use Density Functional Theoretical (DFT) and Molecular Dynamics (MD) simulations coupled with Monte-Carlo (MC) methods to obtain the structural, mechanical, electronic and optical properties and the dynamical stability and behaviour of the atomistic IPG systems. We also have good expertise in developing appropriate interatomic potentials to use in the MD and MC simulations.

We have developed an in-house potential free MC code to generate atomistic models of silica and IPG. We need to know information about the polyhedral units and their connectivity in the glasses and the types of defects that can be present in these glasses to generate small models (300–500 atoms) for quantum mechanical calculations and large models (100,000–1,000,000 atoms) for MD calculations. The MC code is quite versatile and can be used to develop atomistic models for any glass system.

Fig.1 shows the effects of structural distortions (random rotations of the constituent polyhedra) on the internal strain

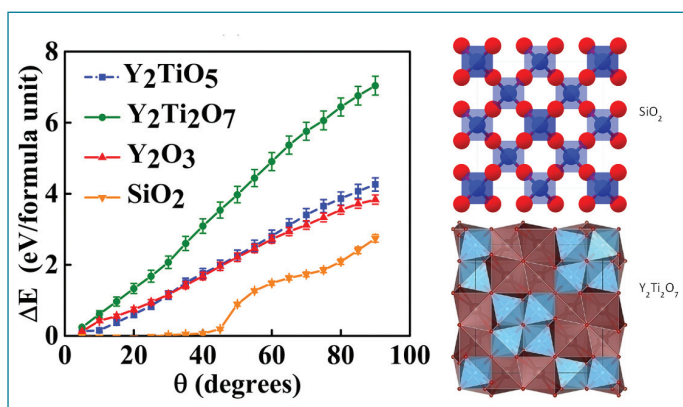


Fig. 1: Effect of polyhedral rotation on crystals

in SiO_2 , yttria, and $\text{Y}_2\text{Ti}_2\text{O}_7$ and Y_2TiO_5 crystals. We can see that the quartz crystal is able to disperse the strain energy to a large extent for rotations up to $\approx 50^\circ$, while $\text{Y}_2\text{Ti}_2\text{O}_7$ can't handle even very small rotations. The reason for this can be seen from the crystal structure for the two, also shown in Fig. 1. SiO_2 has very large interstitial spaces, while $\text{Y}_2\text{Ti}_2\text{O}_7$ has almost none. Thus the SiO_2 tetrahedra can distort to a large extent under rotation while the polyhedral units of $\text{Y}_2\text{Ti}_2\text{O}_7$ can't do that. Thus quartz or silica is a good glass former while $\text{Y}_2\text{Ti}_2\text{O}_7$ is not. This understanding is very important for the structural stability of the glasses.

We have developed in-house MC code for obtaining the atomistic models of SiO_2 (silica) and Iron Phosphate glasses, which works with the connectivity of the polyhedral units in the glasses and is 'potential-free' in the sense that it does not require any energy minimisation as such to obtain the atomistic configurations in a given volume. This is called a 'Continuous Random Network (CRN)'. One such case for silica glass is shown in Fig. 2. We can see that all the tetrahedra are vertex sharing and the Si:O ratio maintained as 1:2.

In addition to the MC method, we can generate the atomistic models of glasses by implementing the experimental Melt-Quench (MQ) procedure in the DFT and MD simulations. In

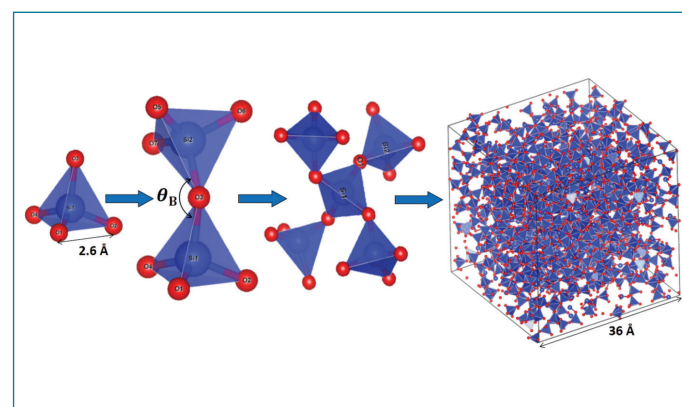


Fig. 2: CRN of silica glass

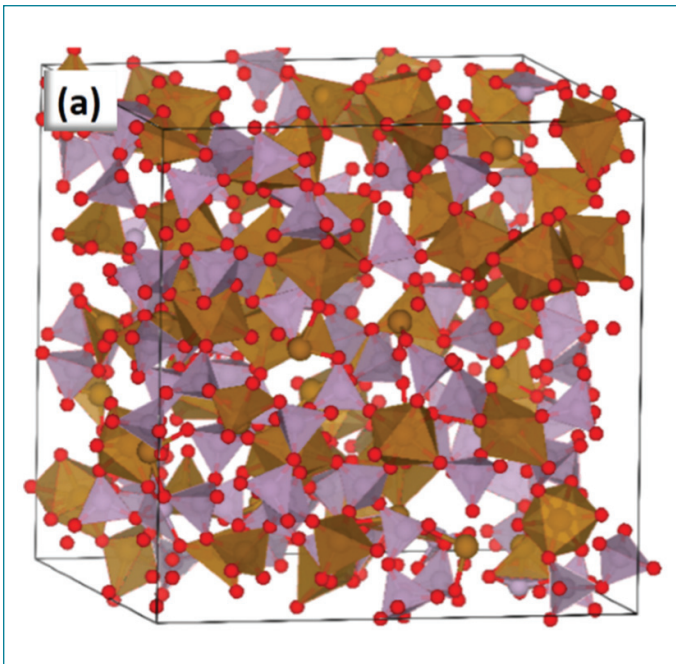


Fig. 3: IPG structure (20 Å side box)

experiments, the starting salts/compounds are heated to above their melting temperature and allowed to homogenise over a time period of few hours. The melt is then cooled quickly (quench) to below room temperatures. This is followed by annealing to remove the internal stresses caused by rapid quench to obtain stable glass phase. The quench rate is the order of 10^3 K/s in experiments. In DFT or MD simulations the whole procedure of quenching has to be completed in some picoseconds (ps), so the quench rate is very high, of the order of 10^{12} K/s. This is shortcoming of the simulations, but it can't be avoided as the simulations can't be carried out for the duration of seconds here, using simple DFT or MD. This procedure is implemented in the simulations, where the starting material is the crystal of the material (e.g., quartz crystal for obtaining silica, or olivine crystal for IPG). The system is taken to very high temperatures (≈ 5000 K) and is equilibrated for duration of 100 s of ps to ensure that the system is fully melted. It is then quenched to room temperature

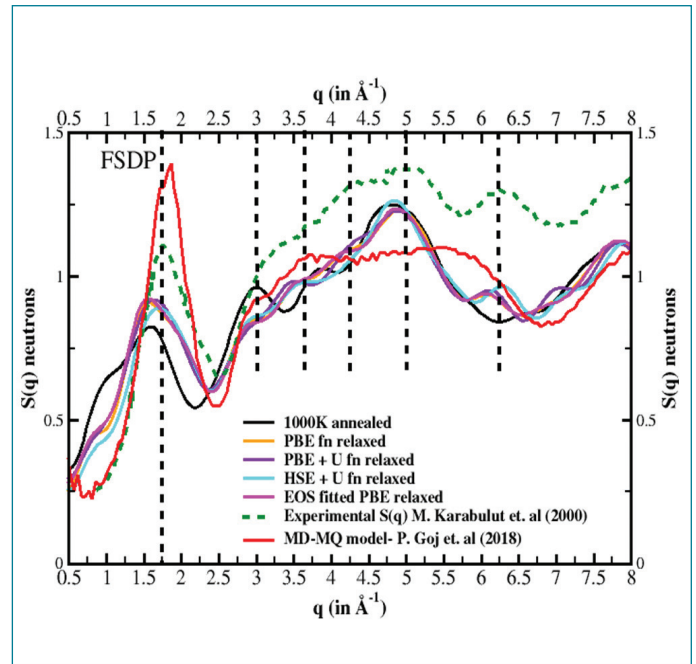


Fig. 4: Neutron $S(Q)$ for IPG, experimental and computed

at a quench rate of 5 K/ps for duration of ≈ 1000 ps. After the system attains the room temperature, it is annealed for further ≈ 100 ps to ensure that the strain is minimised in the system. Another way to obtain the glass configurations is to start with the stoichiometric numbers of atoms required to form the glass, fill them in the simulation box randomly and then equilibrate the system for a long time. For example, for IPG we have a stoichiometry of $\text{Fe}_3\text{P}_4\text{O}_{14}$ for the 40:60 Fe:P ratio. Thus if we want to develop a glass model with 105 atoms containing 15 Fe, 20 P and 70 O atoms, we can place them randomly in the simulation box and equilibrate to obtain an atomistic model of IPG. This method and MQ, both require good interatomic potentials to produce good models. Fig. 3 shows the IPG model obtained by MC method. Similar models are produced by MQ and random methods also.

Fig. 4 shows the experimental (dashed line) and calculated (solid lines) neutron structure factor $S(Q)$ obtained for IPG

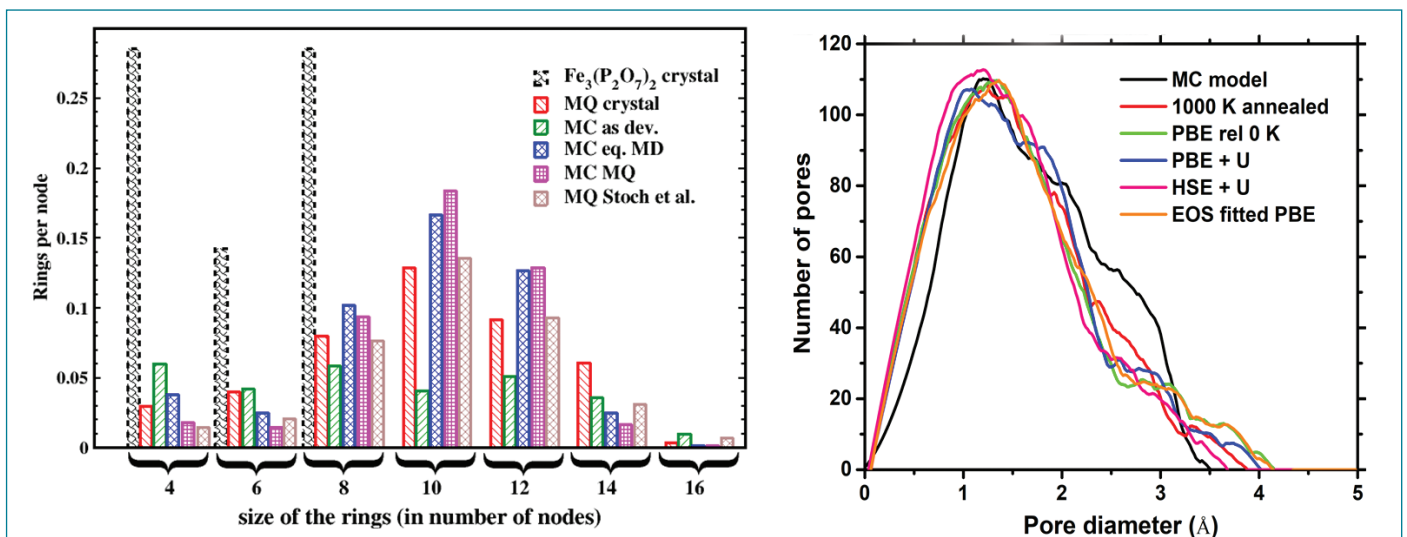


Fig. 5: RINGS distribution (left) and Void distribution (right) in IPG models

glasses. The first sharp diffraction peak (FSDP) is shown the first peak visible in the graph. As we know, the glasses have the short range order (SRO), which is controlled by the local chemistry of the constituent atoms (Fe, P and O). The SRO decides on the types of the polyhedral units present in the glass. In addition, the glasses are also classified by their Intermediate Range Order (IRO) which characterises the connectivity of the polyhedral units. One of few experimental techniques that can be used to study the IRO is FSDP. Its peak position in diffraction (I vs Q or 2θ , $Q = 4\pi \sin\theta/\lambda$) is inversely proportional to the characteristic distance ($R = 2\pi/Q$) of structural units, which is $\approx 5 \text{ \AA}$ for SiO_2 and IPG. The FWHM defines the structural correlation length, $L = 2\pi/\Delta Q$, which is the length over which the quasi-periodic polyhedral connections are maintained before becoming completely random. As the mass density increases, FSDP shifts to higher Q , its intensity decreases and FWHM increases. If there is disruption or change of MRO, then the position, shape and intensity change significantly. FSDP is also related to void distribution or interstitial spaces within glass network which affect the peak intensity (Fig. 5).

RINGS statistics in glasses refer to the distribution of closed-loop, connected structural units that define the IRO. Unlike crystals, glasses possess a statistical distribution of ring sizes (4, 6, 8 etc membered rings) (Fig. 5), analyzed by Raman, neutron/X-ray scattering and modelling. Fig. 6 shows the types of rings that are present in our IPG models. The FSDP in $S(Q)$ arises due to contributions from all such rings and thus is a good indicator of the IRO present in the glass.

Fig. 7 shows the atomistic models obtained for different Fe:P ratios. We don't observe any significant change in FSDP,

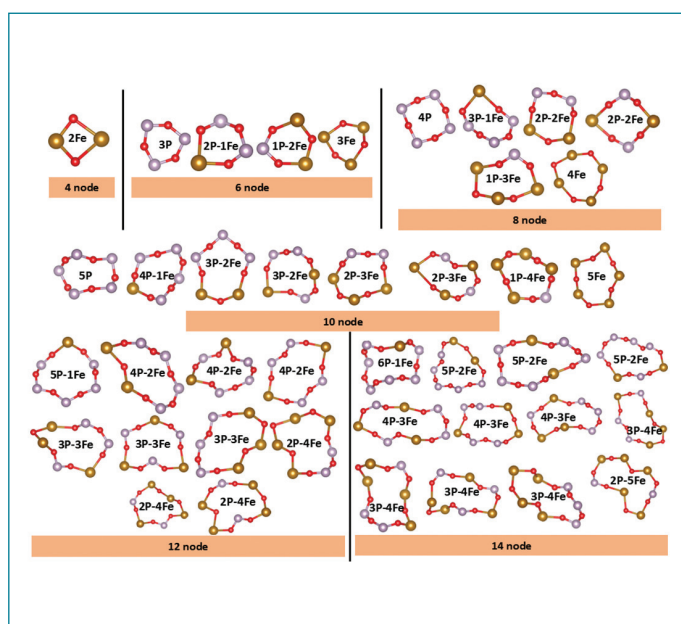


Fig. 6: Different size RINGS present in IPG models

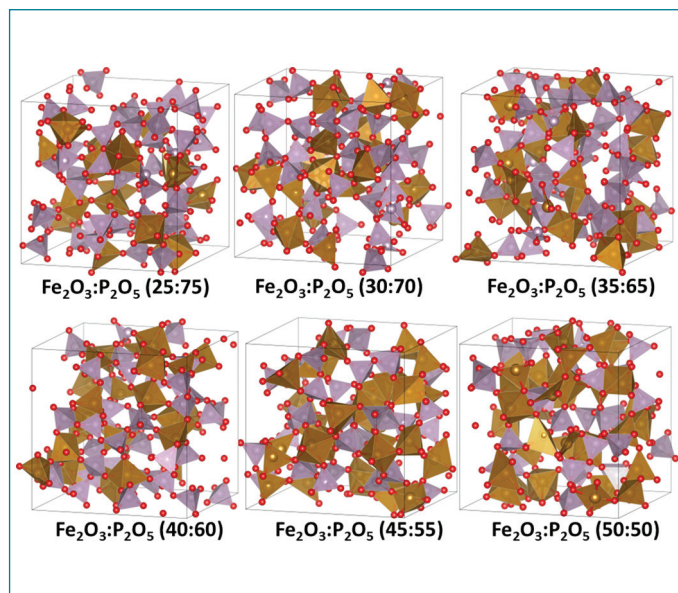


Fig. 7: IPG models with different Fe:P ratios

void fraction, mass density, or other electronic properties calculated using DFT and MD. Fig. 8 shows the electron density of states distribution for all the models, which don't show any significant differences. First neighbour Bond lengths and intra-polyhedron bond angles don't change much as they signify the SRO. Next neighbour bond lengths and inter-polyhedra bond angles change significantly, which affect the mechanical properties.

We have also calculated the diffusion of the Fe, P and O atoms in IPG as a function of temperature and find that Fe^{2+} ions diffuse fastest. Displacement cascade simulations also give a similar behaviour. It is the PO_4 units that are seen to be most stable in our simulations as opposed to the FeO_4 or FeO_6 units. We are currently studying the long time leaching behaviour of IPG models.

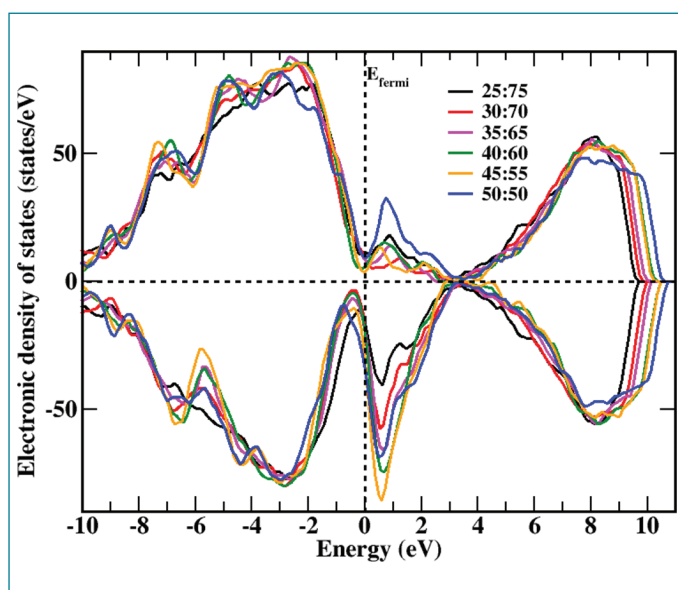


Fig. 8: Electronic DOS for different IPG models with different Fe:P ratios



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LECTURE
SERIES

HYDROGEN PRODUCTION, STORAGE AND TRANSPORTATION: PATHWAYS FOR NUCLEAR-HYDROGEN SYNERGY

HYDROGEN PRODUCTION PATHWAYS

Hydrogen (H₂) is increasingly recognised as an important enabler of deep decarbonisation and the transition to sustainable energy systems. Although emissions from electricity generation are gradually declining, significant carbon dioxide (CO₂) emissions persist in “hard-to-abate” sectors such as steel production, fertiliser manufacturing, petroleum refining, petrochemicals and heavy transport. These sectors cannot rely solely on electrification and therefore require alternative low-carbon fuels. Hydrogen, acting as both an energy carrier and an industrial feedstock, offers a pathway for emission reduction while supporting long-duration energy storage and grid flexibility. Global hydrogen demand currently exceeds 95 million tonnes per year, mainly for ammonia (NH₃) production, petroleum refining and chemical processing. Future energy scenarios indicate that demand may grow as hydrogen applications expand to synthetic fuels, mobility and industrial decarbonisation. Hydrogen production is energy

intensive; water electrolysis typically requires 50–60 kWh of electricity per kilogram of hydrogen, highlighting the need for reliable low-carbon energy sources (Table 1).

NUCLEAR REACTORS AND HYDROGEN PRODUCTION

Nuclear energy can support hydrogen production because of its high reliability and ability to supply both electricity and process heat. Reactor outlet temperature largely determines the hydrogen production pathway.

India’s nuclear fleet is dominated by Pressurised Heavy Water Reactors (PHWRs) that can provide reliable electricity for electrolysis-based hydrogen production. Advanced systems such as Sodium-cooled Fast Reactors (SFRs) operate at higher temperatures and may enable more efficient hydrogen production technologies including high-temperature electrolysis and thermochemical water-splitting cycles (Table 2).

Table 1: Hydrogen production pathways

Method	Energy Source	Temperature (°C)	CO ₂ Emissions (kg CO ₂ /kg H ₂)	Remarks
Steam Methane Reforming (SMR)	Natural Gas	700–1000	9–12	Currently dominant industrial process
Alkaline Electrolysis	Electricity	60–90	0.6–1.2*	Mature and widely deployed technology
PEM Electrolysis	Electricity	50–80	0.5–2*	Flexible operation suitable for variable power
High-Temperature Steam Electrolysis	Electricity + Heat	700–900	0.3–1.0*	Higher efficiency using thermal energy
Thermochemical Cycles	High-temperature heat	500–950	0.1–0.7*	Potential long-term large-scale option

* Lifecycle emissions when powered by low-carbon electricity (nuclear or renewables).

Table 2: Nuclear reactors and hydrogen production

Reactor Type	Outlet Temperature (°C)	Hydrogen Production Pathway	Remarks
PHWR	290–310	Low-temperature electrolysis	Dominant reactor type in India
LWR	280–320	Low-temperature electrolysis	Widely deployed globally
SFR	500–550	High-temperature electrolysis	Advanced hydrogen production pathways
HTR	750–950	Thermochemical cycles	Very high efficiency potential

HYDROGEN STORAGE AND TRANSPORT

Hydrogen storage is challenging because of its low volumetric energy density at ambient conditions. Several technologies are used for safe and efficient storage and transport.

Hydrogen can be transported through pipelines, high-pressure trailers, cryogenic tankers or chemical carriers depending on scale and distance. Safety considerations are important due to hydrogen's wide flammability range and low ignition energy, requiring measures such as leak detection, ventilation and proper system design (Table 3).

STRATEGIC IMPORTANCE

Nuclear–hydrogen integration can support India's clean energy transition. As the country progresses toward its net-zero emissions target by 2070, reliable hydrogen production can strengthen energy security, reduce dependence on fossil fuels and support industrial decarbonisation. Hydrogen will play a key role in sectors that are difficult to electrify directly. Nuclear energy, with its high availability and ability to provide both electricity and heat, offers a robust pathway for large-scale clean H₂ production and long-term energy sustainability.

Table 3: Hydrogen storage and transport

Storage Method	Energy Density (kg H ₂ /m ³)	Operating Conditions	Key Characteristics
Compressed Gas	23–42	350–700 bar	Technically simple but requires high pressure
Liquid Hydrogen	~71	Cryogenic (~20 K)	High density but energy-intensive liquefaction
Metal Hydrides	27–80	Moderate temperature and pressure	Safer storage but relatively heavy
Chemical Carriers (e.g., NH ₃ , LOHC)	~100–120 (equivalent)	Moderate conditions	Suitable for long-distance transport



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LECTURE
SERIES

BREED & BURN TRAVELLING WAVE REACTOR: A REVIEW

Breed & Burn Traveling Wave Reactor (B&B TWR) is an advanced fast reactor concept designed to utilize fertile nuclear fuel, particularly Depleted Uranium (DU), efficiently through a breed-and-burn process. Most nuclear power reactors operating today are Light Water Reactors (LWRs) which typically use enriched uranium as fuel. From one tonne of Natural Uranium, roughly 13% becomes enriched fuel while the remaining is left as DU during the enrichment process. Since DU which is in the form of UF_6 has chances to react with moisture to form corrosive Hydrogen Fluoride, it is stored in sealed, pressure-vessel-grade steel cylinders under dry conditions to prevent air or moisture from entering. International Atomic Energy Agency treats DU as a long-term liability as its long-term storage poses environmental, health, safety, and financial challenges.

Technologies capable of utilizing DU as fuel, such as B&B TWRs, gained considerable interest in industrialised nations in the late 1990's. In B&B reactors, the core is divided into 2 zones: one with highly enriched fuel (starter zone), and other with a larger zone with depleted fuel (breeding zone). A breed/burn wave is then formed in the starter zone and will move to the fertile zone, once it had bred fissile fuel as illustrated in Figs. 1 & 2. In this kind of reactor, the life length would depend on the size of the core itself. This concept leads to propagation of fuel burnup region like a wave and therefore B&B reactors are classified as Traveling Wave Reactors (TWRs). A burnup wave is a self-propagating nonlinear nuclear chain reactions which is similar to a soliton. Soliton-like behavior is key, as it ensures that the wave maintains its shape and stability over long distances, enabling continuous operation. In B&B reactors, another classification is a Standing Wave Reactor (SWR), where the burning zone remains nearly fixed within the core, while periodic fuel shuffling is carried out to sustain a steady burn region without requiring physical propagation of the burnup wave. Time- and space-dependent Partial Differential Equations (PDEs) describing neutron transport and

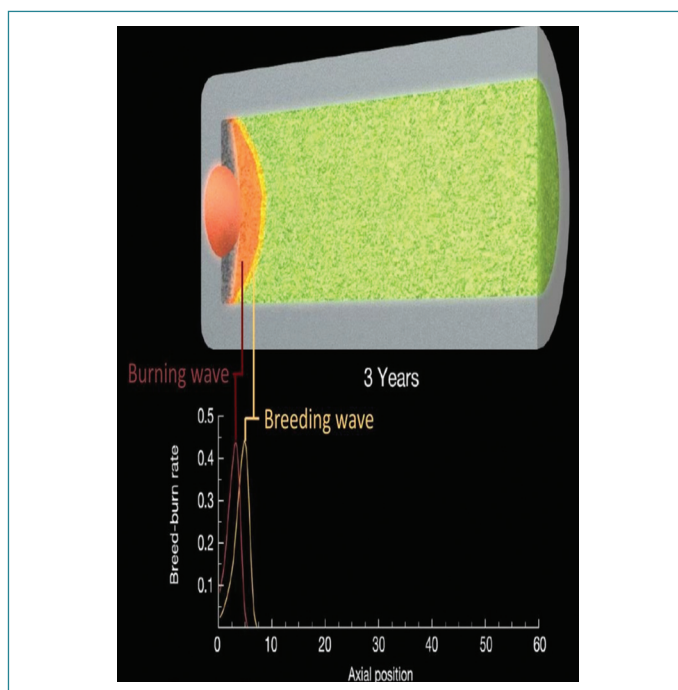


Fig. 1: The movement of burnup region in the fuel

nuclide evolution are employed to evaluate the establishment and sustainability of equilibrium wave propagation, along with neutron balance and fuel burnup characteristics.

The advanced core designs that utilize the TWR(B&B) concept to achieve long fuel cycles and efficient utilization of DU include the Ultra Long Life Fast Reactor (ULFR, 3000 MWt), Ultra Compact Fast Reactor (UCFR, 2600 MWt), Energy Multiplier Module (EM², 500 MWt), and CANDLE (3000 MWt). ULFR is designed for long-term operation without refuelling and employs U-10Mo alloy fuel, HT9 steel cladding, and sodium coolant for efficient heat removal. These reactors operate based on in-situ fuel breeding in central and peripheral blanket regions; as fissile material is depleted in the driver zone and bred in adjacent regions, the fission zone progressively shifts within the core, enabling sustained wave propagation. The initial fuel enrichment in the central region must be carefully optimized to initiate and maintain this process.

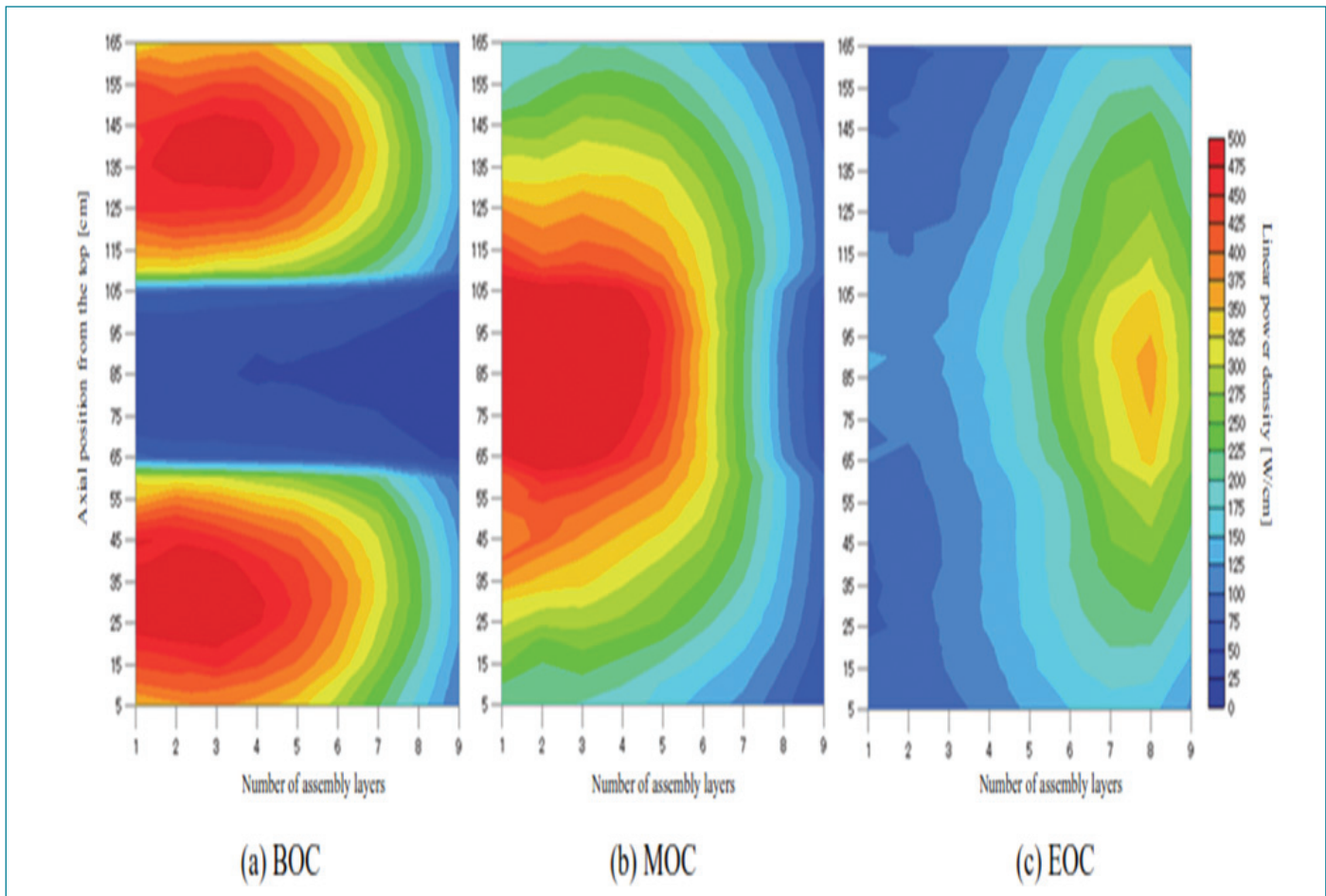


Fig. 2: Temporal evolution of the burnup wave in a breed-and-burn reactor, Yamashita and Takaki, PNST, 2025

In the UCFR and CANDLE designs, fuel zoning (e.g., U-10Zr and UN fuels) typically consists of a highly enriched region at one end and a fertile blanket at the other, leading to a gradual outward movement of the power peak as the reactor power operation progresses. The EM² is a high-temperature gas-cooled modular fast reactor that uses UC fuel, SiC composite cladding, and helium gas as coolant, with a compact, factory-sealed design that enhances proliferation resistance. Despite their potential, fuel performance, material durability, and thermal-hydraulic non-uniformities remain key challenges in these concepts, which have not yet been extensively demonstrated.

The first practical engineering embodiment of a breed-and-burn fast reactor considering all the engineering limits to produce a design concept was launched by TerraPower, a U.S.-based private company developing advanced nuclear technologies, supported by the U.S. Department of Energy. After evaluating various design options and core geometries, TerraPower identified a “standing wave” cylindrical core geometry, a variant of the TWR, as the most promising practical design. Key technologies in the TerraPower TWR include advanced optimised HT9 ferritic–martensitic steel cladding, high uranium-content metal fuel capable of very

high burnup, and innovative fuel pin designs that reduce stress, swelling, and internal pressure. The design also incorporates low-distortion fuel assemblies, a low-leakage core with efficient fuel management, and features like tight pin lattices and reduced sodium content to improve reactivity and inherent safety.

Extensive research and testing programs are being carried out for the TWR to reduce the technical risks associated with its design, development, and deployment. To validate key technologies, several features were intended to be demonstrated through a large-scale prototype. TerraPower initially partnered with China National Nuclear Corporation to construct a 600 MWe prototype at Xiapu. However, the project was discontinued in 2019 due to U.S. technology transfer restrictions. The company has since shifted its focus to advanced reactor systems such as the Sodium reactor, incorporating insights from earlier TWR research. The Nuclear Regulatory Commission formally issued a construction permit for the Kemmerer Unit 1 Sodium reactor on 9th March, 2026.

The successful construction and operation of the Kemmerer Unit 1 will open up a new chapter in the history of nuclear power generation.



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LECTURE
SERIES

FATIGUE CRACK GROWTH IN STRUCTURAL MATERIALS: IMPLICATIONS FOR NUCLEAR REACTOR DESIGN

The broad idea of this work is to examine how fractures and failures of critical infrastructures, such as nuclear facilities, affect society and the country's economic growth. Therefore, fracture and failure studies are carried out with utmost care, particularly during the design, installation, commissioning, and service stages of nuclear components. The science that addresses material failure through crack nucleation and growth is known as fracture mechanics.

Fatigue Crack Growth (FCG) properties of SS316L(N) and modified 9Cr-1Mo steel, which are major structural materials for nuclear, chemical, automotive, and cryogenic industries, are critical for damage-tolerant design and integrity assessment of components subjected to cyclic loading during service. Literature shows that these properties are influenced by test conditions, including temperature, load ratio, frequency, and environment, as well as material conditions, such as cold work, residual stresses from forming and welding, and ageing in service. Additionally, the growth of short cracks cannot be predicted directly using data from long cracks. Two fundamental issues remain: the effect of load ratio on fatigue

crack growth and the reason for higher crack growth rates in short cracks compared to long cracks. This work addresses these issues by characterizing the FCG behaviour of SS316LN base, weld, and cold-worked materials.

The ΔK threshold obtained from FCG data is important for initial design analysis and during service. The effect of load ratio on FCG behaviour of SS316L as a function of nitrogen has been evaluated in the threshold regime. Variations in the threshold regimes are attributed to crack closure. FCG data have been analyzed incorporating crack closure effects at ambient and elevated temperatures. Results from Constant K_{\max} tests, i.e., closure-free conditions, differ from those incorporating crack closure as shown in Fig. 1. Improved FCG resistance at intermediate temperatures (see in Fig. 2), observed as a plateau or increase in the effective threshold and overlapping of FCG curves in the range 623–773 K, is attributed to Dynamic Strain Ageing (DSA). An Arrhenius-type relation was established between crack tip strain rate and temperature (T), and results are presented in Fig. 3. Activation energies of 90 ± 2 kJ/mol (623–723 K) corresponding to

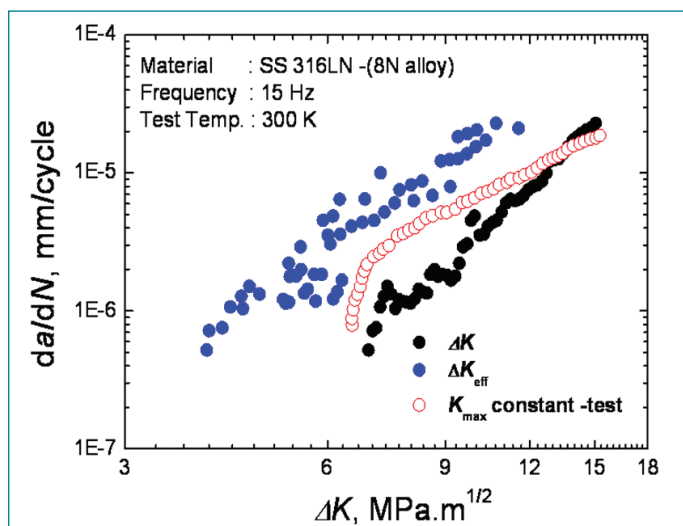


Fig. 1: Effect of constant ΔK and K_{\max} test on the threshold behaviour of SS316L(N) in comparison to the crack closure corrected ΔK_{eff}

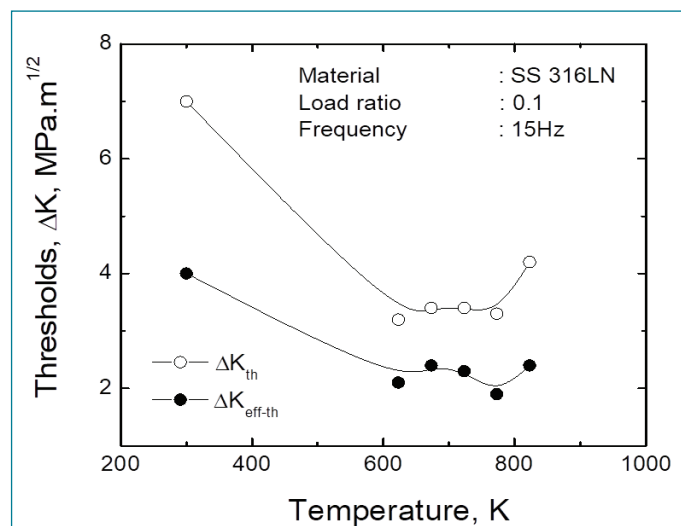


Fig. 2: Effect of temperature on the ΔK threshold of SS316L(N)

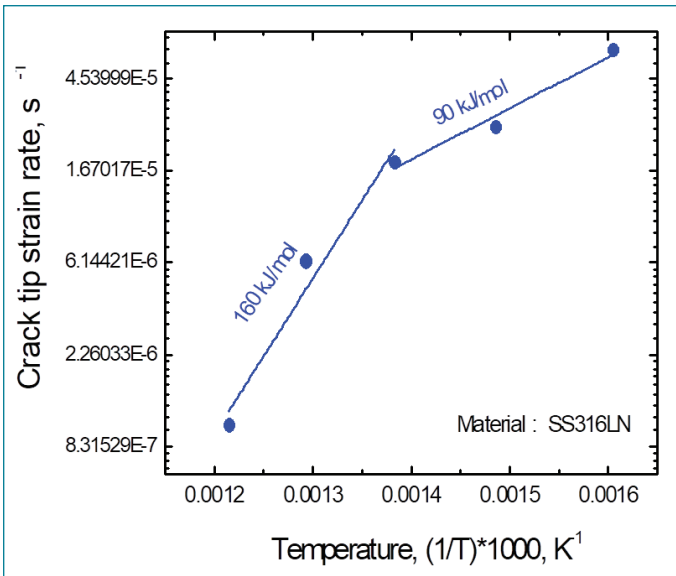


Fig. 3: Arrhenius type of relation was established between crack tip strain rate and temperature in order to determine the activation energy related to the crack growth mechanics

carbon diffusion and 160 ± 5 kJ/mol (773–823 K) for nitrogen diffusion indicate that the diffusion of interstitial solute elements drives DSA. Crack dormancy at low frequency and high temperature is associated with blunting of the crack tip due to creep and/or oxidation, not crack closure. Selecting the appropriate ΔK threshold is therefore essential for design and service considerations.

Further analysis was carried out using the Unified Approach, providing a physically meaningful and self-consistent framework to address load ratio effects, the short crack problem, and residual stresses due to welding and cold working. The role of nitrogen in FCG behaviour was examined at three concentrations (designated as (0.08 (8N), 0.14 (14N) and 0.22 (22N) wt%). FCG rates as a function of R-ratio were determined, and results were analyzed using the two-parameter $\Delta K-K_{max}$ approach. Crack growth trajectory maps were constructed, establishing the effect of nitrogen on the crack growth path. Deformation-Induced Martensitic Transformation (DIMIT) is shown to be a K_{max} -dependent process responsible for deviation of the crack growth trajectory from the pure fatigue line (45°) as shown in Fig. 4. Increased crack growth resistance in these alloys arises from transformation toughening. The Unified Approach also provides a self-consistent analysis of residual stresses introduced during welding. Results for cold-worked material show that increasing cold work improves FCG resistance through DIMIT up to 10%, beyond which no further improvement is observed. The approach also highlights the limitations of using a single crack growth driving force parameter, as currently implemented in many design codes.

According to Griffith's and Orowan's equations, shorter cracks require higher stresses for growth. However, literature shows short cracks often grow at smaller ΔK than long cracks, leading to the concept of similitude breakdown.

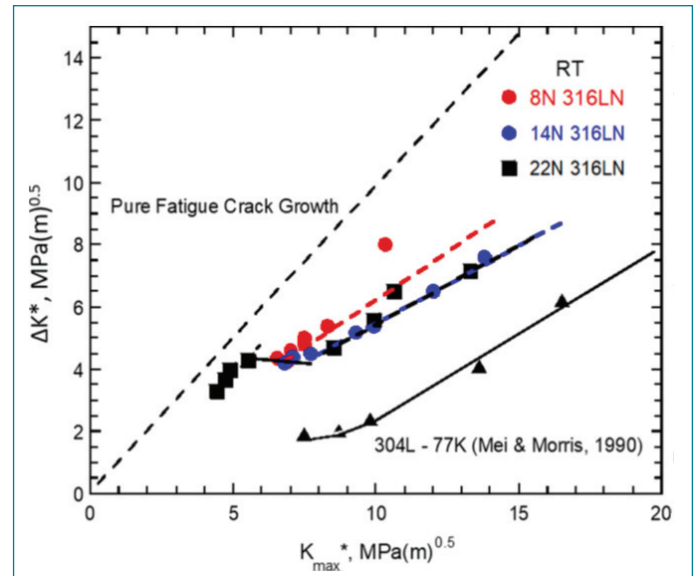


Fig. 4: Influence of nitrogen on crack growth trajectory developed using unified approach

Fatigue damage analysis in the endurance limit shows that large numbers of cycles produce intrusions and extrusions, slip bands, dislocation pile-ups, and deformation bands, generating local internal stresses with gradients. Incipient cracks form under these internal stresses, augmented by remote applied stresses. Classical fracture mechanics does not account for these internal stresses in calculating crack tip driving forces. To address this, a modified Kitagawa diagram was developed to link short crack behaviour with long crack growth by including internal stresses as shown in Fig. 5. The Unified Approach provides a method to compute the minimum internal stresses required, in addition to applied stresses, for short cracks to grow. This approach explains differences in short and long crack growth in SS316(LN) without invoking similitude breakdown. The modified Kitagawa–Takahashi diagram was also used to evaluate contributions of environment-induced chemical driving forces to crack tip stress fields. Overall, the Unified Approach connects fracture and fatigue within a single coherent framework.

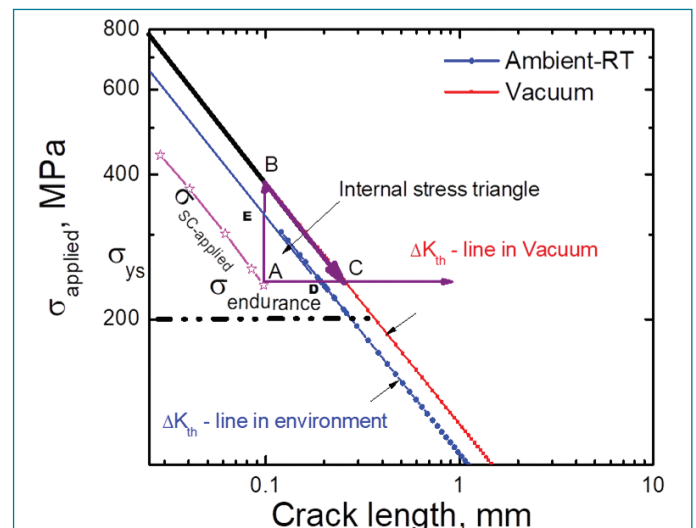


Fig. 5: The modified Kitagawa–Takahashi diagram connects the fatigue limit to the fracture mechanics parameter ΔK threshold for SS316(LN)

12th Biennial DAE-BRNS Symposium on Separation Science and Technology (SESTEC-2026)

February 11th-14th, 2026

The 12th Biennial DAE-BRNS Symposium on Separation Science and Technology (SESTEC-2026) was successfully held from 11th to 14th February 2026 at the DAE Convention Centre, Anupuram. The symposium was inaugurated by Shri Sreekumar G. Pillai, Director, IGCAR, who emphasized the necessity of interdisciplinary research in addressing the complex challenges of the nuclear fuel cycle's back end. Over four days, the comprehensive program featured 10 plenary lectures, 19 invited talks, 4 special invited talks, 72 oral presentations, and 100 poster sessions. These contributions spanned approximately 200 peer-reviewed abstracts focusing on the nuclear fuel cycle, isotope separation, green processes, and waste management using advanced extractants and materials. A major highlight was the special session on spent nuclear fuel reprocessing, showcasing India's long-standing expertise and technical advancements.



In addition to technical deliberations, the Association of Separation Scientists and Technologists (ASSET) conferred the prestigious Dr. P.N. Pathak Memorial Award and the THERMAX-ASSET Award, recognizing outstanding contributions and academic excellence. The valedictory function was graced by Shri S. Satyakumar, Chairman & Chief Executive, Heavy Water Board. Jointly organized by IGCAR, BARC and ASSET, SESTEC-2026 provided a vibrant platform for young researchers to interact with global experts, fostering collaborations that will shape the future of sustainable separation technologies.



Technology Transfer and Incubation Agreement Exchange

February 16th, 2026



Director, IGCAR handing over a Technology Transfer License Agreement from AIC FAST to Botnine Innovation Pvt. Ltd., Chengalpet (Tamil Nadu) for commercializing RpG's patented technology on 16th February 2026.



Director, IGCAR exchanging incubation agreement between AIC FAST and M/s Lablink, Mumbai for developing "Value Additions to Conductivity Meter" on 16th February 2026.

Observance of Swachhata Pakhwada 2026 at IGCAR

February 16th-28th, 2026

Introduction

Swachhata Pakhwada 2026 was observed at IGCAR from 16th to 28th February 2026 with great enthusiasm and active participation from employees, stakeholders, and the local community. The observance aimed to reinforce the importance of cleanliness, hygiene, sustainability, and community responsibility through a series of structured activities and outreach programs.

Display of Awareness Banners (16.02.2026)

The observance commenced with the installation of awareness banners at prominent locations across the IGCAR campus. These banners were strategically placed at Main Gate, IGCAR Gate, Administration Building and HBB.

The initiative served as a visual reminder to employees and visitors, encouraging participation in maintaining cleanliness and promoting Swachhata practices.



Banner displayed at HBB



Banner displayed at Admin Building

Swachhata Pledge (16.02.2026)

On the inaugural day at 12:00 hrs, the Swachhata Pledge was administered to employees by senior officials at their respective workplaces.

The pledge emphasized:

- Personal responsibility for cleanliness
- Commitment to hygiene
- Collective participation in building a cleaner environment

This marked a unified beginning to the fortnight-long campaign.



Swachhata Pledge by employees at HBB and Stores IGCAR

Cleaning and Maintenance of RO Systems in IGCAR Premises (17th & 18th February 2026)

Ensuring access to safe drinking water is a critical component of Swachhata.

During this period:

- RO systems and water purifiers across the campus were cleaned and serviced
- Preventive maintenance was carried out by ESG
- Continuous supply of hygienic drinking water was ensured

This activity highlighted the importance of sanitation beyond visible cleanliness.



Maintenance and cleaning of RO systems at IGCAR

Cleaning of Office Premises, Weeding out of Records and Sending the Segregated Wastes to Stores, DPS for Disposal (19th & 20th February 2026)

A comprehensive cleaning drive was undertaken in office premises across IGCAR.

Key outcomes:

- Identification and segregation of obsolete materials
- Systematic disposal through Stores, DPS
- Approximately 20 tonnes (14 truckloads) of waste cleared
- This initiative promoted:
- Efficient resource management
- Decluttering of workspaces
- Responsible waste segregation practices



Segregating unwanted and obsolete materials and sending to stores for disposal

Shramdaan Activity at Neighbourhood Village – Anupuram Market Area (21st February 2026)

As part of community outreach, a Shramdaan activity was conducted at the Anupuram Market Area.

Highlights:

- 150 volunteers from IGCAR participated
- Conducted from 08:00 hrs to 09:00 hrs
- Cleaning of approximately 1 km roadside stretch
- Removal of plastics and non-biodegradable waste

Impact:

- Approximately 5 tonnes of waste collected and cleared
- Significant improvement in local sanitation

Additional Initiatives:

- Distribution of Swachhata-themed hoodies to volunteers
- Public announcements in Tamil, Hindi, and English
- Active participation of village representatives, including the Vice President of Neykuppe Village Panchayat

This activity strengthened community engagement and awareness of sustainable cleanliness practices.



Shramdaan activity conducted at Anupuram market area in association with Neykuppe Village Panchayat

Conducting Swachh Bharat Essay, Poster & Slogan Competitions for Employees of IGCAR on the theme “Reduce Reuse Recycle” (23th & 24th February 2026)

To foster awareness and creativity among employees, competitions were organized on the theme “Reduce, Reuse, Recycle.”

Events included:

- Essay Writing
- Poster Making
- Slogan Writing

These activities encouraged innovative thinking and reinforced the importance of sustainable practices.



Essay writing, poster making and skits performed during Swachhata Pakhwada events

Tree Plantation Drive (24th February 2026)

A major environmental initiative was undertaken in collaboration with the Tamil Nadu Forest Department, Thirukazhukundram Forest Range.

Key Achievements:

- Plantation along the approach road to Edaiyur Lake
- Clearing of ~3 acres of invasive vegetation (*Prosopis juliflora*)
- Plantation of ~800 native saplings

This effort contributed to:

- Increased green cover
- Ecological restoration
- Long-term environmental sustainability



Shri Sreekumar G. Pillai, Director, IGCAR alongwith his colleagues during tree plantation

Cleaning of Pond near DFRP Plant

A pond serving as a rainwater harvesting source was restored.

Actions Taken:

- Removal of dense vegetation (Nut Grass / Korai)
- Clearing of blockages

Outcome:

- Restoration of water storage capacity
- Enhanced groundwater recharge



Restoration of pond near DFRP plant

Garden Development near HBB and ESG Switch yard at IGCAR

Landscaping efforts were carried out near:

- HBB
- ESG Switch Yard

Improvements:

- Plantation of grass and ornamental plants
- Enhanced aesthetic appeal
- Reduced dust levels
- Improved environmental conditions



Landscaping carried out near HBB & ESG switch yard

Public School Cleaning & Painting

- i. A Government School at Vengambakkam was identified for renovation under Swachhata Pakhwada 2026. The school has strength of approximately 1,400 students; however, the existing toilet facilities were found to be inadequately maintained.
- ii. Originally there were open bathrooms, enclosed only with brick walls. During the renovation, new roof sheeting was installed, and all water pipelines, sewage lines, doors, and sanitary fittings were replaced.
- iii. Proper drainage, water supply, and ventilation were provided to ensure a safe and comfortable environment for the students.



Renovated school toilets with new roof sheets

Swachhata Paintings in School Compound

Students of AECS School actively participated in beautification activities.

Highlights:

- Painting of school compound
- Creation of murals promoting cleanliness and hygiene

Impact:

- Improved school environment
- Increased awareness and responsibility among students



Painting of school compounds and creating murals on cleanliness and hygiene

Closing Ceremony of Swachhata Pakhwada (27th February 2026)

The Swachhata Pakhwada concluded with a closing ceremony held on 27.02.2026, which was presided over by the Director, IGCAR. During the ceremony, the skit that secured the first prize in the competition conducted as part of the Swachhata Pakhwada activities was performed. The Director, IGCAR, the Chief Administrative Officer, the Chairman, SBC and the Co-chairman, SBC distributed prizes to the winners of the various competitions organized during the Pakhwada, appreciating their enthusiastic participation and contribution towards promoting the message of cleanliness and hygiene.



Distribution of prizes to the winners of the competitions conducted as part of Swachhata Pakhwada

*Reported by
Swachh Bharat Cell,
IGCAR*

9th National Conference URJAVARAN – 2025-26

March 03, 2026

Air-Conditioning & Ventilation System Division (AC&VSD), IGCAR organized the 9th National Conference URJAVARAN – 2025-26 in association with Indian Society of Heating Refrigerating & Air-conditioning Engineers (ISHRAE) – Kalpakkam Chapter at Vikram Sarabhai Auditorium on 3rd March, 2026. The theme of the conference was “**ENERGY CONSERVATION & DECARBONIZATION**”. Around two hundred and eighty delegates from various DAE units at Kalpakkam, academic institutions, industries and leading consultants attended the conference. The conference started with the welcome address by convener Shri Biswanath Sen.

The inaugural function was presided over by Shri Sreekumar G. Pillai, Director, IGCAR & GSO. In his presidential address, he emphasized the urgent need to reduce CO₂ emissions, implement climate policies effectively, and leverage the potential of Fast Breeder Reactors (FBRs) in achieving clean and sustainable energy goals. He also stressed the importance of adhering to defined timelines for climate action initiatives.



Release of souvenir during inaugural function: Shri Biswanath Sen, Convener; Shri K.P. Kesavan Nair, Former Director, ESG, IGCAR; Dr. Mylswamy Annadurai, Director (Rtd), ISRO Satellite Centre, Bengaluru; Shri Sreekumar G Pillai, Director, IGCAR & GSO; Dr. T.V. Krishna Mohan, Facility Director, BARCF; Dr. R. Saravanan, Prof. Anna University, Chennai and Society President Elect., ISHRAE HQ, New Delhi and Shri S. Marudhupandiaraja, Organizing Secretary

Shri K.P. Kesavan Nair, Former Director, ESG, IGCAR delivered the inaugural address and highlighted the critical role of energy conservation in ensuring a sustainable future. He introduced the concept “**ACARA – Air-Conditioning As Reasonable As Achievable**”, encouraging its adoption across sectors.

Dr. Mylswamy Annadurai, Director (Rtd), ISRO Satellite Centre, Bengaluru released the Urjavarana Souvenir and delivered the key note address. He shared his invaluable experiences as Project Director of Chandrayaan-1 and Mangalyaan missions. He spoke about his continued contributions to science and society, emphasizing the importance of outreach programs in schools, fostering industry-academia collaborations, and mentoring young entrepreneurs to drive socially relevant innovations.

Shri S. Marudhupandiaraja, Organizing Secretary, proposed the vote of thanks for the inaugural session.

An Exhibition was arranged as a part of the conference and eight exhibitors participated and exhibited their products and demonstrated their models. The Exhibition stalls were inaugurated by Dr. T.V. Krishna Mohan, Facility Director, BARCF.

The conference deliberated on the latest technologies, products and ongoing research on sustainable air conditioning and ventilation of buildings. Four invited talks were delivered by eminent speakers from academia, industries, R&D organizations, leading architects and consultants. Six contributed papers from DAE units (IGCAR, BARCF), educational institutions and industries were presented covering wide spectrum like green building, automobile air-conditioning, concrete wall penetration cooling system, high temperature piping.

Shri S. Chandramouli, AD, FRTG, IGCAR, and Shri P.K. Sharma, ED (O), NRB & GM, INRPK, BARCF, evaluated the presentations from reputed industries were also a part of the conference. The conference facilitated good interaction among the delegates and experts in the area of sustainable HVAC.

During the valedictory function, Mr. Anil Kumar Sahoo, Technical Committee, Urjavarana 2025-26, summed up the one-day conference. Shri I.V.N.S. Kamaraju, Project Director, FRFCF delivered the valedictory address. In his address, he described the nuclear energy as green energy and emphasized on exploring energy conservation in air-conditioning & ventilation systems.

Shri D. Jagadishan, President Elect., ISHRAE Kalpakkam proposed the vote of thanks.



Reported by
Shri Biswanath Sen,
Convener, URJAVARAN – 2025-26,
Engineering Services Group

Awards, Honours and Recognitions

Dr. S. Ningshen, Head, CSTD/MMMG was conferred Fellow of the Royal Society of Chemistry (FRSC-2026), UK and Fellow of the Association for Materials Protection and Performance (FAMPP-2026), USA.

Dr. R. Dhayalan, SO/F, NDED/MMG received Dr. M Pancholy Memorial Award 2025 for Best Oral Presentation in “International Conference on Ultrasonics and Materials Science for Advanced Technology (ICUMSAT-2025)” organized by Ultrasonic Society of India at Easwari Engineering College, Chennai during 21–23 January 2026.

Shri Manoj Udasi, Kinkar Mandal, K.A. Venkatesan and V. Jayaraman received Asset Best Paper Award for the paper “Interphase Calculation using Weir Coefficient Studies in 40 mm Diameter Annular Centrifugal Extractor”, SESTEC-2026, February 2026.

Shri C.H. Sreeram, S. Balasubramonian, R. Rajeev and K.A. Venkatesan received Asset Best Paper Award for the paper “Estimation of Absorbed Dose during the First Codecontamination and Stripping Cycles of Fast Reactor Fuel Reprocessing”, SESTEC-2026, February 2026.

Dr. G.V.S. Ashok Kumar, D. Bola Sankar, Manish Chand, T. Kalaiyarasu, J. Vithya, J.S. Brahmaji Rao, M. Sreenivasulu, S. Rajeswari and K. Sundararajan received Best Poster Award for the paper “Quality Control Assessment of Carrier-Free ^{32}P Orthophosphate Produced via the $^{32}\text{S}(n,p)^{32}\text{P}$ Reaction in FBTR”, SESTEC-2026, February 2026.

Shri Somnath Sengupta, B. Sreenivasulu and C.V.S. Brahmananda Rao received Best Oral Award for the paper “A Combined DFT–MD Investigation of Zr(IV) Selectivity in TAP and DAAP Organophosphorus Extractants”, SESTEC-2026, February 2026.

BIO-DIVERSITY @ DAE CAMPUS, KALPAKKAM



Black Drongo

Black Drongo, formerly known as King Crow, found in DAE Campus, Kalpakkam is a slim and agile glossy black bird with a long, forked tail. Both male and female look alike. It has a tiny white spot near to the base of its bill, and this helps to identify black drongos from other drongos.

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