सत्यमेव जयते

GOVERNMENT OF INDIA

DEPARTMENT OF ATOMIC ENERGY

ANNUAL REPORT

2022–23

राष्ट्र की सेवा में परमाणु

पऊवि
DAE

ATOMS IN THE SERVICE OF THE NATION

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Cover page : Site View of Rajasthan Atomic Power Project (RAPP)-7&8

CONTENTS

EXECUTIVE SUMMARY

The Department of Atomic Energy's vision is to empower India through nuclear technology, creation of more wealth and providing better quality of life to its citizens. DAE is engaged in the design, construction and operation of nuclear research reactors & power reactors and the supporting nuclear fuel cycle infrastructure to achieve these objectives.

Advanced technologies such as accelerators, lasers, supercomputers, advanced materials and instrumentation are developed to encourage transfer of technology to industry which contributes to the national prosperity.

The Department is also engaged in the development of radiation technologies and their applications for better crop varieties (includes climate tolerant crops), techniques for crops protection, radiation based post-harvest technologies, techniques for radio-diagnosis and radiotherapy of diseases particularly cancer, technologies for safe drinking water urban waste management and nuclear power sea water, desalination. The Department also provides supplies and services to industry for radioisotope in engineering applications.

DAE also contributes to the enrichment of knowledge by way of support to basic research in nuclear energy and related frontier areas of science; Interaction with universities, academic institutions & other scientific departments of Government of India; Support to research and development projects having a bearing in DAE's programmes, and international cooperation in related advanced areas of research.

During the year 2022-23, the programmes of the Department achieved impressive growth in all the segments and domains.

NUCLEAR POWER PROGRAMME: STAGE 1

PRESSURISED HEAVY WATER REACTORS

Nuclear Power Corporation of India Limited (NPCIL), formed in 1987, is a Public Sector Enterprise under the administrative control of Department of Atomic Energy (DAE). NPCIL is a dividend paying company with highest credit rating of 'AAA' (Highest Safety) by CRISIL, CARE, ICRA and India Rating. NPCIL is responsible for obtaining siting consent, design, construction, quality assurance, commissioning, operation and upgradation of nuclear power reactors. Safety is given overriding priority in all facets of nuclear power reactors. At present, NPCIL operates 22 nuclear power reactors with an installed capacity of 6780 MW.

Excavation at Kaiga Project Unit-5&6 Main plant commenced with ground breaking on April 28, 2022

Currently NPCIL is constructing eight Reactors (6800 MW) comprising of Kakrapar Atomic Power Project (KAPP) Unit-3&4 (2x700 MW, PHWRs), Rajasthan Atomic Power Project (RAPP) Unit-7&8(2x700 MW, PHWRs), Kudankulam Nuclear Power Project (KKNPP) Unit-3&4 (2 x 1000 MW, LWRs) and KKNPP Unit-5&6 (2 x 1000 MW, LWRs) which are under various stages of construction. Out of these project units, KAPP Unit-3,which is first unit of indigenously designed 700 MW PHWR with state of-the-art technology and enhanced safety features, was synchronized with the Grid for the first time in 2021. The unit has operated at 50% Full Power for collecting further commissioning feedbacks for improvement. Preparatory activities for further power raise with progressive clearances from AERB are in progress. Construction of various buildings is in progress at GHAVP-1&2 and casting of all foundation piles has been completed in both the Nuclear Building (NB) areas. Activities towards obtaining regulatory clearance for casting of nuclear building raft are in advanced stage. Further, various project activities are in different stages

and are being accelerated towards commencement of construction of Ten 700 MW PHWRs (10 x 700 MW) in fleet mode for which administrative approval and financial sanction from GoI have already been accorded. Fleet mode ground activity commenced with 'Ground Break' of Kaiga Project Unit-5&6 on April 28, 2022 after obtaining AERB clearance. Excavation works at this project are in progress. In respect of remaining reactors of Ten 700 MW PHWRs in fleet mode, various pre-project activities such as land acquisition and R&R, Environmental clearance, procurement activities of long delivery equipment, studies for regulatory clearances, site infrastructure development, public outreach, tendering for various contracts/ packages are in various stages of progress towards launching of these projects. Further, in respect of new sites at Jaitapur in Maharashtra (Land Acquisition and Environment Clearance are completed) and Kovvada in Andhra Pradesh, various Pre-project activities related to land acquisition, R&R, environmental studies, Site Studies, Site infrastructure development, regulatory clearances, public outreach etc. and various techno commercial discussions for setting up large sized imported light water reactors (LWRs) based on international co-operation are in progress. In respect of Bhimpur site in Madhya Pradesh, commitment for water is to be confirmed by State Government. In respect of Mithi Virdi site in Gujarat, land acquisition process is to be re-initiated as per new land acquisition Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement (RFCTLARR) Act 2013. In respect of Haripur site in West Bengal, land acquisition is contingent to initiative by State Government. Alternate site is also under consideration by GoI.

NPCIL, in all its endeavours, is committed towards up-gradation and continuous improvements in Quality Management Systems which includes; Quality Assurance (QA), Quality Surveillance, Pre-Service Inspection/In-Service Inspection and Software Quality Assurance (SQA) activities.

Power Generation

During the Calendar Year (CY) 2022, NPCIL registered highest ever commercial power generation of 46195 Million Units (Mus). In addition, KAPP Unit-3 generated 937 MUs of infirm power (non-commercial generation) during CY 2022. In the previous CY 2021, the total commercial power generation was 43918MUs. In addition, KAPP Unit-3 has generated 404 MUs of infirm power during CY 2021.

During the period April - December 2022 in the Financial Year (FY) 2022-23, NPCIL has registered total commercial power generation of 33920 MUs and, in addition, infirm power (non-commercial generation) generation from KAPP Unit-3 is 937 MUs. The expected total commercial generation for the FY 2022-23 is about 45600 MUs. In the previous FY 2021-22, the total commercial power generation was 47112MUs and, in addition, infirm power generation from KAPP Unit-3 was 139 Mus.

During the FY 2022-23, the overall Availability Factor (AF) and Plant Load Factor (PLF) till December 31, 2022 for the reactors in commercial operation were 84% and 85% respectively. Both these figures for last FY 2021-22 were 88%.

During the FY 2022-23, Tarapur Atomic Power Station (TAPS) Unit-4, Kaiga Generating Station (KGS) Unit-1, Unit-3 & Unit-4, Rajasthan Atomic Power Station (RAPS) Unit-3, achieved continuous, safe and reliable operation for more than a year. TAPS Unit-4 registered 475 days of continuous, safe and reliable operation till its planned shutdown on July 11, 2022. RAPS Unit-3 registered 407 days of continuous, safe and reliable operation on October 27, 2022 after which the unit was manually shut down for planned maintenance works. KGS Unit-4 registered 420 days of continuous, safe and reliable operation on November 23, 2022 after which the unit was manually shut down for Biennial Shutdown works. KGS Unit-3 (544 days) and KGS Unit-1 (383 days) continued operating for more than a year as on December 31, 2022. So far, the continuous, safe and reliable operation for more than a year has been achieved 42 times by various reactors operated by NPCIL. Out of these, four reactors KGS Unit-1(962 days), Narora Atomic Power Station (NAPS) Unit-2(852 days), RAPS Unit-3(777 days) and RAPS Unit-5(765 days) have operated continuously for more than two years. The continuous, safe and reliable operation for

962 days registered by KGS Unit-1 is second longest continuous operation in world among all reactor technologies.

Nuclear power reactors in operation registered cumulative 583 reactor years of safe operation as on December 31, 2022.

Operating Units taken in Project mode

Madras Atomic Power Station (MAPS) Unit-1 (220 MW PHWR), Tarapur Atomic Power Station (TAPS) Unit-1& Unit-2 (2x160 MW BWRs) and Rajasthan Atomic Power Station (RAPS) Unit-3 (220 MW PHWR) are under long shutdown and have been taken in project mode for aging management and safety upgrades. Various studies/works are in progress at these units.

Projects under construction

Kakrapar Atomic Power Project (KAPP) Unit-3&4 (2x700 MW PHWRs)

First unit of indigenous 700 MW Pressurised Heavy Water Reactor (Kakrapar Atomic Power Project Unit-3) at Kakrapar, Gujarat, with state-of-the-art technology and enhanced safety features was successfully synchronized with Grid for the first time on 10.01.2021. After carrying out required modifications/ improvements based on commissioning feedback, permission from AERB has been received and the unit was synchronized with grid on 20.07.2022. The unit has operated at 50% Full Power for collecting further commissioning feedback for improvement. The unit has generated cumulative about 1340 Million Units (MUs) as on December 31, 2022. In Unit-4, a major milestone "Hydro test of Primary Heat Transport (PHT) system" has been completed. Various improvements based on the feedbacks from KAPP-3 commissioning challenges are also being incorporated. Preparatory works for Integrated Leak Rate Test (ILRT) of Reactor Building are in progress. The physical progress of the unit was about 94.30% as on December 31, 2022. The overall physical progress of KAPP-3&4 is 97.15% as on December 31, 2022.

Rajasthan Atomic Power Project (RAPP) Unit-7&8 (2x700 MW PHWRs)

In RAPP Unit-7, erection of equipment and piping is in progress. A major milestone "Reactor Building Proof Test and Integrated Leak Rate Test (ILRT)" is completed. Construction of Induced Draft Cooling Tower (IDCTs) and Natural Draft Cooling Tower (NDCTs) are in progress. The physical progress of the unit is about 95.54% as on December 31, 2022. In RAPP Unit-8, civil construction and erection of equipment & components are in progress. Concreting of Outer Containment (OC) dome is completed. Complete coolant channels are installed and Feeders erection is in progress. The physical progress of the unit was about 81.70% as on December 31, 2022.

Kudankulam Nuclear Power Project (KKNPP) Unit-3&4 (2x1000 MW LWRs)

Civil construction and equipment erection works are in progress. Construction of Reactor Building, Reactor Auxiliary Building, Turbine Building, Tunnels, Common service Buildings, Switchyard Buildings and Hydro- technical structures (HTS), etc. is in progress. In KKNPP-3, Inner Containment dome supporting structure (weighing about 310 Metric Ton) was successfully pre-fabricated, lifted and placed as a single assembly in position in Reactor Building, erection of Nuclear Steam Supply System (NSSS) equipment [Reactor Pressure Vessel (RPV), Steam Generator (SG), Reactor Coolant Pump (RCP) and Pressurizer (PRZ)] is completed and a major milestone of "Commencement of Welding of Main Coolant Piping" is achieved. The physical progress of KKNPP Unit-3 and KKNPP Unit-4 were about 66.02% and 62.39% respectively as on December 31, 2022.

Kudankulam Nuclear Power Project (KKNPP) Unit-5&6 (2x1000 MW LWRs)

Construction works are in progress. Foundation Slabs of Reactor Building, Turbine Building and Reactor Auxiliary Building are completed in KKNPP Unit-5. Concreting of KKNPP Unit-6 Turbine building raft of about 11,050 Cubic Meter (Cu.M) was successfully

completed in a single pour, thus creating a new record of highest concreting in a single pour in construction of Nuclear Power Plant. The physical progress of KKNPP Unit-5 and KKNPP Unit-6 were about 16.27% and 11.43% respectively as on December 31, 2022.

Project under launch

Gorakhpur Haryana Anu Vidyut Pariyojana (GHAVP) Unit-1&2 (2X700 MW PHWRs)

Casting of all foundation piles has been completed in both the Nuclear Building areas and activities towards obtaining regulatory clearance for casting of nuclear building raft are in progress. Construction of Switch Yard Control Building, D2O Upgradation Plant, Fire and Industrial Safety House, Fire Water Pump House etc is in progress. Manufacturing and supply of equipment and components are in progress. Two End Shields and four Steam Generators have been received at site and are under suitable preservation. Design activities are in progress in respect of various packages like Nuclear Island packages, IDCTs etc.,

Ten 700 MW PHWRs in Fleet Mode

The Government of India has accorded administrative approval and financial sanction for taking up construction of 10 indigenous 700MW PHWRs in Fleet Mode. These reactors are being set up at Kaiga in Karnataka (Kaiga-5&6), Gorakhpur in Haryana (GHAVP-3&4), Chutka in Madhya Pradesh (Chutka-1&2) and Mahi Banswara in Rajasthan (Mahi Banswara-1 to 4).

Kaiga-5&6 project ground breaking ceremony

Various pre-project activities are in progress at these sites towards launching of the projects. Fleet mode ground work commenced with 'Ground Break' of Kaiga-5&6 project on 28th April, 2022 after obtaining AERB clearance. At GHAVP Unit-3&4, land is available, MoEFCC Clearance exists and siting consent from AERB is received. At Mahi Banswara, land acquisition is in advanced stage and MoEFCC Clearance is under process. At Chutka, land Possession letter has been issued for all types of land and MoEFCC Clearance is available. Proceedings for implementation of the projects at Mahi Banswara and Chutka sites by NPCIL-NTPC JV Company are in progress.

New Project / Sites

Pressurized Heavy Water Reactors (PHWRs)

Bhimpur, Madhya Pradesh: Commitment for water is to be confirmed by State Government.

Light Water Reactor (LWR) Projects

Jaitapur, Maharashtra: Land has been acquired. Statutory clearances are available. Techno-commercial discussions with Électricité de France (EDF), France are in progress.

Kovvada, Andhra Pradesh: Land acquisition process is in progress. Techno-Commercial discussions with Westinghouse Electric Company (WEC) are in progress.

Mithi Virdi, Gujarat: Land is to be acquired as per the new RFCTLARR Act 2013.

Haripur, West Bengal: Land acquisition is contingent to initiative by State Government.

Initiative for Hydrogen Generation

In the context of transitioning to a Net Zero economy by 2070, there is a growing focus on the potential role of Hydrogen. The Hon'ble Prime Minister in his Independence Day speech 2021 has announced a 'National Hydrogen Mission'. There is huge emphasis on Green Hydrogen (Hydrogen produced from clean

energy sources). Nuclear power is a clean base load source of electricity and can be used to generate clean Hydrogen. Considering the emerging business opportunities in production of Hydrogen from nuclear power, NPCIL has resolved to take enabling steps for entering into the business of clean Hydrogen generation from nuclear power at an appropriate time. Hydrogen policy has been approved by NPCIL Board for future entry into Hydrogen business, after evaluation of different technologies for Hydrogen production. Alkaline Water Electrolysis (AWE) & Proton Exchange Membrane (PEM) based technologies have been selected for setting up Hydrogen Generation Units (HGUs) for gaining operational experience. HGUs using above technologies are being set up. Hydrogen produced at these HGUs will be used for in-house consumption.

Indigenization

Indigenous development and Vendor base broadening for various critical components and equipment continued by NPCIL, in line with Atma Nirbhar Bharat. Adoption of the indigenous technologies developed in the recent past, is being done with commercialization for current and future 700 MW reactors.

FRONT END FUEL CYCLE

Front-End Fuel Cycle comprises operations such as mining, milling and processing of ore, and fabrication of fuel. In addition, production of heavy water, used as moderator and coolant in pressurized heavy water reactors, also constitute a major programme segment of the Nuclear Power Programme.

DAE has wide-ranging capabilities in uranium mining and mineral processing, and is self-sufficient in the production of heavy water, zirconium alloy components and other materials and supplies, for pressurised heavy water reactor. The Nuclear Fuel Complex at Hyderabad manufactures fuel assemblies for pressurised heavy water reactors, boiling water reactors and fast breeder reactor.

Heavy Water Production

In view of the INPP plan of commissioning PHWRs in fleet mode, large scale requirement of specialty materials for the front end and back end of nuclear fuel cycle is envisaged and to enable DAE in achieving closed fuel cycle for energy security, HWB has been entrusted to design and develop the technology for industrial scale production of specialty materials, based on the basic synthesis processes developed by research units of DAE. This challenge of setting up bench scale, pilot plant scale and then industrial scale setups was met by HWB without any additional manpower. Thus on one hand HWB continues to perform excellently in handling tons of hazardous chemicals, extreme process conditions and RTC operation, on the other hand it has developed expertise in setting up plants which handle and synthesize a variety of special and hazardous chemicals requiring high end laboratory analytical techniques.

Heavy Water Plants at Hazira, Thal, Kota and Manuguru are in operation on continuous basis. All the activities scheduled during Major Turn Around at HWP, Kota were successfully completed. The Heavy Water Board Facilities at Vadodara and Talcher continued to produce and supply organo-phosphorous solvents as per demand from DAE units. At HWBF, Vadodara, various d-labeled compounds were synthesized as per requirement put up by BRIT. All the components of 24kA prototype cell and associated systems have been installed and tested for sodium metal production. Commissioning activities are in hand. Enrichment of $H_2{}^{18}O$ is in progress at HWP, Manuguru.

Revamping and preservation of systems and machineries at HWP, Tuticorin is in progress for restart up of the plant. Erection work for various systems at Integrated Solvent Production Plant at HWP, Tuticorin is under progress. Consent to establish from state pollution control board was received for Solvent Extraction Plant at HWP, Tuticorin. Various civil and foundation work have commenced at the plant site.

Diversification Activities

In the journey towards diversification from core

heavy water production, HWB continued in its program for production of several specialty materials. These include demonstrating solvent extraction technologies for nuclear hydrometallurgy; producing organo-phosphorous solvents and stable isotope products like ^{10}B enriched boron carbide pellets for control & safety mechanisms in Fast Breeder Reactors; production of nuclear grade Sodium for FBRs. HWB is also in the process of synthesizing ^{18}O enriched water for medical applications for societal benefits. New initiatives taken in some of the key areas in these activities during the period are as follows:

Solvent Production

The existing solvent production facilities at Baroda and Talcher continued to meet the demand placed by various DAE units like, NFC, BARC, IREL, KARP, IGCAR etc. for nuclear grade solvents required for extraction of various materials through solvent extraction process. For meeting future requirements of DAE-Nuclear Power Program, an industrial scale Integrated Solvent Production Plant (ISP) is being set up at HWP, Tuticorin for production of organo-phosphorus solvents. Solvents like TiAP, D2EPHA-II, TBP, TOPO and DHOA will be produced in the facility. Erection and commissioning activities for ISP are in progress.

Boron Production

For applications in control & safety systems of fast breeder reactor program and enriched BF_3 gas for neutron detector systems, HWB has taken up indigenous production of ^{10}B enriched Boron and Boron Carbide pellets.

BF_3 gas finds application in neutron detection in nuclear reactors. The most famous type of boron-based neutron detector is the BF_3 proportional counter. Among various types of boron-containing gases, BF_3 has high concentration of boron and is therefore a good detector material.

At HWBF, Talcher, CaF_2-BF_3 complex enriched with ^{10}B (IP>90%) is produced by the reaction of Calcium Fluoride with Boron Tri-fluoride di-ethyl etherate complex enriched with ^{10}B (IP>90%) produced in Boron Exchange distillation Unit. This complex is

Boron Trifluoride production facility at HWBF, Talcher

supplied to users like ECIL and Solid State Physics Division, BARC. This is a highly hygroscopic complex. At the user facility, this complex is repeatedly processed to remove traces of water by heating and passing through LN_2 trap. Thereafter, thermal decomposition of the complex releases BF_3 gas.

At HWP, Manuguru, Boron Carbide Pelletization Plant was in operation for production of enriched Boron Carbide pellets of various isotopic purities. The ^{10}B IP $\geqslant$ 50% and 90% Boron Carbide pellets were produced based on the request from IGCAR. Samples of these pellets were tested for physical and chemical properties at IGCAR for confirming suitability for use in FBTR. Subsequent to acceptance & clearance of finished product of B_4C of ^{10}B IP $\geqslant$ 50% & 90% by IGCAR, mass production was initiated. Requirement of B_4C pellets of ^{10}B IP $\geqslant$ 50% for poison sub-assembly of FBTR has been already met. Production of B4C pellets of ^{10}B IP $\geqslant$ 90% is in hand for meeting the demand placed by ICGAR. A second stream of B_4C pelletization plant is being set up in the premises for which a few machineries like HVIF and CNC have already been procured.

Sodium metal

Sodium metal is used as coolant in the fast breeder reactor technology. This material of nuclear grade purity is imported by India at a premium cost. In order to achieve self-reliance of DAE in Sodium metal

Scrubber system for 24kA sodium cell at HWBF, Vadodara

supply for FBRs, HWB had drawn up elaborate roadmap by operating Sodium cells at HWBF, Vadodara. After carrying out test operation of various configurations of 2kA electrolytic cells, adequate operational data was generated. Technology for removal of the impurities like oxides of Sodium and Calcium, Carbon, Iron, Magnesium etc. to produce nuclear grade Sodium metal was completely developed by HWB at bench scale Sodium metal purification unit. For scaling up the process, 24 kA prototype cell and sub-assemblies have been designed, procured and installed at HWBF, Vadodara.

Mineral Exploration and Mining

Atomic Minerals Directorate for Exploration and Research (AMD) has accelerated the pace of exploration activities by integrated, multi-disciplinary methodology and judicious utilisation of man-power with a focussed approach for augmentation of uranium, thorium, rare metals and rare earth resources.

During the year 2022, the exploration efforts of AMD have resulted in augmentation of 30,546 tonnes uranium oxide from the exploration areas in Andhra Pradesh, Karnataka, Rajasthan and Jharkhand. About 45.26 million tonnes of heavy mineral resource has been augmented from the exploration areas in Odisha and Andhra Pradesh.

Geochemical surveys (4,914 sq km) have indicated anomalous concentration of Uranium and Lithium in Rajasthan and of Uranium along Andhra Pradesh, Chhattisgarh and Rajasthan.

Multi-parametric heliborne geophysical surveys over 28,929 line km have been carried out in parts of Jharkhand, Chhattisgarh and Rajasthan. Three potential blocks have been identified for further exploration in Rajasthan.

Ground geophysical surveys of 1425.40 Sq. km. (Regional: 900 sq. km; detailed: 525.40 sq.km) have delineated potential zones in Karnataka and Rajasthan.

A total of 3,65,287.73m drilling was carried out. Significant uranium mineralised intercepts / bands have been identified in Uttar Pradesh, Andhra Pradesh, Karnataka, Jharkhand, Rajasthan, Maharashtra, Chhattisgarh and Madhya Pradesh and in addition, reconnoitory drilling has been taken up in several potential/significant blocks in varied geological domains.

Rare Metals and Rare Earths (RMRE) surveys have been carried out in Chhattisgarh, Madhya Pradesh, Odisha, Rajasthan, Gujarat and Karnataka. A total of 37,021.85 m drilling has been carried out for RMRE investigations in various potential areas of the country.

Significant zones of concentration of Total Heavy Mineral (THM) have been located in Kerala and Tamil Nadu. Sonic drilling has been carried out in Odisha.

The mining and processing of uranium ore in the country are being undertaken by Uranium Corporation of India Ltd. (UCIL), a Public Sector Enterprise under Department of Atomic Energy (DAE). Presently, UCIL is operating seven underground mines, one opencast mine and three mills located in Jharkhand (in East Singhbhum and Seraikela-Kharsawan districts) and Andhra Pradesh (in YSR district).

For the Financial Year 2020-21, UCIL received 'Excellent' MoU rating for the fourth year in a row with a score of 92.63 from the Department of Public Enterprises, Ministry of Finance, Government of India (Office Memorandum No: 'F. No. M-03/0011/2021-DPE

(MoU)' dated 18th January, 2022). During Financial Year 2021-22, UCIL has once again met all parameters for achieving 'Excellent' rating in MoU performance.

The provisional MoU rating of IREL for the year 2021-22 was 'Excellent'. This rating has been achieved for the 5th consecutive year.

During the period April to December 2022, production of minerals increased by 3.0 % as compared to the corresponding period of last year. Further production of chemicals increased by 4% as compared to corresponding period of last year. Production of Nuclear Grade Ammonium di-Uranate (NGADU) and Mixed Rare Earths Chloride (MRECL) stood at 16.875 tons and 3967 tons respectively.

A Pilot Plant is established at RED Unit in Aluva, Kerala for production of 99.99 %Yttrium Oxide through Ion -Exchange column. This adds to IREL's basket of products.

IREL carried out a 5 day virtual training program for Vietnam delegation in April 2022 on Rare Earths. Subsequently, a technical delegation from Vietnam visited IREL in July 2022. This was carried out as a part of the MoU entered between GCNEP, DAE and VINATOM.

At BARC, a solvent extraction based process has been developed for production of nuclear grade Zirconium oxide (ZrO_2) from Zirconium nitrate feed solution (ZNFS) using an in-house synthesized Alkyl Phosphineoxide (APO) ligand in a novel differential contactor pulsed stirred column (PSC).

Suitability of Pulsed Disc and Doughnut Column (PDDC) for solvent extraction of uranium from crude uranyl nitrate slurry feed was successfully demonstrated in a 3-inch diameter column. For simulation of solvent extraction process in a columnar contactor, a new module of ANUSim (a python-based simulator dedicated for nuclear chemical processes) was developed.

Two highly valuable rare earth elements - yttrium and europium - were recovered from Compact Florescent Lamps (CFLs) of electronic waste through employing the technology of aqueous processing. Besides, mercury of highly hazardous nature was separated from them using in-house developed selective polymeric resins.

Studies on developing a process scheme for the recovery of uranium values in the form of high purity uranium peroxide were carried out using composite bore-hole core ore samples. These efforts were focused on uranium occurrences at Jahaz of Sikar district in Rajasthan which fall under the North Delhi Fold Belt (NDFB). Uraninite is the main uranium carrier phase with U_3O_8 assay of 0.04%. Pyrite, pyrrhotite, molybdenite along with traces of chalcopyrite are the predominant sulphides and heavy oxides include ilmenite and rutile. The ore being rich in siliceous minerals, acid based hydrometallurgy based recovery process was adopted. Detailed optimization of various process parameters across different unit operations viz. oxidative atmospheric leaching, purification of leachate on anion exchange resin, precipitative removal of excess Fe and sulfates followed by uranium precipitation gave final U-peroxide product assaying 79% U_3O_8 with 83% recovery.

The Naktu U ore at Son Valley in Sonbhadra district of Uttar Pradesh contains on an average about 0.02%. of rare earth elements (REEs). These REEs occur in the form of monazite and REE-silicate complex. About 70% of REE values co-dissolved along with uranium during oxidative sulfuric acid leaching of the ore. The REE content in the raffinate was enhanced sequentially by first extracting them with D2EHPA as solvent followed by treating the strip liquor in chloride medium with TBP. The purity of REE-fluoride was 84% with overall recovery of about 45%.

Large quantities of maraging steel scrap are generated at Mishra Dhatu Nigam Limited (public sector undertaking) as part of its regular operations. Maraging steel contains good amount of these metals. A hydrometallurgical process has been developed to recover these from the scrap in >99% purity with >90% recovery rate. The process has been demonstrated to Heavy Water Board for implementation at its plant.

Based on experimental studies, a pilot plant has been installed in BARC for purification of uranium from MgF_2 slag leached solution (SLS). The pilot plant has

facilities of SLS storage, chemical treatment of SLS with aluminium nitrate, purification of SLS, nuclear pure uranium storage and effluents storage.

A detailed study has been conducted to understand the utilization of uranium mill tailings generated from the Turamdih process plant. Different bricks and paver blocks were prepared from tailings at various compositions by pressing and moulding techniques. Radioactivity analysis indicated the radium equivalent activity varied from 628 to 1650 Bqkg-1, which suggest that these bricks and paver blocks are suitable as construction materials for various utilities, including industries, roads and bridges.

Fuel Fabrication

Nuclear Fuel Complex (NFC), an ISO 9001, 14001 & 45001 organisation under Department of Atomic Energy (DAE), is engaged in the production of natural Uranium fuel bundles for Pressurized Heavy Water Reactors (PHWRs), enriched Uranium fuel assemblies for Boiling Water Reactors (BWRs), Reactor Core Structurals (Calandria tubes, Coolant tubes, Square channels etc.), Reactivity Control Mechanisms and special materials like Tantalum, Niobium etc. In addition, for Fast Breeder Reactors, NFC produces all the core sub-assemblies and other critical components like fuel cladding tubes, hexagonal wrapper tubes etc. made out of special stainless steels/D9 materials. NFC also caters to the demand of high quality stainless steel tubes/pipes, Steam Generator tubes, Super Ni tubes, Zr 1%Nb and titanium alloy products for critical and strategic applications in Nuclear Power Plants, Reprocessing Plants, Defence and Space establishments.

Some of the significant achievements of NFC during the year were Development of highest ever triple expanded Maraging steel 350 grade shell of size OD 330mm x ID 270 mm for strategic application of BARC; Manufacturing and reverse forming of zirconium – 1% niobium (Zr-1%Nb) tubes; Development of process for preparation of advanced Ni based super alloy by electron beam melting followed by vacuum arc remelting for applications at MMD, BARC; Development of process for preparation Nb55Ti alloy by combination of Electron beam melting & Vacuum arc remelting route for superconducting applications at RRCAT, Indore; Indigenous development of 360kW Vacuum Arc Re-melting (VAR) furnace for producing 280 mm dia primary melted Zircaloy ingot with 100% indigenously developed mechanical assemblies; Indigenous development of new State-of-the-Art Automated Machining Center contributing to Govt. of India's initiative “Aatmanirbhar Bharat”; Development and commissioning of completely automated tube ID cleaning system for final pass fuel clad tubes etc.

BACK END FUEL CYCLE

Fuel Reprocessing and Waste Management

A new Integrated Nuclear Recycle plant (INRP) is coming up in Tarapur for reprocessing of spent fuel of all classes of PHWRs operating in India (220MWe / 540 MWe / 700 Mwe). All major works at the plant are in advanced stages of implementation.

Activities of management of High Level Liquid Waste generated during reprocessing of spent fuels of research reactors at Trombay was successfully continued. Partitioning of Liquid Waste has been continued successfully for recovering worthy fission products from waste streams.

Treatment of legacy Intermediate Level Liquid Wastes (ILLW) was re-started soon after the completion of refurbishment of Pump House Ion-Exchange (PHIX) system. This waste stream is characterized by high salt load and presence of inactive Aluminium, which requires a highly selective separation process. After completion of testing and commissioning of automation based Ion Exchange process, processing of Legacy Declad ILW stored in TK–5 of WTF in PP had been resumed.

ETP and DC facilities were put to regular operation for managing waste arising from various nuclear and radiological facilities of BARC Trombay.

RWMF is an upgraded vitrification facility being installed at WIP, Process Building, BARC, Trombay to

address various O & M feedback generated during management of High-Level Liquid Waste (HLLW).

An upgraded vitrification facility is in advanced stages of installation for treating of HLLW obtained from reprocessing of spent fuel. The facility is characterized by minimum maintenance, increased production of Cesium pencils.

A plant based on fluidized bed denitration technology is in advanced stages of commissioning in UOF (K) (BARC), for production of ammonium nitrate.

A modified process was developed for purification of precursor DTBDB18C6. The hydrogenation process resulted around 90% pure crown ether DTBDCH18C6, which is primarily Strontium selective. Refurbishment of Glass-based Radiation Shielding Windows (RSWs) was undertaken after completion of designated service life requirements. RSWs are critical viewing aids in nuclear installations, which facilitate direct viewing of radioactive area with a high level of visual clarity.

A customized remote pencil cutting machine was installed for recovering rejected Cesium glass pencils from hot cells. Using this facility, around 9 Cesium pencils were recovered in perfectly good condition and were routed to BRIT.

A novel geo-polymer matrix has been developed for the managing and containing Technetium-99 bearing waste stream to address long half-life and highly mobile nature of Technetium.

R&D OF POWER SECTOR

The Research and Development support to the Nuclear Power Programme is provided by the research centres of DAE.

Detailed microstructural examination and hydrogen analysis of various pressure tubes have been carried out to assess the performance in terms of corrosion behaviour, hydrogen pick-up and hydride platelet distribution, which help in assessing the overall worthiness of the tubes after different irradiation levels.

Post Irradiation Examination (PIE) of fuel bundles was carried out inside the hot cells using various non-destructive and destructive techniques. The effect of transient heating on the transverse tensile properties of irradiated clad was studied. Gamma scanning of fuel elements indicated burn-up profile along expected lines. Non-destructive tests performed on fuel elements did not show any evidence of clad failure.

Under the evaluation of mechanical properties of irradiated calandria tube of PHWR, fracture toughness of irradiated calandria tube material was found to be satisfactory even after 15 years of operation. Calandria tube material has shown expected irradiation behaviour and acceptable operating experience.

Tensile, impact and fracture toughness tests were carried out on RPV surveillance specimen of Kudankulam Nuclear Power Plant to ascertain various properties that entail safe operation of the reactors.

High sensitivity Helium-3 proportional counters have been developed, tested and qualified for fuel loading in Light Water Reactor (LWR). The detector with 19 mm diameter & 350 mm length provides a neutron sensitivity of ~ 10 cps/nv. The detector offers improved counting statistics and reduced uncertainties during fuel loading, criticality and reactor start-up.

HEALTH SAFETY & ENVIRONMENT

At BARC, a compact table-top Personal Dosimetry System with high level of performance repeatability has been installed and commissioned for monitoring exposure to radioactive doses among the radiation personnel stationed across the country. The system is built around a 12 mega pixel digital camera and a distributed diffused LED illumination source mounted inside an enclosed imaging unit.

An Artificial Intelligence (AI) based decision support system has been employed for monitoring exposure to various radiation sources among the occupational personnel.

Charcoal cartridge standards for calibration of Iodine monitors

A long-lived charcoal cartridge standard was developed for the first time and is being used for calibration of iodine monitors of Area Radiation Monitoring System (ARMS) system of Kudankulam Nuclear Power Project.

A radiation map of India was prepared from countrywide survey data for Natural Background Radiation (NBR) dose-rate (cosmic and terrestrial components) collected by different measurements around the country by Health, Safety & Environment Group, BARC.

An instrument for simultaneous sampling of different forms of ^{3}H and ^{14}C in air has been developed in BARC. The instrument comprises single air sampling channel connected to a pump for sampling of air, 4 sampling units and one catalytic convertor cell.

For the removal of uranium from water resources, Sodalite was developed through modifying Coal Combustion Residue (CCR) by alkali fusion, followed hydrothermal crystallization method.

Environmental and radiological safety surveillance, radiation protection and industrial hygiene services were provided for essential and round-the-clock shift operations for the front-end nuclear cycle facilities like UCIL (Jharkhand, Turamdih and Tummalapalle), IREL (Kerala & Tamil Nadu), Orissa Sands Complex (Orissa) and NFC (Hyderabad) for the protection of occupational workers, public and the environment.

NPCIL has recorded about 583 reactor years of safe operation of nuclear reactors by the end of December 2022. Review of safety of operating stations was carried out on a regular basis. All safety significant proposals and documents were reviewed by a multidisciplinary Safety Review Committee (SRC) to meet the regulatory compliance. Oversight of Operating Plants is being ensured through monitoring and trending of nuclear safety parameters.

NPCIL is committed in the implementation of ALARA (As Low As Reasonably Achievable) philosophy in all radioactive works carried out at NPPs to ensure that occupational exposures and releases of radioactive effluents from NPPs were maintained well within the limits stipulated by AERB. NPCIL continued to maintain low radiation exposure in the public domain due to operation of nuclear power stations.

At operating stations of NPCIL, certified Environmental Management System (EMS) as per IS/ISO-14001 and Occupational Health and Safety Management System (OHSMS) as per IS-18001/ ISO-45001 were maintained and regular audits were carried out for continual improvement.

Safety being an integral part of Operation and Maintenance of HWPs/HWBFs, it is always accorded the highest priority. Annual Safety & Technical Audits of all units of HWB were carried out. Two interactive sessions of Safety, Operation and Maintenance Engineers were organized for knowledge sharing. Annual medical examination of all occupational workers was carried out for monitoring their health status.

NUCLEAR POWER PROGRAMME: STAGE 2

FAST BREEDER REACTORS

For the second stage of the Nuclear Power Generation Programme, the Indira Gandhi Centre for Atomic Research (IGCAR) is pursuing development of sodium cooled fast breeder reactors and associated fuel cycle technologies. Breeder reactors produce more fuel than they consume.

The Fast Reactor Programme of IGCAR is supported by its research and development endeavour in a range of disciplines such as reactor engineering,

metallurgy, materials science, instrumentation, safety, and others. The Fast Breeder Test Reactor (FBTR), operating at Kalpakkam for over 25 years, also caters to technology development related to fast reactor.

Based on the fast breeder reactor technology developed by IGCAR, a 500 MWe Prototype Fast Breeder Reactor (PFBR) is coming up at Kalpakkam. The project is being executed by the Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI), a public sector undertaking of DAE.

BARC contributes to the research & development and manufacture of fuels for fast reactors, technology for reprocessing of fuels, waste management and health and safety of the work force.

NFC is entrusted with the responsibility of fabrication of core subassemblies for Fast Breeder Test Reactor (FBTR) and 500 MWe Prototype Fast Breeder Reactor (PFBR).

Fast Breeder Test Reactor

Fast Breeder Test Reactor (FBTR), the flagship of IGCAR is continuing its objectives as a test bed for irradiation of fuel & structural materials in fast neutron flux and a training hub for fast reactor operators. In the 37 years of operation so far, 30 irradiation campaigns have been successfully completed and 31st campaign is in progress. Since FBTR engineering systems are designed for 40 MWt, there was a constant urge in increasing the FBTR Power to 40 MWt, which would provide an experience in testing the systems at design power. A modified core with 69 MK-I FSAs (Fuel Sub-Assemblies), one IFZ (Special experimental) Test SA at center and four poison SAs with 50% B^{10} in second ring was chosen and with this modified core configuration, FBTR power was raised to 40 MWt on 7th March 2022 for the first time and operated for 45 Effective Full Power Days (EFPD). Turbo Generator was in operation throughout the campaign producing ~10 MWe. Presently the 31st campaign with 40 MWt and Turbo Generator connected to grid, producing ~10 MWe is under progress and is expected to complete cumulative campaign duration of 100 days by this year end. The electrical energy produced from March to December 2022 is 27.26 Million units; equivalent to savings of about 27,808 tonnes of CO_2.

Prototype Fast Breeder Reactor

Prototype Fast Breeder Reactor (PFBR) at Kalpakkam is a 500 MWe (1250 MWt) liquid sodium cooled, pool type reactor using mixed oxide of uranium and plutonium as fuel.The plant is located 500 m south of the existing Madras Atomic Power Station. After completion of construction, manufacture & erection of all the systems / components of PFBR, commissioning of the individual system and the integrated commissioning are in progress. The major activities that have been completed during the reporting includes Integrated Leak Rate Test of Reactor Containment Building using superimposition method; High temperature testing (~120 deg C) of In-Service Inspection (DISHA) vehicle at Site Assembly Shop followed by in-pile testing on dissimilar weld joint at ambient temperature; Independent Verification & Validation of systems required sodium filling in Main Vessel; Commissioning works of Fuel Handling equipment.

IGCAR is continuing to provide necessary support for the 500 MWe Prototype Fast Breeder Reactor (PFBR). The reactor is in advanced stage of integrated commissioning.

Experimental verification of performance of DHX-B in SADHANA facility, Hydraulic performance testing of purger subassembly, Regeneration experiment to optimise cold trap parameters with reduced sodium level in cold trap, manufacturing and calibration of spare Eddy current flow meter for Primary sodium pump, Sodium calibration of eddy current sensor for core flow monitoring at low flow rates, Deployment of DISHA in one In-service inspection opening in PFBR for pre-commissioning stage inspection, Completion of verification & validation works including site validation of I&C systems related to main vessel sodium filling and Design & development of SHAKTI IP core based CPU card for embedded systems are some of the important works carried out in support of PFBR.

FBR Fuels

During the year, 100,000 fuel elements of Prototype Fast Breeder Reactor (PFBR) were fabricated as per the desired specification at the Fuel Fabrication Facility under the supervision of Nuclear Recycle Board.

Fast Reactor Fuel Reprocessing

Compact Reprocessing of Advanced fuels in Lead Cells (CORAL), the only facility currently operating in the world for reprocessing of high burn up carbide fuels, continued to operate safely at the mandated capacity. Spent fuel from FBTR is being reprocessed, achieving excellent decontamination and recovery factors, and also providing a wealth of information and feedback for the design, construction and commissioning of future plants. Two successful reprocessing campaigns have been completed during this year with an excellent decontamination factor and recovery. Presently 64th campaign is under progress. A new Access Control System at CORAL has been commissioned.

Demonstration fast reactor Fuel Reprocessing Plant (DFRP), built with the objective of regular reprocessing of FBTR spent fuel and demonstration of reprocessing of PFBR fuel, has reached advanced stage of commissioning. The cold commissioning of DFRP has been successfully completed in November 2022. The activities for hot commissioning of DFRP have commenced. Indigenous development and manufacturing of chopper spares, RAM tong assembly, forearm tubes and cask transport trolley for DFRP have been completed. The performance of chopper at DFRP, has been tested by cutting fuel pins containing natural uranium and successfully validated with all the integrated systems during the test.

Lightning Protection System has been commissioned; Design, fabrication, erection, testing and commissioning of wire rope retainer mechanism for the in-cell crane of dissolver cell have been completed. A rotary linear actuator, suitable for capping/ de-capping of delicate bottles/containers has been developed & demonstrated. Design development & demonstration of a special pipe embedment for in-situ replacement of cable/ cables along with the connector from bunch of cables applicable to contaminated enclosures has been completed. The prototype lighting system for Waste Tank Farm Hot Cells of DFRP has been fabricated, installed and tested at site.

Nuclear Recycle Board is implementing the construction of a mega Fast Reactor Fuel Cycle Facility (FRFCF) to cater to the requirements of fuel cycle of fast breeder reactor facilities at Kalpakkam. Construction activities of FRFCF in the nuclear island at Kalpakkam, including Main Power Station, Core Sub-Assembly Plant (CSP) building, Waste Management Plant, Centralized Surveillance Safety & Health Physics and Central Workshop are in advanced stages of implementation.

Future FBRs

Sodium testing of dismountable type ultrasonic transducer, calibration of Mutual inductance type level probes for sodium technology complex, Decay power measurements in structural materials based on irradiation experiments in KAMINI, Qualification of Inconel-625H bellows for sodium service valves and Development of sodium pressure measurement device are some of the key R&D works carried out for future FBRs.

Dismountable type UT Assembly

Health, Safety & Environment

Integrated Radiation Monitoring Facility (IRMF) established by IGCAR at Anupuram Township for DAE Kalpakkam complex, was inaugurated and will provide radiation monitoring services to radiation workers during normal operations as well as public during any radiation emergency. This facility is augmented with state of art in-vivo and in-vitro monitoring laboratories and radiation emergency medical centre.

First responder training course for 244 personnel in six batches was conducted for National Disaster Responses Force (NDRF), Arakkonam on Nuclear & Radiological Emergencies. The training includes series of lectures, table top exercises, practical's, field exercises and visits to Madras Atomic Power Station, FBTR and Radiation Safety Facilities at IGCAR.

NABL Accredited Regional Calibration Facility (RCF) has been augmented with high active Co-60 source of 20Ci. More than 400 radiation monitoring equipments from hospitals, institutions and DAE units were calibrated.

NUCLEAR POWER PROGRAMME: STAGE 3

THORIUM BASED REACTORS

Nuclear power employing closed fuel cycle is the only sustainable option for meeting a major part of the world energy demand. World resources of thorium are larger than those of uranium. Thorium, therefore is, widely viewed as the 'fuel of the future'. The Indian Nuclear Power Programme Stage-3 aims at using thorium as fuel for power generation on a commercial scale.

Kalpakkam MINI (KAMINI) Reactor

The U-233 based Kalpakkam Mini Reactor (KAMINI) was available for neutron activation analysis, neutron radiography and testing of indigenously developed neutron detectors. This research reactor has been utilized by many units of DAE and institutions for irradiation of various samples, testing and calibration requirements.

Critical Facility Reactor

The Critical Facility reactor was operated 68 times during the year for surveillance, irradiation experiments, neutron activation and testing of detectors. Neutron Activation of 166 samples was done as per desired requirement. Feasibility of monitoring 'approach to criticality' using Lanthanum Bromide based gamma radiation detectors was evaluated.

Hydrogen Energy

Hydrogen is considered as one of the highly promising energy medium for future fuel requirements. The technology for production of hydrogen by Iodine-Sulfur process (I-S) process using industrial materials has been successfully demonstrated, which is now being scaled up.

R&D activities on process development for copper-chlorine thermochemical cycle for hydrogen production were continued and offline product looping of all four steps (hydrolysis, thermolysis, electrolysis, and crystallization) was successfully carried out at laboratory scale.

Under hydrogen energy program, BARC has developed a polysulfone-zirconia mixed-matrix membrane diaphragm as a substitute of asbestos and imported commercial diaphragms for alkaline water electrolyser, which has several important applications.

Research Reactors

Operation of Apsara-U at rated power of 2 MW was demonstrated successfully. The reactor operated with an Availability Factor (AF) of 52.7 % during the year. Silicon wafers of 100 mm diameter were irradiated at the immediate vicinity of reactor core for development of silicon-based radiation detectors as part of feasibility study for neutron transmutation doping of silicon in Apsara-U reactor. The setup for irradiation of silicon ingot is expected to be commissioned by March 2023.

Dhruva was operated with an Availability Factor (AF) of 73.2% during the calendar year 2022. Isotope production in Dhruva was continued and 510 radioisotope cans were irradiated and delivered successfully.

Forty eight plates of Fission Moly were irradiated on a trial basis in the Fission Moly Tray Rod (FMTR) facility as part of hot commissioning of Fission Moly Plant at a BRIT facility. Upon obtaining necessary approval from Radio Pharmaceutical Committee,

regular production of fission moly from Dhruva is expected to commence by March 2023.

A study was carried out for production of high specific activity (more than 650 Ci/ gm) of ^{192}Ir for making Brachytherapy sources, by carrying out trial irradiations of enriched (80%) samples of Iridium at Dhruva.

Trombay Programmable Logic Controller (TPLC-32) Platform based Electrical Supervisory Control and Data Acquisition (ESCADA) system has been developed for interlocks and monitoring of Electrical Subsystems of Dhruva reactor. The system consists of TPLC-32 based dual redundant nodes in hot-standby configuration, data servers and display stations. Hardware integration and environmental qualification testing has been completed, and all the hardware panels have been dispatched to Dhruva.

A new remote-operated system was developed and deployed at research reactor CIRUS for ageing assessment program, as part of studies related to material characterization and mechanical property analysis.

Active samples of CIRUS reactor vessel are required as part of ageing assessment program for material characterization, mechanical property analysis and also for radio-characterization of Reactor Vessel as a vital input for future decommissioning of the pile block. A Remotely Operated Sample Cutting & Retrieval System has been developed and deployed for on-site execution of actual campaigns.

ADVANCED TECHNOLOGIES

The research centres of DAE are engaged in developing advanced technologies such as accelerators, lasers, advanced materials, robotics, supercomputers, instrumentation and others. BARC, RRCAT, VECC and BRIT are also engaged in the development of radiation technologies and their applications for better crop varieties, techniques for crops protection, radiation based post-harvest technologies, techniques for radio-diagnosis and radiotherapy of diseases particularly cancer, technologies for safe drinking water, better environment and industrial growth.

Accelerators

Three HB650 Super Conducting RF cavities developed at RRCAT have been qualified for assembly in Proton Improvement Program-II prototype Cryo-Module at Fermi lab USA. Successful integration of 650 MHz cavities in pCM is an important milestone towards development of superconducting technologies for accelerator.

String Assembly for pCM of PIP-II with 3 cavities from RRCAT, India and 3 from Fermi lab, USA

The electron beam radiation processing facility has been offered to industry under incubation activities. The facility uses a 10 MeV, 6 kW in-house developed electron linac. It has ISO 9001 and ISO 13485 certificates. Further FDA licence along with AERB licence has been obtained. The facility has been used by industries from various parts of the country for sterilization of medical items.

Laser Technology Development and Applications

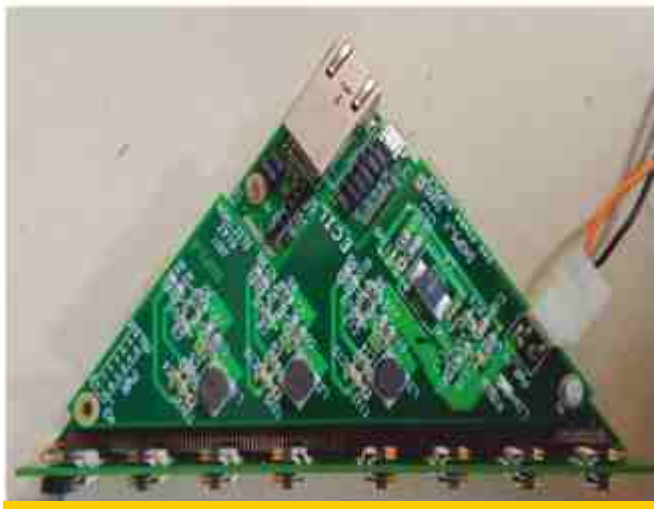
At RRCAT, in the area of lasers, development of engineered versions of 1.5 kW average power and 30 kW peak power long pulse Nd: YAG laser and 1 kW CW fiber laser have been completed. Several laser based systems for applications in the area of nuclear energy are developed. They include, underwater cutting of end

plates of fuel bundle, welding of fuel pins, cutting 30 mm recirculation tubes etc. Development of specialized lasers has been carried out which includes, ultra-narrow line-width laser (100 Hz), 2 W mode locked ultrafast fiber laser etc.

Laser Additive Manufacturing (LAM) setup has been augmented with addition of 2 kW Fiber Laser for Directed Energy Deposition System. Components from dissimilar metals - Inconel 625 and SS 304L with graded interface have been developed using this set up. Intricate conformal cooling channels have been fabricated using Powder Bed Fusion based Additive Manufacturing.

Electronics & Instrumentation

BARC, ECIL and IGCAR have jointly developed Programmable Logic Controller (PLC) NUCON series 1000 and 2000 as part of development activities to ensure safety and cyber resilience of critical electronic systems. A low power, high performance 128-channel Data Acquisition Module (DAM) has been developed for Iron Calorimeter (ICAL) experiment of Indian Neutrino Observatory (INO).



128-channel DAQ Module

Laser based sensors were designed, developed and demonstrated for taggant detection, perimeter intrusion and customised solution for fuelling machine alignment for TAPS-3&4 of NPCIL.

RADIOISOTOPES & RADIATION TECHNOLOGY AND THEIR APPLICATIONS

DAE has been playing a significant role in the development and applications of various radioisotopes in healthcare, industry, agriculture and research. India is one of the leading countries in the isotope technology today as a result of the consistent efforts of DAE.

Radioisotopes are produced in the research reactors at Trombay, accelerator at Kolkata and the various nuclear power plants of NPCIL. During the report period, a wide variety of radioisotopes for medical, industrial and research applications were produced and supplied by BARC. The Board of Radiation and Isotope Technology (BRIT) produced and supplied a wide range of radioisotope products, and radiation technology equipment for medical and industrial uses. BRIT's plants for radiation sterilization of medical products and radiation processing of spices and allied products continued to offer services to medical and agro-industry. Radiation technology based tools and techniques benefitted variety of industries and social sector.

Agriculture

In crop improvement, 7 Trombay crop varieties, which include 4 of mustard, 1 of groundnut and 2 of rice varieties have been released and Gazette notified for commercial cultivation by Ministry of Agriculture & Farmers Welfare, Govt. of India. Breeder seed production of Trombay crop varieties has been carried out in groundnut (254 quintals), rice (80 quintals) and pulses (65 quintals). Biopesticide formulation based on Trichoderma virens mutant has been registered with Central Insecticide Board & Registration Committee (CIB&RC), Govt. of India, becoming the first mutant microorganism registered for field applications. Indian Council of Agricultural Research (ICAR) has recommended Tricho BARC formulation for seed treatment in chickpea. Two new technologies (Superabsorbent BARC-Hydrogel & ANU-CHAITANYA) related to crop production have been launched.

Food Technology

Based on the R&D output in the division, large scale successful commercial storage (50 Ton) of radiation processed onion was carried out by a DAE licensee. Sea route shipment of about 16 Ton of Kesar mangoes, processed with the BARC developed (USDA approved SOP) was carried out in the month of June 2022 under a MoA. Technologies for shelf stable luscious and nutritious Chiku fruit bites anddevelopment of ready-to-eat fish spread were advertised at the entrepreneur's corner on BARC website. The commercial deployment of the Strawberry product as well as Gluten Free- Multigrain Premix has been accomplished by the launch of these products on online portals. The total number of commercial irradiation plants in the country has reached 26 and eight more plants are proposed to be commissioned in coming years.

BARC technology 'Long Lasting Delicious Strawberry Candy Roll (SCR)'

Nuclear Medicine and Healthcare

Production & supply of medical radioisotopes and ready-to-use radiopharmaceuticals to nuclear medicine (NM) centres all over India, continued during the reported Year 2022-23.

Installation and commissioning of the BRIT Fission Moly Production Facility (FMP) for the production of medical grade high specific activity (HSA) Mo-99 was completed. Successful trial batch production has been done in Dec. 2022.

Coltech (^{99}Mo/^{99m}Tc) Generators (Product Code:TCM-1) using high specific activity ^{99}Mo-sodium molybdate were produced and supplied to various hospitals in India. Demand for Coltech generators saw an upward trend during this period. In addition, low specific activity ^{99}Mo in the form of sodium molybdate solution was also suppllied for Solvent Extraction Generators (Product code:TCM-2) to avail Technetium-99m at the hospital end, as per demand.

Technetium-99m cold kits (19 Products; Product Code: TCK) for diagnostic imaging of diseases in various organs of the body were supplied to nuclear medicine centres in India.

Supply of Iodine-131 based products, in the form of ^{131}I-sodium iodide (oral solution & capsules with Product Code IOM-1 & IOM-5 respectively) for efficient management of thyroid disorders was continued. Production and supply of I-131 labelled mIBG for diagnosis and therapy of Neuro Endocrine Tumors (NET) was also continued, during the reported period.

There was significant increase in the demand for ^{177}Lu based products namely ^{177}Lu-DOTA-TATE for treatment of neuroendocrint tumors and ^{177}Lu-PSMA-617 for treatment of prostate cancers. Other therapeutic products supplied by BRIT during the reported period included the ^{90}Y-HA and ^{177}Lu-HA for treatment of rheumatoid arthritis.

Radioimmunoassay (RIA) kits & Immunoradiometric Assay (IRMA) kits were supplied to pathology laboratories & nuclear medicine centres throughout the country for in-vitro diagnosis of thyroid disorders.

EXECUTIVE SUMMARY

Around 370 batches of radiopharmaceutical samples (which includes TCK kits, ready-to-use radiopharmaceuticals injections and oral solution and capsules and 99Mo-99mTc COLTECH Generators, were routinely analysed and certified by QC during the reported period, Apr 2022-Dec 2022. Another, nearly 130 batches of products are expected to be analyzed upto March 2023.

Regular Quality Assurance was performed before the batch release of all the radiopharmaceuticals which were supplied during the reported period. Batch release certificates were issued for a total of 301 batches of TCK cold kits, ready-to-use radiopharmaceuticals injections, oral radiopharmaceuticals. This also includes radiopharmaceuticals based on Lu-177, Ga-68 and 99Mo-99mTc COLTECH Generators.

Quality Control services were provided for New Products that were produced at RPhP, Vashi, such as (a) Trial batches (3 Nos.) of FMP-generated 99Mo (99Mo-99mTc COLTECH Generators); (b) one batch of a modified formulation for the preparation of lyophilized TRODAT-1 [Technetitium Cold Kit (TCK-55)]; (c) Trial batches of mIBG sample, synthesized by BOD, BARC, made as an injectable 131I-radiopharmaceutical was tested for its efficacy; (d) QC tests were standardized for the New product, 177Lu-Hydroxy Apetite Injection; (e) ST& BET for Trial batches of 68Ga-NODAGA-JR11 kits (received from RLG, BARC); and (f) QC tests for Trial batches of TCK-37 (Stannous Pyrophosphate injection), were all carried out during the reported Year 2022-23.

QC Laboratory received ISO 9001:2015 continuation certification after the third-party audit was conducted by AJA authorized agency.

The Medical Cyclotron Facility (MCF) of BRIT continued the synthesis and supply of Positron Emitting Tomography (PET) radiotracers, the maximum being [F-18]-FDG. Other PET radiopharmaceuticals include [F-18]-NaF, and [F-18]-FET, which are produced in smaller scales. So far ~176 Ci of [F-18] FDG have been supplied to various hospitals in Mumbai for PET imaging. More than 15000 patients are benefitted with PET investigations in the reported year 2022-23.

Routine production of various Cyclotron-produced radiopharmaceuticals like [^{18}F] FDG, ^{68}Ga-PSMA-11 and ^{68}Ga-DOTA-TATE were carried out and were supplied to various Nuclear Medicine (NM) Centres in Kolkata.

Regular Quality Assuarance (QA) was performed before the batch release of all the radiopharmaceuticals which were supplied. The Quality Control (QC) for [18F] FDG (110 batches) and other radiopharmaceuticals like , 68Ga-PSMA-11 and 68Ga-DOTA-TATE were routinely analyzed and certified.

Services towards the supply of TCK Cold kits to various NM Centres in and around Kolkata, were also part of the activities performed by RC, Kolkata.

Apart from these, RC, Kolkata, is also involved in product oriented Research & Developmnt (R&D) work, which involves (i) Preparation of Ga-Ni alloy target using constant current electrolysis technique on a gold-plated Cu-base material and development of separation module for ^{68}Ge from Ga-Ni alloy target for ^{68}Ge/^{68}Ga Generator production; (ii) A semi-automated separation and purification module was developed to obtain [^{68}Ga] Ga-Chloride from ^{68}Zn solid target for the sybthesis of pharmaceutical grade [^{68}Ga] Ga-PSMA-11 and [^{68}Ga] Ga-DOTA-TATE. Software development towards remote operation of the system is also prepared; (iii) Bulk recovery of enriched ^{68}Zn from the irradiated target solution and recycle of recovered ^{68}Zn for the preparation of electroplated solid targets after chemical processing.

Custom synthesis and supply of radiolabelled compounds, mainly, 14C based compounds, is provided to research institutes. These find extensive applications as tracers in the field of biology.

Production and supply of 14C Urea Capsules was continued for 'Urea Breath Test', useful in the diagnosis of the infections caused by microorganisms named, Helicobacter pylori, a spiral bacterium, and may be responsible for gastritis, gastric ulcer, and peptic ulcer disease. These capsules were supplied to Mangalore University & Jawaharlal Institute of Post Graduate Medical Education & Research, Puducherry, during the reported period.

Another product, 14C-Planchet source, used in environmental studies, was standardized and supplied RPAD, BARC.

Thymidine-Methyl-T was made and supplied to Molecular Biology Division of BARC.

Based on MoU between BRIT and Heavy Water Board, deuterated NMR solvents were dispensed and supplied to various customers. All the solvents supplied had >99.8% Deuterium abundance.

During the Year 2022-23, more than 15000 Tritium Filled Sources (TFS) sources of various sizes, shapes and tritium content were supplied to defence establishments.

Completed the setting up of in-cell gadgets for the Tritium gas handling operation related to Tritium Filled Light Sources (TFLS) and Tritium labelled compounds production activity and cold trial experiments were completed successfully.

During the period, the Medical Cyclotron Cyclone-30 machine availability was satisfactory and it has delivered beam for irradiation of O18 to produce F18 and FDG (Fluorodeoxyglucose) which is produced by BRIT. Production was carried out everyday morning for 5 days a week without any major interruption. Two hot cells operated in automatic process for regular production of FDG from medical cyclotron. Trial production of Ga67, Th201 and Ga68 were carried out using this facility and supplied to local hospital by BRIT.

The Radiation Medicine Centre (RMC), a constituent unit of BARC provides nuclear medicine services in India. During April-December 2022, advanced diagnostic services were extended to 8,717 patients using 68Ga-, 99mTc- and 18F- based radiopharmaceuticals. 1976 patients with thyroid, prostate and neuroendocrine cancer were provided radionuclide therapy. For thyroid cancer patients, radioactive iodine therapy was provided to more than 476 patients. 177Lu- DOTATATE therapy was given to over 378 patients of neuroendocrine cancer. 90Y-DOTATATE therapy was offered to over 8 patients with large progressive disseminated metastatic neuroendocrine tumours.

RMC has started providing treatment using alpha radionuclide therapy using 225Ac-DOTATATE among patients suffering with small single cell neuroendocrine tumours. 177Lu-PSMA therapy was offered to more than 97 prostate cancer patients. Various thyroid function tests (TSH, T4, fT4, AMA and Tg) were performed using RIA for 4259 patients. The Medical Cyclotron Facility produced 377 batches of 18F based PET radiopharmaceuticals and these were supplied to 6 Nuclear Medicine Centres across Mumbai. 64CuCl2 produced at research reactor Apsara-U was evaluated as a PET radiotracer.

For radioimmunotherapy of non-Hodgkin's lymphoma and breast cancer, 177Lu-DOTA-Rituximab and 177Lu-DOTA-Trastuzumab, respectively were approved by RPC for use in diagnostic and further approval for therapy is expected next year.

A new Nuclear Medicine Facility is coming up within the premises of new DAE Campus at Rajarhat in Kolkata. The facility comprises state-of-art infrastructure for providing various services, including nuclear medicine diagnostics and therapeutics. The development of infrastructure and installation of equipment is in progress.

RMC regularly conducted various academic courses for science graduates. During the year, admissions to M.Sc. in Nuclear Medicine and Molecular Imaging Technology, Hospital Radiopharmacy as well as MD in Nuclear Medicine were carried out successfully. The affiliation to these courses was granted by Homi Bhabha National Institute.

Alternative Applications of Heavy Water

Non-nuclear applications of heavy water picked up momentum in recent years and Indian industries as well as academics have unique opportunity to grow in this field. HWB has taken lead to accelerate the research and industrial scale activities by collaborating with them. Organizations from USA, France, Japan, South Korea, Switzerland and Russia which are involved in production of deuterium labeled NMR solvents, semiconductors, optical fibres and d-labeled

Heavy water drums being stacked in container for shipment to USA

compounds have approached HWB for long term stable supply of heavy water in bulk quantities.

Export orders have been executed for M/s Millipore Sigma, USA, M/s. Linde Electronics & Specialty Gases, USA and M/s. KC Industrial, S. Korea and revenue of 14.7 million USD has been generated. Export request received from M/s CMR, Russia, M/s Millipore Sigma, USA, M/s LaboTecc GmbH, Germany, M/s Eurisotop, France, M/s Iwatani Corporation, Japan, M/s Cambridge Isotopes Ltd., USA, M/s LG Chemicals, S. Korea, M/s. Zeochem, Switzerland, M/s. Hyosung Chemical Corporation, South Korea, M/s. Merck KGaA, Germany etc. are under various stages of execution. It is being observed that many countries are approaching again for further supply, establishing India as a global leader in HW production and supply. In the current financial year 2022-23, export demand reached all-time high for non-nuclear applications. Domestic demand for heavy water is also increasing with widening of commercial activities in various non-nuclear fields viz, optical fibre, semiconductors, NMR solvents, deuterated API intermediates etc.

^{18}O enriched water in medical diagnostics

HWB is synthesizing ^{18}O enriched water which is a precursor for generation of radiopharmaceutical ^{18}F-FDG in cyclotron. This provides the images of PET scanning by radioactive decay with emission of positron. PET is a diagnostic technique used in oncology, neurology and cardiology. Nuclear grade Heavy Water is used as raw material in first indigenously developed ^{18}O production plant at HWP, Manuguru. The unit remained under steady operation. In the enrichment columns, 95.5% IP ^{18}O enriched liquid was produced in the facility in the financial year.

Cancer Diagnostics & Treatment Services

There was 20% increase in the total number of new patients' registrations at the Tata Memorial Centre (TMC) hospitals across India. From a figure of over hundred and ten thousand (>110,000) in year 2021, it rose to over hundred and forty thousand (>140,000) in 2022. There was similar increase in the numbers of radiological and of the laboratory investigations performed at all centres across India. The pan India bed strength was just over 1800.

The commissioning of the Homi Bhabha Cancer Hospital & Research Centre, Mullanpur in Punjab was done by the Honorable Prime Minister of India, Shri Narendra Modi on August 24, 2022.

A new Preventive Oncology Rural service for cancer screening & its early detection was initiated from February 2022 at Khopoli (Raigad district) in Maharashtra,

Industrial Applications of Radioisotopes & Radiation

BRIT continued the tasks related with the safe supply of Cobalt-60 sealed sources such as Cancer treatment Cobalt-60 Teletherapy Sources & Multi-Purpose Gamma irradiator sources.

BRIT-RAPPCOF continued the tasks related with the storage, fabrication and safe supply of Cobalt-60 sealed sources, which are used for Cancer treatment-Cobalt-60 Teletherapy Sources, & Multi Purpose Gamma Irradiator sources. RAPPCOF Processed 6.468 MCi of Cobalt-60 activity in the reported Year 2022-23, upto December 2022, and fabricated Four hundred and twenty-four (424) Multi-Purpose Gamma Irradiator Sources and Thirty-one (31) numbers of Cobalt Teletherapy Sources (CTS).

BRIT supplied a total 6.123 MCi of Cobalt-60 sealed sources activity in the country and abroad during the financial year 2022-23. This includes Eighty-seven (87) numbers of W-91 Irradiator sources, Four hundred and one (401) numbers of BC-188 irradiator sources and Six (06) numbers of CTS.

The export orders of 2.0 MCi to M/s Nordion, Canada & 1.0 MCi to Malyasia are successfully executed during the reported period. Likewise, the domestic demands of supplying a total of 3.12 MCi to various Multi-Purpose Gamma Irradiators within the country, could also be executed in a safe manner. Thus, a total demand of 3 MCi of ^{60}Co as export orders and ~ 3.5 MCi for domestic use, upto December 2022, was duly fulfilled.

A total of six CTS to various Radiotherapy Cancer Hospitals within the country, with 191-245 RMM in single batch of operation were fabricated & supplied during the period.

Co-60 & Cs-137 CMR sources, 41 nos., with total activity 3714 mCi & 2 Nos. of Cs-137 source with 1570 mCi activity, were fabricated and supplied, up to Dec 2022. Another 5 CMR sources with 400 mCi is planned up to March 2023.

About 551 nos. of ^{192}Ir & 04 Nos. of ^{60}Co Radiography sources, with total activity 22858 Ci, were fabricated & supplied up to Dec 2022. Another 200 sources with activity ~ 8000 Ci are expected to be fabricated & supplied up to March 2023.

Around 90 nos. of devices containing Cs-137 sources were collected from NTPC, Korba. Collection of remaining devices from 3 institutes is planned up to March 2023. Source are to be removed from devices for repatriation to USA.

Total 83 numbers of devices containing various types of radionuclides were handled at RSMS, BARC for safe management of disused sources. Another 50 nos. of these devices are expected to be supplied by March 2023.

Successful installation of Cryo-Irradiator with 95 kCi of Co-60 for irradiating marine products. Commissioning dosimetry is going on for marine products.

Analysis and experimental test of Remotely Operated Tungsten Shielded Exposure Device (ROTEX-I) radiography device under 9m drop & 1m punch test, to qualify it as a Type B(U) package, is completed.

Design approval for Mobile Food Irradiator (MFI), which is a category-II, panoramic, dry storage, batch type gamma irradiator, designed to irradiate low and medium dose food products like fresh fruits and vegetables, cereals, pulses etc., is awaited.

Development of commercial operational prototype COCAM-A radiography device (launched last year) for effective marketing & its validation is completed.

Designed the Package for Transportation of Molybdenum-99 (MTP-1200) to carry 44.4 TBq (1200 Ci) of Mo-99 radioisotope. Type B (U) approval of “MTP-1200” “Mo-99 Transportation Package”, is awaited from AERB.

Designed Cobalt Pin Cask to carry a maximum of 50 kCi of Cobalt-60 produced from Co-NU fuel bundle of Indian PHWR to Cobalt handling facility of BRIT at Kota during the reported period.

Radiation Processing

BRIT signed Five MoU's for setting up Gamma Radiation Processing Plants (GRPF) at various places within the country for disinfestations, shelf-life extension of food products and sterilization applications of healthcare products during the reported year 2022-23. These are namely M/s Tarsons Products Pvt. Ltd.for setting up plant at Howrah, West Bengal, M/s Q-Line Healthcare Pvt. Ltd., for setting up plant at at Lucknow, Uttar Pradesh, M/s Microwin Sterisolutions Pvt. Ltd. For setting up the plant at Palakkad, Kerala, M/s Greenrad Ventures for setting up the plant at Aurangabad, Maharashtra, and M/s Vishvesh Agroded Pvt. Ltd. For setting up the processing plant at Nagpur, Maharashtra. Apart from these MoU's, Gamma radiation processing

plant of M/s Gamma Tech (India) Pvt. Ltd., Tirunelveli, Tamil Nadu and M/s Ansell Sterile Solutions Pvt. Ltd., Coimbatore, Tamil Nadu, were commissioned during the reported period.

ISOMED continued to offer commercial Gamma Radiation Processing services in GIC-5000 to the vendors of NPCIL, under equipment qualification programme. Radiation Processing Plant, Vashi has provided gamma radiation processing services for Spices and allied products to various exporters from all over the country. Forty seven new customers were registered during the current year. Main products processed were spices (both, whole & ground), pet feed, ayurvedic raw materials & healthcare products. Industrial samples like polymer components, electric cables, transmitter, RTDs etc., were received from NPCIL vendors & exposed with desired doses of gamma radiation, as per qualification test criterion. During the current financial year, 2022-23, 2730 MT of spices, Ayurvedic raw material, healthcare products and other products were processed. Another 900 MT of spices & allied products are expected to be processed during Jan-Mar 2023. Surveillance audits for ISO 9001:2015, 22000:2018 and ISO 13485:2016 were got carried out by certifying agency, and found in full compliance with the Standard's requirement.

Dosimetry services during the commissioning of three Radiation Processing Plants (private vendors) for sterilization of medical products and for Class VI and Class III food products, were completed during the reported period. Recommissioning dosimetry was carried out for two radiation processing plants. Dose rate certification was provided to Six blood irradiators (BI-2000) and three Gamma Chamber-5000 during the reported period. Dose rate certifications to be provided for two Laboratory Irradiators is planned for the next quarter, i.e. upto March 2023. Production and supply of 2.4 Lakhs Ceric-Cerous sulphate dosimeters was made available for various gamma irradiators in the country, to measure the absorbed doses during April 2022 to December 2022. Another 20,000 Nos. of these dosimeters and export of these dosimeters to Sri Lanka are expected to be supplied from Jan 2023 to March 2023. Production & supply of ~ 800 Biological Indicators were made available to the various customers of Radiation Processing Plants in India. Fifty-Four lots of tissue grafts were received from Biocover Laboratories, Tissue banks, Tata Memorial Hospital (TMC) and Novo tissue bank, which were duly tested for Sterility & Bio-burden and the results were communicated.

Radiation Technology based Equipment & Services

A total of 16 numbers of Radiography Cameras, which includes ROLI series, and recently launched COCAM-120 radiography device, were supplied to various NDT users within India, upto December 2022. Two Blood Irradiators-2000 units with Co-60 source have been supplied to hospitals in India during April 2022 to December 2023 and supply of 02 units of BI-2000 is expected to be supplied upto March 2023. Supply of Three units of GC-5000 with Co-60 source were supplied during Apr 2022 to Dember 2022, and supply of 01 Unit is expected upto March 2023. A new automation-based treatment planning software – DOSAGE – which optimizes important parameters of radiotherapy administered through Bhabhatron-II has been developed in BARC.

Water Purification, Water Desalination & Isotope Hydrology

The deployment of water purification technologies developed in BARC was taken up in a mission mode for providing safe drinking water to rural households as part of Government of India's Jal Jeevan Mission. Arsenic decontamination devices of 24 LPD capacity were deployed at Samastipur district in Bihar.

A 1000 litres per hour capacity community-scale arsenic removal plant with water dispensation facility was installed at Ichhapur-I Village Panchayat, Dist. North 24 Parganas, West Bengal based as part of DAE's Vision-6 project on “Deployment of Water Purification Technologies in Rural India”. The arsenic concentration was reduced from 400 ppb in feed water to less than 10 ppb in product.

BASIC & APPLIED RESEARCH

Basic and applied researches relevant to DAE's programme are carried out in the research centres of the department. Following were the notable developments in the fields of basic and applied research carried out during the report period, by these research institutes.

Mathematics & Computational Sciences

TIFR continued to work on several questions and problems in Geometric Group Theory, Probability Theory, Complex Analysis, Conformal Dynamics, and Reflection Groups, Geometry and Topology, Lie Groups, Arithmetic Groups and Algebraic Geometry. In the School of technology and Computer Science at TIFR, research work was pursued in the areas of computer science as well as systems science.

The central themes of research of the mathematics group at HRI were in the areas of Finite Group Theory, Representation theory and Lie Algebras, Algebraic Geometry, Differential Geometry, Harmonic Analysis, and Number Theory.

At SINP, the Long Range Kitaev (LRK) spin chain has been studied in the context of global quench in the power describing the range of the interactions. Integrable properties of local as well as nonlocal vector nonlinear Schrödinger equation with a general cubic nonlinearity in the presence of a linear term, which under certain condition incorporates balanced loss and gain of energy, have been investigated.

Physics

Statistically significant gamma-ray photons have been detected by the Major Atmospheric Cherenkov Experiment (MACE) telescope from the active galactic nuclei Mrk 501 in a live time of approximately 07 hours. During the year-under-review, the telescope was deployed for more than 150 hours to monitor high energy gamma-ray emission from galactic and extragalactic sources.

A recent study conducted in BARC demonstrated for the first time novel quasi-particle excitations of strong spin entangled ground state of a quantum spin-1/2 trimer-chain antiferromagnet.

In non-equilibrium nuclear fission, from the pre-scission multiplicity data recorded at the Pelletron Linac Facility, it was found that pre-scission alpha particle multiplicity makes a changeover from high to a very low value while making a transition from symmetric to relatively asymmetric heavy-ion collisions. This development is expected to contribute positively to the understanding of nuclear fission dynamics and the processes involving super heavy elements synthesis.

The Dhruva Reactor based ISMRAN detector is being used regularly for measuring antineutrinos through Inverse Beta Decay (IBD) process. Ongoing data analysis is expected to provide measurements of antineutrino spectra. Significant data has been acquired during the year in both reactor-ON and reactor-OFF conditions.

At TIFR, in Astronomy and Astrophysics, researchers presented design and performance of TANSPEC (TIFR-ARIES Near-infrared Spectrometer), a medium-resolution 0.55-2.5 ㎛ cryogenic spectrometer and imager, now in operation at the 3.6 m Devasthal Optical Telescope (DOT), Nainital, India.

A plastic balloon designed and fabricated at TIFR Balloon Facility, having a volume of 286,652 cubic metres, was launched on 7th December 2022 at 0545 hrs (IST) from TIFR Balloon Facility, Hyderabad.

A 64-pixel prototype of 256-pixel SiPM-based camera was mounted in the focal plane of the vertex element of the TACTIC telescope at Mt Abu. Test runs were carried out during April-May 2022 demonstrated proper functioning of the prototype.

The effect of weak binding of ^{9}Be on complete fusion has been studied through the emission of Intermediate Mass Fragments (IMFs) from ^{20}Ne + ^{9}Be reaction. The yields of the fragments ^{6,7}Li and ^{7,9}Be emitted from the excited compound nucleus ^{29}Si* have been compared with the respective statistical model predictions.

A systematic study has been performed to understand the (N-Z) asymmetry dependence on the nuclear level density by measuring the emitted neutrons from ^{4}He + ^{112,116,124}Sn reactions in the excitation energy range of 25-42 MeV.

Microscopic interaction from the realistic nuclear equation of state has been successfully implemented in the Canonical Thermodynamical Model of nuclear multi-fragmentation in order to calculate different fragmentation observables at intermediate energies. Effect of effective mass on mass fractions and average mass of heavy clusters for warm stellar matter has been investigated in the framework of the Nuclear Statistical Model approach. Nuclear collective dynamics has been studied using inputs obtained from the nuclear energy density functional theory.

Synchrotrons and their Applications

The synchrotron radiation sources (Indus-1 and Indus-2), at RRCAT operated as the National facility in round-the-clock mode for 253 days from April to December 2022. At present 7 beam lines in Indus-1 and 18 beam lines in Indus-2 respectively are operational. The availability of synchrotron radiation beam for users has been of the order of 5210 Hrs. (20 hours/day) in Indus-1 and 4327 Hrs. (17 hours/day) in Indus-2 respectively. Over 796 user experiments have been carried out with around 120 research publications. Pharma industry users have also utilised the facility and for this purpose MoU is signed with each of the industry users.

A new X-Ray Magnetic Circular Dichroism (XMCD) beamline has been commissioned. Operational enhancements for beam-lines have been carried out which included Soft x-ray fluorescence and absorption measurement setup on BL-03 and x-ray fluorescence and total reflectance system on BL-16.

A new high intensity and high resolution undulator based beamline called Atomic, Molecular and Optical Science beamline has been developed by BARC at Indus-2 Synchrotron source at Raja Ramanna Centre for Advanced Technology in Indore, which can deliver high flux photons (flux $\geqslant 10^{12}$ photons/sec) in the photon

AMOS beamline at Indus-2

energy range of 6-800 eV at a high resolving power (~10000).

At SINP, the GIXS beamline (BL-13) at Indus-2 is now fully operational and commissioned to the users' operation. All the safety related issues have been cleared and the permission from AERB has been obtained for its regular use. Following this, the beamline is accepting scientific proposal through online portal of Indus-2, RRCAT website and also a few scientists from research institutes and universities have started using this beamline as the regular users. Two post-doctoral researchers have been stationed in the facility to assist the users as well as to carry out their own research work.

Cyclotrons & their utilisations

The K130 room temperature cyclotron has been operating round the clock and delivering light and heavy ion beams for various types of experiments. The K130 cyclotron has two ion sources (internal PIGIS and external ECRIS) to produce light and heavy ions. Presently PIGIS are in use to produce light ion beams like proton, deuteron and alpha for conducting the research program.

Electron cloud trapping time extended up to 800s in Room Temperature Penning Trap at VECC: A cloud of electron have been trapped using five electrode cylindrical penning trap with 0.1 Tesla Permanent magnet arrangement. Resonant based detection circuit has acquired induced image current due to oscillation of trapped particle. The electrons for trapping were generated Field Emission Point (FEP) on application of 830V. The primary high energy electrons from FEP

collided with the background gases and generated secondary electrons which were eventually confined in the Penning trap.

Fusion and Other Plasma Technologies

In advanced technologies & applications category, IPR has completed a major milestone towards India's first indigenously built 5 TPD plasma pyrolysis system for biomedical waste disposal, with the successful testing of three 100kW graphite electrode-based plasma torches for 120 hours continuously. A novel supersonic plasma plume torch system has been developed & characterized for creating functional coatings at very low pressure. A new, compact, easy-to-handle DC plasma based system has been developed for sterilization of medical equipment and tools. A plasma fireball-mediated ion implantation system has been developed, with potential applications for nonvolatile memory applications. It has been shown that treatment of catheters with low pressure oxygen plasma is able to reduce bacterial adhesion and biofilm formation on catheter surfaces significantly ($\geqslant$ 99 %) without the use of antibiotics, and is remains efficient up to 30 days after plasma treatment when stored under ambient conditions. As a contribution to R&D in green hydrogen, IPR has conducted preliminary experiments on plasma electrolysis; initial results are promising, and further R&D is in progress to improve the energy efficiency. In a joint study with a Public Sector agency, it has been shown that sanitization with Plasma Activated Water of milk cans and other containers used in the dairy industry gives significant reduction in the microbial load; this method appears more cost effective than existing methods.

An LN_2 based high-throughput cryo-sorption pump, having speed 26000 l/s for water vapour has been specially developed and deployed on the SST-1 tokamak. Cryosorption cryopumps for cryovac chambers have also been indigenously developed and supplied to SAC-ISRO, and the technology has been transferred to industries for commercialization. Development of a 14 kA Nb3Sn Cable In Conduit Conductor (CICC) has been done jointly by IPR and Atomic Fuel Division of BARC Fabrication and testing of a high-temperature superconductor (HTS)-based 1 Tesla solenoid magnet has been completed. A 1 m long, 3 kA high temperature superconducting cable has been fabricated and tested. An IPR-developed 100 kV, 25 Regulated High Voltage Power Supply has yielded good performance on the LEHIPA facility at BARC. Technology has been transferred to several private parties, such as Plasma Activated Water, Cryosorption cryopump, production of metal oxide nano powder using a plasma process and plasma pyrolysis.

In fusion plasma activities, a variety of new sub-systems and diagnostics have been added to the Aditya-U tokamak. These include indigenously developed fast reciprocating probe for radial density & temperature measurement; Dust injector for safe boronization; X-ray crystal spectrometer to study plasma rotation, ion temperature & impurities and Laser heated double headed emissive probe to study plasma potential & their fluctuations. A series of experiments has been done in Aditya-U to study role of gas puff & MHD in Sawtooth-induced instabilities & heat pulse propagation, triggering Geodesic modes and impurity transport, particle influx, recycling & confinement. In a contribution to Atmanirbhar Bharat, IPR has developed, along with an Indian company, an import substitute visible high-resolution single channel spectrometer with a CCD array detector. In the SST-1 tokamak, several new systems have been added/upgraded, such as a hardware-in-loop for integrated control system, an indigenously developed 1.5MW tetrode-based RF source, etc.

Chemistry

At BARC, a functionalized poly-propylene fabric was developed for selective recovery of gold (III) from aqueous media. The developed fabric expressed promising potential for use as an effective adsorbent for recovery of gold from electronic waste.

Nanocomposites were developed using polymeric materials and sands for treatment of low-level waste comprising radioactive Cesium.

A gelatin based composite gel has been fabricated for topical delivery of curcumin. The gelatin-curcumin composite gel shows efficient wound healing activity in animal models.

Bacteria-laden granules were nitrate evaluated for treating ammonium containing water. The granules were able to remove ammonium nitrate by converting it to Nitrogen (N2) through a nitrification-denitrification process. The process is being developed for applications in treating ammonium nitrate containing effluents generated in nuclear fuel reprocessing operations.

The robustness of hgSBR was evaluated in the presence of toxic pollutants. Biogranules were found to perform biological treatment in the presence of heavy metals in ppm concentration.

Novel hybrid granular biofiltration system was designed and evaluated for treating grey water and wastewater generated from domestic use. The newly developed biological treatment system was aimed at minimizing infrastructure and aeration requirements. It is suitable for decentralized wastewater treatment systems, including household applications.

Screening of the new synthetic organoselenium compounds for anticancer activity has led to the identification of pyridine based diselenides as potent anticancer agents for treating lung cancer. DSePA has been demonstrated to show better tumour control in combination to radiation therapy. The regulatory dossier for DSePA has been prepared.

Study of spatially oscillating chemical phase formation on silicon nano ripple by mixed ion beam irradiation were carried out at VECC. SiOxNy/SiC system is a promising seed for fabricating electronic devices. However, for a practical application, one must have a high-quality interface. Current methods for synthesis of interface such as chemical vapor deposition or epitaxial growth are not free from contamination and are time-consuming. Therefore, we seek a method to fabricate such material by ion implantation. The formation of varying chemical interfaces in Si (100) by implantation of N2+ and CO+ molecular beam from the RIB facility.

The study of atomically flat 2D sheets with atomic or molecular thickness is emerging due to their wide application in electronic, optoelectronic, and photonic devices. Muscovite mica [KAl2(Si3Al)O10(OH)2] is a layered, multi-elemental, and insulating material with an atomically flat surface. Techniques, like thermo-luminescence, exfoliation, and swift heavy ion irradiation are not effective in modifying specific selected layer of mica in a controlled manner, whereas using ion-beam one can fine tune the implantation energy and study the modification of the selected layer. Defects were introduced on the top layer of mica by 3 keVAr+ ion bombardment using ion-beams from the RIB facility

Biology

Liposomal vaccine for COVID -19, which induces very high titre neutralization antibodies, was evaluated for its in vivo efficacy in viral challenge experiments in hamster model at IISc Bangalore. Data obtained from extensive studies suggested that vaccinated hamsters likely saw protection from SARS-CoV-2 in as compared to control. Further, viral load in vaccinated mice was reduced by more than 4 log units (99. 99%) when compared to unvaccinated control. The vaccine is now ready for clinical trials.

As part of efforts for developing a COVID-19 vaccine, RBD gene of SARS-CoV-2 was cloned in BCG to understand the immunogenicity of recombinant BCG, and its effectiveness as a vaccine is being tested on BALB/c mice through heterologous prime boost strategy.

Early adversity is an important risk factor that influences vulnerability to psychopathology and to brain aging. Researchers of the Department of Biological Sciences at TIFR, attempted to uncover the impact of early adversity and the role of specific monoamine neurotransmitters in mediating the consequences of early stress on the rodent brain at distinct epochs of life. It was found that early stress accelerates hallmark features such as mitochondrial dysfunction and oxidative stress, evoking impairments in neuronal bioenergetics. Early adversity also drives neuroinflammatory states, thus cumulatively driving

cellular senescence, neuronal and cognitive decline.

At the National Centre for Biological Sciences, Bengaluru, a study investigated the effects of native, leaf-inhabiting bacteria (genus Methylobacterium) on traditionally cultivated rice varieties in a crop field.

Hepatitis B Virus (HBV) is the leading cause of liver disease ranging from acute and chronic hepatitis to liver cirrhosis and Hepatocellular Carcinoma (HCC). A novel mechanism of epigenetic reprogramming by HBV have been reported at SINP.

Materials Science

A novel Ni-Cr-Mo-Ti based alloy has been developed at Materials Science Division, BARC for structural application in the Indian MSBR. Microstructural characterization showed that the alloy contains prominent carbides of Mo and Ti, many of which are located at the grain boundaries.

As part of the ongoing program to benchmark the newly developed indigenous materials, Reactor Pressure Vassal (RPV) weld samples was irradiated using proton beam at the variable energy cyclotron. 160 mev oxygen ion has been used to emulate the fission and fusion reactor damage in pure Ni. Microstructural evolution and associated changes in mechanical properties as a function of irradiation dose has been determined. Molecular Dynamics (MD) simulation studies have also been carried out to substantiate the results. Proton irradiation of alloy 800h samples have been carried out in the indigenously developed high temperature target station at 200, 250 and 300^{0}C.

On the photonics front, several research and development activities like, development of machine vision based automated metrology system for measurement of dimensions of PHWR fuel punches, development of GaAs and GaN based detectors, investigations on antiviral photodynamic therapy are carried out at RRCAT.

Cancer Research

The link between metabolic rewiring, stemness of cancer cells and chemo-resistance phenotype were explored by BARC to understand metabolism in different cancers, including Lung, Prostate, Thyroid, Liver, Leukemia and Breast.

Studies on identifying miRNA/s as potential early diagnostic markers for the diagnosis of pancreatic cancer were carried out. The RNA extracted from normal pancreatic and pancreatic cancer cell lines was identified for next-generation sequencing. The data is expected to provide potential clues about the specific miRNA expressed in pancreatic cancer cell line. The pancreatic cancer cell line will further be used to grow tumors in SCID mouse, and the miRNA would be screened at different stages of tumour development.

Studies were carried out with ^{68}Ga-PentixaFor as diagnostic and (^{64}Cu-ATSM) as potential therapeutic radiopharmaceutical for lympho-proliferative carcinoma and hypoxic lesions of cancer respectively, at Radiation Medicine Centre (RMC) of BARC. The ^{68}Ga and ^{64}Cu radio-labelled drugs formulations have undergone preclinical studies proving their potential for diagnosis and treatment of chemo-resistant lymphoma and hypoxia lesions in cancer, respectively.

Antibody based radiotherapy agents, including ^{177}Lu-Trastuzumab and ^{177}Lu-Pertuzumab were developed at RMC for targeting HER2 expressing and ER negative breast carcinomas. Pre-clinical evaluation of the developed Her2 targeting RPs was performed for in vitro and in vivo pharmacokinetics and dynamics indicating significant target specificity and stability.

Studies were pursued to evaluate the new Technetium-99m and ^{68}Ga labelled small peptides for prostate-specific membrane antigen and RGD peptides expressed on different cancers and its feasibility as a tumour-imaging agent in specific cancer, including prostate, lung, thyroid and gastrointestinal cancer. Preclinical evaluation of the developed RPs was performed for in vitro and in vivo pharmacokinetics and dynamics indicating significant target specificity and stability.

The research efforts at SINP were aimed at understanding structural basis of enzyme action of L-asparaginase. L-asparaginase is a chemotherapeutic drug approved for childhood leukemia.

International Research Collaborations

The Department continues to nurture its long standing collaboration with CERN through continued participation in ALICE and CMS experiments.

The scientist and scholars from DAE institutes takes part on regular basis in all these experiments. In addition, two of the DAE institute (TIFR and VECC) maintains remote computational resources and are part of Tier-II computational network of CERN.

The experimental high energy group of Institute of Physics (IOP) remained actively involved in the collider-based experiments at various international laboratories, such as CMS and ALICE experiments at CERN-LHC, STAR experiment at RHIC, BNL (USA), and the proposed CBM experiment at FAIR, GSI (Germany). The group played a leading role in the development of tau lepton reconstruction and identification techniques in the CMS experiment at CERN as well as in the development of algorithms for the reconstruction of hadrons.

The SINP-CMS group has made significant contributions in Higgs and BSM physics analyses using the 135 fb-1 of pp collision data collected by the CMS experiment during the Run II of the LHC. During the long shutdown period, the group made significant contributions in tracker operations, hadron calorimeter calibration, electron-photon identification, research and development of the upgraded tracker, muon and calorimeter endcap for future high luminosity runs.

At IPR, the major activities carried out during April-December 2022 for the LIGO project include two contracts and allied works namely Contract for procurement of integrated vacuum vessel with dimensions 1.24m ID X 20.6m Length, Contract for procurement of 80K Cryopump fabrication and Development of Vacuum Control & Monitoring system for outgassing measurement system.

A new funder-to-funder collaboration between DAE and Scientific & Technologies Facilities Council (STFC)-UK is in pipeline to streamline collaborative research between the 2 countries in the field of Radio Astronomy, Gravitational Waves, Advanced Accelerators, Bio-imaging etc.

ITER-Project

In the ITER mega-project, India's in-kind contributions have been running as per schedule, including the cryostat, cooling water system, in-wall shields and cryo-lines. An ITER-grade 170 GHz Gyrotron has been tested in IPR's newly set up Integrated Gyrotron test facility, up to 860 kW power for 260s; this facility uses indigenously built 55kV, 100A HV power supply & control system. The achieved performance of this facility is at par with similar gyrotron performance demonstrations in Japan and Europe.

Test Gyrotron at ITER-India lab, IPR

RESEARCH EDUCATION LINKAGES

The Department of Atomic Energy supports the research education linkages mainly through grants-in-aid to institutes of national eminence, funding of extra-mural research, DAE-UGC consortium for scientific research and others.

Under the Research Education Linkage category, 19 units of IPR's low-cost X-ray digitizer have been supplied to ICMR for AI4TB India program. IPR's AI

software DeepCXR, which lies at the heart of an ICMR-coordinated national programme, has now been trained on over 70,000 pre-diagnosed images supplied by 20 medical institutions across the country. The software has been yielding good accuracy and is targeted at deployment in areas where experts are not readily available.

AMD has signed fourteen (14) MoUs with Universities/Institutes for promotion of research during the periods.

HUMAN RESOURCE DEVELOPMENT AND KNOWLEDGE MANAGEMENT

Homi Bhabha National Institute

Homi Bhabha National Institute (HBNI), a Deemed to be University, is a grant-in-aid institute of DAE. It has successfully completed 17 years. During this period, it has established itself as one of the best research universities in the country, encouraging research in various facets of nuclear science and technology including mathematics. HBNI was placed in the 11th position in NIRF-2022, under the research institutions category, based on high-quality publications during the calendar year 2021, in 82 Journals of high impact, the Nature Index 2021 has placed HBNI in the second position, among all institutions in India and in the top position among all institutions with regard to publications in the discipline of physical sciences. During the period January to December 2022, HBNI awarded 67 MD degrees; 25 DM and 25 MCh degrees, contributing significantly to the number of specialists in medical oncology in the country. Till December 2022, HBNI has awarded 2208 PhD degrees in a variety of disciplines. HBNI has created an HBNI Industry Linkage Centre (HILC) which helps in the skill development of HBNI students and facilitates their internship in Industry. The cell also facilitated R&D collaboration between Industry and HBNI students/faculty with the aim of scaling up processes, commercializing or incubating new technologies, developing new processes/ products of interest to DAE, etc. During the year, HBNI organized several value addition courses for HBNI students across the eleven CIs/OCC, viz., Research Methodology, Research and Publication Ethics; An executive management programme for senior executives of DAE organizations in collaboration with IIM, Ahmedabad in May and September, 2022; Advanced Materials Chemistry, and French language for research scholars of IGCAR.

Training

The Human Resource Development Division of BARC continued to provide highly skilled human resources to DAE through two flagship programs – OCES (Orientation Course for Engineering graduates and Science Postgraduates) and DGFS (DAE Graduate Fellowship Scheme). The linkage of BARC Training School programmes with Homi Bhabha National Institute (a deemed to be university) ensured continuous availability of professionally qualified and well trained scientific and technical manpower for induction into various DAE units.

A total of 101 graduating TSOs (75 engineering, 10 physics, 07 chemistry, 03 biosciences, 06 Radiological Safety and Environmental Science (RSES)) have completed their training in 65th batch of BARC Training School and were placed in various units of DAE.

Eight Trainee Defence Officers (three in Mechanical stream, three in Electrical, and two in RSES), who passed out in this batch were assigned to different Divisions/ Units for undertaking project for pursuing M. Tech programme under the aegis of Homi Bhabha National Institute (HBNI).

A total of 85,588 candidates have applied for OCES/DGFS-2022 (66th batch) programme of BARC Training School. However, 2394 candidates have been screened in for selection interview. Finally, a total of 163 TSOs (104 Engineering, 25 Physics, 16 Chemistry, 18 Geology) out of 187 selected have finally joined various different BARC Training Schools across the country.

In the realm of Human Resources Development, twenty young trained scientists and engineers (OCES-2021, 16th Batch) have successfully completed their orientation programme at BARC

Training School at IGCAR and have been placed in various units of DAE. At present twenty nine trainee scientific officers (OCES-2022, 17th batch) are undergoing training. From the current batch (OCES-2022), Seventeen Trainee Scientific Officers from Engineering discipline have enrolled for their M.Tech Programme. Also, one hundred and thirty-six category-I & II trainees have successfully completed their training programme and have been placed as Scientific Assistants and Technicians in various groups of IGCAR. Recently, 44 Category-I Trainees have been inducted for the Category-I training programme. The programmes of Homi Bhabha National Institute (HBNI) continue to progress satisfactorily. During this period, 15 researchers have submitted their Ph.D. thesis and 11 have been awarded the degrees.

BARC Training School AMD Campus, Hyderabad continued its activity wherein 17 (Geology) Trainee Scientific Officers (TSO) of the 12th batch (OCES-2021) completed induction training on 31st October 2022 and 12 Officers of OCES-2019 batch (Geology:10 and Geophysics: 2) were awarded M.Tech degree by HBNI. In addition, induction training of 16 TSOs of Geology discipline of the 12th batch (OCES-2022) is in progress.

At, RRCAT 14 Trainee Scientific officers (TSOs) from the batch OCES-2021 have completed one-year orientation program and have been placed in RRCAT, BARC and VECC respectively. In the new batch (OCES-2022) 6 TSOs are undergoing the training course.

NPCIL has strong and dedicated workforce of 10727 employees as on December 31, 2022 consisting of Engineers, Technicians and Supervisors, Non-Technical Executives, Staff and Auxiliary support staff who spearhead the activities of the organization. All HR initiatives were directed towards fulfilling the NPCIL's mission and vision by attracting, motivating and retaining the right talent and intellect.

The Administrative Training Institute (ATI) of DAE continued witnessing new initiatives during the year 2022-2023. It contributed in the field of Training and Development by conducting 47 training programs covering a training population of 1272 with 3807man days till December 2022. Management Development Programmes (MDP) were conducted in coordination with institute of good repute.

SPONSORED RESEARCH

Promotion of Extra-mural Research in Nuclear Science

Board of Research in Nuclear Sciences (BRNS) as an extra-mural funding agency of DAE, continued to provide funding to Indian universities and national research institutes of the country for pursuing various research projects. Besides funding research projects, BRNS also continued to provide financial assistance to organize symposia/conferences/workshops on topics of relevance to the DAE programmes. BRNS lays emphasis on collaborative programmes between the DAE scientists and the scientific community outside the DAE fraternity.

During the calendar year 2022, 79 new research projects were sanctioned. Most of the projects have an implementation period of 2 to 3 years. A sum of ₹ 28.04 Crore has been disbursed for ongoing and new research projects, symposia, and Olympiad programme for training the Indian students contingent by Homi Bhabha Centre for Science Education (HBCSE). Financial support of ₹ 127 Lakh was extended for conducting 98 symposia and other events on topics of DAE relevance. Twenty, out of these 98 symposia, were fully funded symposia organised by the DAE institutes. Five patents were granted for the works originating from the BRNS research projects. Four ongoing MoUs were reviewed by the respective committees of BRNS.

Under the fast-track Covid-19 research project scheme, 9 ongoing projects with a budget of about ₹ 2.13 Crore were reviewed for closure by HLC Committee. These projects were completed successfully in the stipulated time frame with active collaboration from BARC. One Principal Investigator (PI) along with a Collaborator from BARC, has filed an Indian patent based on the outcome of the research project.

Towards a new Coordinated Research Project (CRP) Scheme, BRNS has completed the evaluation of 47 project proposals submitted by PI's from various academic institutes. Grants for 8 shortlisted sub-projects were released to the PI's institute.

One of the notable initiatives was the consolidation and closure review of all 29 BRNS-sanctioned research projects aimed at generating the baseline data on the concentration profile of Radon, Thoron, and their progeny in the environment and associated radiological dose to the public. These projects were distributed among 14 states and 1 Union Territory across India with a total budget of about ₹ 8 Crore. Another significant outcome was the development of various indigenous dosimeters and online monitoring systems for radon, thoron, and their progeny studies.

Promotion of Mathematics

The National Board of Higher Mathematics (NBHM) was set up by the Government of India under the Department of Atomic Energy (DAE), in the year 1983, to foster development of higher mathematics in the country, to formulate policies for development of mathematics, help in establishment and development of mathematical centres and give financial assistance to research projects and to doctoral and postdoctoral scholars.

Some of the schemes/activities of NBHM that were continued during the year includes Financial Support to Mathematical Institutions; Research Project Grant; Mathematical Olympiad/Madhava Mathematics Competition (MMC); Mathematical Training and Talent Search Programme (MTTS); Undergraduate / Postgraduate / PhD Scholarships, Post-Doc Fellowship; Indian Women in Mathematics (IWM) and Financial Support to Libraries & Book Distribution Schemes.

During the year DAE allocated ₹ 19.58 Crores for various NBHM schemes for the FY 2022-23. Allocation of funds to various activities was re-worked according to the proportion of actual expenditures in previous years to match the sanctioned amount of ₹ 19.58 Crores.

Olympiad Programme

The Asian Pacific Mathematics Olympiad (APMO) is a mathematical competition held annually for countries in the Pacific Rim Region. India secured 1 Gold, 2 Silver, 4 Bronze and 3 Honourable Mentions and ranked 6th among 35 countries of the Western Pacific and in Asia in APMO 2022.

INFORMATION TECHNOLOGY APPLICATION DEVELOPMENT

At RRCAT, deployment of various software packages for parallel scientific computing applications on Kshitij-5 High Performance Computing Cluster (HPCC) has been completed.

TECHNOLOGY TRANSFER

Department has inked 178 agreements with small-to-big industry partners for transfer of 87 technologies (on limited period non-exclusive right basis) besides renewing licenses for 14 technologies during the year.

The technologies transferred for commercial use were in the domain of agriculture & bioscience, post-harvest cold supply chain, radiation technology, advanced instrumentation, medical equipment, engineering, environment and water.

Additionally, 26 new technologies have been released into public domain during the year.

COLLABORATIVE PROGRAMMES

Department has signed an MoU with the governing body of National Mission for Clean Ganga for carrying out technology demonstration of waste water treatment using electron beam accelerator and associated pre-and -post irradiation solution for water laden with impurities from leather tanning industries. This technology was included for incubation activities.

SOCIETAL INITIATIVES

Through its Advanced Knowledge & RUral Technology Implementation (AKRUTI) program, DAE is propagating deployment of 17 spin-off technologies. During the year, 3 agreements were signed and 9 licences were granted for deployment of AKRUTI technologies in rural and semi-urban areas. The licensed technologies are Rapid composting technology for decomposition of Dry Leaves, Kitchen waste and Temple waste; Process for Long Lasting Ready-To-Eat Intermediate Moisture Fruit Cubes; Solar Dryer (25 kg capacity); Foldable Solar Dryer; Banana Tissue Culture; Nisargruna Biogas Plant based on biodegradable waste (one ton per day capacity); Soil Organic Carbon Detection & Testing Kit and Mass Multiplication Medium of Biofungicide Trichoderma spp.

At present, AKRUTI Center at BARC is operational. Four new AKRUTI Centres are coming up at various DAE locations viz., Heavy Water Plant Manuguru, BARC Vizag at Dibbapalem, Institute of Physics at Bhubaneshwar, and Special Material Facility at Chitradurga.

As part of its Corporate Social Responsibility (CSR) program, NPCIL is in the process of setting up AKRUTI Centres for demonstration and deployment of DAE technologies in the vicinity of its nuclear power plants.

Training offered under AKRUTI was organized for ~30 interested entrepreneurs from various parts of India.

INTELLECTUAL PROPERTY RIGHTS

DAE-IPR Cell constituted by the Department, works as a nodal agency for all Intellectual Property Rights (IPR) related matters including filing of patents within India and abroad for all the Units including Public Sector Undertakings and Autonomous Institutions under DAE. During the period, eighteen new patent proposals and three Patent Cooperation Treaty (PCT) international applications were reviewed for filing national phase applications. Eleven patent applications were filed during this period. This includes seven in India, one each in Australia, Europe, South Africa and USA. Among the patent applications that have been filed till date, nine patent applications were published during the year. These include five in India and two each in Europe and USA. Seventeen of the previously filed patents were granted to the Department. These include twelve in India, three in Europe and one each in Australia and China.

PUBLIC SECTOR UNDERTAKINGS

Financial performance of DAE's public sector undertakings namely, the Nuclear Power Corporation of India Ltd., Uranium Corporation of India Ltd., Indian Rare Earth Ltd. and Electronics Corporation of India Ltd. are given below.

NUCLEAR POWER CORPORATION OF INDIA LTD.

The provisional profit after tax (Total Comprehensive Income) up to end December 2022 in current FY 2022-23 is ₹ 3523 crore and the estimated profit for FY 2022-23 is around ₹ 4750 crore. The net profit after tax (Total Comprehensive Income) for previous FY 2021-22 was ₹ 6454 crore. NPCIL Bonds are rated 'AAA' (Highest Safety) by CRISIL, CARE, ICRA and India Rating.

URANIUM CORPORATION OF INDIA LTD.

The performance of all major units of the company during the year 2021-22 remained excellent. The total income of the Company during the year 2021-22 was ₹ 2614.72 Cr as against ₹ 2352.90 Cr during the previous year. The Company has registered a Profit before Tax of ₹ 777.48 Cr in the year 2021-22 as against ₹ 623.21 Cr in the previous year.

INDIAN RARE EARTHS LTD.

During the financial year 2021-22, the company

achieved sales turnover of ₹ 1480.00 crore as against ₹ 974.13 crore during previous year. The company achieved highest ever Profit Before Tax (PBT) of ₹ 746.68 crore registering growth of 80% as compared to corresponding previous year.

During the period April to December 2022, the company has achieved Sales Turnover of ₹ 1379.88 crore as against ₹ 1019.06 crore achieved during the corresponding period of previous year, registering growth of 35%. The Company achieved Profit Before Tax (PBT) of ₹ 761.47 crore during the period April to Dec, 2022 as against ₹ 451.12 crore during the corresponding period in previous year.

IREL paid dividend amounting to ₹ 166.67 crore for the financial year 2021-22. Based on the half yearly performance during the financial year 2023-23, IREL has paid interim dividend (first installment) of ₹ 118 crore on 22.12.2022.

ELECTRONICS CORPORATION OF INDIA LTD.

During the financial year 2021-22, ECIL recorded a turnover of ₹ 1610 crores as compared to ₹ 1504 crores in the previous FY. Revenue from Operations has increased by 7.05% and the corresponding Profit Before Tax (PBT) and Profit After Tax (PAT) have increased by 97.37% and 102.75% respectively in comparison to the previous financial year. Increase in contribution margin and service revenue resulted in higher profitability during the year. During the year, Nuclear vertical has contributed 17%, Defence vertical 34%, Aerospace vertical 10%, Homeland Security Solutions 9% and IT &e-Governance and others 30% of the company's revenue. In terms of the MoU signed with DAE in accordance with DPE guidelines, the company has been rated 'Very Good' for the FY 21-22.

The order book position of ECIL as on 01 April 2022 is ₹ 4016 crores. The bulk executable orders comprise of Electronic Voting Machines and VVPATs, Military Radios, electronic Fuzes, Ground based systems for Akash Missiles, ECM Jammers, SATCOM Terminals, Antenna Systems, Ultra Stable High Voltage Power Supplies, Integrated Security Systems, Advanced Radiation Detectors and Monitoring systems. Towards meeting the time bound delivery of the EVM and VVPAT, ECIL has augmented the manufacturing infrastructure. Further, Under the guidance of Technical Expert Committee (TEC) constituted by Election Commission of India (ECI), ECIL has developed and deployed the Secure Manufacturing Facility (SMF 2.0).

DPE has set a target of ₹ 2700 crores for the year Financial Year 2022-23. Against the set target, ECIL has achieved an Income of ₹ 1092.06 crores till end December 2022.

OTHER ACTIVITIES

CRISIS MANAGEMENT

The Crisis Management Group (CMG) was created in the Department in 1988 based on the first 'Crisis Management Plan' issued by Cabinet Secretariat, Government of India (GoI) in 1987. The Plan identifies DAE as the nodal ministry/department to deal with any radiation emergency in the country. The CMG of the Department better known as CMG-DAE, draws senior officials from various units of DAE and AERB for overseeing the Department's emergency preparedness for responding to any radiation emergency in the public domain and coordinating response actions with state or national level public officials / agencies. CMG-DAE continued to function as the contact point of DAE to provide its expertise in the field of nuclear / radiological emergency management at various National and International fora. During the year 2022-23, up to December 2022, India participated in two International Convention Exercises, known as “ConvEx”, conducted by IAEA, which are designed to test various aspects of the international Emergency Preparedness and Response (EPR) framework. As the Competent Authority, CMG-DAE coordinated India's active and satisfactory participation in these exercises. To ensure that the emergency plans are in high state of readiness, major nuclear facilities like nuclear power stations and heavy water plants periodically carried out variety of emergency exercises. During the stated period, CMG-DAE participated in off-site emergency exercises

conducted in 'Integrated Command Control and Response (ICCR)' mode at Kakrapar and Rawatbhata NPP sites. The exercises were found to be effective and satisfactory.

INTERNATIONAL RELATIONS

India, a founding member of the Board of Governors (BoG) of the International Atomic Energy Agency (IAEA), continued to take active part in policy management and programmes of the IAEA. India was represented on a number of IAEA Committees, including those on safety, safeguards, nuclear radiation, nuclear engineering and application, nuclear law etc. India hosted several IAEA Workshops, Technical Meetings etc., and offered the services of its experts under the IAEA Technical Cooperation programme in a number of fields. India made contributions towards Innovative Nuclear Reactors and Fuel Cycles (INPRO), Technical Cooperation Fund (TCF) and Regular Budget of the IAEA.

Considering the primacy of the IAEA General Conference in India's international engagement in the field of Civil Nuclear Energy, Chairman, AEC and Secretary, DAE led the Indian delegation comprising senior officials of DAE and Indian Mission at Austria to the IAEA 66th GC conference from 26-30 September, 2020.

On the sidelines of the 66th General Conference, Chairman, AEC had bilateral meetings with DG, IAEA and delegations from USA, U.K., Russia, EU, Japan, Argentina, Kazakhstan, INVAP Argentina, Uzbekistan, Canada and Bangladesh. Apart from the above, bilateral meetings were conducted with delegations from France, Canada and Argentina.

Memorandum of Understanding between Atomic Energy Regulatory Board (AERB), of the Republic of India and State Committee on Industrial Safety (SCIS) of the Republic of Uzbekistan was also signed.

DAE represented India at RCA (Regional Cooperative Agreement) meet of IAEA to commemorate its 50 years in which India is founding member.

The MoU between Department of Atomic Energy of Government of India and Department for Business Energy and Industrial Strategy (BEIS) of the Government of the United Kingdom of Great Britain and Northern Ireland concerning Cooperation with India's Global Centre for Nuclear Energy Partnership (GCNEP) was signed on 18.04.2022.

VIGILANCE

The overall responsibility for vigilance in any unit of the Department of Atomic Energy (DAE) rests with Chief Vigilance Officer (CVO). To ensure effective functioning of the vigilance machinery, a senior level officer in each of the Constituent Units and Aided Institutions of the Department has been designated as Alternate Vigilance Officer/ Chief Vigilance Officer. In the case of Public Sector Undertakings of the Department, full-time Chief Vigilance Officer discharges these responsibilities. As per the directives of CVC, “Vigilance Awareness Week 2022" was observed in DAE and its constituent Units/PSUs/Aided Institutions from 31st October, 2022 to 6th November, 2022 on the theme of "Corruption free India for a developed nation”- भ्रष्टाचार मुक्त भारत-विकसित भारत। Various competitions such as quiz, poster, elocution, songs etc. were conducted. Vigilance Awareness Week was also observed in the Constituent Units, Public Sector Undertakings and Aided Institutions of DAE.

RIGHT TO INFORMATION ACT (RTI) COMPLIANCE

The Right to Information Act of Government of India which came into force on 12th October 2005 has been implemented at DAE and all its constituent units. The provisions contained in RTI Act, 2005 were fully complied by DAE and its constituent units. The RTI applications and appeals received at DAE and its constituent units were promptly attended.

SCIENTIFIC INFORMATION RESOURCE MANAGEMENT

A digital system named Home Office Anywhere

(HOoA) facility, which provides remote access to important information resources of BARC, is being maintained at BARC. The total collection of books of all kinds and across all formats in BARC Central Library stands at over 190,000. Digitization of printed copies of proceedings of conferences sponsored by Board of Research in Nuclear Sciences (BRNS) was in full swing in BARC Central Library. All important documents of BARC have been printed and published in-house in a time-bound manner despite facing severe resource crunch. Five issues of newsletter on important and interesting themes, with articles mostly on research and development work in BARC were published. These include Waste Management and Reprocessing, Beam Technologies, Astrophysics, and Materials for Sustainable Energy. BARC published a special publication in Hindi (Vishisht Sankalan-1), comprising interesting articles on advancements in nuclear reactor technologies in India. The special issue was released officially during a function in BARC to mark the World Hindi Day 2023. Internal, external and restricted reports on specific scientific and technology outcomes of BARC were prepared and published. BARC Hospital magazine Pulse with articles on hospital management practices and clinical procedures was published. New short-term courses in French and Russian were conducted during the year for the benefit of BARC scientific community. BARC subscribed to 389 journals in electronic form and 53 print-based journals besides several popular magazines. It is working proactively for the implementation of One Nation One Subscription (ONOS) initiative floated by the Government of India for enhancing the accessibility of wide spectrum of journals.

PUBLIC AWARENESS

The Department of Atomic Energy (DAE) carried out a gamut of Public Awareness programmes in order to alleviate unwarranted fears, misconceptions and apprehensions harboured against nuclear energy. To keep the public abreast of the latest developments and contributions of atomic energy towards societal welfare, DAE organized a spectrum of events comprising exhibitions, seminars, workshops, essay and quiz contests in different parts of the country which were well received by the targeted audience.

Few major public awareness events in which DAE and its units participated are mentioned below:

DAE participated in the National Panchayat Raj Day- 2022 held at Palli Village, Samba district, Jammu & Kashmir during April 24-26, 2022. Vigyan Prasar, an autonomous institute under Department of Science and Technology organized and coordinated the event. DAE had put up an exhibition on various technologies at the event. It was witnessed by a large number of gathering.

DAE organized Journalists' Workshops (2 nos.) along with the National Union of Journalists (NUJ) at IGCAR, Kalpakkam during May 4-7, 2022 and at Hyderabad during July 20-23, 2022. The objective of this workshop was to reach out to the general public through articles, news coverage, magazine articles and press releases by reputed Journalists. An exhibition on DAE technologies was also put up for the benefit of Journalists.

NUJ journalists being briefed about DAE technologies at the DAE-NUJ workshop held at Kalpakkam during May 4-7, 2022

"Rise in Uttaakhand" an exhibition was organised at Dehradun during July 7-9, 2022. The event was organized to showcase the schemes, Policies & Initiatives undertaken by the Government in the field of Nuclear Power Technology, Applications of Radiations & Skill Development training programmes for the youth and general masses etc. DAE exhibition was visited in a big way by students of schools and engineering colleges across the state. The Chief Minister of

Uttarakhand Shri Pushkar Singh Dhami and senior cabinet ministers of the state government also visited the pavilion.

DAE organised the "34th DAE Online All India Essay Contest" for undergraduate students on topics related to "Nuclear Science & Technology. Thirty participants were selected for giving oral presentation at DAE headquarters and also, visited DAE units such as BARC, BRIT, TMC to get first hand experience about DAE activities and facilities through interaction with scientist working on this facilities. The winners were awarded with prize money and certificates on the

Winners of the 34th DAE All India Essay Contest

Founder's Day celebration at BARC.

During the year, DAE released 3 books, two illustrated picture books, one on "Dr. Vikram Sarabhai" & another on Sir C. V. Raman and a book on "The Story of Uranium in India" written by Dr. R.K. Garg and Dr. D.S. Shukla. Copies were given to AEES so that they get inspired by the life and achievements of DAE scientists.

DAE participated in the "State S&T Ministers' Conclave" at Science City, Ahmedabad during 10 – 13 September, 2022. The conclave deliberated on some of the key issues like Centre and States co-ordination to address key challenges and gap areas, strengthen the ecosystem in the States by promoting R&D, innovation and entrepreneurship, assist States in formulating State S&T policies apart from various other issues of mutual concerns. The S&T Ministers, Chief Secretaries, Secretaries in charge of the S&T from all the State and UTs, Member Science, NITI Aayog, PSA to the GoI, Secretaries of the Science Departments, Senior officials from GoI, selected Industry leaders, Key officials from all the States etc. participated in the event.

DAE pavilion at the State S&T Ministers' Conclave organised at Science City, Ahmedabad during 10 – 13 September, 2022

The "Shining Maharashtra 2022" exhibition was organised from 22-24th December 2022 at Akluj, Maharashtra with focus on spreading knowledge and awareness among visitors, particularly students and scholars about nuclear energy. DAE had put up an exhibition which was visited by large number of students, teachers and the general.

The 108th Indian Science Congress (ISC) was held during January 03-07, 2023 at Rashtrasant Tukadoji Maharaj Nagpur University Campus, Nagpur. It was inaugurated by the Hon'ble Prime Minister of India, Shri Narendra Modi. The focal theme of ISC was "Science & Technology for Sustainable Development with Women Empowerment. DAE participated in this mega event along with its units and had setup a grand exhibition on DAE Technologies. A large number of

Principal Scientific Adviser to Prime Minister Dr. A. K. Sood being briefed about DAE activities at the DAE pavilion during the 108th Indian Science Congress

students and general public visited the exhibition.

Students of Gujarat along with their teachers visited BARC (June 17-18, '22) during which they interacted with BARC community extensively. As part of an exclusive outreach program, senior officials of BARC visited prominent colleges in the vicinity of Kolkata during April 26-30. BARC participated in a Mega Exhibition in Dehradun (July 7-9), promoted by the Government of Uttarakhand. BARC participated in the 2022 edition of annual Rajbhasha Divas Samaroh (Hindi Day) held during September 13-14 in Surat, Gujarat. At the 2023 edition of Indian Science Congress in Nagpur, BARC has set up a technology exhibition, which was visited by wide set of audience, including students, teachers, industry players, academia, senior delegates among others.

DAE has planned, organized and conducted the newly launched Parmanu Jyoti program in which more than 80 young scientists of BARC were deputed to visit pan-India Jawahar Navodaya Vidyalayas (JNVs) in two phases during the year. More than 5000 students from 100 plus schools from 34 states participated in the program.

Few glimpses of BARC scientists interacting with the students of pan-India Jawahar Navodaya Vidyalayas in 2022 as part of Parmanu Jyoti Program

Under public outreach activities in addition to the several programs to celebrate Azadi Ka amrit Mahotsav, a unique museum to arouse interest among the students in science, technology and applications of light has been established in the heritage building of 'Sukhniwas Palace' in the RRCAT campus.

The cumulative outreach activity of NPCIL in the year 2022-23 up to December, 2022 has reached to around 52,13,600 people. NPCIL has always reached out to the masses by following a multi-pronged approach. NPCIL prepared its social media framework and guidelines and launched Social Media pages on Facebook & Instagram besides a channel on YouTube on December 30th, 2022 for wider reach. Through Web based public awareness, Webinars / online / offline lectures, Halls of nuclear power, Miniature nuclear galleries, Nuclear power plant models, Participation in exhibition and seminars, Site visits, Public awareness campaign by means of distribution of printed material and through Films & Multimedia, NPCIL continued its public awareness activities and reached out to masses across India.

DAE Iconic Week, as part of Azadi Ka Amrit Mahotsav (AKAM) was celebrated during August 22-28, 2022 to commemorate the activities and achievements of Department. All the units of DAE including PSU's and aided institutions organised various activities and programmes and made DAE's iconic week celebrations

Smt. and Shri K. N. Vyas, Chairman, AEC & Secretary, DAE; Dr. A. K. Mohanty, Director, BARC; Smt. and Shri B. C. Pathak, CMD, NPCIL; and Smt. and Shri B. K. Jain, Director, DCSEM accompanied by the senior officials of the DAE family pedal alongside the cyclists to the Gateway of India.

a grand success.

Senior scientists of Bhabha Atomic Research Centre (BARC) participated in the "Chain Reaction" Cyclothon and they cycled for 1700 km starting from India Gate in Delhi on August 13, 2022. The purpose of the campaign was to spread awareness about nuclear energy as clean, green and safe energy resource. The Cyclothon crisscrossed five states – Delhi, Rajasthan, Madhya Pradesh, Gujarat and Maharashtra and concluded at the iconic Gateway of India on August 23, 2022.

SOCIAL WELFARE

Corporate Social Responsibility

NPCIL is committed to economic and social development of the local communities around all its Sites. CSR programme is implemented at the 14 Sites of NPCIL, where either the operating stations or the projects are located. These Sites are located mostly in rural and under developed areas. The area within 16 Km radius from these sites is designated as Local Area for implementation of CSR programme. During the FY 2022- 23, the Company allocated an amount of ₹ 130.55 Crore for implementation of CSR programme. NPCIL has spent more amount on CSR programme than that was mandated by Companies Act during that year.

The CSR Policy of NPCIL is available at the company website i.e. www.npcil.nic.in. The effective and expeditious implementation of CSR program is monitored and facilitated at various levels in NPCIL including the Board Sub Committee (BSC) for CSR and Sustainability.

The CSR projects have been taken up in line with Schedule VII of Companies Act, 2013 which falls in the areas of education, healthcare, infrastructure development, skill development, sustainable development.

Swachha Bharat Mission

Swachhta Pakhwada was introduced in all Central Government Ministries & Departments on the directives of the Hon'ble Prime Minister as a part of the Swachh Bharat Mission. Swachta Pakhwada was observed in DAE Headquarters from 16th - 28th February, 2023 on the occasion of World Science Day on 28th February, 2022. Various competitions such as Swachch Section Competition, Quiz Contest, Essay Contest, Poster Contest, Slogan Contest etc. were organised. The staff members of DAE participated whole heartedly in all these contests. The results of these contests were announced on 28th February, 2023. Prizes were distributed to the winners of the various contests, felicitation of the employees of the department who were selected for their contribution in cleanliness were also done.

As part of Swachhata, DPS disposed of about 1973 MT of scrap generating a revenue of ₹ 10.13 Crore.

EMPLOYEES' WELFARE

The Contributory Health Service Scheme (CHSS), introduced in the Department in the year 1962 continued to provide the specialised and personalised health care to its employees and the members of their families even after retirement (against one-time subscription).

The Atomic Energy Education Society (AEES), an autonomous institution of DAE, continued to provide quality education to the children of the employees of the DAE units working at different centres/establishments across the country in an environment in which every student discovers and realizes his/her full potential. AEES also provided education to the economically backward children from the rural/tribal areas around its establishments through its Societal Enrichment and Education Programme (SEEP).

AWARDS & PRIZES

Several awards in areas of Safety Performance, Public Awareness and Official Language (OL) were bagged by various units of NPCIL and Headquarters.

TAPS-1&2 received the National Safety Council India (NSCI) Safety Award (Prashansa Patra) for the assessment period of three years 2018-2020.

TAPS-3&4 was conferred with Lowest Average

Awards received by TAPS-3&4 from NSCI

Accident Frequency Rate for the year 2019 and Longest Accident Free Period for the year 2019 and 2020 by National Safety Council India (NSCI) - Maharashtra Chapter. It received 'Golden Peacock Occupational Health & Safety Award' for the year 2022 on August 25, 2022 and it also received the Certificate of appreciation from National Safety Council awards for the Year 2021.

MAPS-1&2 received Certificate of appreciation from National Safety Council awards for the Year 2021.

NPCIL Bagged Second prize shield awarded in PSU category to Tarapur Maharashtra Site (TMS) at district level by TOLIC (Town Official Language Implementation Committee), Thane for best implementation of official language Hindi in a programme organised on August 29, 2022.

TAPS received second prize shield from TOLIC, Thane

NPCIL was adjudged with Third prize in the category of Best Public Awareness Program by the Public Relations Society of India at the Public Relations Conference on Aatma Nirbhar Bharat: Role of Public Relations held at Bhopal during December 25 - 27, 2022.

ECIL was awarded IEI Industry Excellence Award 2021 for demonstrating a high order of business excellence Telangana Water Conservation Award 2021 was given to ECIL in recognition of significant contributions made by ECIL towards Water Conservation.

"9th Greentech CSR Award 2022" for "Outstanding Achievements in Promotion of Healthcare" and "Greentech Export Award 2022" for "Outstanding Achievements as Manufacturer Exporter" was given to IREL.

“Outstanding Business Leadership Award 2022” was awarded to CMD, IREL by International Achievers Conference.

CHAPTER 1

Tube Grinding cum Polishing machine
8-20mm – Received at NFC, Kota

NUCLEAR POWER PROGRAMME STAGE-I

Site View of Rajasthan Atomic Power Project RAPP-7&8

PRESSURISED HEAVY WATER REACTORS (PHWRs) & LIGHT WATER REACTORS (LWRs)

Nuclear Power Corporation of India Limited (NPCIL), formed in 1987, is a Public Sector Enterprise under the administrative control of Department of Atomic Energy (DAE). NPCIL is a dividend paying company with highest credit rating of 'AAA' (Highest Safety) by CRISIL, CARE, ICRA and India Rating. NPCIL is responsible for obtaining siting consent, design, construction, quality assurance, commissioning, operation and upgradation of nuclear power reactors. Safety is given overriding priority in all facets of nuclear power reactors. At present, NPCIL operates 22 nuclear power reactors with an installed capacity of 6780 MWe. Currently NPCIL is constructing eight Reactors (6800 MWe) comprising of Kakrapar Atomic Power Project (KAPP) Unit-3&4 (2x700 MWe, PHWRs), Rajasthan Atomic Power Project (RAPP) Unit-7&8(2x700 MWe, PHWRs), Kudankulam Nuclear Power Project (KKNPP) Unit-3&4 (2 x 1000 MWe, LWRs) and KKNPP Unit-5&6 (2 x 1000 MWe, LWRs) which are under various stages of construction. Out of these project units, KAPP Unit-3, which is first unit of indigenously designed 700 MWe PHWR with state of-the-art technology and incorporating enhanced safety features, was synchronized with the Grid for the first time in 2021. The unit has operated at 50% Full Power for collecting further commissioning feedbacks for improvement. Preparatory activities for further power raise with progressive clearances from AERB are in progress. In addition, construction of various buildings is in progress at GHAVP-1&2 and casting of all foundation piles has been completed in both the Nuclear Building (NB) areas. Activities towards obtaining regulatory clearance for casting of nuclear building raft are in advanced stage. Further, various project activities are in different stages and are being accelerated towards commencement of construction of Ten 700 MWe PHWRs (10 x 700 MWe) in fleet mode which are having administrative approval and financial sanction from GoI. Fleet mode ground activity commenced with 'Ground Break' of Kaiga Project Unit-5&6 on April 28, 2022 after obtaining AERB clearance. Excavation works at this project are in progress. In respect of remaining reactors of Ten 700 MWe PHWRs in fleet mode, various pre-project activities such as land acquisition and R&R, Environmental clearance, procurement activities of long delivery equipment, studies for regulatory clearances, site infrastructure development, public outreach, tendering for various contracts/ packages are in various stages of progress towards launching of these projects. Further, in respect of new sites at Jaitapur in Maharashtra (Land Acquisition and Environment Clearance are completed) and Kovvada in Andhra Pradesh, various Pre-project activities related to land acquisition, R&R, environmental studies, Site Studies, Site infrastructure development, regulatory clearances, public outreach etc. and various techno commercial discussions for setting up large sized imported light water reactors (LWRs) based on international co-operation are in progress. In respect of Bhimpur site in Madhya Pradesh, commitment for water is to be confirmed by State Government. In respect of Mithi Virdi site in Gujarat, land acquisition process is to be re-initiated as per new land acquisition Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement (RFCTLARR) Act 2013. In respect of Haripur site in West Bengal, land acquisition is contingent to initiative by State Government. Alternate site is also under consideration by GoI. NPCIL, in all its endeavours, is committed towards up-gradation and continuous improvements in Quality Management Systems which includes; Quality Assurance (QA), Quality Surveillance, Pre-Service Inspection/In-Service Inspection and Software Quality Assurance (SQA) activities.

Operating Performance

At present, NPCIL operates 22 nuclear power reactors with an installed capacity of 6780 MWe. Out of 22 operating reactors, fourteen reactors with total installed capacity of 4380 MWe, are under IAEA safeguards.

Generation

During the Calendar Year (CY) 2022, NPCIL registered highest ever commercial power generation of 46195 Million Units (Mus). In addition, KAPP Unit-3

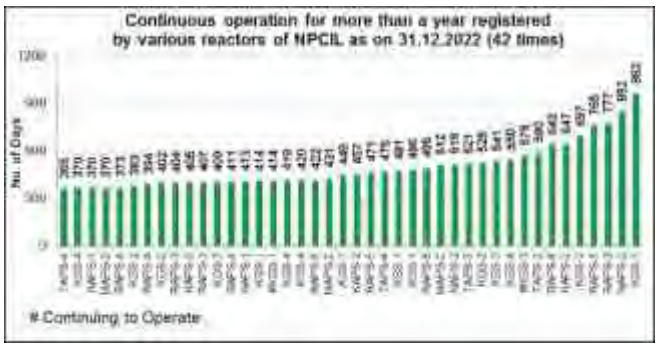
generated 937 MUs of infirm power (non-commercial generation) during CY 2022. In the previous CY 2021, the total commercial power generation was 43918 MUs. In addition, KAPP Unit-3 has generated 404 MUs of infirm power during CY 2021.

During the period April - December 2022 in the Financial Year (FY) 2022-23, NPCIL has registered total commercial power generation of 33920 MUs and, in addition, infirm power (non-commercial generation) generation from KAPP Unit-3 is 937 MUs. The expected total commercial generation for the FY 2022-23 is about 45600 MUs. In the previous FY 2021-22, the total commercial power generation was 47112 MUs and, in addition, infirm power generation from KAPP Unit-3 was 139 Mus.

During the FY 2022-23, the overall Availability Factor (AF) and Plant Load Factor (PLF) till December 31, 2022 for the reactors in commercial operation were 84% and 85% respectively. Both these figures for last FY 2021-22 were 88%.

Continuous Operation for more than a year

During the FY 2022-23, Tarapur Atomic Power Station (TAPS) Unit-4, Kaiga Generating Station (KGS) Unit-3, Rajasthan Atomic Power Station (RAPS) Unit-3, KGS Unit-4 and KGS Unit-1 achieved continuous, safe and reliable operation for more than a year. TAPS Unit-4 registered 475 days of continuous, safe and reliable operation till its shutdown on July 11, 2022.RAPS Unit-3 registered 407 days of continuous, safe and reliable operation on October 27, 2022 after which the unit was manually shut down for planned maintenance works. KGS Unit-4 registered 420 days of continuous, safe and reliable operation on November 23, 2022 after which the unit was manually shut down for Biennial Shutdown works. KGS Unit-3 (544 days) and KGS Unit-1 (383 days) continued operating for more than a year as on December 31, 2022. So far, the continuous, safe and reliable operation for more than a year has been achieved 42 times by various reactors operated by NPCIL. Out of these, four reactors KGS Unit-1 (962 days), Narora Atomic Power Station (NAPS) Unit-2 (852 days), RAPS Unit-3 (777 days) and RAPS Unit-5 (765 days) have operated continuously for more than two years. The continuous, safe and reliable operation for 962 days registered by KGS Unit-1 is second longest continuous operation in world among all reactor technologies.



Reactor Years of operation

Nuclear power reactors in operation registered cumulative 583 reactor years of safe operation as on December 31, 2022.

Operating Units taken in Project mode

Madras Atomic Power Station (MAPS) Unit-1 (220 MWe PHWR), Tarapur Atomic Power Station (TAPS) Unit-1 & Unit-2 (2 x 160MWe BWRs) and Rajasthan Atomic Power Station (RAPS) Unit-3 (220 MWe PHWR) are under long shutdown and have been taken in project mode for aging management and safety upgrades. MAPS Unit-1 has been taken in project mode since April 1, 2018. TAPS Unit-1 & Unit-2 (2x160MWe) have been taken in project mode since April 1, 2020 and August 1, 2020 respectively. RAPS Unit-3 (200 MWe PHWR) has been taken in project mode since October 28, 2022 for En-masse Coolant Channel Replacement (EMCCR) and En-masse Feeder Replacement (EMFR) works.

Projects under Construction

Currently NPCIL is constructing eight Reactors (6800 MWe) comprising of KAPP Unit-3&4 (2 x 700 MWe, PHWRs), RAPP Unit-7&8(2 x 700 MW, PHWRs), KKNPP Unit-3&4 (2 x 1000 MWe, LWRs) and KKNPP Unit-5&6 (2 x 1000 MWe, LWRs), which are under various stages of construction.

Kakrapar Atomic Power Project (KAPP)-3&4 (2x700 MW PHWRs)

These units are the first pair of indigenously designed 700 MW Pressurized Heavy Water Reactors. First unit i.e. KAPP-3, with state –of-the-art technology and incorporating enhanced safety features, was successfully synchronized with Grid for the first time on 10.01.2021. After carrying out required modifications/ improvements based on commissioning feedback, permission from AERB has been received and the unit was synchronized with grid on 20.07.2022. The unit has operated at 50% Full Power for collecting further commissioning feedback for improvement. The unit has generated cumulative about 1340 Million Units (MUs) as on December 31, 2022.In KAPP-4, a major milestone "Hydro test of Primary Heat Transport (PHT) system" has been completed. This will be followed by major critical activities i.e. Hot Conditioning, Fuel loading,

Main Plant Construction area view – KAPP-3&4

approach to first criticality, first synchronisation with the grid and finally commencement of commercial operation, all with progressive clearances from AERB. Towards these, balance activities are in progress. Various improvements based on the feedbacks from KAPP-3 commissioning challenges are also being incorporated. Preparatory works for Integrated Leak Rate Test (ILRT) of Reactor Building are in progress. Final box-up of all High Pressure & Low Pressure Turbines is completed. Concreting of Calandria Vault opening is completed. Emergency Core Cooling System (ECCS) integrated test is successfully completed. The physical progress of KAPP-4 was about 94.30% and the overall physical progress of KAPP-3&4 is 97.15% as on December 31, 2022.

Rajasthan Atomic Power Project (RAPP)-7&8 (2x700 MW PHWRs)

These units are the second pair of indigenously designed 700 MW Pressurized Heavy Water Reactors.

Site View of RAPP-7&8

In Unit-7, erection of equipment and piping is in progress. A major milestone "Reactor Building Proof Test and Integrated Leak Rate Test (ILRT)" is completed. Construction of Induced Draft Cooling Towers (IDCTs) and Natural Draft Cooling Towers (NDCTs) are in progress. Calandria Integrity/Proof test along with Helium leak test is completed. This will be followed by major critical activities viz. Hot Conditioning of PHT system, fuel loading, approach to first criticality, first synchronisation with the grid and finally commencement of commercial operation, all with progressive clearances from AERB. The physical progress of the unit was about 95.54% as on December 31, 2022.

In Unit-8, civil construction and erection of equipment & components are in progress. Complete coolant channels are installed and Concreting of Outer Containment (OC) dome is completed. Erection of all doors and bellows of Auxiliary Air Lock (AAL) is completed. Feeder erection work is in progress. The physical progress of the unit was about 81.70% as on December 31, 2022.

Kudankulam Nuclear Power Project (KKNPP)-3&4 (2x1000 MW LWRs)

Kudankulam Nuclear Power Project Unit - 3&4

located at Kudankulam in Tirunelveli district of Tamil Nadu, where two units of 1,000 MW (KKNPP Units-1&2) already operating, is under implementation in co-operation with Russian Organizations within the framework of the Inter-Governmental Agreement (IGA) signed between the Governments of Russian Federation (RF) & Republic of India in December 2008 and General Framework Agreement (GFA) signed in April 2014 between Joint Stock Company Atom story export (ASE) and Nuclear Power Corporation of India Limited (NPCIL). Manufacturing and progressive delivery of various equipment and components are in progress. In Unit-3, civil construction and equipment erection works are in progress. Construction of various buildings including Reactor Building (RB), Reactor Auxiliary Building (RAB), Turbine Building (TB), Tunnels, Common service Buildings, Switchyard Buildings and Hydro- technical structures (HTS), etc. is in progress.

In KKNPP-3, Inner Containment dome supporting structure (weighing about 310 Metric Ton) was successfully pre-fabricated, lifted and placed in position as a single assembly in Reactor Building, erection of Nuclear Steam Supply System (NSSS) equipment [Reactor Pressure Vessel (RPV), Steam Generator (SG), Reactor Coolant Pump (RCP) and Pressurizer (PRZ)] is completed and a major milestone of "Commencement of Welding of Main Coolant Piping" is achieved and welding work is in progress. Rebar works for concreting of Inner Containment Dome is in progress.

View of IC Dome Liner erection in Reactor Building-3

In Unit-4, Concreting of walls up to +30.7 meter elevation is in progress in Accident Localization Area (ALA) of RB-4. The physical progress of KKNPP Unit-3 and KKNPP Unit-4 were about 66.02% and 62.39% respectively as on December 31, 2022. However, some of the issues related to availability of quarries in Tamil Nadu for construction materials as well as Russian supplies due to ongoing geopolitical conflicts, are having some impact on project implementation schedule.

Kudankulam Nuclear Power Project (KKNPP)-5&6 (2x1000 MW LWRs)

Kudankulam Nuclear Power Project Units -5&6 are under implementation at Kudankulam in Tirunelveli district of Tamil Nadu in pursuance of Inter-Governmental Agreement (IGA) of December 2008 signed between the Governments of Russian Federation (RF) & Republic of India and General Framework Agreement (GFA) of June 2017 signed between Joint Stock Company Atomstroyexport (ASE) and Nuclear Power Corporation of India Limited (NPCIL).

Construction works are in progress. In Unit-5, Concreting of Foundation Slab of Reactor Building, Turbine Building and Reactor Auxiliary Building are completed. Construction of walls above elevation (El) +5.4meter (M) slab is in progress in RB. Construction of walls above raft is in progress in Reactor Auxiliary Building (RAB) and Turbine Building (TB). In Unit-6, construction of raft of about 11,050 cubic meter in single pour was achieved in Turbine building. The physical progress of KKNPP Unit-5 and KKNPP Unit-6 were about 16.27% and 11.43% respectively as on December 31, 2022.

Development of Working Documentation (WD) is in progress. Manufacture of Long Manufacturing Cycle Equipment; Reactor pressure vessel and Internals, Steam generator, Condenser, Turbo generator etc. are in progress.

However, some of the issues related to availability of quarries in Tamil Nadu for construction materials as well as Russian supplies due to ongoing

geopolitical conflicts, are having some impact on project implementation schedule.

Projects Under Launch

Gorakhpur Harayana Anu Vidyut Pariyojana (GHAVP) Units-1&2 (2x700 MW PHWRs)

Land is available. MoEFCC clearance for plant site, siting consent from AERB and consent to establish from Haryana State Pollution Control Board exist. Consent for First Pour of Concrete (FPC) has been granted by AERB. Casting of all foundation piles including various tests has been completed in both the Nuclear Building (NB) areas and activities towards obtaining regulatory clearance for casting of nuclear building raft are in progress. Construction of Switch Yard Control Building, D_2O Upgradation Plant, Fire and Industrial Safety House, Fire Water Pump House etc is in progress. Manufacturing and supply of various equipment and components are in progress. Two End Shields and four Steam Generators have been received at site and are under suitable preservation. Design activities are in progress in respect of Turbine Island Packages and IDCTs, etc.

Main plant area of GHAVP-1&2

Ten 700 MW PHWRs in Fleet Mode

The Government of India has accorded administrative approval and financial sanction for taking up construction of 10 indigenous 700MW PHWRs in Fleet Mode. These reactors are being set up at Kaiga in Karnataka (Kaiga-5&6), Gorakhpur in Haryana (GHAVP-3&4), Chutka in Madhya Pradesh (Chutka-1&2) and Mahi Banswara in Rajasthan (Mahi Banswara-1 to 4).

Kaiga Unit-5&6

Fleet mode ground work commenced with 'Ground Break' of Kaiga-5&6 project on 28th April, 2022 after obtaining AERB clearance and excavation works are in progress.EPC package for Turbine Island has been awarded.

Excavation works of Kaiga-5&6

GHAVP Unit-3&4

Land is available. MoEFCC Clearance is available. Siting consent from AERB is received. EPC package for Turbine Island has been awarded. Geo-Technical Investigations, field and laboratory tests, determination of foundation parameters etc, for GHAVP-3&4 is completed. Various testings are completed and report review and finalisation is under progress.

Mahi Banswara Rajasthan Atomic Power Project (MBRAPP) Unit-1 to 4

Land acquisition is in process. MoEFCC Clearance is under process. Construction of R&R

View of Mahi Banswara Plant Boundary Wall

colony is in progress. Erection of plant boundary wall is in progress. Proceedings for implementation of the project by NPCIL-NTPC JV Company are in progress.

Chutka Madhya Pradesh Atomic Power Project (CMPAPP)-1&2

Land Possession letter has been issued for all types of land. MoEFCC Clearance is available. Stage-II Forest Clearance accorded. Construction of all 330 dwelling units for R&R colony has been completed. Infrastructure facilities of R&R colony has been completed and ready for handing over. Field investigations will be taken up after availability of access to site. Proceedings for implementation of the project by NPCIL-NTPC JV Company are in progress.

New Projects / Sites

Pressurized Heavy Water Reactor (PHWR) Projects

Bhimpur, Madhya Pradesh: Commitment for water is to be confirmed by State Government.

Light Water Reactor (LWR) Projects

Jaitapur, Maharashtra: Land has been acquired. All statutory clearances are available. Techno-commercial discussions with Électricité de France (EDF), France are in progress.

Kovvada, Andhra Pradesh: Land acquisition process is in progress. Techno-Commercial discussions with Westinghouse Electric Company (WEC) are in progress. Proposal seeking additional funds for the Land acquisition (LA) for Kovvada Site, Rehabilitation and Resettlement (R&R) benefits and balance pre-project activities under consideration of DAE/GoI.

Mithi Virdi, Gujarat: Land is to be acquired as per the new RFCTLARR Act 2013.

Haripur, West Bengal: Land acquisition is contingent to initiative by State Government. Alternate site is also under consideration by GOI.

Quality Assurance

NPCIL, in all its endeavours, is committed towards up-gradation and continuous improvements in Quality Management System which includes Quality Assurance (QA), Quality Surveillance, Pre-service Inspection/ In-service Inspection and Software Quality Assurance (SQA) activities. Quality Assurance/ Surveillance activities (domestic and international locations) have been carried out expeditiously for projects and stations. Pre-service Inspection/ In-service Inspection (PSI/ISI) activities of Projects/ Stations has been carried out as per the Projects/ Stations schedules. NPCIL continued to provide QA consultancy services to BARC and BHAVINI/ NFC. SQA activities such as Independent Verification and Validation (IV&V) activities for 700 MWe and 1000 MWe Projects are carried out stage wise. Verifications & Validations after up-gradations of software systems at various operating stations are completed as per the program.

Quality Management System Audits are carried out at NPCIL Project Sites and at manufacturing locations of major equipment suppliers. Pre-Service and In-Service Inspection Audits are carried at operating plants of NPCIL. As part of continual improvement, effectiveness of Quality Management Program is assessed, monitored and upgraded regularly on the basis of self-evaluation, external feedbacks, peer review etc.

Safety Performance of Reactors

NPCIL is engaged in various RSA activities such as performing deterministic and probabilistic safety assessment of nuclear power plants for design, siting, commissioning of new projects; and safe operation, periodic safety review, extension of operating license/life management of operating plants, and also for obtaining regulatory clearance for the projects and operating stations. Some of the major contributions of NPCIL related to RS&A are as follows:

A Generic Final Safety Analysis Report (FSAR) is prepared for Standard 220 MW PHWRs, applicable to KGS Units-1 to 4 and RAPS Units-3 to 6 which are similar in design.

Alternate Hydrogen and Steam Concentration Monitoring System (AHSCMS)

Alternate Hydrogen and Steam Concentration Monitoring System (AHSCMS) has been designed, experimentally validated and developed to measure Steam and Hydrogen concentration in containment environment during postulated severe accidents. This is a first of a kind system which uses gas chromatograph and condensation chamber to analyze steam and non-condensable gaseous mixture.

The combined Proof test and Primary Containment Integrated Leakage Rate Test (PCILRT) of RAPP-7 was conducted successfully. Containment Filtered Venting System (CFVS) was also successfully tested for the first time in Indian PHWRs.

Probabilistic Safety Assessment (PSA) studies, involving Level-2 PSA of TAPS-3&4 for Internal Fire and Level-1 PSA for KGS-3&4 (Standard 220 MW), were completed. Internal Flood PSA revision for KGS-1&2, TAPS-1&2 and RAPS-3&4, Shutdown and Low power PSA of KGS-1&2, KGS-3&4 and RAPS-3&4 were completed.

Various Computational Fluid Dynamics (CFD) studies were carried out to support design. These included investigation of thermal stratification in pressurizer surge line under hot shutdown condition, estimation of pressure drop across fuel locator under its inadvertent advancement from normal position and estimation of secondary shutdown system margins during system actuation.

NPCIL has recorded about 583 reactor years of safe operation of nuclear reactors by the end of December 2022. Review of safety of operating stations was carried out on a regular basis. All safety significant proposals and documents were reviewed by a multidisciplinary Safety Review Committee (SRC) to meet the regulatory compliance. Oversight of Operating Plants is being ensured through monitoring and trending of nuclear safety parameters.

NPCIL is committed in the implementation of ALARA (As Low As Reasonably Achievable) philosophy in all radioactive works carried out at NPPs to ensure that occupational exposures and releases of radioactive effluents from NPPs are maintained well within the limits stipulated by AERB. NPCIL continues to maintain low radiation exposure in the public domain due to operation of nuclear power stations. Average dose received by a hypothetical person at Exclusion Zone boundary of NPP sites for the year 2021 was in the range 2.70 x10-3 μSv to 24.14 μSv which is much lower than the regulatory limit of 1000 μSv/year and continues to be negligible in comparison to the annual average dose to population due to natural background radiation which is about 2400 μSv/year.

At operating stations of NPCIL, certified Environmental Management System (EMS) as per IS/ISO-14001 and Occupational Health and Safety Management System (OHSMS) as per IS-18001/ ISO-45001 are maintained and regular audits are carried out for continual improvement. In line with Hon. National Green Tribunal (NGT), Chennai directives for Environmental Clearance (EC) for Kaiga 5&6, actions were initiated for additional studies to be completed before commissioning of the project. Various activities related to obtaining EC / extension of Environmental Clearance (EC) for NPCIL projects from MoEFCC and monitoring their compliances continued during the year.

NPCIL is strongly committed to ensure safety culture and safety values. Industrial and Fire Safety aspects are being ensured through comprehensive oversight and support functions. Industrial and Fire Safety practices are monitored and implemented by Safety Management System in NPCIL. Various Operating Stations and Construction Projects of NPCIL received prestigious National Awards from Atomic Energy Regulatory Board and National Safety Council of India. Details of awards are listed in Annexure-1.

The Environment Stewardship Program (ESP) is an initiative of NPCIL which focuses on the scientific study of the biodiversity, particularly the avifauna, in and around the Exclusion Zones of Indian nuclear power plants for the improvement of habitat and conservation of nature.

NPCIL is associated with various expert agencies like, Wildlife Institute of India (WII), Wilderness India, Turtle Surveillance India, Bombay Natural History Society etc, to enhance its' ESP activities manifold. NPCIL - NAPS and WII, are associated for the 'Namami Gange' activities of the Government of India Programme. Various activities like, Nadi Utsav, Jalaj Urja, Ghat Pe Haat, fishermen education, development of posters, lectures on clean Ganga to villagers, awareness to students on clean Ganga, rescue and rehabilitation of species for clean Ganga mission etc., are done for Namami Gange Programme. The Turtle facility at NAPS is also enhanced with expert help of WII. Bird marathons are being organized periodically at Kaiga Generating Station (KGS), KKNPP and NAPS to update database on the bird species found in the region with the active participation of professional environment conservation agencies. The artificial Mud-Flat is developed and mangroves are planted in and around township and plant areas at KKNPP with the expert help of Bombay Natural History Society (BNHS). Release of Fish, Honey Bee Hive distribution, Making of Bags, Eradication of use of Plastic, Wonders with Butterflies etc, are implemented at KGS site under various ESP programmes.

FRONT-END FUEL CYCLE

Heavy Water Production

In view of the INPP plan of commissioning PHWRs in fleet mode, large scale requirement of specialty materials for the front end and back end of nuclear fuel cycle is envisaged and to enable DAE in achieving closed fuel cycle for energy security, HWB has been entrusted to design and develop the technology for industrial scale production of specialty materials, based on the basic synthesis processes developed by research units of DAE. This challenge of setting up bench scale, pilot plant scale and then industrial scale setups was met by HWB without any additional manpower. Thus, on one hand HWB continues to perform excellently in handling tons of hazardous chemicals, extreme process conditions and RTC operation, on the other hand it has developed expertise in setting up plants which handle and synthesize a variety of special and hazardous chemicals requiring high end laboratory analytical techniques.

Heavy Water Plants at Hazira, Thal, Kota and Manuguru are in operation on continuous basis. All the activities scheduled during Major Turn Around at HWP, Kota were successfully completed. The Heavy Water Board Facilities at Vadodara and Talcher continued to produce and supply organo-phosphorous solvents as per demand from DAE units. At HWBF, Vadodara, various d-labeled compounds were synthesized as per requirement put up by BRIT. All the components of 24kA prototype cell and associated systems have been installed and tested for sodium metal production. Commissioning activities are in hand. Enrichment of $H_2{}^{18}O$ is in progress at HWP, Manuguru.

Revamping and preservation of systems and machineries at HWP, Tuticorin is in progress for restart up of the plant. Erection work for various systems at Integrated Solvent Production Plant at HWP, Tuticorin is under progress. Consent to establish from state pollution control board was received for Solvent Extraction Plant at HWP, Tuticorin. Various civil and foundation work have commenced at the plant site.

Heavy Water Plant, Manuguru

Heavy water Plant, Manuguru continued to operate safely and efficiently with sustained production of nuclear grade Heavy Water with optimum energy consumption, enriched Boron pellets and O-18 enriched water. Three export consignments were executed, to M/s. Millipore Sigma, USA, M/s K.C. Industrial, South Korea and M/s Linde Corporation, USA. Several consignments of Heavy Water were dispatched to Indian firms for non-nuclear applications.

At Boron Carbide Pelletization Plant, trial operation of Hot Press with natural B_4C powder using graphite lining was found to be successful as pellets

could be ejected easily. Two numbers of finished natural B_4C pellets produced with and without graphite sheet lining in the multi cavity die were handed over to IGCAR for analysis. Chemical analysis report was received from IGCAR in Nov 2022. Expansion of the boron facility at HWP, Manuguru is taken up and accordingly procurement & other related activities are under progress.

At ^{18}O water production Plant, RCU (Recombination Unit) was operated intermittently. The targeted quantity of 95.5% IP ^{18}O enriched liquid as $D_2{}^{18}O$ was withdrawn and $H_2{}^{18}O$ concentration in the system is progressively building up.

HWP, Manuguru received Group Achievement Awards for the Year-2020 "for Modernization of Instrumentation & Control System in H_2S based Heavy Water Production Plant, HWP (Manuguru) & for Fabrication and Supply of 5 Stacks consisting 40 pellets of Enriched B_4C of $^{10}B \geq 50\%$ as per specification and approval of IGCAR, Kalpakkam to NFC Hyderabad" during DAE Awards 2020 function held at DAE Convention Center, Anushaktinagar on National Technology Day 2022, 11-May-2022.

AKRUTI (Advanced Knowledge and RUral Technology Implementation) centre at HWP, Manuguru for techno-economic growth of the rural sector to derive technology enabled societal benefits, was formally inaugurated on 15.10.2022 by Sri. K.V.Tale, General Manager in the presence of CAO and DGMs at Primary school premises, HWP, Manuguru colony.

Sri.K.V.Tale, General Manager, HWP, Manuguruinaugurating AKRUTI centre

World Environment Day was celebrated on 04th June 2022 at HWPM colony. The function was held at AECS Auditorium Building. Environment Day pledge in Telugu, Hindi and English was administered. Subsequently, Neem saplings were planted by the present employees and also by employees who are due for superannuation from June 2022 to May 2023.

Heavy Water Plant, Kota

Plant was operated smoothly and in safe manner till 31.07.2022 after which Major Turn Around (MTA) activities were taken up. Plant was re-started on 30.11.2022 after completion of in-service inspections, meet statutory requirements and other major maintenance activities.

For carrying out Major Turn Around activities, the H2S gas was shifted from Exchange Unit (XU) to H2S Storage Tanks; whole exchange unit along with all the equipment were decontaminated and declared non-hazardous on 18.08.2022. During MTA, inspection and maintenance of Towers, Vessels, Heat Exchangers, Gas Boosters, Valves, Motors, Transformers, Switchgears, Digital Control System and Instruments were carried out. Safe working condition was maintained and ensured during maintenance through Safety Work Permit system. ISI activities have been carried out during MTA. RLA studies have been carried out for all Exchange Unit towers as part of aging management.

Statutory testing of 23 SRVs & thickness measurement of H_2S Storage Tanks was carried out in presence of competent agency authorized by Chief Controller of Explosives (CCOE).

Heavy Water Plant, Hazira

The plant continued to be in smooth and regular operation meeting the heavy water production target within the target specific energy consumption.

The Hybrid Granular Sequencing Batch Reactor (hgSBR) is a compact biological waste water treatment system for effective removal of contaminants from domestic and industrial waste waters. hgSBR technology utilizes the unique features of SBR technology and bio-beads for effective waste water treatment in a single tank without requiring secondary settler. It makes use of the native microbes of waste

Construction of Sewage Treatment Plant by HWB for Surat Municipal Corporation

water in the form of bio-beads (biofilms and granules) for removing contaminants. The technology is developed by BARC and first STP based on this technology in public domain having capacity of 150 KLD is being commissioned by HWB in collaboration with Surat Municipal Corporation for technology demonstration purpose. Foundation stone of the plant was laid on 18.11.2022 and it is expected to become operational by May 2023. Presently civil construction work is in progress.

Heavy Water Plant, Thal

Both units remained under shutdown since 23.02.2022 due to non-availability of oil drain header of syn. gas compressor. Both units were restarted in June 2022 after system restoration and approval of AERB. Subsequently, Stream B was shut down in August 2022 due to underperformance of cracker catalyst. Fresh catalyst was not available. Old Catalyst was re-used and unit-B was started on 30.09.2022.

Ammonia cracking catalyst is similar to promoted iron-based ammonia synthesis catalyst. However, in order meet the specific condition of high ammonia percentage in the feed, the catalyst is made with large amount of cobalt and is palletized unlike ammonia synthesis catalyst.

The Ammonia Cracker unit of HWP (Thal) was originally designed and commissioned by M/s HTAS in 1986 and is being operated with their proprietary catalyst till date. In the last few years, supply of such proprietary catalyst from European countries was becoming difficult and was also found to be very costly.

Oxidized Sud Chemie Catalyst

Further, there was no alternative ammonia cracking catalyst manufacturer. Anticipating non availability of catalyst and high cost from M/s HTAS, HWB took up development of indigenous catalyst for ammonia cracker in collaboration with M/s Sud Chemie. In 2009, bulk procurement of indigenous oxidized Sud Chemie catalyst (C17-T1) was done at one third of the cost of M/s. HTAS catalyst. Sud Chemie catalyst was used for catalyst replacement of Main Cracker B in August-September 2022.

Further catalyst development work is in progress with M/s Sud Chemie and recently improved version of oxidized catalyst was procured in 2022 and is being tested in Mini Cracker at HWP (Hazira). Similar testing is also planned in Mini Cracker at HWP (Thal) in March 2023.

Heavy Water Plant, Baroda

The plant is producing Tributyl phosphate, potassium metal and deuterated compounds under the diversified activities of Heavy Water Board. Two DAE sanctioned projects are under implementation i.e. 24kA test cell as well as industrial scale Sodium plant and Versatile Deuterated Compounds Production Plant (VDPP).

At TBP plant, production of targeted quantity of TBP was achieved for the year. The potassium metal plant was operated to produce the annual target of potassium metal production for supply to ammonia based HWPs at Hazira and Thal where it is used as catalyst.

In the laboratory, Deuterated Chloroform (CDCl3) with Deuterium enrichment ⩾ 99.80% was produced as per demand put up by BRIT. Deuterated sodium hydroxide (NaOD) of Isotopic Purity ⩾ 99.8% has been synthesized for carrying out the synthesis of Deuterated Chloroform. Deuterated solvents namely, Deuterated Chloroform, Deuterated Acetonitrile, Deuterated Benzene, and Deuterated Acetone have been dispatched for sale to BRIT, Mumbai.

HWBF, Vadodara has provided services of its laboratory for analysis of 47 No. of Gas samples received from Atomic Minerals directorate for Exploration and Research for Helium content.

Helium Analyser at HWBF, Vadodara

Application for siting and construction clearance for Versatile Deuterated Compounds Production Plant (VDPP) has been submitted to AERB. Tendering for civil work is under progress. Procurement of various mechanical items is under progress. Procurement of laboratory equipment/instruments along with its installation, commissioning and testing has been completed for glove box, Analytical Balance, Digital burettes, Digital dispensers under laboratory augmentation under VDPP project.

For the 24 kA Prototype Cell for sodium production, 15 m^3 FRP vessel for caustic lye storage tank was received at site in June 2022. Civil work such as pedestal work and dyke, structural platform and shed for

24 kA Cell at HWBF, Vadodara

storage of caustic flakes have been completed. Piping work, cabling work, instrumentation and circulation pump trial run, etc have been completed. Modifications in scrubber as per the AERB observations and introducing new buffer vessel between cell and chlorine scrubber have been completed. Trial Run of scrubber carried out. Minor deficiencies observed during trial run are being attended. PLC logic implementation and reviewing has been completed for 24kA sodium cell system.

Procurement of Crusher for eutectic salt lumps and Melter for feeding molten NaCl to cell is completed. Commissioning activities are in progress.

Heavy Water Plant, Tuticorin

For re-startup of HWP, Tuticorin, systems are being progressively refurbished/revived and upgraded, followed by preservation for resuming production. Exhaustive mechanical maintenance and testing activities are in progress. The system for ammonia cracking has been changed over from Naphtha based to Natural Gas based system as part of energy conservation measure and work is in progress. Conversion of Conventional Pneumatic control system to Digital Control System (DCS) is in progress. Safety, laboratory and firefighting systems as well as effluent

Storage tanks installed at SPP with MVWS system, HWP, Tuticorin

disposal system are being upgraded as per statutory norms.

Integrated Solvent Production Plant (ISP) is being set up to produce five types of solvents (TBP, TiAP, D2EHPA-II, DHOA, TOPO) at HWP, Tuticorin. Necessary approvals were obtained from various statutory authorities for the erection/ commissioning of the unit. Civil works are completed and erection & commissioning work is nearing completion.

For erection & commissioning of Solvent Extraction Plant (SXP), newly acquired land was developed and secured by constructing compound wall. Routing of phosphoric acid lines from the fertilizer unit and utility lines are finalized and foundation job is in progress for pipe rack erection pile. M/S Mecon, Bangalore has been assigned the job of commissioning.

Heavy Water Plant, Talcher

Enriched Boron (^{10}B) production plant at HWBF, Talcher employs Boron Enrichment Exchange distillation (BEXD) process for production of 50 Kg per year of Control rod grade Enriched Boron (B^{10}) of 65% isotope purity (to be used in control rods of Fast Breeder Reactors) and 5 Kg per year of Detector grade Enriched Boron (B^{10}) of 90% isotope purity (to be used in neutron detectors).

The product complex, containing enriched ^{10}B, is required to be converted into KBF_4 for further processing at HWP, Manuguru. The basic conversion process of $BF_3.O(C_2H_5)_2$ into KBF_4 was developed at HWBF, Talcher laboratory. The process has been successfully adopted in glassware setup and then in industrial scale facility. The batch size of 50 kg of KBF_4 powder is adopted to reduce the stock inventory in the form of liquid BF_3 complex, which is corrosive, thermally degradable, toxic and difficult to handle. This facility, which is an extension to existing Boron Enrichment Exchange Distillation (BEXD) facility, is designed to cater the requirement for supply of enriched boron control rods for Fast breeder reactors.

Selective separation of ^{137}Cs from high-level waste is being done at WIP, Trombay, using 1,3-Dioctyloxycalix [4] arene-crown-6 (Calix Crown-6) for making Cesium pencils and for waste management. The synthesis of CC-6 is difficult because of its low yield, multi-unit and multi-step operation. Hence, synthesis of this molecule at industrial scale is a challenge.

Starting with laboratory scale trial-runs in 50 L glass reactors to synthesize CC-6 which began in 2018, the procedure of synthesis of CC-6 has been established in-house at HWBF, Talcher. The desired quantity and purity of CC-6 has been produced and supplied to WIP, BARC during the period of report.

Synthesis of Calix Crown-6 at HWP, Talcher

Waste Immobilization Plant (WIP), BARC has projected a requirement of around 100 kg of CC-6 for 5 year operation, for extraction of Cs-137 from aqueous solutions of Medium Level Waste (MLW) as part of waste management process. Cs-137 is used for production of Cesium pencils.

CC-6 production unit at HWBF, Talcher

Calix Crown-6 is highly expensive commercially available material. To reduce the cost incurred by WIP for procuring this solvent, HWB took up the task of in-house production of CC-6 at HWBF, Talcher. With very little literature available on the novel compound CC-6, successful synthesis of the compound was eventually achieved.

To reduce process steps involved in production of this solvent, the readily available intermediate in the market, Calix-3 was utilized. Process was further fine-tuned by optimizing quantities of solvent & reagents and better temperature control during both the reactions and the yield was considerably improved to as high as 80% with excellent purity.

The requirement put up by BARC for the financial year was produced at the facility. HWBF, Talcher is supplying the material to WIP, BARC by producing it at much cheaper than market rate.

New Initiatives

Extraction of Gallium

Gallium is widely used in production of semiconductor compounds, LED, Solar Cells, magnetic materials and in nuclear industry. Gallium is commonly found in Bauxite ores in the range of 20-80 ppm. In Bayer process for extraction of aluminum, 70% of Gallium present in Bauxite ore gets leached out and it end up in the Bayer liquor up to a concentration of 100-200 ppm.

NALCO has entered into an MOU with BARC for developing technology for recovery of Gallium from Bayer's liquor. For extraction of Gallium, Ion Exchange has been identified as the most cost-effective, environment friendly process with low energy consumption and is suitable for handling low feed concentrations. BARC has developed an Ion Exchange process for recovery of Gallium from Bayer's liquor involving use of specialized Amidoximated resins.

To further develop the technology at HWBF, Mumbai (TDP), three R&D setups are installed, viz., 2" acrylic multi column setup, 3" single column of HDPE and 3" single column of SS316L. Optimization of superficial velocities for adsorption and elution was

2" multi column acrylic setup for Gallium recovery at HWBF, Mumbai

carried out. Breakthrough curve for adsorption was generated. Reusability of resin under alkaline elute conditions was studied. Basic engineering documents has been prepared based on alkaline elute solution for setting up Pilot Scale Demonstration Facility at NALCO complex, Damanjodi, Odisha. Electrolytic efficiency for gallium recovery from alkaline elute solution is reported to be low as compared to acidic elute solution. Presently, trial runs with acidic elute solution are under progress.

Recovery of Cobalt

At present, MIDHANI (Mishra Dhatu Nigam Limited) meets its demand of Cobalt totally through imports. The PSU is engaged in development, manufacture and supply of critical alloys and products of national security and strategic importance. MIDHANI generates about 200 to 300 ton/annum of special alloy scraps which is a rich secondary resource for Cobalt, Nickel and molybdenum. This scrap alloy contains 8 to 12% Cobalt and 18 to 20% Nickel.

HWB has taken up the task of demonstrating technology for recycling steel alloy scrap for recovery of Cobalt and Nickel, aiming at reducing import load and

foreign exchange burden for the country. The process know-how developed at Materials Processing & Corrosion Engineering Division, BARC involves hydro-metallurgical process of leaching of metals from scrap, removal of impurities by precipitation, solvent extraction, etc. Based on bench scale data and operational experience, basic engineering has been completed for industrial scale plant.

IREL has indicated requirement of about 2 ton per annum of Cobalt for permanent magnet production (SmCo5 & SmCo17) at its Vizag unit. HWB is setting up a 5 ton per annum plant for recycling of this scrap material for recovery of Cobalt and Nickel at existing solvent extraction facility at HWBF, Mumbai. Tendering activities are in progress for mixer-settlers, reactors, filters, etc. Tendering for procurement of 8 no. of mixer settler is in progress. Cobalt oxalate powder produced at TDP was successfully converted to cobalt metallic powder and further into pallet at BARC. Molybdenum extraction from MDN scrap was also demonstrated in the bench scale facility at HWBF, Mumbai.

An Automatic Drum Handling System for remote filling and emptying of D_2O storage drums was commissioned in BARC. The system is capable of mitigating the potential risks involved in handling of contaminated drums and also reduces man-rem exposure to the plant personnel. The system comprises a 7-axis robot with gripper for capping/de-capping operations and a roller bed belt conveyor for drum transfer. The on-board profiling sensor and software estimate exact position and orientation of cap onto the top portion of the drum.

The Automatic Drum Handling System of BARC for deployment in operations involving remote filling and emptying of D_2O storage drums

Heavy water upgradation plant in BARC was operated round-the-clock for processing of downgraded heavy water of research reactor Dhruva. Around 10 tons of downgraded Heavy water was processed and 8.5 tons of upgraded heavy water of industrial purity upwards of 99.92% was delivered to meet the requirements of the reactor.

Mineral Exploration

Atomic Minerals Directorate for Exploration and Research (AMD) plays a vital role in front end fuel cycle of nuclear power programme and carries out survey, prospecting and exploration of atomic minerals required for the nuclear power programme of the country. The activities include assessment, analysis, evaluation, characterization and categorization of atomic minerals; design and fabrication of radiometric survey instruments and laboratory scale leaching studies.

The Atomic Minerals Directorate for Exploration and Research (AMD) with a major mandate to identify and evaluate mineral resources of uranium, thorium, niobium, tantalum, beryllium, lithium, zirconium, titanium and rare earths containing uranium and thorium, has carried out integrated multi-disciplinary exploration in various geological domains in the country.

During the Annual Programme 2021-22, substantial inputs of radiometric, geological, ground & heliborne geophysical, geochemical surveys and drilling (Departmental and Contract) were deployed for exploration of U, Th, REE, Nb - Ta, Li, Be and Zr.

Uranium investigations have been continued in the thrust areas for establishing Proterozoic unconformity, granite-related, carbonate, metamorphite, Palaeo-QPC and metasomatite type uranium deposits in Proterozoic basins and sandstone and surficial types in Phanerozoic basins. Similarly,

substantial exploration inputs were deployed for augmentation of Rare Metal and Rare Earth resources in pegmatite belts of Chhattisgarh, Odisha and Karnataka and in hard rock terrains such as Ambadungar Carbonatite Complex, Gujarat and Siwana Ring Complex, Rajasthan and heavy mineral deposits in coastal beach placers in parts of Kerala, Tamil Nadu, Odisha, Andhra Pradesh, Maharashtra and Gujarat and in the inland placers in parts of Jharkhand, West Bengal and Tamil Nadu. In addition, collection of columbite – tantalite (Nb-Ta mineral) and xenotime (REE mineral) bearing poly-mineral concentrate was continued in the units established in Odisha, Karnataka and Chhattisgarh.

Gravity, Magnetic & DGPS base setup and Field measurement with CG5 Gravimeter

All the laboratories in AMD Headquarters and Regional Headquarters have been utilised to their full capacity and have contributed actively by providing speedy analytical support to the ongoing exploration programme.

Uranium Investigations

Geological and radiometric surveys

Reconnaissance (6,946 sq km) and detailed (354.80 sq km) surveys helped in locating the following promising new uranium anomalies/extension of known occurrences in various geological environs:

Dighul-Jarha, Sonbhadra district, Uttar Pradesh hosted in pegmatoidal leucosome of Chhotanagpur Granite Gneiss Complex (CGGC) [up to 0.25% U_3O_8].

Korlakunta, [up to 0.19% U_3O_8] and **Dudyala** [upto 0.31% U_3O_8], in basement fractures [mylonite and granite mylonite], YSR district, Andhra Pradesh.

Khadandungri-Khejurdari, East Singhbhum district, Jharkhand, hosted in biotite rich magnetite bearing quartzite in Singhbhum Shear Zone (SSZ) [up to 1.80% U_3O_8].

Laikera-Nagalkata, Sundergarh district, Odisha hosted in basement granite [up to 0.18% U_3O_8].

Yum Nala-Orange Garden-Demwe Nala, Lohit district, Arunachal Pradesh hosted in quartzo-feldspathic veins of Sewak Group [up to 0.059 % U_3O_8].

Kundala [up to 0.50% U_3O_8], **Nanagwas** [up to 0.27% U_3O_8] and **Kalakhora ki Dhani** [up to 0.15% U_3O_8], Sikar district, Rajasthan, hosted in albitite of Khetri sub basin in North Delhi Fold Belt (NDFB).

Bhura Sidh, Alwar district, Rajasthan hosted in gritty/pebbly quartzite in Rajgarh Formation of North Delhi Fold Belt (NDFB) [up to 1.08% U_3O_8].

Bijakutumbh, Gondia district, Maharashtra hosted in in Bijli Rhyolite of Nandgaon-Khairagarh Basin [up to 0.20% U_3O_8].

Geochemical Surveys

Geochemical surveys (4,914 sq. km) have indicated anomalous concentration of U (up to 4,588 ppb) and Li (up to 2,632 ppb) in brine samples along Luni River course around Jhakarra-Sayar Ka Koseeta-Arwa-Gira tracts, Barmer and Jalore districts, Rajasthan. Anomalous U in ground water samples along Nolivedu-Gangarupavandlapalle (upto 11,400ppb) and Galivedu-Nagurivandlapalle (upto 4,002ppb) tracts, YSR and Chittoor districts, Andhra Pradesh; Ghatbahra (upto 294 ppb), Korba district, Chhattisgarh and Dhorimanna-Ogala area (upto 95 ppb), Barmer and Jalore districts, Rajasthan have been recorded.

Ground Geophysical surveys

Ground geophysical surveys (Regional: 900 sq km; Detailed: 525.40 sq km) have delineated potential NE-SW trending low magnetic-low resistivity-low chargeability zones in Tantloi area, Birbhum district, West Bengal; a number of gravity lows trends around Marlagalla-Allapatna area, Mandya district, Karnataka; thin conductors in Vindhyan Basin, Gwalior district, Madhya Pradesh and high chargeability-low resistivity zones in Sewa Ki Dhani area, Sikar district, Rajasthan.

Airborne survey and Remote Sensing

Heliborne geophysical (TDEM, magnetic and Gamma-ray spectrometric) survey has been carried out over 28,929 line km in CGGC, Jharkhand and Chhattisgarh; northwestern margin of Chhattisgarh Basin, Chhattisgarh and in parts of Great Boundary Fault and Jahazpur Basin, Rajasthan.

Three (03) potential blocks have been identified after processing of heliborne data in Naurangpura, Bodhgaon and Chandawaji-Mewal area which have been ground validated and targets zones delineated for further exploration in Alwar Basin of NDFB.

Preparation of heliborne geophysical survey with VTEM system, Rajasthan

Exploration by Drilling

A total of 3,65,287.73m (Departmental: 90,154.58m and Contract: 2,75,133.15m) drilling (reconnoitory, exploratory and evaluation) has been carried out to establish (a) additional uranium resource in the known deposits and (b) sub-surface continuity of mineralisation in new promising areas.

Departmental drilling unit at in field area of Eastern Region

Drilling has established significant correlatable uranium mineralised intercepts / bands in the areas given below:

Anjangira and Kudar, Sonbhadra district, Uttar Pradesh: Associated with pegmatoidal leucosome of Chhotanagpur Granite Gneiss Complex (CGGC).

Motnutalapalle and Nallagondavaripalle Blocks, YSR district, Andhra Pradesh: In Vempalle Dolostone of Cuddapah Basin.

Rachakuntapalle, Rachakuntapalle East, Gidankivaripalle and Velamvaripalle Blocks, YSR district, Andhra Pradesh: In Vempalle Dolostone of Cuddapah Basin.

Sarangapalli, Guntur district, Andhra Pradesh: Associated with basement granite / Banaganapalle Quartzite of Kurnool Group in Palnad Sub-basin (Cuddapah Basin).

Hulkal-Dornahalli, Yadgir district, Karnataka: Associated with brecciated limestone and granite in the eastern extension of Kanchankayi uranium deposit.

Baglasai-Mechua, East Singhbhum district, Jharkhand: Associated with sericite-chlorite-quartz schist in Singhbhum Shear Zone (SSZ).

Kudada, East Singhbhum district, Jharkhand: Associated with serpentinite in SSZ.

Bagjata, East Singhbhum district, Jharkhand: Hosted in silicified chlorite-biotite-quartz schist / feldspathic schist in SSZ.

Pathargora, East Singhbhum district, Jharkhand: Hosted in biotite-quartz schist / feldspathic schist/ biotite chlorite schist in SSZ.

Rohil Central, Narsinghpuri, Jahaz and Geratiyon ki Dhani, Sikar & Jhunjhunu districts, Rajasthan: Associated with albitite zones in North Delhi Fold Belt (NDFB).

Umra, Udaipur district, Rajasthan: Associated with carbonaceous phyllite of Aravalli Supergroup in Umra NE extension area.

Bijepar, Gondia district, Maharashtra: Associated with rhyolitic conglomerate/ porphyritic rhyolite (Bijli Rhyolite) in Dongargarh-Kotri Belt of Central India.

Jhapar, Balrampur district, Chhattisgarh: Associated with pegmatoidal leucosome of Chhotanagpur Granite Gneiss Complex (CGGC).

Dharangmau, Betul districts, Madhya Pradesh: Associated with feldspathic sandstone of Lower Gondwana in Satpura-Gondwana basin.

In addition to the above, potential/significant blocks have also been taken up for sub-surface exploration in Uttar Pradesh, Himachal Pradesh, Andhra Pradesh, Jharkhand, Arunachal Pradesh, Rajasthan, Madhya Pradesh, Chhattisgarh and Andhra Pradesh.

Rare Metal and Rare Earths (RMRE) investigations

Reconnaissance (895 sq km) and detailed (7 sq km) surveys have been carried out for identification and evaluation of Rare Metals and Rare Earths resources in Chhattisgarh, Madhya Pradesh, Odisha, Rajasthan, Gujarat and Karnataka. This has resulted in establishing additional resource of 427 kg of columbite-tantalite in pegmatites from extension areas of Pandikimal-Nayakpalli, Jharsuguda district, Odisha.

Collection of columbite-tantalite along with beryl as by-product, spodumene and polymetallic xenotime bearing concentrate was achieved at Pandikimal and Jangapara units, Jharsuguda district, Odisha; Allapatna-Marlagalla sector, Mandya district, Karnataka and Siri River unit, Jashpur district, Chhattisgarh.

Core of Spodumene bearing pegmatite, Marllagalla, Mandya district, Karnataka

A total of 37,021.85 m (Departmental: 4,829.85m and Contract: 32,192m) drilling has been carried out for RMRE in Allapatna-Marlagalla sector, Mandya district, Karnataka; Ambadungar, Chhota Udepur district, Gujarat and Siwana Ring Complex, Barmer district, Rajasthan.

Depth continuity of REE-Nb mineralised peralkaline granitoid has been established in Ramaniya, Bhatikhera, Phulan and Nal blocks of Siwana Ring Complex upto 375m, 315m, 230m and 450m respectively.

Beach Sand and Offshore Investigations

Survey (Reconnaissance: 150.50 sq km and Detailed: 21.92 sq km) and prospecting (drilling, sampling and evaluation) were continued along the coastal tracts of Kerala, Andhra Pradesh and Odisha to establish additional beach sand mineral resources.

Exploration/Evaluation

Conrad bunka (1,386 boreholes) and Sonic drilling (51 boreholes) have been carried out with a cumulative meterage of 11,242.50m and 8,363 samples have been generated.

The following potential Total Heavy Mineral (THM) zones have been delineated:

- Aroor-Poothotta (up to 21%), Alappuzha and Kottayam district, Kerala.
- Tamirabharani River sediments around Agaram (up to 38%), Thoothukudi district, Tamil Nadu.

Garnet rich heavy mineral layering in Riverine sands of Tamirabharani, Tamil Nadu

- Bajrakot (upto 25%), Ganjam district and Brahmapur (upto 56%), Puri district, Odisha.

Sonic drilling, on contract, has been carried out along Brahmagiri coast, Odisha which established the persistence of sand column up to 60m with up to 35% THM content.

Mining & Mineral Processing

Mining and processing of uranium ore in India is done by the Uranium Corporation of India Ltd. (UCIL). The corporation operates in Jharkhand state with seven mines at Jaduguda, Bhatin, Narwapahar, Turamdih, Bagjata, Banduhurang, Mohuldih and two processing plants at Jaduguda and Turamdih. One opencast mine and three mills located in Jharkhand (in East Singhbhum and Seraikela-Kharsawan districts) and Andhra Pradesh (in YSR district). The Indian Rare Earth Limited (IREL) is a Mini Ratna (Category-I) Company and it is engaged in mining and production of beach sand minerals and rare earth compounds. The minerals produced by IREL find use in the Nuclear Power Programme and wide-ranging industrial applications. The minerals separated by IREL from the beach sand at its three units located at Chavara, Kerala; Manavalakurichi, Tamilnadu and Chatrapur, Odisha are ilmenite, rutile, leucoxene, zircon, monazite, sillimanite and garnet. IREL also produces uranium, thorium and rare earth compounds.

For the Financial Year 2020-21, UCIL received 'Excellent' MoU rating for the fourth year in a row with a score of 92.63 from the Department of Public Enterprises, Ministry of Finance, Government of India (Office Memorandum No: 'F. No. M-03/0011/2021-DPE (MoU)' dated 18th January, 2022). During Financial Year 2021-22, UCIL has once again met all parameters for achieving 'Excellent' rating in MoU performance.

During the year 2021-22, UCIL has taken up several initiatives like modification of promotion policy for Group-A executives at par with M/s. IREL (India) Limited, amendment in post-retirement medical facilities in line with CGHS, modification in payment of Annual Production Incentive for workmen, inclusion of E0 to E2 employees in the existing superannuation scheme, discontinuance of interviews up to Group-B cadre in all kinds of promotions and recruitments for other than Scientific & Technical (S&T) field. These reforms will help in maintaining healthy industrial relations.

In the 'R&D, Innovation and Technology Upgradation' front, Commissioning of Horizontal Belt Filters in place of drum filters at Jaduguda mill has been completed for better Uranium recovery from the leached slurry.

Project for setting up of the facility for the production of 'Heat Treated Uranium Peroxide (HTUP)' in place of 'Sodium Di-Uranate (SDU) at Tummalapalle in line with Jharkhand region has been awarded to M/s. MECON Limited vide reference no. UCIL/TMPL/MILL/PROJECTS /HTUP/90/1 -Dated: 09/05/2022. The production of yellowcake in the form of HTUP which is being of superior grade contains lower impurities, also reduces radioactive waste handling load and other treatment issues at NFC Hyderabad.

In-house development of eco- friendly chemical method for treatment of mine water to lower the

radioactive nuclides present in the mine water at Tummalapalle has been taken up. The trials carried out in lab and pilot scale studies for lowering of U and Ra content in mine water has given encouraging results.

Upgradation and adoption of latest available mechanization/technology through procurement of new equipment as well as overhauling of existing equipment has been undertaken in order to sustain the present level of production operations for the next five years in Jharkhand region. As a part of this, the overhauling of old mining equipment has been completed at total cost of about ₹ 20.54 crores and purchase order (about ₹ 62 cr.), has also been placed for procurement of 17 nos new underground production equipments. The mining operations at Bhatin mine have been resumed as per the contract awarded.

For achieving the 'Vision 2031-32 Self Sufficiency in Uranium Production' and attaining sustainable long-term energy security of the country, the Atomic Energy Commission (AEC) had accorded in-principal approval for 13 new projects in different parts of the country. The pre-project activities for these projects, such as, obtaining of statutory clearances, land acquisition, site development, and carrying out of R&D activities for formulation of the detailed project reports, have been undertaken and are in different stages of execution.

During the year, the Company has achieved significant progress in activities related to different green-field and expansion projects. Letter of Intent (LOI) for granting the mining lease for Rohil Project has been received from Govt. of Rajasthan. On 13.09.2022, MoEF&CC has communicated that UCIL projects shall be dealt by Nuclear, Defence and other strategic sector. Based on which, UCIL has applied for obtaining of ToR from MoEF&CC for Rohil Project which is under process. Besides, the state govt. of Jharkhand has undertaken DGPS survey for proposed mining lease demarcation, preparation of land schedule etc., for Banadungri project.

UCIL continues to maintain the ISO 9001:2015 certifications for Quality Management System, ISO 14001:2015 certification for Environmental Management System. UCIL also continues to maintain ISO-45001:2018 certification for Occupational Health and Safety Management System.

In view of the allegations made by the local villagers and NGO's on operations of UCIL, Isotope and Radiation Application Division (IRAD), BARC carried out an isotope hydrological study at Tummalapalle to identify the source of uranium contamination in ground waters. The report concluded that the presence of high uranium observed in some wells were geogenic in nature and not derived from the tailing pond or decant pond.

As per the directives of APPCB, the lining of tailing pond with HDPE along with heightening of tailing pond (2nd Stage) has been completed at Tummalapalle.

The provisional MoU rating of IREL for the year 2021-22 was 'Excellent'. This rating has been achieved for the 5th consecutive year.

During the period April to Dec. 2022, production of minerals increased by 3.0 % as compared to the corresponding period of last year. Further production of chemicals increased by 4% as compared to corresponding period of last year. Production of Nuclear Grade Ammonium di-Uranate (NGADU) and Mixed Rare Earths Chloride (MRECL) stood at 16.875 tons and 3967 tons respectively.

A Pilot Plant is established at RED Unit in Aluva, Kerala for production of 99.99 %Yttrium Oxide through Ion -Exchange column. This adds to IREL's basket of products.

IREL carried out a 5 day virtual training program for Vietnam delegation in April 2022 on Rare Earths. Subsequently, a technical delegation from Vietnam visited IREL in July 2022. This was carried out as a part of the MoU entered between GCNEP, DAE and VINATOM.

The suitability of Pulsed Disc and Doughnut Column (PDDC) for intensified solvent extraction of uranium from crude uranyl nitrate slurry feed was successfully demonstrated in a 3-inch diameter column. Plant grade Lean Solvent (LS, ~32% TBP in n-

Dodecane, ~5 gpl DBP) was used for carrying out solvent extraction of uranium from uranyl nitrate slurry feed. For simulation of solvent extraction process in a columnar contactor, a new module of ANUSim (a python-based simulator dedicated for nuclear chemical processes) was developed.

A hydrometallurgical process has been developed in BARC to recover highly valuable materials, including nickel, cobalt and molybdenum, which are typically present in maraging steel scrap occurring in large quantities in day-to-day operations of Mishra Dhatu Nigam Limited (a Govt. of India PSU). Nickel, cobalt and molybdenum could be recovered through this process with over 99% purity. The process has been demonstrated to Heavy Water Board for implementation as part of their operations.

Cobalt and associated materials recovered from maraging steel scrap

Two highly valuable rare earth elements - yttrium and europium - were recovered from Compact Florescent Lamps (CFLs) of electronic waste through employing the technology of aqueous processing. Besides, mercury of highly hazardous nature was separated from them by employing selective polymeric resins developed in-house.

Studies on developing a process scheme for the recovery of uranium values in the form of high purity uranium peroxide were carried out using composite bore-hole core ore samples. These efforts were focused on uranium occurrences at Jahaz of Sikar district in Rajasthan which fall under the North Delhi Fold Belt (NDFB). Uraninite is the main uranium carrier phase with U_3O_8 assay of 0.04%. Pyrite, pyrrhotite, molybdenite along with traces of chalcopyrite are the predominant sulphides and heavy oxides include ilmenite and rutile. The ore being rich in siliceous minerals, acid based hydrometallurgy based recovery process was adopted. Detailed optimization of various process parameters across different unit operations viz. oxidative atmospheric leaching, purification of leachate on anion exchange resin, precipitative removal of excess Fe and sulfates followed by uranium precipitation gave final U-peroxide product assaying 79% U_3O_8 with 83% recovery.

The Naktu U ore at Son Valley in Sonbhadra district of Uttar Pradesh contains on an average about 0.02% of Rare Earth Elements (REEs). These REEs occur in the form of monazite and REE-silicate complex. About 70% of REE values co-dissolved along with uranium during oxidative sulfuric acid leaching of the ore. The REE content in the raffinate was enhanced sequentially by first extracting them with D2EHPA as solvent followed by treating the strip liquor in chloride medium with TBP. The purity of REE-fluoride was 84% with overall recovery of about 45%.

Based on experimental studies, a pilot plant has been installed in BARC for purification of uranium from MgF_2 Slag Leached Solution (SLS). The pilot plant houses facilities for SLS storage, chemical treatment of SLS with aluminium nitrate, purification of SLS, storage of nuclear pure uranium storage and effluents storage.

Pilot Plant in BARC for purification of MgF_2 slag leached solution (SLS)

A detailed study has been conducted to understand the utilization of uranium mill tailings generated from Turamdih process plant. Different bricks and paver blocks were prepared from tailings at various compositions by pressing and moulding techniques. Radioactivity analysis indicated the radium equivalent activity varied from 628 to 1650 $Bqkg^{-1}$, which suggest that these bricks and paver blocks are suitable as construction materials for various utilities, including industries, roads and bridges.

A solvent extraction based process has been developed for production of nuclear grade Zirconium Oxide (ZrO_2) from Zirconium Nitrate Feed Solution (ZNFS) using an in-house synthesized Alkyl Phosphineoxide (APO) ligand in a novel differential contactor Pulsed Stirred Column (PSC). Studies on separation were carried out in PSC of 20mm ID and 1m active section height. Extraction and stripping were found to be stable. ZNFS contains significant quantities of silica, which leads to operational difficulties like flooding, emulsion formation in mixer settler.

Miniaturized Pulsed Stirred Column

Nuclear Fuel Fabrication

Nuclear Fuel Complex (NFC), an ISO 9001, 14001 & 45001 organisation under Department of Atomic Energy (DAE), is engaged in the production of natural Uranium fuel bundles for Pressurized Heavy Water Reactors (PHWRs), enriched Uranium fuel assemblies for Boiling Water Reactors (BWRs), Reactor Core Structurals (Calandria tubes, Coolant tubes, Square channels etc.), Reactivity Control Mechanisms and special materials like Tantalum, Niobium etc. In addition, for Fast Breeder Reactors, NFC produces all the core sub-assemblies and other critical components like fuel cladding tubes, hexagonal wrapper tubes etc. made out of special stainless steels/D9 materials. NFC also caters to the demand of high quality stainless steel tubes/pipes, Steam Generator tubes, Super Ni tubes, Zr 1%Nb and titanium alloy products for critical and strategic applications in Nuclear Power Plants, Reprocessing Plants, Defence and Space establishments.

NFC has successfully manufactured PHWR fuel bundles from UO_2 powder to pellet route and met the requirement of fuel bundles for all the PHWRs in time. All the indigenous raw material in the form of MDU/HTUP/SU received from M/s UCIL was converted into 19 element and 37 element fuel bundles for meeting the requirement of out of safeguard (OSG) reactors. NFC has achieved production of 620 MT of PHWR fuel bundles and 205 MT of pellet packing in addition to bundle production in the financial year till December, 2022. NFC has dispatched 684MT of PHWR fuel bundles till December, 2022.

PHWR fuel

The Uranium Oxide Plant (UOP)

All the safety and process interlocks have been implemented in the Programmable Logic Control (PLC) based SCADA System. Features like automatic feed rate control, pressure control in the rotary furnaces through feedback loop have been envisaged & implemented for the first time in NFC. Centralized operation of all the wet and dry processes have been integrated & are presently being carried out through the central control room.

In order to ensure additional production capacity and improve equipment availability, one line of rotary furnaces (1 no. of calcination furnace, 1 no. of reduction furnace and 1 no. of stabilization unit) were procured under MAZ4F Project. The new rotary furnaces deployed in regular production activities have improved features like online replacement of heating coils, PID control system for temperature and increased heating capacity etc.

Online element weight monitoring system has been implemented on all the PHWR element double head turning machines. This has resulted in introduction of automatic inspection without need of scanning of all the element by X ray Equipment and reduction in man power.

An automatic pellet unloading system is installed and commissioned in one of the grinding machines to eliminate manual unloading of pellets into automatic pellet feeding system for grinding. This development has significantly reduced radiation exposure to the operator.

Installation & commissioning of 2 nos. of Automatic end cap welding machines

Installed & commissioned 2 nos. of Automatic end cap welding machines. The system consists of online stack length verification, End cleaning and Evacuation of elements indexing on conveyor. Bowl feeder and Auto End cap feeding system, auto element rotation system for both side welding & data acquisition system for storing of weld parameters required for weld evaluation.

Fabrication of Jig for assembly of PHWR fuel bundles with PEEK (Poly Ether Ether Ketone) material which has good electrical insulation properties to eliminate defects like Cut mark on the End cap, Pits on side of the End cap due to shot circuit of current during welding and scratches on element.

Commissioning of Batch Calcination furnace for processing of Uranyl Nitrate Raffinate Cake (UNRC) to augment the production capacity for Processed Uranium Cake (PUC) generation. With this batch calcination furnace about 10MT/month of UNRC is being calcined to produce 2.5MT/month of PUC.

In house development of new vehicle tracking system for tracking of fuel consignments despatched to Nuclear Power Reactors at various locations in the country. Main features of the system were No third-party server, built on dedicated embedded system, Real time SMS based coordinate/location data messaging over BSNL network, local storage of data in case of non-availability of network. The server system is standalone (not connected to internet). The system is implemented and under observation.

Structural Materials & Components

Zirconium activities

About 477 MT of nuclear grade zirconium oxide and 280 MT of zirconium sponge were produced during this financial year till December, 2022.

A data based process model for zirconium stripping operation developed, validated and implemented for model predictive control of the complete zirconium extraction and stripping operations. Adoption of this model based control resulted in improved zirconium stripping operation. This in turn improved the effectiveness of solvent washing step adopted for zirconium recovery prior to solvent treatment (sodium carbonate wash to remove degraded products). Effective solvent washing enabled improved sodium carbonate treatment. As a result, specific chemical consumption of sodium carbonate reduced by about 30%, along with corresponding reduction in specific generation of sodium nitrate process effluent.

Modified bleeding scheme (Bleed frequency of 20 min) has been implemented in all the Reduction Units

which has resulted to 10% reduction in reaction time and thereby increase in productivity.

Zircaloy fabrication

About 7651 nos. of extrusions have been carried out during the period.

Development & Manufacturing of large ID Shell preform of maraging steel (MDN-350) for BARC

A modified 3-stage hot expansion process route was developed to successfully manufacture shell of OD 330mm X ID of 270 mm. Process parameters such as preheating temperature, speed, reduction per stage along with modification in tool design were carried out to meet the requirement. The technology development is first of its kind and process is developed successfully for future requirement in large numbers as per RMP, BARC requirement.

Finished Hot expanded Preform of MDN 350

Preform of MDN 350 showing excellent OD and ID surface finish

Fuel Tubes

During the current financial year 2022-23, 18.13 lakhs of PHWR Fuel Tubes have been produced which is highest ever during this period since inception with overall recovery of more than 95% at Ultrasonic Testing.

Apart from the Fuel tubes required for PHWRs and BWRs fuel assemblies, the Fuel Tubes section has produced & supplied 700 nos. of Titan 24 tubes, 5000 nos. of SuperNi 42 tubes, Titan 11 tubes, UNS NO-6690/6600 tubes, and Ni-Cr-Mo alloy tubes required for strategic purposes.

Some of the achievements during the year included the followings:

Development & commissioning of real time Temperature Uniformity Survey system. This has made Furnace temperature survey more accurate (survey under actual processing condition), time saving (more than 90% as no shut down / cold start-up required) and without manpower dependency.

Hot box housing with data logger for real time temperature survey

Automatic Tube ID cleaning

Development and commissioning of completely automated tube ID cleaning system for final pass fuel clad tubes (after grit blasting) leading to increased UT recoveries and improved productivity.

Automatic Tube ID cleaning

Establishment of New Degreasing and pickling Section at ZFP

New Degreasing and Pickling section of total area 2200 Sq. m with Plant Capacity of 160MT/Annum to process Zirconium, Titanium & Nickel based alloys is equipped with facilities such as Degreasing Facility, Pickling Facility, De-scaling Facility, De-Jacketing Facility, Primary Ventilation and Stack monitoring system and Acidic water treatment facilities.

Establishment of New Degreasing and pickling Section at ZFP

All the operations and ventilation systems were controlled by SCADA based system with required interlocks. This facility will cater the various requirements of M/s NPCIL, Defense, Space and other Strategic applications.

Installation of 6 Head & 4 Head Grinding machines. These equipment have advanced features in automation and passive safety systems which have enhanced the existing capacity with superior and consistent quality product.

6 Head grinding machine

4 Head grinding machine

Revamping and automation of Continuous Annealing furnace-1, NZFP

To reduce operator intervention and improve productivity and quality of tube, CAF#1 at NZFP was revamped and automated. The furnace was provided with automatic inlet table, outlet table and driving mechanism of tube was replaced from tandem belt driven to individual Brush Less DC (BLDC) driven system.

Old 200kW Furnace

To further improve the quench rate, high thermal conductivity graphite bushes were installed inside the quenching chambers. To improve temperature uniformity ageing heating elements were replaced with Silicon carbide heating elements. Deformed hot chamber and cooling chambers were also replaced.

Revamping of 200kW furnace used for beta quenching of Zr slabs for PHWR is completed, resulting in improved reliability of the equipment.

BPS & Bar Operations

Design, Development, Installation & Commissioning of Automated Machining Center for Billets

Indigenously developed new State-of-Art Automated Machining Center contributing to Govt. of India's initiative "Aatmanirbhar Bharat". The Automated Machining Center is a group machining cell consists of five working stations with integrated automatic material handling by Gantry and controlled by SCADA system, also integrable with exclusive online immersion billet UT system. The system is used for automated machining of Billets of various sizes and grades with complete automation with multi-folds improved productivity and variety. This automated system will cater billets for variety of products viz Core Structural, Reactivity mechanisms & Fuel bundles for the reactors coming under Fleet mode.

Design, Development, Installation & Commissioning of Automated Machining Center for Billets

Structurals

Manufactured and supplied one reactor charge consisting of 6 Nos. of Liquid Zone Control Unit Assemblies to upcoming 700 MWe PHWR (RAPP-8 reactor site). Manufactured 26 Nos. of AR Mechanism Assemblies for upcoming 700 MWe PHWR (GHAVP-1 & 2), thereby completing 2 reactor charges of these Assemblies. Manufactured of 6 nos. of Cobalt Absorber Assemblies and supplied 4 assemblies to KAPS 1 & 2 PHWR 220 MWe. Manufactured 4 nos. of Vertical Flux Unit assemblies for 540 MWe PHWR (TAPS-3 & 4 site).

Special Tube Plant received the order for manufacturing of calandria tubes for upcoming 700 MWe pressurized heavy water reactor. The process route was re-qualified and total 560 numbers of calandria tubes is made and qualified with reference to all quality checks. Remaining 290 numbers will be manufactured by March 2023.

In-house development of reverse spinning facility to carry out reverse spinning of Zr 1%Nb tubes. 200 No's of Zr-1%Nb tubes were made & reverse formed and are ready for dispatch to BARC.

Manufacturing and reverse forming of zirconium – 1% niobium (Zr-1%Nb) tubes

Grit blasting equipments are self-destructive type because of high abrasion of equipment structures with abrasive grits. Revamping of the equipment was taken up and completed. Some parts of the equipments e.g. bucket elevators system and dust collector system was modified for improved filtration and lower dust emission in the surrounding environment. This has resulted in better efficiency and availability of the equipment.

Flaring is carried out in the calandria tube after it is cleared from all NDT (non-destructive testing) quality checks. In flaring, the end of tube is expanded to facilitate sandwich rolled joint with end shield assembly of reactor. Earlier, the end flaring of calandria tubes was done manually and was highly dependent on the

Automation of Calandria tube end flaring machine

operator skills. Any deviation form required dimensions will lead to rejection of final tube. In-house automation of flaring machine was taken up and was completed. The entire cycle of flaring is automated with PLC.

Special Materials

The Plant has produced 3050kg of Niobium metal granules.

Some of the major achievements during the year were as follows:

Developed alternate route for preparation of Nb sheets by cold forging instead of hot extrusion to avoid pick up of O, N during processing. Successfully prepared 2 Nos. of Niobium sheets (600 mm x 300 mm x 2.5 mm) meeting the desired mechanical & chemical specifications of BARC.

Developed process for preparation of advanced Ni based super alloy by electron beam melting followed by vacuum arc remelting for applications at MMD, BARC & prepared 10 kg alloy. The alloy is a candidate material for applications such as high temperature structural materials in back end nuclear technology and high temperature nuclear reactors.

Successfully developed process for preparation Nb55Ti alloy by combination of Electron beam melting & Vacuum arc remelting route for superconducting applications at RRCAT, Indore. Prepared 90kg Nb55Ti alloy.

Commercial Activities

The Stainless Steel Tube Plant (SSTP) the production of Steam-Generator for fleet mode reactors (10x700MWe PHWRs) was commenced. All the processes were fine-tuned and successfully qualified to meet this new requirement. Till date, 1,250 no. of tubes (1/2 set) have been manufactured and finishing operations are under advance stages of completion. 1st SG set comprising of 2,489 tubes is planned to be completed by March'2023.

NFC marked the dispatch of final consignment of SS304L tubes for Fast Reactor Fuel Cycle Facility (FRFCF) coming up at Kalpakkam.

SSTP has successfully supplied 13,209 Fuel Clad tubes & 4,052 Blanket clad tubes for Prototype Fast Breeder Reactor and 3,879 SS316M Fuel clad tubes for Fast Breeder Test Reactor.

Only facility in NFC for carrying out heat treatment of 27m long length Steam Generator tubes for PHWR and D9 tubes of PFBR. The imported furnace is more than 40 years old exhibiting ageing related problems. As a part of Atmanirbhar Bharat, furnace Hot Zone & Controls' revamping is initiated. All materials including Hot Zone and Control System are received at NFC.

Internal View of Old Furnace (left)
Internal View of New Furnace (right)

Projects

Green field Projects of NFC

NFC-Kota

NFC-Kota Project (revised sanction cost: ₹ 4256.20 crores with time upto July 2022), Rawatbhata, Rajasthan, a green field project, is envisaged to produce 500 TPY of Nuclear fuel for 700 MWe PHWR type nuclear reactors.

NFC-Kota Project

Some of the major events during the period were as follows:

Extension of time period up to September 2024 for completion of the Project without any cost revision was granted in May 2022 and the cumulative physical progress achieved up to November 2022 is 65% and financial progress as on date is 45% respectively.

Major machinery such as Electron beam welding Unit, Plasma Melting furnace, 32mm CRTM/Pilger Mill, Tube Grinding cum Polishing machine 8-20mm, Ultrasonic tube testing system (ROTA),

32mm CRTM/ Pilger Mill – Under installation

Tube Grinding cum Polishing machine 8-20mm – Received at site

Several process tanks, agitators, pumps for powder plant, Sintering furnaces, Automatic storage & retrieval system for pellet rod trays, Roll Press, End cap welding machines, End plate welding machines, Vacuum baking ovens, Automated Immersion density system, Automated end cap weld scanning system, Control Lab analytical equipments etc. are received at Project Site.

Plasma Melting furnace was installed & commissioned in Melt Shop. Installation of 2 No's of Vacuum arc remelting furnaces completed and melting trials are commenced. Two no. of Deep hole drilling machines were installed and commissioned in Forge shop. Installation of 1 no of Extrusion press completed in Extrusion shop and trials have been commenced. 1 No of Walking beam furnace commissioned. 65mm CRTM/Pilger Mill was installed & commissioned in Fuel Tube shop. Ultrasonic Tube testing system (ROTA) was installed and commissioned in QA-Fuel Tube shop.

Plasma Melting furnace – commissioned

Vacuum Arc Remelting furnace with trial melts

Deep hole drilling machine- Commissioned

Extrusion press

Several Control Lab equipments like C & S analyser, Hydrogen Analyser, Laboratory Infrastructure, inductively coupled plasma optical emission spectrometer (ICP-OES), Nitrogen analyser, Gamma ray spectrometer with HPGe detector etc. were commissioned at site. Compressed air plant has been commissioned.

ICP-OES

Mechanical erection of Dissolution section completed in Module-II of PFFF. Solvent extraction and Precipitation section are in the advance stage of completion in Module-II. Structural erection and positioning of tanks is progress in PFFF Module-I. 80 No's out of 92 No's of tanks are positioned in Module-I. Screw paddle Dryer, Solvent extractor & Drum Filter erection done in Module-I. Piping Works Started in Dissolution Area in Module-I.

Construction of UOC Containers platforms has been completed. Construction of major Plant and non-Plant buildings is nearing completion.

Civil works for construction of raw water treatment plant & DM Plant are nearing completion and that of Effluent Treatment Plants are in progress. Pipe rack and piping works - 4500 MT (approx.) pipe rack erected out of the total requirement of 5000 MT Pipe rack. About 4,25,000 IM of piping is completed out of 5.00 lakh IM piping. EOT cranes at Melt Shop, Forge Shop, Fuel Tube Shop and Tool Room are commissioned and the same in Pickling & Cleaning

Shop are under commissioning. In Township site - Construction of Quarters (Type II, III, IV & V total 416 nos.) and Guest House is in progress. Total value of the purchase orders, work orders placed and value of the purchase & works proposals in progress amounts to approximately ₹ 3231 crores.

Zirconium Complex

About 390 MT of nuclear grade zirconium oxide and 190 MT of zirconium sponge were produced during the year till December, 2021.

Flattening of Zircaloy cut tubes for increasing chlorine utilization

Cut tubes received from NFC were flattened using compaction press and the flattened tubes have been processed in WSR. Feeding flattened tubes resulted in higher packing ratio inside the reactor which resulted in increased chlorine utilization from 90% to 93% and thereby reducing the load on the chlorine scrubbing units. 101.9 MT of zircaloy scrap has been recycled in the water cooled scrap reactor with a specific chlorine consumption of 6.6 % lower than the previous year.

Installation and commissioning of hydraulic positive displacement briquetting machine

Pug-mills (screw type extruders) have been employed for the production of briquettes (mixture of zirconium oxide, petroleum coke and starch solution). Briquette production capacity of each pug mill is 200 kg/h. Hydraulic positive displacement briquetting machine was installed and commissioned with a capacity of 1000 kg/h for enhancing briquette production.

Hydraulic positive displacement briquetting machine

Installation of Solid Trap at Chlorination Section

Solid trap has been installed in Chlorination Section to trap uncondensed chlorides and particulate matter thereby improving the ventilation and reducing load on scrubbing units of off-gas treatment facility.

Solid Trap at Chlorination Section

Installation and commissioned of CCTV cameras

Installed and commissioned 27 No. of CCTV cameras with advanced features and 90 days storage capacity for improved security surveillance. Extended and implemented various digital office facilities such as Visitor Management System (VMS), Material Gate Pass Application etc.

Magnesium Recycling Technology Development and Demonstration Facility (MRTDDF)

MRTDDF is being set up at Zirconium Complex to convert magnesium chloride generated during the production of zirconium sponge into magnesium and chlorine.

Major civil and electrical works have been completed. EOT crane has been installed and commissioned. Purchase orders placed for electrolytic cell and vacuum ladle. Procurement activities of various equipments such as scrubbing systems and chlorine compressor are in progress.

Augmentation of production capacity

Augmentation of production capacity to 500TPA from existing 250TPA is planned by addition of few equipment without addition of major civil infrastructure to meet the projected future requirement. Proposal for capacity expansion has been approved by NFC Board and in-principle approval of competent authority has been obtained. Work order released for consultancy services for carrying out Environment Impact Assessment study and preparation of EIA /EMP report for obtaining statutory clearances for capacity expansion.

BACK END FUEL CYCLE

Fuel Reprocessing

A new Experimentation & Equipment Test Facility has been commissioned for performance testing of high diameter pulse columns for the upcoming high throughput reprocessing facilities. RTD studies were initiated with 30% TBP as organic phase and 0.01N nitric acid as aqueous phase by operating the 12" extraction column in organic continuous mode. The obtained results clearly demonstrated that the radial distribution of the liquid phase in the column was uniform at all three different axial locations in the Extraction Column, and no significant flow malfunction was observed. CFD analyses were also carried out with the trends shown by RTD studies.

Newly Commissioned Radiation Shielding Window of Integrated Nuclear Recycle plant (INRP) in Tarapur

A new Integrated Nuclear Recycle plant (INRP) is coming up in Tarapur for reprocessing of spent fuel of all classes of PHWRs operating in India (220MWe / 540 MWe / 700 MWe). The first-of-its-kind plant is equipped with the capacity to process 600 tons of heavy metal per annum. All major works at the plant are in advanced stages of implementation.

Waste Management

Around 50,000 litres of Uranium and Cesium lean stream of High Level Liquid Waste (HLLW) was subjected to TEHDGA cycle, for selective recovery of Sr-An rich product from various contaminants by utilizing in-cell mixer settler units and organic solvents prepared in-house. The Sr-An product generated during the operation cycle was further concentrated in waste concentration system to obtain an excellent volume reduction factor. Finally, only two vitrified waste product canisters were generated from the waste stream volume of 50,000 litres.

The In-cell Mixer Settler Unit of Waste Immobilisation Plant in Trombay

The treatment of legacy Intermediate Level Liquid Wastes (ILLW) was re-started soon after the completion of refurbishment of Pump House Ion-

Ion Exchange columns at PHIX System for treating of legacy Intermediate Level Liquid Waste

Exchange (PHIX) system in BARC. ILLW waste stream is characterized by high salt load and inactive Aluminium, which necessitate employing a highly selective separation process. After completion of testing and commissioning of automation based Ion Exchange process, processing of Legacy Declad ILW stored in Plutonium Plant had been resumed. Close to 500 m^3 of declad ILLW had been treated safely in this campaign thereby achieving a Volume Reduction Factor of 70 and overall DF of 1400.

Metallurgical waste, generated during value recovery of Special Nuclear Material from slag and crucible residue comprises high concentration of inactive salts and highly corrosive environment due to presence of fluoride ions and is acidic nature. A process scheme was developed and deployed for management of MWPF waste at the plant level. The process equipment and mixer settler system which regularly process HLLW was used for MWPF waste processing as well. Extensive decontamination of this mixer settler system was carried out to reduce the contamination level. A detailed downstream treatment methodology was also formulated to handle various inferring metal ions and achieve the ETP liquid transfer criterion. 6.6 cu.m. of raffinates from MWPF waste was successfully managed for the first time, through partitioning process of WIP Trombay. It has helped in separation of actinides and could demonstrate Decontamination Factor of 5000 for actinides. High alpha bearing stream could be managed and converted to low active dischargeable effluents by this process. This process could be implemented for processing of an additional volume of 10 cu.m. MWPF raffinates.

Effluent Conditioning and Transfer System for processing of MWPF laden waste

A novel Highly Performing Monoanionic Pyridinium (HPMP) resin was developed in BARC for selective recovery of technetium from intermediate level liquid waste in continuous mode. Overall radioactivity of the waste stream was found to have been reduced significantly by an order of 100 after interaction with the resin.

A cold crucible induction melter equipped with electric plenum heater for melter start-up operation was developed in BARC to demonstrate melting of Radiation Shielding Window (RSW) glass cullets. Activities involving installation of $MoSiO_2$ based plenum heater (36 kW) and electric power connection from main

RSW undergoing Melting and casting operation in BARC

supply; commissioning of Thyristor based power supply were completed. Maximum glass temperature of 950oC was achieved with the newly installed start-up heater. The system was controlled through PLC based controller. Further, experiments were done to establish the process parameters of RSW glass melting and casting. Nuclear Recycle Group, BARC has been pursuing a program for development of RSW glass production technology through in-house efforts. Under this, a BRNS funded project for "Synthesis characterization of intermediate densitis RSW glass" was initiated jointly with CGCRI Kolkata.

Refurbishment of Glass-based Radiation Shielding Windows (RSWs) was undertaken after completion of designated service life requirements. The exercise involving demonstration of dismantling of RSW was carried out successfully with an old inactive RSW with reduced visibility and rusted housing at the facility. Three Glass slabs, two flanges and MS housing have been dismantled safely. Mock trials using dummy loads were planned. Subsequent to this, assembly of RSW glass slabs in MS housing alongside quality testing of the refurbished RSW using laser based visible light transmittance measurement setup was also planned. RSWs are critical viewing aids in nuclear installations, which facilitate direct viewing of radioactive area with a high level of visual clarity.

Radiation Shielding Windows' Refurbishment Facility in BARC Trombay

New activities have been taken up for expanding the existing capacity at Radioactive Solid Waste Management Site (RSMS) in Trombay. Under this, new RCT trenches and tile holes have been

The fully refurbished laboratory facilities of Effluent Treatment Plant in Trombay

constructed. Extension of gantry girder-with-rail for 10/1 Ton crane in RSMS Zone-8 was carried out. Mobile covers were fabricated and installed above the Multi-Tier Radioactive Waste Disposal Facility. Additional LLT tanks are under advanced stages of fabrication to cater to an additional storage capacity of about 1000 m^3. The dedicated lab of the Effluent Treatment Plant was also refurbished during the year.

Magnesium potassium-based phosphate cement $MgKPO_4.6H_2O$ (MKP) is a promising matrix for immobilization of waste generated from nuclear fuel reprocessing activities. In order to assess the long-term performance of MKP based cementitious matrices under harsh service conditions, it is important to investigate the radiation effects on the material properties. The radiation effect of hydrated and dehydrated Magnesium Potassium Phosphate (MKP) materials using 10 MeV electron beam irradiation for doses ranging 10-20 MGy was studied under a program 'Ion Beam Irradiation for High Level Nuclear Waste Form Development, 2020-2024)', supported by the IAEA. The electron beam irradiation of the material was performed at the LINAC facility of Electron Beam Centre in Kharghar.

HEALTH, SAFETY AND ENVIRONMENT

At BARC, a compact table-top Personal Dosimetry System with high level of performance repeatability has been installed and commissioned in Radiological Physics and Advisory Division (RP&AD),

BARC for monitoring exposure to radioactive doses among the radiation personnel stationed across the country. The system is built around a 12 mega pixel digital camera and a distributed diffused LED illumination source mounted inside an enclosed imaging unit. The dosimetry software onboard host computer automatically detects and counts electro-chemically etched neutron tracks on the exposed detector foil. The track count extracted from the acquired detector image is converted into dose estimate through a carefully followed calibration process. The software is capable of size/shape based track filtering and resolving of touching/overlapping tracks.

TLD badge based on $CaSO_4$:Dy is used in India for monitoring exposure to X-rays, beta and gamma radiations in occupational personnel. Glow curve of TLD readout serves as an important tool for ascertaining genuineness of radiation exposure. However, Glow Curve (GC) shape is observed to vary due to influence of workplace conditions as well as factors involved in processing and handling of TLDs. The distortions in the shape of GC may lead to variations in the estimated dose.

An Artificial Intelligence (AI) based decision support system has been employed for monitoring exposure to various radiation sources among the occupational personnel. The system could effectively overcome potential distortions in glow curve (GC) of TLD readout to provide accurate/genuine exposure to X-rays, beta and gamma radiations in occupational personnel. The system was deployed in Personnel Monitoring Laboratory in BARC.

A charcoal cartridge standard was developed for the first time for calibration of Iodine monitors of Area Radiation Monitoring System (ARMS). A long-lived charcoal cartridge standard was developed for the first time and is being used for calibration of iodine monitors of ARMS system of Kudankulam Nuclear Power Project. Iodine is a radionuclide of high concern mainly because, in the event of nuclear accident, the released Iodine by virtue of being highly volatile is capable of causing serious danger to human life as it manifests itself in human thyroid mostly through inhalation and ingestion. Therefore, continuous monitoring of ^{131}I in the gaseous

Charcoal cartridge standards for calibration of Iodine monitors

form is an essential requirement for nuclear reactors and in isotope production facilities. Sampling of radioiodine is mostly done using activated charcoal cartridges, where ^{131}I is impregnated in the charcoal. Maintaining an ^{131}I standard similar to that of the sample for calibration of iodine monitors is challenging due to its short half-life of 8.02 days. For the preparation of charcoal cartridge standard, radioactive solutions of ^{133}Ba, ^{60}Co, ^{137}Cs were standardized by primary and secondary methods. The charcoal standard was prepared in a cartridge, which is used in the iodine monitor for sampling. The charcoal powder in the cartridge was spiked with mixed standard radioactive solution and the spiked charcoal was studied for homogeneity with HPGe, and was found to be within ± 1%, indicating good uniformity of the spiked charcoal powder.

A radiation map of India was prepared from countrywide survey data for Natural Background Radiation (NBR) dose-rate (cosmic and terrestrial components) collected by different measurements around the country by Health, Safety & Environment Group. 18957 sampling grids with more than 100,000 survey data in India were processed using Geographic Information System (GIS). More than 93% of the NBR dose-rate data was collected using GM-Tube based radiation monitors and the rest using Thermo-luminescent Dosimeters, handheld radiation survey-meters (GMT and NaI(Tl)-based) and vehicle-mounted NaI(Tl) detectors. The mean dose-rate (including terrestrial and cosmic component at 1 meter height) was found to be 112 ± 43 nSv/h, with a median value of 107 nSv/h. The geometric mean (GM) was 105 nSv/h with a Geometric Standard Deviation of 1.46.

A standalone e-mapping and geospatial information system which can be accessed through

secure LAN or Intranet connection by BARC users for all their scientific/strategic purposes was made available online. The e-mapping portal uses data fetched and digitized from publicly available sources like SOI, GSI, ISRO, NRSC, GOI Data portal etc. The portal is being developed using Free and Open-Source Software (FOSS) and the maps can be extensively customized as per user to cater to different research needs e.g. environmental, hydrological and remote sensing studies.

An instrument for simultaneous sampling of different forms of ^{3}H and ^{14}C in air has been developed in BARC. The instrument comprises single air sampling channel connected to a pump for sampling of air, 4 sampling units and one catalytic convertor cell. Sampled air is subjected to traps for HTO species by Peltier condensation technique followed by NaOH or Carbosorb traps for ^{14}C in the form of CO_2 and then fed to the catalytic convertor cell to convert HT and T_2 to HTO, and similarly, CO and CH_4 etc. to CO_2, which are further collected. The system is characterized by several advantages - better differential evaluation and distinction of inorganic and organic forms, use of low-cost Cu based catalyst in comparison to Pt and Pd which are typically used in imported systems.

Integrated Tritium and Radiocarbon Sampling System

For the removal of uranium from water resources, Sodalite was developed through modifying Coal Combustion Residue (CCR) by alkali fusion, followed hydrothermal crystallization method. Laboratory experiments were conducted on spiked water samples at various conditions such as solution pH, contact time, temperature and initial concentration etc. Results show that the modified material has appreciable sorption capacity for uranium at pH 6 and can be used for the removal of uranium from contaminated groundwater.

Safety being an integral part of Operation and Maintenance of HWPs/HWBFs, it is always accorded the highest priority. Annual Safety & Technical Audits of all units of HWB were carried out. Two interactive sessions of Safety, Operation and Maintenance Engineers were organized for knowledge sharing. Annual medical examination of all occupational workers was carried out for monitoring their health status. Periodic Safety Training was imparted. Special lectures were organised for enhancement of Safety Culture. Safety reviews of ongoing projects were carried out. Authorisation scheme was implemented to ensure that authorised manpower is always available for operation of plants. Major maintenance activities were carried out safely at HWP Kota, Thal & Tuticorin. It was ensured that all statutory documents are approved and are in place for use at sites. HWP Tuticorin bagged AERB's Industrial Safety and Fire Safety Awards for the year 2021.

RESEARCH & DEVELOPMENT

NPCIL is engaged in setting up of R&D Facilities and carrying out experimentation, development & qualification of remote tools for inspection/ maintenance of Nuclear Power Plant (NPP) components/ equipment, indigenization and adoption of state of the art technologies. These activities are aimed at achieving continual enhancement of nuclear & radiation safety, reliable operation, Vendor base broadening, product development and cost reduction of Nuclear Power Plants. For financial year 2022-23, major achievements/ progress achieved are as follows.

R&D Facilities

Initiative for Hydrogen Generation

Hydrogen policy has been approved by NPCIL Board for future entry into Hydrogen business, after evaluation of different technologies for Hydrogen production. Alkaline Water Electrolysis (AWE) & Proton Exchange Membrane (PEM) based technologies have been selected for setting up Hydrogen Generation Units (HGUs) for gaining operational experience. One HGU each using above technologies is being set up. Hydrogen produced at these HGUs will be used for in-house consumption. Commissioning of AWE based HGU at Tarapur NPP Site is nearing completion.

Primary Coolant Pump Test Facility (PCPTF)

PCPTF is being set up at R&D Centre, Tarapur for design qualification and performance evaluation of indigenously manufactured PCP for future 700 MW reactors. Various works are in progress.

PCP Test Facility Structural Building

Reliable Electrical Power Supply System (REPS)

REPS is being set up as an extension to TAPS#1&2 Switchyard for supplying enhanced capacity electrical power to the present installations of NPCIL and BARC at Tarapur as well as for upcoming facilities. This is being established under MoU between NPCIL and NRB, BARC.

50 MVA Transformers Erection in Progress

Calandria Tube Rolled Joint Qualification at 150 °C

As part of experimental verification of model analysis carried out about adequacy of the pressure relief openings provided in Calandria Vault of different reactors, a scaled down Calandria Vault Test Facility was fabricated. All planned experiments were conducted at different power levels and opening sizes simulating reactor conditions of 220 MW, 540 MW and 700 MW PHWRs.

Calandria Vault Test Facility

Hydrogen Recombiner Test Facility

A new design of Passive Catalytic Hydrogen Recombiner has been developed and performance tests are carried out.

Steam and Hydrogen Concentration Measurement Test Set up

Alternate Steam and Hydrogen Concentration Measurement System

Test set up is fabricated for demonstration of method for measurement of Hydrogen and steam concentration based on gas chromatography and thermodynamic variables. A number of experiments completed successfully and results are found satisfactory.

Fuelling Machine Test Facility (FMTF)

Functional testing of indigenously developed Proportional Flow Control Valves by two Vendors were completed successfully for use in newly designed Mobile Fuel Transfer Machine at 700 MW projects.

Proportional Flow Control Valves Testing in FMTF

Environmental Qualification (EQ) Activities

During 2022-23, major components tested include scaled down Motor of Shutdown Cooling Pump of different Vendors for KGS#1&2 and TAPS#1&2.

New LOCA Chamber Control Room

Remote Tooling

Coolant Channel Life Management Related Activities

As part of planned shutdown activities, In-Service Inspection (ISI) campaign of PHWR coolant Channel Pressure Tubes using BARCIS system was carried out successfully at 220 MW Operating Units viz. NAPS-1, RAPS-4, KGS-2 & 4, RAPS-2 and planned in Jan.-March-2023 for NAPS-2, TAPS-3. Modified Inspection Heads (IH) manufactured, calibrated with enhanced techniques and delivered to Sites.

Hatch Beam Opening Sealing System (HBOSS) for KAPS

The HBOSS assembly with remote manipulator and welding system was tested and qualified with a mock up at Kakrapar Site. Subsequently, the sealing system was used for closure of openings of Top Hatch Beams of KAPS-1 Calandria Vault and successfully completed.

HBOSS Welding Manipulator Being Lowered to Exact Location

Remotely Operated Delivery System

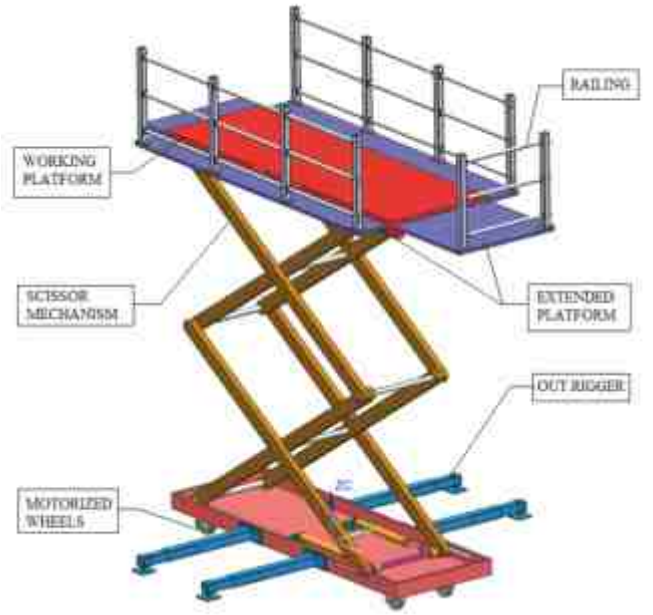
The Remotely Operated Delivery System (RODS) has been developed to enable remote inspection of the Moderator Heat Exchangers Tubes of

the 220 MW Nuclear Power Plant (NPP) in radiation environment. The system is ready for development at any PHWR site.

Scissor Lift Motorized Platform for Single Coolant Channel Replacement

Single coolant channel replacement activity is planned to be carried out for the first time in Indian NPP. Self-propelled semi-automatic elevating Scissor Lift Motorized (SLiM) Platform is being developed.

It can be aligned to required coolant channel with significant reduction in time and manpower required for the operation/ positioning of the platform.



Schematic of Scissor Lift Motorized (SLiM) Platform

Transportation Qualification of Garter Spring Shielding Flask

The Flask is qualified for safe transport of radioactive material. The design for immobilization arrangement of the Flask on trailer bed considering accelerations during transportation was successfully carried out and design for immobilization arrangement (tie down) is also qualified.

Indigenization

Indigenous development and Vendor base broadening for various critical components and equipment continued by NPCIL, in line with Atma Nirbhar Bharat. Adoption of the indigenous technologies developed in the recent past, is being done with commercialization for current and future 700 MW reactors.

Drive Motor of 700 MW Reactor Drive Mechanisms

The development of Drive motor is successful. All the tests on the motor were successful including those special tests like climatic test, degree of protection and 1000 hrs endurance test. The motor was proved to be a rugged one as it could withstand all the non-destructive and destructive tests without any deterioration in its performance.

Magnetic Brake & Motor

Boiler Feed Pumps for 700 MW Reactors

Indigenous development Boiler Feed Pump (BFP) for 700 MW reactors by second Vendor was

Indigenously Developed BFP at Vendor's Workshop

completed successfully. It had undergone various performance tests in the Test Loop.

Design & Manufacturing of Lead Shielding Flask for 700 MW Cobalt Adjuster Rods

Subsequent to design of full-scale lead Shielding Flask for removal of Cobalt Adjuster Rod (Co-AR) Assemblies after irradiation in the reactor core of 700 MW PHWR Units, manufacturing completed. Functional testing & radiometry of the Flask was carried out with full scale dummy Co-AR and handling tools at Suppliers premises. An evener beam was also made for safe & proper handling of the Flask.

Engineering

Design, Development, Analysis and Detailed Engineering for various projects and Design Support to all Operating Power Stations were continued.

KAPP-3&4

Regulatory clearance was obtained progressively for various modifications to overcome high temperature issues at KAPP-3. Design support was provided for first successful on-power refueling of KAPP-3 in fully auto mode with First of a Kind (FOAK) Fuel Transfer System.

TAPS-3&4

In order to get improved alignment feedback during clamping of Fuelling Machine to End Fitting, a non-contact type Laser based Tilt Measurement System was designed and developed. The prototype was manufactured & tested at Calibration and Maintenance Facility (CMF), TAPS-3&4 and test results were found satisfactory.

Wet Quarantining Plug (WQP) was designed in two parts to meet the requirements of coolant channel assembly. Detailed engineering, procurement and qualification testing of WQP was carried out.

Operating Stations

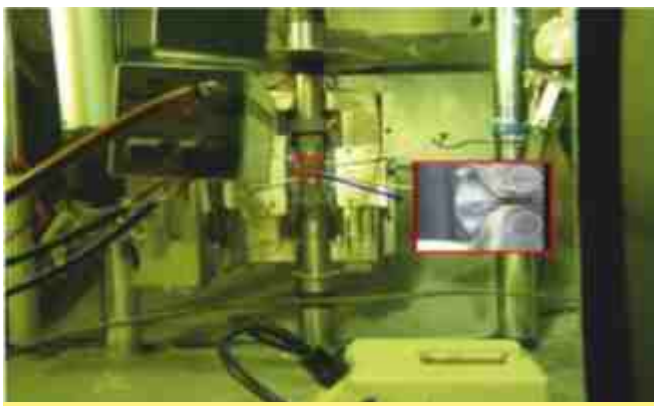
As part of planned shutdown activities, In-Service Inspection (ISI) campaign of PHWR coolant Channel Pressure Tubes using BARCIS system was carried out successfully at 220 MW and 540 MW Operating Units. Enhancement of inspection techniques for the same continued.

Qualification of Spent Fuel Storage Bays for Beyond Design Basis Earthquake and Extended SBO conditions for enhancement of fuel storage capacity for various stations were carried out.

Structural integrity assessment of Reactor Pressure Vessel for In-vessel corium retention-of TAPS-1&2 has been completed.

R&D relating to PHWR

Post Irradiation Examination (PIE) is important to evaluate the performance as well as to generate database on metallurgical aspects irradiated pressure tubes manufactured in-house. Detailed microstructural examination and hydrogen analysis of Pressure tubes from KAPS-1, RAPS-2 and MAPS-1 were examined inside the hot cells to evaluate their performance in terms of corrosion behaviour, hydrogen pick-up and hydride platelet distribution, which help in assessing the overall worthiness of the tubes after different irradiation levels. Fracture toughness and Delayed Hydride Crack (DHC) growth velocity was found out at different temperatures. All pressure tubes showed a good value of fracture toughness, thereby meeting the required margins for safe operation of PHWRs. Mechanical properties of current generation pressure tubes fabricated from quadruple melted ingot are quite superior to the pressure tubes of previous generation made using double melted ingot.



Testing of irradiated pressure tube specimen inside the Lead Cell for evaluating its fracture toughness

PIE of fuel bundles was carried out inside the hot cells using various non-destructive and destructive techniques. The effect of transient heating on the transverse tensile properties of irradiated clad was studied. Gamma scanning of fuel elements indicated burn-up profile along expected lines. Non-destructive tests performed on fuel elements did not show any evidence of failure of clad.

Under the evaluation of mechanical properties of irradiated calandria tube of PHWR, fracture toughness of irradiated calandria tube material was found to be satisfactory even after 15 years of operation. Calandria tube material has shown expected irradiation behaviour and acceptable operating experience.

Tensile, impact and fracture toughness tests were carried out on RPV specimen of Kudankulam Nuclear Power Plant to ascertain various properties, including tensile strength and critical brittle temperature, which are responsible for ensuring safe operation of the reactors.

Understanding the phenomenon of Delayed Hydride Cracking (DHC) in Pressure Tube (PT) is critical to assessing the safety aspects of Nuclear Reactors. The exercise of determining KIH, which is associated with DHC in radial direction of the PT, was undertaken by using an experimental setup which employs 4-point bend geometry to ascertain the orientation of crack growth.

The Pressure Tubes of Indian PHWRs are made of Zr-2.5Nb alloy and are the main structural components which act as the pressure boundary for the High-Temperature and High-Pressure (HTHP) coolant. Currently, the final step of PT fabrication involves autoclaving in steam at 400°C, which forms a shiny, black, protective oxide layer of thickness ~ 1m on all the PT surfaces. The surface oxide restricts hydrogen pick-up by the PTs during reactor service and it is widely established that high hydrogen pick-up can potentially lead to PT failures. However, steam oxidation may also lead to some hydrogen pick-up prior to service, since hydrogen formation is a by-product of oxidation. The feasibility of forming an oxide in air, instead of steam in the final step of PT fabrication has been explored, as a means to restrict hydrogen pick-up prior to service. Oxides of similar thickness were formed in air and in steam at 400°C on as-fabricated bare Zr-2.5Nb PT specimen. The oxidation kinetics of oxides so formed by two different methods were evaluated in HTHP steam for 85 days. The PT with air-formed oxide showed similar long-term oxidation and hydrogen pick-up behaviour in HTHP steam. The outer surfaces of the PTs in PHWRs were exposed to carbon dioxide containing small quantities of oxygen. Therefore, the nodular corrosion behaviour of the PT in this environment, containing small quantities of hydrochloric acid as a contaminant (to accelerate nodular corrosion tendency) was also studied. The PT with an air-formed oxide showed a higher resistance to nodular corrosion in gas phase, compared to the steam-formed oxide as indicated by significantly smaller nodules formed. The study confirmed that an air-grown oxide film in the final step of pressure tube fabrication as opposed to the existing autoclaving renders the following advantages without compromising on the long-term oxidation and hydrogen pick up during service in reactor - a lower H content in the PT prior to service and - a higher resistance to nodular corrosion in the CO_2 and O_2 gas mixture.

Studies on irradiated surveillance coupons of MAPS-1 end shield material

Tensile testing of miniaturized specimens (3.0 mm gage length, 1.5 mm gage width and 1.0 mm thickness) of the irradiated end shield material extracted from the un-deformed portions of the Charpy tested specimen was carried out at IGCAR. It was observed that the tensile strength of the irradiated material has increased to 1.5 times that of unirradiated material due to neutron irradiation and the ductility in terms of uniform elongation has decreased to half the value of that of unirradiated material. Recovery of toughness and ductility of the irradiated material was studied by performing annealing treatments using the specimens extracted from un-deformed portions of the Charpy tested specimens. Annealing at 300°C for 70h resulted in a reduction of irradiation induced hardening by 80%, while ductility was recovered to nearly that of unirradiated material.

Characterization of Calibration Notches in Reference Pressure Tube and Roll Joint Pressure Tube Spools of different PHWRs using Ultrasonic and Replica Techniques

In response to a requirement from Expert Group on Coolant Channel (EGCC) of AERB, measurement of dimensions of calibration notches in the reference tubes used for setting sensitivity for inspection of coolant channels of Indian PHWRs using BARC Channel Inspection System (BARCIS) was undertaken. Immersion ultrasonic imaging and replica-based methodologies have been developed and implemented successfully for dimensional measurements of calibration notches used in reference Pressure Tube (PT) and Roll Joint Pressure Tube (RJPT) spools used in different Indian PHWRs viz. RAPS, KAPS, MAPS, TAPS and at Kaiga with a resolution of about ±2 ㎛. The depths measured by the two techniques are found to be in good agreement with the nominal values (66 μm and 150 μm for notc notches in PT spools and RJPT spools, respectively) for most of the reference notches.

R&D relating to LWR

Indigenous in-core high-sensitivity Helium-3 proportional counters have been developed for applications in LWR fuel loading. The detector with 19mm diameter & 350mm length offers neutron sensitivity of ~ 10 cps/nv. The detector offers improved counting statistics and reduced uncertainties during operations involving fuel loading, criticality and reactor start-up.

High sensitivity Helium-3 proportional counter for fuel loading in LWR

CHAPTER 2

Containment Box (CB)

NUCLEAR POWER PROGRAMME STAGE-II

Helium Leak Tight Flange

FAST REACTORS

The second stage of the nuclear power generation programme is geared towards setting up of fast breeder reactors. These reactors produce more fuel than what they consume. The DAE organisations that are involved in the implementation of the Fast Reactor Programme are the Indira Gandhi Centre for Atomic Research (IGCAR), Bhartiya Nabhikiya Vidyut Nigam Ltd. (Bhavini) and Bhabha Atomic Research Centre (BARC).

IGCAR is engaged in the design and development of liquid sodium cooled fast breeder reactors, with associated fuel cycle technologies. This programme is supported by a strong research and development endeavour of IGCAR in disciplines such as reactor engineering chemistry, metallurgy, material science safety and instrumentation.

BHAVINI, a public sector company of DAE, was incorporated on 22nd October, 2003 at Chennai, Tamil Nadu, as a Special Purpose Vehicle, for implementing India's first prototype 500 MW Fast Breeder Reactor project.

BARC contributes towards the research and development of fuels for fast reactors, technology for reprocessing of fuel elements, waste management and health and safety of the work force.

NFC is entrusted with the responsibility of fabrication of core subassemblies for Fast Breeder Test Reactor (FBTR) and 500 MWe Prototype Fast Breeder Reactor (PFBR).

Fast Breeder Test Reactor (FBTR)

Fast Breeder Test Reactor (FBTR), the flagship of IGCAR is continuing its objectives as a test bed for irradiation of fuel & structural materials in fast neutron flux and a training hub for fast reactor operators. In the 37 years of operation so far, 30 irradiation campaigns have been successfully completed and 31st campaign is in progress.

In 2022, for raising the reactor power to rated power of 40MWt, preparatory works viz., normalization of 3 blanked tubes in each of the four SG modules, refurbishing of the main cooling tower and introduction of new reactor trip parameter based on high reactor inlet temperature were completed. The MOX & MARK-II fuels were removed from FBTR Core and the core was modified with addition of four poison subassemblies (B10 enriched to 50%) to overcome the reduction of shutdown margin (SDM). Introduction of poison subassemblies also helped in flattening the neutron flux in the core, thereby increasing the thermal power from core peripheral fuel subassemblies. The 40MWt core consists of 69 MK-I fuel subassemblies, one special experimental fuel subassembly (IFZ100) in center location for high dose irradiation, two special steel subassemblies in first ring for test irradiation of metal fuel pins and four poison subassemblies in the second ring. The core also contains special steel SA containing yttria capsule for production of Strontium-89 and few special steel subassemblies for material irradiation in the core periphery. With the modified core configuration, FBTR power was raised to 40 MWt on 7th March 2022 for the first time in the 30th irradiation campaign and operated for 45 Effective Full Power Days (EFPD). Turbo Generator was in operation throughout the campaign producing ~10 MWe. 30th Irradiation campaign was completed on 7th May 2022. After obtaining regulatory clearance, the 31st irradiation campaign was commenced and reactor is operating at 40 MWt presently with Turbo Generator connected to grid and expected to complete cumulative campaign duration of 100 days during this year end. It is planned to commence 32nd irradiation campaign in the beginning of year 2023 after carrying out mandatory surveillance tests and maintenance works.

The present license for operation of FBTR ends in June 2023. In order to renew the license and to continue the operation of reactor for next ten years, the periodic safety review report is being prepared considering the cumulative ageing, modifications, operating experience and technical developments and will be submitted to regulatory body by this year end for review. The life of FBTR is governed by the life of grid plate which supports the core subassemblies. Considering limiting operation to 10% residual ductility and earlier lower temperature phase of operation, it is

inferred that FBTR grid plate can withstand a dose level of 6.3 dpa. In order to reduce the flux seen by grid plate and thereby enhancing the life FBTR, the FBTR fuel subassemblies will be fabricated with tungsten carbide as axial shield instead of the present steel rods. It is expected that with this change, FBTR life can be further extended by 2 more years, (i.e.) up to 2032.

Quality assurance and inspection activities pertaining to fabrication of 4 nos of SG Water subheader was completed for FBTR and heat treatment procedures were developed. 11 nos of CS end caps were qualified after obtaining satisfactory results from visual, dimensional examinations, chemical tests, sub-size tensile tests, hardness tests, LPE on both inside & outside surfaces, and Ultrasonic tests. Components are ensured for integrity tests as per design and validated for erection and installation.

Prototype Fast Breeder Reactor

Government of India accorded administrative approval and financial sanction for setting up of 500 MWe Prototype Fast Breeder Reactor (PFBR) at Kalpakkam, in September, 2003. Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI), a Government Company was established on 22nd October 2003 at Chennai, Tamil Nadu, as a Special Purpose Vehicle, for implementing the India's first Prototype Fast Breeder Reactor (PFBR) project.

The major activities that have been completed during the reporting period and the plan ahead for the current financial year are mentioned below.

Reactor Containment Building Integrated Leak Rate Test using Super imposition method was carried out and integrity of containment structure was demonstrated.

As a part of Fuel Handling commissioning activities, manual entry was made into the hot pool to carryout visual inspection during Transfer Arm operation to ensure that all design intends are met and also to inspect other core handling components. During the trial operations of lifting the selected Dummy Sub-Assemblies (DSA) with Transfer Arm from the Grid Plate sleeve, few DSAs experienced higher extraction force.

Scoring marks were observed on the hexagonal surface of the DSAs and on the Grid plate Sleeves. Root cause analysis was carried out and recommended that few modifications have to be carried out in DSAs. This necessitated discharging of all 731 DSAs from the pile, carrying out sharp edge correction & guide machining of DSAs out of pile, buffing & cleaning of Grid plate sleeve & loading back the DSAs on pile. Work stations were established inside Reactor Containment Building for taking up correction works of Subassemblies.

Based on the clearance given by regulatory authorities, required no. of Subassemblies (SA) was discharged from the core for creating the pocket for carrying out the DSA and Grid Plate sleeve rectification jobs. Subsequently, Grid Plate sleeve buffing, cleaning, boroscope inspection of buffed sleeves, dummy foot gauge checking and Foreign Material Exclusion accounting were carried out at the sleeve locations.

Guide machining and sharp edge correction for the all the 731 DSAs were done at the work stations and were reloaded back in respective core positions after carrying out internal cleaning of DSAs with compressed air.

On establishing procedure for cleaning the grid plate top at permanent Sub-Assembly locations, all the 1806 locations corresponding to the gaps formed between each of the three permanent Sub–assemblies were cleaned. All the above activities required meticulous planning and this job was executed in round the clock shift basis.

Trial handling of selected DSAs after modification was attempted and it was observed that the gripper hoist load was increasing gradually and after certain operations it crossed the load limit. Visual inspection of Transfer Arm revealed scratch marks on the outer tube. Hence, Transfer Arm was removed from block pile for replacement of outer tube and shielding sleeve.

Towards boxing up of Main Vessel prior to purging/preheating, box-up committee has visited the hot pool and cleared for boxing up. However, the committee has observed a white coloured foreign material in the cold pool region. Personnel entry was

made to cold pool and sample was collected, analysed and confirmed to be sodium. Leak source was preliminarily identified to be from the top window of IHX-1 (NE) and flown to cold pool through the outlet window to the outer periphery of Core Support Structure and on the Main Vessel cooling pipe. Initial investigations of accessible areas of remaining three IHXs did not reveal any leak. Preparatory works are under progress for replacing the leaky IHX with a spare IHX.

Refurbishment works on all nine Control Safety Rod Drive Mechanism (CSRDM) which includes greasing of gripper screw nut mechanism, replacement of existing locking cap with modified locking cap and installation of modified Digital Oil Level Measurement Sensor (DOLMS) on upper part of CSRDM were completed.

Multipurpose flask assembly demonstration after integration with airlock, VAT valve and retaining shell over Observation port location was completed.

High temperature testing (~120 deg C) of In-Service Inspection (DISHA) vehicle with all Ultrasonic Examination & Eddy Current Testing probes and qualification of Anti-convection barrier plug handling at Site Assembly Shop has been completed. With respect to on-pile demonstration of ISI vehicle (DISHA), the vehicle (DISHA) was deployed in the interspace region between Safety Vessel & Main Vessel in one of the six ISI openings and vehicle was moved in the clockwise and counter clockwise direction. Auto scanning for Eddy Current Test & Ultrasonic Test was carried out on the dissimilar weld joint in the roof slab.

Application for regulatory consent for sodium filling in Main Vessel was submitted to Atomic Energy Regulatory Board.

The activities that are planned to be completed for the remaining period of this financial year i.e. from January 2023 to March 2023; includes Replacement of leaky Intermediate Heat Exchanger (IHX) with spare IHX; Preparatory works for purging & preheating of Main Vessel prior to Sodium filling and Purging of Main Vessel with nitrogen and integrated preheating.

Presently, leaky Intermediate Heat Exchanger (IHX) is being replaced with spare IHX prior to boxing up of Main vessel. After replacement of IHX, pre-heating of reactor assembly will be done towards commencement of sodium filling in Main Vessel. This will be followed by isothermal testing and fuel loading towards first approach to criticality.

Towards 2nd Core requirements, the items manufactured and supplied by NFC included 8,319 Fuel clad (D9) tubes (crimped with middle plug), 3,000 Bead formed spacer wires and 6,500 springs were supplied to AFFF, BARC, Tarapur for fabrication of MOX fuel pins; In-house fabrication of 14 No's of Upper Parts of PFBR Fuel Sub-assemblies and 14 PFBR Fuel Sub-assemblies were manufactured at IFSB, IGCAR, Kalpakkam.

R&D relating to PFBR

Studies related to PFBR

Performance Testing of Decay Heat Exchanger Type-B in SAADHANA Facility

The Safety Grade Decay Heat Removal (SGDHR) System consists of four independent natural circulation sodium loops with one sodium-sodium heat exchanger (DHX), one sodium-air heat exchanger (AHX) and connected piping. Diverse designs are provided in both the heat exchanger types. Earlier qualification tests were done for DHX type-A and presently the same was repeated for DHX Type-B. A common AHX type-A is used in both the above tests. Heat removal capacity was verified for sodium pool temperatures varying from 350°C to 547°C. The stability of the SGDHR system without flow reversal ans oscillation was also established.

Regeneration Experiment to Optimise Cold Trap Parameters

A series of experiments have been performed to establish the methodology of regeneration of cold traps in the secondary sodium loops. Following three campaign of experiments done earlier, a fourth campaign regeneration experiment was carried out in a model cold trap in Steam generator test facility. Sutained

release of hydrogen was realised by controlled heating, reduced sodium level and maintaining uniform axial temperature across the sodium column. The recommended process for in-situ regeneration of cold trap of PFBR was arrived at.

Deployment of DISHA in one ISI opening in PFBR

DISHA is the In-service inspection vehicle used for visual and volumetric inspection of the dissimilar weld between main vessel and roof slab. After qualification of DISHA in the high temperature mock-up specially built for that purpose, the vehicle was deployed in one of the six openings in PFBR. Before deployment of DISHA, the anti-convection barrier plug was also remotely deployed using a special gripper. Satisfactory movement of the vehicle was demonstrated over a travel length of 2.9 m. Both visual and volumetric inspection data of dissimilar metal weld could be acquired successfully at room temperature.

DISHA deployed in PFBR

Fast Reactor Safety Studies

Sodium leak simulation experiments were conducted to demonstrate availability of adequate design margin in roof slab of PFBR. Magnesia based core catcher protection material has been developed for sodium cooled fast reactors. Severe accident simulation experiments were carried-out to investigate Molten Fuel Interaction with sodium. The melt fragmentation mechanism was studied using X-ray radiography.

Methane injection experiments in sodium of engineering scale sodium loop (SOWART)

Hydrocarbon based lubricant oil is used as the coolant of the shaft of operating centrifugal pump in large sodium loop. Lubricant oil will come in contact with sodium in the event of the sealant failure. Hydrocarbon lubricant oil is expected to crack in hot sodium producing carbon, methane, hydrogen and other hydrocarbon gases. In order to simulate this event methane gas was injected into liquid sodium in SOWART (Sodium Water Reaction Test Facility) loop. This facility has both in-sodium hydrogen sensors namely Electro Chemical Hydrogen Meter (ECHM) and Sputter Ion Pump (SIP) based sensor, and hydrogen-in-argon sensor namely Thermal Conductivity Detector (TCD) and tin oxide sensors.

The responses of both in-sodium and cover gas hydrogen sensors is shown below. The response of the in-sodium hydrogen sensors namely ECHM and SIP were negligible towards hydrogen. Hydrogen sensors installed in the cover gas section showed good response for hydrogen. Sample gas from the cover gas section was collected and analysed by Gas chromatography-Mass Spectrometry. The analysis showed the presence of large amount of methane gas in the cover gas section. The study revealed that the in-sodium sensors like ECHM and SIP may not be able to detect the methane evolved during the decomposition of lubricant oil that leaks in sodium.

Structural Dynamic Studies

Seismic Qualification Tests on Distributed Digital Control System (DDCS) Components

Seismic qualification tests have been carried out for DDCS server and Data Exchange & Procession Unit (DEPU) housed individually in cabinets. Tests were done on 100T shake table. Loading equivalent to five OBE and one SSE cycle was simulated. The above components were found to qualify seismic category-1 requirements.

Cabinet mounted on Shake Table

Spatial Variation of ground motion for large raft structure at Kalpakkam

Flexible and long structures, like raft foundation of nuclear power plants, which have characteristic length comparable to or longer than the wavelengths of the strong ground motion selected for design, are sensitive also to the differential motion of their supports, and require time histories of ground motion specified at an array of closely spaced points. The wave-passage effect accounts for the time lag of seismic excitation, i.e. the time needed for the wave to travel from one support to another. The wave attenuation effect accounts for the gradual decay of seismic wave amplitudes due to the geometric spreading and energy dissipation on the ground medium. The loss of coherency occurs due to the reflection and refraction of seismic waves in heterogeneous soil medium, and the superposition of waves coming from the seismic source. Coherency functions for the IGCAR site are developed. Uncertainties in the slip model are also considered. The coherency is observed to be a function of frequency and lagged distance. Here, absolute value of coherency is found to reduce as lag distance increases (>50m) and is having comparatively higher value at lower frequencies (<0.8Hz). The phase spectrum of coherency function is observed to be randomly distributed; also, the variation is increasing with frequency. Coherency function model is developed for the study region with functional. The coherency function developed from the study can be used in the generation of hazard consistent spectrum compatible acceleration time histories incorporating spatial variability.

Technology & Prototype Development

Design & development of SHAKTI IP core based CPU card for embedded systems

Nuclear power plants are designed to operate for around 60 years whereas the electronic components used in Computer Based Systems (CBS) become obsolete in 10 to 15 years. The obsolescence of processor used in CBS creates demand not only on the hardware but also on the software used in the system. The entire software toolchain needs to be changed and the software is to be programmed in a new platform. To overcome processor obsolescence, open source RISC V instruction set architecture based SHAKTI soft core processor developed by IIT-M, Chennai is considered for CBS of Fast Breeder Reactors (FBR). SHAKTI IP Core based CPU card was designed and developed to act as a replacement for the existing Motorola based ED-20 CPU card used in CBS of PFBR. Safety applications were ported into the SHAKTI CPU card and tested at IGCAR. The SHAKTI based CPU card was evaluated against the ED-20 CPU card and the results were satisfactory. A procedure for porting existing PFBR I&C

SHAKTI CPU Card

system applications onto the SHAKTI CPU card is formulated and standardized. A Data acquisition system based on the SHAKTI CPU card is developed and deployed in an electrical substation. The system is running continuously and the performance of the system is observed to be satisfactory.

Sodium Testing of Dismountable type Ultrasonic Transducer

Dismountable type ultrasonic transducers have been developed to facilitate in-situ replacement of the transducer in the Under sodium ultrasonic scanner. The scanner is used in fast breeder reactors to give clearance for fuel handling prior to the rotation of rotatable plugs after a rector operational campaign. Sodium testing of the transducers were carried out in the temperature range of 120-225°C. Subsequently, testing of the transducers at 225°C for one week duration was carried to check the integrity under sustained exposure. The developed transducers were found to meet the qualification requirements.

Dismountable type UT Assembly

Bellows after removal from Test Setup

Qualification of Inconel-625H Bellows for Sodium service valves

Bellows sealed globe valves are used in sodium service with bellows provided for primary sealing purpose. A graphite gland packing is provided as secondary seal. Inconel-625H bellows are proposed in place of SS-316Ti due to their superior resistance to stress corrosion cracking and knife line attack. Inconel-625H bellows suitable for 50Nb valve were cycle life tested in sodium at 525°C and were successfully qualified for the valve application.

Sensor development

Indium Tin Oxide thin-film as Sensor cum Heater Material

Chemical sensors find their use in various areas not only in the areas of the public domain like agriculture, automobiles, pharmaceuticals, explosive detection but also in more-oriented applications in the programs of nuclear and space. In particular, monitoring any steam leak into the sodium systems of fast breeder reactors made use of semiconducting metal oxide sensors to detect at their inception. Also, chemical gas sensors find their place at the back end of the fuel cycle to monitor the levels of hazardous gases released during the process. Semiconducting metal oxides work at higher temperatures and require a rear-side platinum heater for their operation. Indium Tin Oxide (ITO) is a solid solution of tin oxide in Indium oxide and is known for its usage as a conducting electrode for decades. The base oxides of indium and tin are n-type semi-conducting oxides and are also well-studied for their gas-sensing applications.

The possibility of integrating the functions of the sensing element and the heater by tapping the potential of ITO was explored in the current study. Thin films of ITO were deposited by pulsed laser deposition and the temperature and tested towards sensing hydrogen. A typical response toward 130 ppm of hydrogen is shown below. This gives a good insight into the development of self-heating sensor films.

Material Development

Post Irradiation Examinations (PIE) on FBTR mixed carbide fuel sub-assembly discharged after 105 GWd/t burn-up

The burn-up limit, estimated by thermo-mechanical modelling, for the fuel sub-assemblies irradiated at peak Linear Heat Rating (LHR) of 400W/cm and inlet/outlet temperature of 380/510°C from beginning of life is approximately 103 GWd/t . The PIE of one such sub-assembly was taken up to explore the feasibility of extending the burn-up beyond this value.

Non-Destructive Examinations (NDE) such as dimensional measurements of wrapper & fuel pins, X-ray & neutron imaging, eddy current inspection and gamma spectrometry of a set of representative pins extracted from the sub-assembly have been completed. Eddy current inspection carried out using a circumferential and segmented probe confirmed that the fuel pins are remaining intact. The peak variations in diameter and axial strain exhibited by fuel pins are in the range of 2-4% and 0.2-1% respectively. The maximum axial fuel swelling observed from X-ray & neutron imaging and gamma scanning was ~4%. The swelling strains in the SS316 cladding/wrapper and fuel of this sub-assembly were found to be significantly higher than that observed for a carbide sub-assembly irradiated to the same burn-up at 320W/cm LHR. Based on the results of non-destructive examinations five fuel pins were selected for destructive examinations. The evaluation of swelling and microstructure of fuel and clad, fission gas release, mechanical properties of clad tube, using these pins are progressing. The outcome of the PIE campaign will help the designers to determine the burn-up to which the sub-assemblies can be safely irradiated at high LHR of 400 W/cm and higher inlet sodium temperature of 380°C.

Micro-analytical Characterization of irradiated fuels using Scanning Electron Microscopy

A customised electron microscopy facility with glove box interface has been commissioned for the examination of irradiated fuels. This facility has enabled fuel micro-structural studies at very high magnifications with compositional details. Examinations of irradiated Mixed Oxide (MOX) fuel of PFBR compositio and metallic fuel (Nat.U-6Zr) have been carried out using the facility. Redistribution and segregation of fission products and fuel constituent elements within the fuel matrix studied using X-ray microanalysis is providing information to assess fuel design and improve safety margins.

Corrosion and Tensile Properties of AISI Type 316L(N) stainless steel and modified 9Cr-1Mo steel – 50,000 h on Long term Sodium Exposure

AISI Type 316LN Stainless Steel (SS) and modified 9Cr-1Mo steel (P91) used in the intermediate heat exchanger and steam generator assembly, respectively, of the Prototype Fast Breeder Reactor were subjected to long-term sodium exposure for 50000 h in a BI-Metallic (BIM) loop, and micro-chemical & mechanical properties were evaluated. Type 316LN SS on prolonged sodium exposure for 50000 h caused selective leaching of alloying elements (depletion of Cr, Ni, and Mo), Fe enrichment, and the ferrite layer's subsequent formation. The sodium exposed P91 steel, on the other hand, showed no significant changes in microstructure, micro-chemical and tensile properties after sodium exposure for 50000h. The carbon depth profiles using Secondary Ion Mass Spectrometry (SIMS) on sodium exposed type 316LN SS, and P91 steel showed a surface carbon concentration of 0.85 and 0.32 wt.%, respectively. These studies show that type 316LN SS exhibits carburized zones with increased hardness at the surface (272 HV), and a reduction in ductility by nearly 40%.

Role of short-term ageing on thermal creep behaviour of Alloy D9I SS

As short-term thermal exposure of Sodium-cooled Fast Reactor (SFR) clad tubes to high temperatures is inevitable during service, it is proposed to examine the effect of short-term thermal ageing (40 hours, 973 K) on thermal creep of 20% CW D9I SS at 973 K in the stress range of 150-250 MPa. The studies indicated a beneficial effect of short-term ageing on creep life during long creep exposure.

Cold work effects on tensile properties of high nitrogen steel

Tensile properties of high nitrogen 316LN SS with 0.12 wt.% N subjected to prior cold work of 5% and 15% were investigated, wherein dynamic strain ageing resulted in a lowering of ductility at 523 to 873 K. Though strength is enhanced with higher prior cold work level, microstructural recovery in the form of dynamic recrystallization is prominent at temperatures above 873 K.

Thermophysical Properties of Natural Boron Carbide and Effect of 10B Enrichment

Around 90% enriched B_4C ($90EB_4C$) and 50% enriched B4C ($50EB_4C$) have been proposed for absorber and poison rod applications in FBTR respectively. Thermophysical properties of indigenously prepared hot pressed natural B_4C (NB4C), $90EB_4C$ and $50EB_4C$ have been estimated as a function of temperature following appropriate ASTM standards, to qualify these materials for reactor operating conditions. Isobaric heat capacity (Cp), CTE (Amean), thermal diffusivity (a) and thermal conductivity (k) of NB4C, $90EB_4C$ and $50EB_4C$ have been measured in the temperature range from 20 to 900°C. A systematic change in Cp and Amean has been observed for B_4C as a function of ^{10}B enrichment. However, the thermal conductivity for NB_4C is intermediate between $90EB_4C$ and $50EB_4C$ for the entire temperature range.

Wear Characterization of polymeric material used in PFBR ISI equipment

Fluoroelastomers, abbreviated as 'FKM', are presently used as a wheel material for in-service inspection vehicle in PFBR. As a part of the efforts of improve the functionality, alternate materials such as 'Polyamide-Imide (PAI)' which are thermosetting/ thermoplastic amorphous polymers are being considered from the viewpoint of enhanced mechanical properties. In order to establish the suitability of PAI as a wheel material, and to identify suitable grades thereof, two grades of PAI were subjected to wear characterization. These two grades, designated 4203 and 7000, were subjected to pin-on-disk tribological experiments at room temperature. These tribological experiments simulated the sliding wear between the wheel and vessel material. The coefficient of friction of PAI 4203 (vs SS 304L) was found to be higher (0.3-0.7) compared to PAI 7000 (vs SS 304L), which was 0.1 to 0.2. The lower wear rate of PAI 7000, relative to PAI 4203 was found to correlate with the difference in hardness, with PAI 7000 being harder than PAI 4203.

Mechanical Properties and Microstructural Characterization of Aged and Repair Welded Alloy 617

Weld joints of Alloy 617 tube were fabricated by multi-pass manual TIG welding process using ERNICrCoMo-1 welding wire. Service exposure was simulated in base metal and welded tubes by ageing heat treatment at 700°C and 750°C for 1000h and 4000h. The yield and tensile strengths of base and as-welded tubes increased by ~20-30% after ageing treatments, while the impact energy from Charpy V notch tests showed a reduction of ~60% post ageing. Extensive carbide precipitation along the grain boundaries and Γ'-Ni3(Al, Ti) within the grains were observed in the aged base and weld metals. Repair of partially penetrated weld joints were carried out and these tubes on ageing showed presence of intergranular micro-fissures in the heat affected zone (HAZ). However, a solution annealing heat treatment at 1160°C for 1h to aged Alloy 617M before repair welding was found to produce a sound weld that qualified the liquid penetrant test, radiography and cross weld tensile test as per ASME Section IX. The dissolution of precipitates formed during high temperature solution annealing restored the ductility and toughness. The present study revealed that solution annealing heat treatment of service exposed material prior to repair welding minimizes risk of intergranular fracture and resulted in repair welds of acceptable quality and required properties.

Hot deformability studies of additively manufactured metallic alloys

The amenability of additively manufactured alloy 625 to deformation processing has been studied and compared with cast alloy 625. The AM alloy was produced by Direct Energy Deposition (DED) at RRCAT,

Indore, wherein a high-energy laser beam and alloy powder was simultaneously delivered onto metallic substrate in inert argon atmosphere. The alloy powder was melted and deposited on the substrate in a sequential layer-by-layer fashion. The reference cast material was manufactured by vacuum induction melting of the alloy followed by casting in a sand mould. Uniaxial compression tests were carried out on both the materials at temperatures of 750°C ('warm working' temperature) and 1050°C ('hot working' temperature) to study the deformation behaviour from the true stress-true strain curves. At the warm working temperature of 750°C, the AM alloy exhibited significantly higher strength than the cast alloy, while at 1050°C, both materials show similar flow behaviour. The fine dendritic microstructure of the AM alloy compared to the coarse microstructure of the cast alloy, contributes to the strength by boundary strengthening. However, at higher temperatures of 1050°C, these microstructural differences are nullified, conferring the AM alloys ductility similar to cast alloy. Further studies are being carried out to understand the extent of anisotropy in deformation response of AM alloys, so as to establish optimal processing routes.

Microstructural evolution in equiatomic CrFeMoV alloy during high temperature exposure

The concept of multi principal elemental alloy design allows the possibility to investigate the unexplored central region of multicomponent alloy phase space, which is a radical departure from conventional theories, opening up new avenues of alloy design to be explored in depth. The novel properties of HEAs are promising for many advanced industrial applications. Microstructural evolution of equiatomic CrFeMoV alloy during prolonged thermal exposure in the temperature range of 673-1773K has been studied. The dendritic microstructure of the as cast alloy is retained up to 1573K, while an equiaxed microstructure results on annealing at 1773K. Detailed microstructural analysis of the heat treated alloy, showed that the bcc structure of the Mo rich dendrites is retained till 1573K, while the Fe rich interdendrites with bcc structure showed a series of microstructural changes with increase in temperature from nucleation of coherent Fe-V type tetragonal Σ phase at 773K, along with Fe-Mo type of tetragonal Σ phase till 1073K, to complete transformation from bcc to Fe-Mo type Σ phase at 1273K, with a slight coarsening of V-rich precipitates and finally the dissolution of Σ phases with increase in annealing temperature to 1573K. These microstructural changes were attested by XRD patterns, and microchemistry of phases. The experimentally observed phase evolution with annealing temperature is understood based on theoretical predictions from CALPHAD based thermodynamic simulations. Since the major elemental segregation in the Σ phases predominantly involves Fe, Mo and V, the alloy system has been considered as a ternary system of (Fe, Mo, V) and isothermal sections of ternary phase diagrams have been simulated through Thermocalc software at different temperatures from 773 to 1773 K, At 773 K, Σ phase formation on (Fe-V) side of the phase diagram is evident. As the temperature increases up to 1573 K, the Σ phase field shifts from (Fe-V) to (Fe-Mo) side, while V-Mo remains as solid solution in all cases. At 1773 K, dissolution of all the Σ phases take place, resulting in a single solid solution BCC phase.

Infrastructure Development

Facility for development of remote inspection devices for FBRs

Facility to accommodate devices a) RHIDS (Remote Handling & ISI Devices Section) & b) SGIDS (Steam Generator Inspection Devices Section) was proposed. Both involve robust engineering systems for In-Service Inspection (ISI) systems and remote handling system developments.

RHIDS facility will be utilized for the design and development of a remote system for Dissimilar Metal Weld Inspection system (DISHA) for inspecting the carbon steel to stainless steel welds in the Anti-Convection Barrier (ACB) location.

SGIDS facility will be utilized for the design, analysis and development of Steam Generator (SG) inspection devices for both PFBR as well as the FBR-1 & 2 Reactors. The developed device caters to Pre-Service

Inspection (PSI) and In-Service Inspection (ISI) of PFBR steam generators and also involves the development of various modules for the design of remote tooling for SG tube inspection and development of appropriate remote SG tube plugging system.

The building has two high bay ares on either side of building. The central portion of the building is G+3 in configuration. After completion of design, at present the two high bays of 30m X 15m & 30m X 12m in size and 21m height with a central portion upto G+1 storey is envisaged and construction is under progress.

Integrated Top Shield Test Facility (ITSTF) for qualification of systems and components

The extension of the present ITSTF facility for the qualification of all the safety related systems and components of FBR for various operating conditions, with sufficient margin against various buckling failure mode such as buckling due to static load, strain controlled buckling, dynamic buckling and creep buckling. The size of the new extension building is 60 m length by 26m width and it is fully fabricated with structural steel members, Z-purlins, Galvalume roofing sheets, puffed panel wall cladding on the existing pedestal of the ITSTF phase I building. Towards demonstrating the buckling strength of thin vessels, a dedicated buckling test facility is proposed which houses different buckling test setups. Tests will be performed using various hydraulic actuators of different capacity. The project involves civil construction of the laboratory and strong floor with embedment. The construction of the building is completed.

Integrated top shield test facility

Integration of SPT test rig with tensile machine

A Small Punch Rig (SPT) was designed, fabricated and integrated to the screw driven tensile machine. SPT rig was designed based on ASTM standard E3205-20 and its functionality was verified by performing test on 316LN SS at 300 K with a cross-head speed of 0.005 mm/sec. Load-displacement profile displayed all five stages characteristic of SPT deformation: elastic bending, plastic bending, membrane stretching, thinning and localized necking followed with load drop and fracture.

FBR - FRONT END FUEL CYCLE

PFBR Fuel Elements Fabrication

During the year, 100,000 fuel elements of Prototype Fast Breeder Reactor (PFBR) were fabricated as per the desired specification at the Fuel Fabrication Facility under the supervision of Nuclear Recycle Board (NRB).

Fabrication of U-6%Zr slugs in Injection casting system for DND studies

Casting of 170 numbers of natural Uranium – 6 % Zirconium slugs (Φ 4.94 mm x 80 mm length) for the manufacture of delayed neutron detector sub assembly (DND SA MK 2) for the calibration of bulk DND system was completed. Heel of the previous campaigns of U-6%Zr were taken for melt and cast in the form of the slugs. Graphite crucible was designed to accommodate the heel by reducing the effective wall thickness. The casting furnace was augmented by providing teflon feedthrough for the induction coil, mounting structures and clamping copper block for mould heater. Thermocouple located inside the vacuum furnace is interfaced with dedicated PID controller through vacuum tight connectors by making appropriate modifications in the vacuum chamber and the control panel. After successful upgradationand qualifiing the system casting of U-6Zr slugs wascompleted in two batches. The cast slugs were qualified by physical & chemical characterisation.

Measurement of phase transformation temperature of U-Pu-Zr by TG-DTA

A glove box facility qualified for handling Pu-bearing samples have been established and phase transformation temperatures of U-Zr & U-Pu-Zr were recorded by using a TG-DTA equipment housed in it. This work involved installation of all gas and water service lines including replacement of instrument's PVC water lines into metal hoses. All these service lines were tested & qualified after installation. Signal & electrical feedthroughs were fabricated, tested and also qualified. Functional testing of auto-recirculation cum purification system, installation of moisture and oxygen sensor to check real time purity inside the glove box was also completed. The glove box was leak tested and qualified for handling radioactive materials.

Temperature calibration of the instrument was carried out with high purity standards such as In, Bi, Sn, Zn, Al, Ag & Au. The heat of fusion was also measured in each case. Calibration of weight was also completed with prescribed standards. All these measured values were satisfactory and agree with the standard prescribed values. The leak testing of the glove box was completed and the leak rate was within the permissible limit for handling the radioactivity. The thermogram of U-6Zr metallic fuel obtained using this facility is shown below. The following phase transformation temperatures were identified at a heating rate of 5 K min-1 i.e., i) at 808 K (d → g transition), ii) at 850 K (a → b transition), iii) at 948 K (g → g` transition), iv) solidus temperature at 1439 K and iv) liquidus temperature at 1505 K. The thermogram of U-19Pu-6Zr metallic fuel at a heating rate of 10 K min-1 and a solid state transformation at 927 K could be identified.

FBR- BACK END FUEL CYCLE

Engineering development activities and achievements on metal fuel reprocessing at Pyro Process R&D Facility (PPRDF)

An engineering scale Pyro Process Research and Development Facility (PPRDF) was commissioned to demonstrate the flow sheet of metal fuel reprocessing of U alloys at 10 Kg per batch. PPRDF, an Engineering scale facility is commissioned to demonstrate the high temperature electrorefining and cathode consolidation of uranium and uranium based alloys. This facility is established to demonstrate metal fuel pyro processing flow sheet at 10 kg of U alloys per batch. The High Temperature ElectroRefiner (HTER) and a Automated Vacuum Distillation and Melting System (AVDMS) is housed inside a 500 m^3 Containment Box (CB). The containment box is also annexed with an anode loading glove box, Argon Recirculation and Purification System (ARPS) to maintain the temperature and requisite moisture & oxygen purity (less than 50 ppm), Argon Pressure Control System (APCS), Liquid Argon storage & purging system. A stringent leak tightness requirement of less than 0.1 box volume % per hour in CB at negative pressure of -20 to -40 mmWC was achieved. Several trials were performed to have experience on remote handling of cadmium loading vessel, cadmium chloride loading basket, salt sampler, handling anode basket, scraping mechanism, anode titling mechanism, ingot collection vessel, cable reel mechanism of 5 T in-cell crane and remote handling tools. The HTER process vessel was purged with UHP (Ultra High Pure) argon. One ton of eutectic salt was prepared and purified in 26 batches each weighing ~ 50 kg and analyzed for impurities. The eutectic salt of requisite purity was stored and the purity was maintained for 2 years in storage tank. The temperature of the process vessel and pipelines were raised to 450°C

Electrorefiner inside CB

Containment Box (CB)

Cathode with 4.5 Kg U deposit

at 50°C per hour rate and 1 ton eutectic salt was transferred to HTER vessel from the storage tank. 427 kg of Cd, 15 kg of $CdCl_2$ were transferred to the vessel provided with stirring facility. Uranium ingots were added to eutectic salt and prepared LiCl-KCl-UCl3 mixture in-situ at 450°C. The first electro-refining campaign has been successfully completed; in this campaign, 10 kg of uranium metal was loaded in the anode basket and electrodeposited on a fresh solid cathode. About 4.5 Kg of dendritic uranium was deposited on solid cathode and scrapped. The uranium which has fallen in the Cd pool present inside the vessel was also recovered by making the vessel (and in-turn Cd pool) as anode and electro-depositing the U on cathode. Further electro-deposition, scraping at various stages, consolidation of uranium after distillation of occluded salt, melting and consolidation of uranium need to be carried out and is in progress.

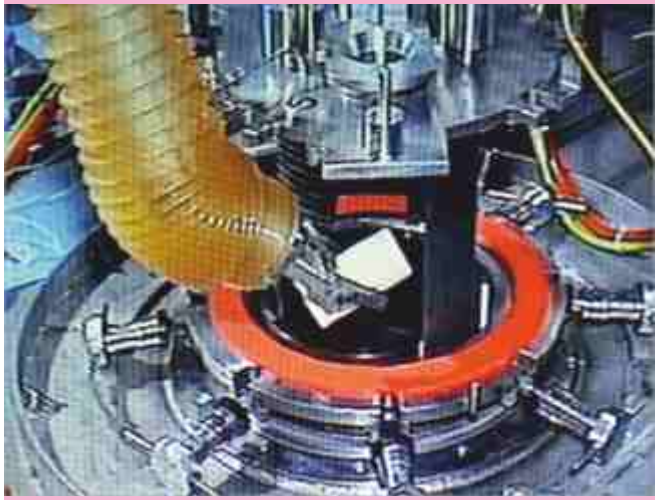
Pyro-processing of irradiated U-6Zr in hot cells

Pyro-processing of spent metal fuels is based on electrochemical recovery of actinides in high temperature molten salts (LiCl-KCl eutectic with 58.5 mol.%LiCl). The flow sheet for the pyro-processing of spent metallic fuel consists of four major steps such as 1) Head end step 2) Separation 3) Spent Salt Treatment 4) Waste disposal and re-fabrication. After the head end steps, the separation step consists of a) Electro-refining (ER) and b) Salt & Cadmium distillation process. In order to demonstrate the remote operation feasibility of the ER process of irradiated U-6Zr inside hot cells and also to study the process parameters, a laboratory scale (100g scale) pyro process facility was set-up in hot cells of MC&MFCG. For this purpose, the existing hot cell facility was augmented with necessary modifications and customized to the experimental needs.

Electro refining (ER) of irradiated U-Pu-Zr alloy fuel was carried out in the laboratory scale pyro-process augmented hot cell experimental facility of MC&MFCG. About 22.9g irradiated fuel (with clad) was loaded with 21g of fresh U-Pu-Zr alloy in anode basket. ER was carried out employing 2.819 Kg of LiCl-KCl-UCl_3 (Salt) as

Salt and Cd balls loaded to reaction vessel

Fuel loaded to anode basket



Eutectic salt loaded to reaction vessel

electrolyte (3.55 wt% UCl_3), 10 mm dia SS rod as cathode and irradiated U-Pu-Zr as anode. Ag wire along with LiCl/KCl/AgCl salt loaded inside a quartz tube which was further inserted in a SS 430 perforated thermo well with Ag wire extension of 10 mm was used as reference electrode. Before starting the ER runs, potential of cathode (vs. Ag+|Ag ref.) and anode (vs. Ag+|Ag ref.) was measured to be -0.310 and -1.236 V, respectively at 500 °C. ER was carried out at 500 °C in potentiostatic mode by varying the potential at -1.4 V to -1.5 V for 15 hrs. The total cathode deposit recovered is 15.9g. The metal deposit was scrapped from the cathode under hot condition. Three samples of salt solution and two samples of metal deposit were taken using manipulators during the run under hot condition using indigenously fabricated samplers. The samples were taken out of hot cell for characterization.

Three salt samples taken in different time durations were analysed for uranium content using spectrophotometric method. The concentration of uranium after electrolysis was found to be about 3.1 wt.%. The diluted salt sample was analysed by gamma spectrometry. The radioisotopes ^{134}Cs, ^{137}Cs, ^{144}Ce, ^{154}Eu and ^{155}Eu were found to be present. The cathode deposit was analyzed for uranium and zirconium contents and their concentrations were estimated to be 70 mg and 210 μg respectively.

Development of an indigenous ion exchange based radioactive radionuclides removal method from the routine laboratory organic liquid waste

The organic liquid waste generated in the radiochemical laboratory poses serious problem due to alpha-emitting radionuclides composed of the different isotopes of americium, curium, neptunium, plutonium and uranium. The radioactivity levels of these wastes (approximately 2,00,000Bq/mL) was not suitable for the disposal to the Centralized Waste Management Facility (CWMF), who is responsible for the final treatment of the waste. The regulatory body had recommended reducing the radioactivity level due to alpha radionuclides to less than 5000Bq/mL. The radioactive laboratory organic liquid waste (with the pH mostly varying from 1 to 3) generally comprises different organic solvents, such as tri-n-butylphposphate (with other trialkylphosphates too), amides, phosphine oxides and cocktails contaminated with different radionuclides.

A novel diglycolamic acid anchored cation exchange resin prepared through chemical modification of the commercially available polystyrene-divinylbenzene resin (PS-DVB-DGAH), to treat the radioactive organic liquid waste through cation exchange mechanism, both by batch and column modes of operation. An excellent decontamination of the radionuclides was accomplished using this PS-DVB-DGAH resin, as disclosed by the gamma spectrometry and liquid scintillation counting. The removal of alpha activity was demonstrated for nearly 1000 mL of the organic waste solution in column mode using this diglycolamic acid anchored resin. The studies

are also underway in developing a miniature lab-scale set up for the treatment of large volume of radioactive organic waste through automated solid phase extraction methodology.

R&D on Fast Reactor Fuel Reprocessing

CORAL (COmpact Reprocessing facility for advanced fuels in Lead shielded cells) continued to operate with an excellent recovery factor and radiation safety record. The 63rd campaign was successfully completed. As part of aging management, the AHUs (Air Handling Unit) of the ventilation system and aviation warning lamps of stack have been replaced. Action has been initiated for re-licensing of CORAL to continue the operations in plant mode. As a part of the preparatory work for re-licensing of the plant, secondary Process Cooling Water System (PCW), Air handling units, Chilled water system and fire water pumps (Diesel & Electrical) have been replaced and commissioned successfully. Safety assessment of other safety related systems and hot cell equipment are in process.

At the Demonstration Fast Reactor Fuel Reprocessing Plant (DFRP), the fourth stage of commissioning namely Cold run with natural Uranium has been completed successfully.

As part of the natural Uranium runs, testing of fuel pin chopper, dissolver, solvent extraction, solvent wash, diluent wash and reconversion laboratory equipment were carried out and validated. The performance of all the equipment and systems were found to be satisfactory. Based on this, consent is being sought from Atomic Energy Regulatory Board (AERB) for hot commissioning.

Several novel mechanical systems and mechanisms have been developed for hot cell applications, some of which are patentable. Patent has been obtained for the development titled, “Remotely operated helium leak tight self-locking fixture for wall mounted equipment for contaminated enclosures”. Processing of patent is in an advanced stage of evaluation for the work titled, ”Leak-proof flange and gasket assembly”. Other developments which are

Uni motored Rotary Linear actuator

potentially patentable include a “Fastener free Quick-lock fixture” for mounting structures & equipment remotely in a very short time, “Rotary linear actuator”, driven by single prime mover, suitable for capping/de-capping of delicate bottles/ containers, “Analytical sample handling equipment” for handling radioactive liquid samples, special pipe embedment for in-situ replacement of cable/ cables along with connector(s) from bunch of cables applicable to contaminated enclosures, etc. Technology transfer activities are underway for the developments namely: (i) Remotely

Helium leak tight Remotely Operated Self-Locking Fixture

Helium Leak Tight Flange

operated helium leak tight self-locking fixture for wall mounted equipment and (ii) Leak-proof flange and gasket assembly.

A heat pipe based Chip On Board (COB) LED lamp with fins was developed for hot cell lighting application. This LED light source produces about 85% of input power as heat. To achieve maximum expected lifetime, the case temperature of LED must be maintained below 85 deg C. Heat pipe based thermal system is attached to the LED, whose high thermal conductance facilitates greater heat transfer, thereby maintaining the LED temperature lesser than 85 deg C. The light fixture was subjected to radiation tolerance testing in the gamma chamber, in collaboration with SQRMG, IGCAR and was qualified for long term use. The system was installed in DFRP and tested. This work has also been recognized by DAE with a group achievement award.

Indigenous Computer codes for reprocessing

An indigenous thermodynamic model, SEESPEC (Solvent Extraction Equilibrium SPEciation Calculation) has been developed for the prediction of distribution coefficient of uranium, plutonium and nitric acid in the solvent phase for the first time. The model was suitable for the perdition of actinides in fast reactor fuel reprocessing flow-sheet, which was not available so far and it is found to be superior to the existing models.

Equipment for reprocessing

An ultrasonic bath with suitable resonator was designed, fabricated and commissioned successfully in

Plutonium oxalate precipitation and thickening

the plant, and a method for de-choking the centrifugal extractor bowl by ultrasonic cleaning was demonstrated. A glove box adaptable continuous precipitator-thickener-clarifier has been developed for plutonium reconversion. Exhaustive studies have been performed using the plutonium surrogate to evaluate the performance of the newly developed system. The new equipment could process the metal nitrate solution up to a throughput of 38 litre per hour with less than 1% solid carryover.

A prototype annular centrifugal extractor with 60 mm internal diameter bowls have been fabricated and tested for solvent extraction and flooding experiments. The photographic view of the single-stage ACE 60 mm setup is shown in the Figure. The results were satisfactory.

Photographic view of single stage ACE 60 mm setup (a) Complete ACE setup with drive and (b) 60 mm ID ACE rotating bowl

Radiation resistant PolyEtherEtherKetone (PEEK) coated housing assembly have been fabricated for the LED lamps deployed for plant application. Similarly, for the protection of LED lamp borosilicate glass domes with EPDM gasket for alpha leak tightness have been fabricated and deployed for plant application.

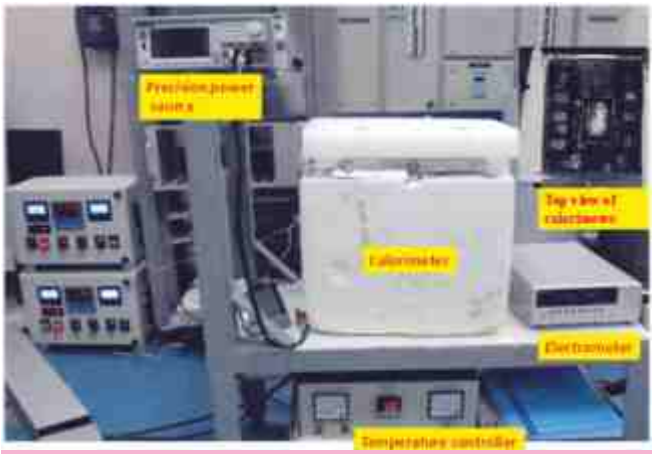
Materials for reprocessing applications

Uranous nitrate was required for partitioning step in reprocessing. For this purpose, a new Pt/SiO_2 catalyst material was developed and the performance of the same was assessed for the catalytic reduction of uranyl nitrate by hydrogen over Pt/SiO_2. Similarly, a novel magnetically separable silica coated iron oxide supported platinum catalyst has been developed for the generation U(IV). A new method was developed for the estimation of anionic surfactant degradation products formed in reprocessing plants using a suitable chromogenic agent.

In-house Developed Small Volume Calorimeter for Non-Destructive Assay of Plutonium based nuclear fuels

Radioactive calorimetry is a non-destructive technique for quantitative estimation of radionuclides, especially plutonium-containing fuels such as powders, and metals. The measurement of total heat in terms of power associated with radioactive decay is the basis of this calorimetry technique. This report describes the in-house design and development of a small volume single cell radioactive calorimeter, and its associated Microsoft Visual Basic 6.0 (VB) software for data acquisition. The calorimeter was calibrated by both electrical using thermistor and plutonium standards. Further, assay of plutonium of known isotopic composition in uranium plutonium oxide pellets (MOX) and U-Pu-Zr metallic alloy fuels and the results are compared with potentiometric method.

In-house developed a small volume single cell isothermal heat flow radiometric calorimeter consists of three chambers (aluminum sheet), peltier elements (heat flow sensors) connected in series and Keithley electrometer (signal measurement) which connected to computer through a RS232 serial port. The middle chamber (30°C) and outer chamber (15°C) were maintained a constant temperature using nichrome heating wire and recirculation chiller respectively. Temperature was monitored using K-type thermocouples. A photograph of the single cell calorimeter is shown. Electrical calibration was performed using 2kR thermistor for current ranges from 1 mA to 16 mA using a high precision power source. Similarly, the calibration was also carried out using Pu standards of known isotopic compositions.



The single cell radioactive calorimeter

The sensitivity coefficient (S, V/mW) of the instrument was calculated by both electrical and Pu (MOX) standard and found to be 90.87 0.17 and 90.75 1.35 V/mW respectively. The baseline (empty cell) and sample (MOX of Pu wt varies from 0.3 to 5.0 g) measurement were carried out in triplicate, till it reaches to constant thermal equilibrium value. The equilibrium value with relative standard deviation less than 1% is considered for calculation. The oxide and metallic samples of plutonium were estimated and the results were compared with potentiometric analysis and the error is found to 5 % for samples with equivalent to Pu $\geqslant$ 1 g.

Non-destructive assay of MOX Pellets for the isotopic composition of Pu using High Resolution Gamma Spectrometry

Isotopic composition (IC) of Pu is mandatory requirement to determine the fissile worth of MOX [$(U,Pu)O_2$] pellets which are to be used as fuel in fast reactors. The present study focused on the non-destructive assay of Pu-IC using High Resolution Gamma Spectrometry (HRGS) which has several advantages over conventional technique i.e. Thermal Ionization Mass Spectrometry (TIMS) in terms of easy sample preparation, rapid analysis and applicability on final products irrespective of their physical or chemical state. MOX pellets were assayed by HRGS using a planar HPGe detector having 600 eV FWHM at 122 keV with thin Be window. Cd sheets of 1.5 mm thickness were used as a to minimize the intense 59.5 keV photo peak of ^{241}Am.

Gamma energies (E) of ^{239}Pu were used in the energy range of 120-420 keV to construct the in-situ relative efficiency calibration plot. Logarithmic polynomial with 3rd order was used to fit each experimental ratios and obtained the fitting parameters to calculate the relative efficiencies for different isotopes of Pu. For the two isotopes of Pu, the atom ratio can be determined and were used to calculate the atom % abundances of different Pu isotopes. However, due to the complex nature of Pu gamma spectra, the respective photo peaks are needed spectral interferences corrections. 152.68, 171.39 and 148.56 keV photo peaks of ^{238}Pu, ^{239}Pu and ^{241}Pu respectively were used to determine the atom ratios of ^{238}Pu/^{241}Pu and ^{239}Pu/^{241}Pu. The 160 keV photo peak is a combination of 159.96 keV (^{241}Pu), 160.19 keV (^{239}Pu) and 160.31 keV (^{240}Pu). Appropriate corrections were given to obtain the peak area of 160.31 keV (^{240}Pu) and used for atom ratio (^{240}Pu/^{241}Pu) calculations. In the case of ^{242}Pu, isotopic correlations reported for PHWR grade Pu was used to calculate the atom ratio of ^{242}Pu/^{241}Pu. All the atom ratios were converted in to their respective weight ratios and compared with the results of the same obtained using TIMS. The relative precision values of 0.5-5% were obtained for ^{239,240,241}Pu isotopes and about 10% for ^{238,242}Pu.

Production of the radiopharmaceutical ^{89}Sr for Ensuring Increased Availability and Complete Imports Substitution

Various, medically important carrier free radioisotopes, are being produced in fast and thermal reactors across the globe. This article focuses on the production of ^{89}Sr radioisotopes useful for medical applications using the Fast Breeder Test Reactor (FBTR), Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam, India. The production of carrier free $^{89}SrCl_2$ radiopharmaceuticals using ^{89}Y(nfast,p)^{89}Sr reaction and standardization of flow sheet for chemical processing to obtain pure ^{89}Sr source which meets prescribed International Quality Control norms.

^{89}Sr (β- emitter, $T_{1/2}$ 50d) is one of the US FDA approved radioisotopes and used for bone pain palliation in metastatic bone cancer due to its biological resemblance with Ca. Several irradiation campaigns for

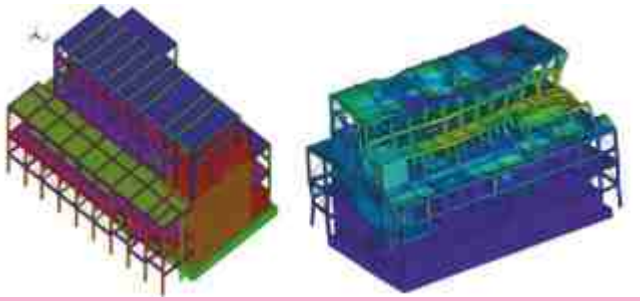
the production of ^{89}Sr was carried out by irradiating high density yttria pellets in various locations of FBTR, namely core centre, fourth and fifth ring, depending upon the need and availability of irradiation positions. Post irradiation, de-cladding of the SS irradiation capsule and chemical processing steps were carried out to obtain the pure ^{89}Sr source from the irradiated yttria target. Chemical separation methods involving solvent extraction, extraction chromatography, supported liquid membrane and ion exchange technique were employed for the purification of ^{89}Sr from various activated impurities produced during the irradiation of yttria matrix and SS clad. The flowsheet was standardised and demonstrated both in analytical scale as well as bulk scale using a shielded facility like Hotcell by solvent extraction method using Tri-n-Butyl Phosphate (TBP) as well as 4,4'(5') tert-butyl cyclo-hexano-18-Crown-6 (DtBuCH18C6).

In the latest irradiation campaign, the yttria pellets were irradiated in FBTR at 40 MWt for a period of 45 days. The chemical processing of irradiated yttria pellets was carried out by solvent extraction using DtBuCH18C6 followed by anion separation, removal of dissolved organic traces of the extractants, vacuum distillation to reduce the volume and all stringent quality control norms were followed as per US, European, International and Indian Pharmacopeia. Quality control (QC) measures such as appearance, pH, residual anion ion content, spectral identification, radioactive, non-radioactive impurities, and biological quality control studies such as sterility and bacterial endotoxin were carried out using various techniques standardised in our laboratory with the actual ^{89}Sr source and found satisfactory. Approval was obtained by Board of Radiation and Isotope Technologies (BRIT) for the animal bio-distribution studies of IGCAR produced $^{89}SrCl_2$. The number of doses at the end of the different irradiations varied from 5-275, when a single dose corresponds to 4mCi of ^{89}Sr in 4 mL solution. The sample tube preparation, sample irradiation with the associated protocol and the irradiated sample transportation to RCL by ROD, ROMG, RIRD, MMG of IGCAR, Kalpakkam and technical discussion with BRIT, Mumbai are gratefully acknowledged.

^{89}Sr Production at IGCAR

Demonstration Fuel Reprocessing Plant (DFRP)

Seismic re-evaluation has been completed for process and exhausts buildings of DFRP and is in progress for DFRP stack as a part of the regulatory requirement.



FEM Model

High performance Electrically insulating Plasma Sprayed Alumina coating

Solid cathode bottom plate is a part of the cathode in the electro-refining in pyro-chemical reprocessing of spent metallic fuels. Electrical insulation is provided on the bottom plate so as to avoid downward growth of Uranium deposits on the cathode and thus preventing the electrical short circuiting of cathode with the vessel. Plasma sprayed alumina or yttria stabilized zirconia coating (min. 200 μm) on bottom plate (9Cr-1Mo) with NiCrAlY bond coat (~100 μm) is recommended to provide electrical insulation in molten salt electrolytic medium. However, the 10-15% porosities in the plasma sprayed top coat affect the functionality by forming micro shorting and favours local dendritic growth. The problem is effectively overcome by sealing surface and sub-surface pores by high

Plasma sprayed alumina coating on solid cathode mounting plate top and bottom view

Surface sealing of alumina coating using high temperature adhesive top and bottom view

temperature ceramic adhesive. M/s. Aremco make alumina based high temperature adhesive (Ceramabond 569) is suitably applied on plasma sprayed alumina top coat and subjected to curing at 200 °F for 2 hrs. The sealed alumina coating exhibited superior performance in the actual batch process.

Vacuum brazing of copper and SS316L using Ni–P eutectic alloy filler for nuclear applications

Dissimilar metal joining of austenitic stainless steel 316L to oxygen free electronic grade copper by vacuum brazing technologies is required for developing DC conduction pumps of fast reactors. Towards this, a suitable braze filler alloy with a continuous operation at 500 - 600 °C and low brazing temperature <1000 °C is chosen from a family of Nickel-based braze alloy fillers. Ni-P eutectic braze alloy with 11 wt.% of P in the form of paste is found to be best suitable for present applications. The vacuum brazing parameter optimization accompanied by detailed micro structural and mechanical characterization on butt and lap joint specimens as per AWS specifications were carried out. A braze zone thickness of ~50 μm, joined at 930 °C for 30 minutes (Figure 28a) hold time is optimized, resulting in superior braze joint quality and strength towards joining SS316L to OFE Cu.

HEALTH, SAFETY & ENVIRONMENT

Emergency Backup Evacuation System for Radio Metallurgy Laboratory

Radio-Metallurgy Laboratory (RML) hot cell facility employs high purity nitrogen environment for the examination of irradiated mixed carbide fuels, maintained at negative pressure with respect to the adjacent operating area, warm work areas, isolation areas and high bay. An Inert Gas Recirculation System (IGRS) consisting of inlet/outlet headers, charcoal bed, HEPA filter, cooling coil, recirculation fan, prevent heat and radio-activity build up inside the hot cells, and a nitrogen a feed arrangement and an automated bleed arrangement are provided in the IGRS ensure maintenance of negative pressure. The suction side main header of RML phase-I exhaust system-III is maintained at an internal pressure approximately -160mm WC with respect to RML operating area. In order to improve the operation margin, an additional Emergency Backup Evacuation System (EBES) has been designed and commissioned in RML. The system is designed to be activated in case of a failure in existing hot cell ventilation system, to maintain the pressure in the hot cells below the adjacent areas, and thereby avoiding the possibility of spread of radio-active contamination during emergency situations. This system is independent of the components of the existing ventilation system which eliminates the possibility of common mode failure.

Radiological and Industrial Safety

Health physics surveillance was provided in all active facilities of IGCAR. TLD personal monitoring services covering about 3500 occupational workers of IGCAR and BARC facilities have been carried out. In-vivo and in-vitro monitoring services were provided to 900 occupational workers of IGCAR.

Gamma measuring instruments (355 nos.) and Neutron survey meters (33 nos.) from DAE and non DAE institutions were calibrated in NABL accredited Regional Calibration Facility of IGCAR.

Integrity evaluation of process cells of DFRP were carried out by using high active gamma source (60Co- 90Ci) in Industrial Gamma Radiography Exposure Device with minimum man-rem expenditure.

Integrated radiation monitoring facility has been established at hospital complex of Anupuram Township. This facility is first of its kind in southern part of DAE units which contains in-vivo and in-vitro monitoring laboratories along with Radiation Emergency Medical Centre. The Radiation Emergency Medical Centre is designed as per NDMA and AERB guidelines.

Industrial & Fire safety inspections and physical hazard surveillance are carried out for maintaining safe work environment in all facilities of IGCAR. Industrial safety training was provided to young officers/ engineers/ supervisors and contract employees of IGCAR. Online work permit system has been introduced for all industrial safety work permits.

R&D in radiological safety, dosimetry, environmental monitoring and radiological services

Retrospectively dosimetry has been established using dental enamel. A linear Kalman-filter method has been developed for accident source term estimation in emergency decision support system and online chemical emergency response system has been developed for chemical impact assessment and disaster management at industrial sites. Green cover data base was generated for DAE campus, Kalpakkam using high resolution (2.5 m) satellite remote sensing techniques.

Indigenously developed waste assay system was calibrated in segmented gamma scanning mode and validated with blind test waste drum from reprocessing plant for estimation of Special nuclear materials & fission products.

Mangroves and associated floral diversity were studied in DAE campus, Kalpakkam. A Gamma ray induced mutated plant garden was established with Guava, Casuarina and Crossandra to showcase the application of ionizing radiation in the field of agriculture. 'Butterflies of Kalpakkam' were photographed and

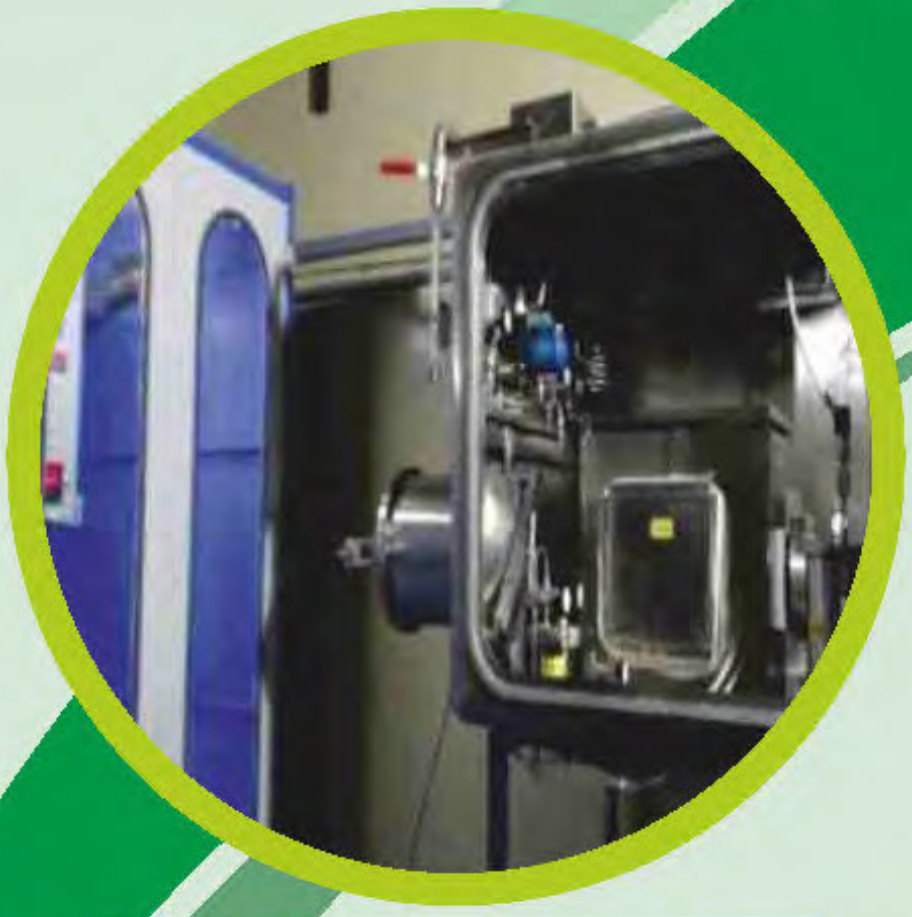
Gamma Garden a) Corrsandra, b) Casuarina and c) Guava)

systematically documented and published as a book. ASTM international has honoured IGCAR for extensively utilizing its database.

CHAPTER 3

Operator Console of ICIS of KAMINI Reactor

NUCLEAR POWER PROGRAMME STAGE-III



Experimental setup for Hydrogen Adsorption/Desorption studies

THORIUM BASED REACTORS

Nuclear power employing closed fuel cycle is the credible and sustainable option for meeting a major part of the world energy demand. World resources of thorium are larger than those of uranium. Thorium, therefore is, widely viewed as the 'fuel of the future'. The Indian Nuclear Power Programme Stage-3 aims at using thorium as fuel for power generation on a commercial scale. In the thorium fuel cycle, Thorium-232 is transmuted into the fissile isotope Uranium-233 which is a nuclear fuel. A special purpose 30 KW research reactor, named KAMINI and located at IGCAR, is in operation, which has the distinction of being only reactor in world presently operating with U^{233} fuel. As a part of this programme, BARC has been developing a 300 MWe Advanced Heavy Water Reactor (AHWR). Fuelled by thorium and using light water as coolant and heavy water as moderator, this reactor will have several advanced passive safety features.

Kalpakkam MINI (KAMINI) Reactor

The U-233 based Kalpakkam Mini Reactor (KAMINI) was available for neutron activation analysis, neutron radiography and testing of indigenously developed neutron detectors. De-bonding of fuel plates in some of the fuel subassemblies was observed during inspection in October 2021. Presence of any solid fission products in reactor water has not been noticed so far. Reactor operation was resumed in January 2022 with 3 gas leaker fuel subassemblies in the core after obtaining regulatory clearance.

Operator Console of ICIS of KAMINI Reactor

Sub-System-II Panel of ICIS of KAMINI Reactor

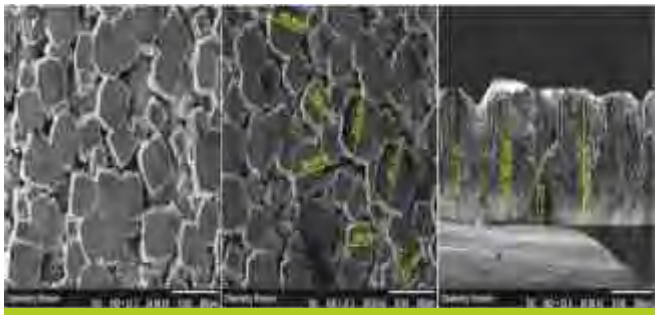
Software Upgradation of KAMINI Reactor

The software system of KAMINI reactor underwent a major upgrade in the form of installation of Integrated Control and Information System (ICIS) to meet the requirements of IGCAR. The system upgrade had been approved by the competent Safety Committee of AERB, and the performance of the system has been quite satisfactory.

Thorium Fuel Cycle

Uo_2 based Cermet Dispersion Nuclear Fuels with MSBR Applications

Phase behaviour and thermophysical properties of UO_2 based cermet dispersion nuclear fuels have been evaluated over 298 K to 773 K and the effect of prolonged annealing on heat transport behaviour of the fuel has been delineated. High temperature



Electron micrograph of highly oriented CVD diamond film

thermophysical properties of fluoride-based fuel salt for Molten Salt Breeder Reactor (MSBR) application, and ZrO_2-based inter matrix fuel hosts and rare earth phosphate-based waste hosts were evaluated over 298 K to 1473 K. Indigenous experimental facility has been set-up for decarburization of heavy metals and metal decarburization was demonstrated at lab-scale. For alkaline dissolution of uranium-aluminum intermetallic fuels, process parameters were optimized at lab-scale to achieve rapid dissolution within the permissible range of temperature of the dissolution system. Large numbers of Poly Crystalline Diamond (PCD) films were synthesized using plasma CVD route and PCD-based alpha detectors (10 nos.) were fabricated and tested in air / liquid medium. A special substrate holder was designed to provide steep radial temperature gradient over 2-inch diameter silicon substrate. Using this substrate assembly, thick PCD films (> 500 mm) consisting of highly oriented (100) large diamond crystallites (sub-millimetre) were synthesized for the first time.

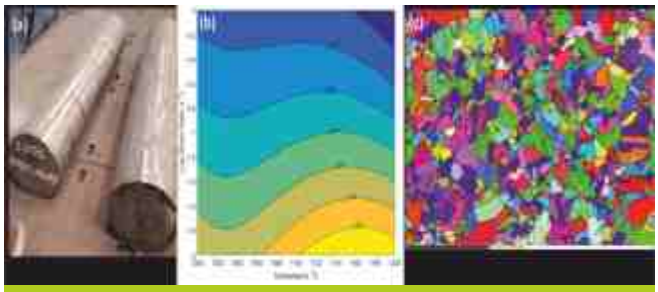
Novel Fuel Salt System

A detailed thermo-physical database for a new fuel salt system composition without ThF_4 has been generated in BARC. Using techniques such as DTA and DSC several important parameters, including eutectic temperature, enthalpy of fusion of the fuel salt system were determined. Heat capacity, density, viscosity, enthalpy increment, coefficient of thermal expansion was determined as a function of temperature. In addition, thermodynamic stability of large number of ternary fluoride compounds, which are formed due to potential interaction of fuel salt with fission products, had been determined.

Materials Research

NiMoCrTi-C alloy for MSBR Loop

Ni-12%Mo-8%Cr-2%Ti-C alloy is considered as a structural material for Indian molten salt breeder reactor. The initial small scale trial melts (~20kg) of the alloy with nominal composition range was melted using vacuum and open air induction melting. SEM-EDS characterization of samples from open air induction melted route showed presence of undesirable carbide stringers and excessive carbo-nitrides. Therefore, vacuum induction melt route was considered a preferred route for further alloy preparation. Commercial scale ingots required for the fabrication of proposed test loop for molten salt circulation were produced by vacuum induction melting. The as-cast ingots were successfully forged at ~ 1200°C. The final components of MSBR loop such as tube, plates and welding wire are being fabricated from the forged billets.



(a) The as-cast ingots, (b) Processing map and (c) Dynamic recrystallized microstructure of Ni-12%Mo-8%Cr-2%Ti-C alloy

HYDROGEN ENERGY

An experimental setup consisting of a high temperature furnace alongside closed loop recirculation system, analytical facilities and control instrumentation has been commissioned in BARC and was employed for carrying out Adsorption/ Desorption studies of hydrogen isotopes (very high, low and very low level) in air/ inert background onto structural and insulating material. Helium leak test by MSLD was carried out and the leak integrity was confirmed for the intended service requirement. Trial runs were conducted and the system was operated up to 300°C in closed loop air flow rates up to 200 NLPH.

Experimental setup for Hydrogen Adsorption/Desorption studies

Hydrogen is considered as one of the highly promising energy options for the future. The technology for production of hydrogen by Iodine-Sulfur process (I-S) process using industrial materials has been successfully demonstrated and the process is being scaled-up further. Hydrogen has been produced at 150 Nlph (normal litres per hour).

R&D activities on process development for copper-chlorine thermochemical cycle for hydrogen production were continued and offline product looping of all four steps (hydrolysis, thermolysis, electrolysis, and crystallization) was successfully carried out at laboratory scale (10 Nl/h equivalent hydrogen).

Laboratory scale setup for demonstrating Cu-Cl thermochemical cycle for hydrogen production

Under hydrogen energy development activities in BARC, a polysulfone-zirconia mixed-matrix membrane diaphragm (700 mm width) was developed as a substitute for asbestos and imported commercial diaphragms for alkaline water electrolyzer, which has several important applications. The samples were benchmarked with commercially available alternatives (e.g., Zirfon). The V-I characteristics of in-house diaphragm was found to be 2.97 V at a current density of 5000 ASM.

A laboratory scale hydrogen generator based on alkaline water electrolysis technology was developed capable of delivering up to 20 NLPH of hydrogen at ~5 bar and of 99.9 % purity. The unit is capable of simultaneously producing high purity oxygen at nearly the same pressure. This system can act as a clear import substitute and has potential widespread laboratory applications. The generator can be employed for green hydrogen production when coupled with solar photovoltaics.

High purity Hydrogen & Oxygen Gas Generator

BARC has successfully developed alkaline water electrolyzers (Tank type) for high leak integrity applications. The electrolyzer is characterized for its capability to withstand - high temperature, high electrical resistance and highly corrosive alkaline media. System trial runs confirmed thermodynamic

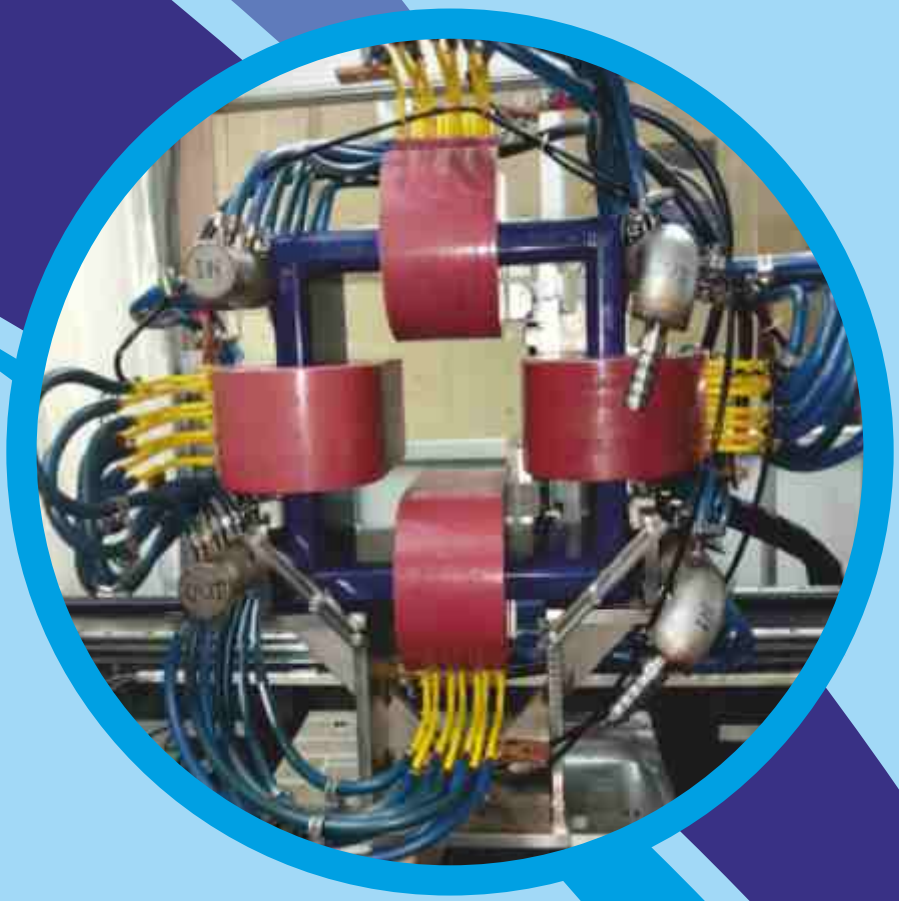
High purity Hydrogen generator based on Tank type Alkaline Water Electrolysis Technology

efficiency of ~50% at current density of 7500 ASM. Hydrogen gas of over 99.98% purity coupled with Oxygen stream of ~99.5% purity.

Bipolar filter press type single electrolyser stack consisting of 50 cells and 50 kW capacity has been designed and fabricated. This is a first-of-its-kind single stack module, which has been scaled up from the earlier version with 25 cell stack of 25 kW capacity. The assembled cell was integrated with process skid of the balance electrolyser plant and the performance evaluation of plant was carried out successfully. Performance of the plant is as per the design intent. The plant produces > 99.9% pure H_2 and > 99.5% pure O2 at cell exit itself up to 1.5 bar (a) discharge pressure. To make the system economically viable for the industry, low cost effective measures, without compromising performance and safety of the system have been taken-up. An elastomer based gasket material has been tested to achieve same leak tightness and compatibility with the process fluid. To reduce machining cost of SS bipolar plates, a Polymer molded bipolar plate is fabricated at a smaller scale for its performance testing.

Alkaline Water Electrolyzer plant integrated with a 50 cell stack

CHAPTER 4



New steering magnet for the Super-conducting cyclotron beam line and measured field profile of the magnet has been designed at RRCAT

APPLICATIONS OF ADVANCED TECHNOLOGIES AND RADIATION TECHNOLOGIES

A four stage end-pumped Laser amplifier has
been developed by RRCAT

Advanced technologies and radiation technologies development and their applications, is one of the major programmes of the DAE's research organizations such as BARC-Mumbai, IGCAR-Kalpakkam, RRCAT-Indore, VECC-Kolkata and the industrial organization BRIT, Mumbai.

These organisations have developed a number of advanced technologies, hi-tech facilities and various sophisticated equipments over a period of time under this programme. This includes Research Reactors, Accelerators, Lasers and laser based equipment, Synchrotrons.

Applications of radiation technologies are immensely beneficial in the areas of healthcare, nuclear agriculture, food preservation and industry.

DAE has been working in close cooperation with other organizations of the Government of India to widen the reach of the technologies for the benefit of common man.

The Tata Memorial Centre which functions through its three units viz., Tata Memorial Hospital (TMH), the Advanced Centre for Treatment, Research and Education in Cancer (ACTREC) and Centre for Cancer Epidemiology (CCE) and provides the Cancer Diagnostic and Treatment Services to the masses. It also engages in the programmes aimed towards Cancer awareness and its Prevention.

RESEARCH REACTORS

APSARA – Upgraded

Operation of Apsara-U at rated power of 2 MWth was demonstrated successfully. The reactor operated with an Availability Factor (AF) of 52.7 % during the year. Silicon wafers of 100 mm diameter were irradiated at the immediate vicinity of reactor core for development of silicon-based radiation detectors as part of feasibility study for neutron transmutation doping of silicon in Apsara-U reactor. The setup for irradiation of silicon ingot is expected to be commissioned soon. Facilities for neutron imaging and neutron depth profiling are being installed in Apsara-U facility.

Neutron Imaging Facility at Apsara-U

DHRUVA

Dhruva was operated with an Availability Factor (AF) of 73.2% during the calendar year 2022. Isotope production in Dhruva was continued and 510 radioisotope cans were irradiated and delivered successfully.

About 48 plates of Fission Moly were irradiated on a trial basis in the Fission Moly Tray Rod (FMTR) facility as part of hot commissioning of Fission Moly Plant at a BRIT facility. Upon obtaining necessary approval from Radio Pharmaceutical Committee, regular production of fission moly from Dhruva is expected to commence by March 2023.

A study was carried out for production of high specific activity (more than 650 Ci/ gm) of 192Ir for making Brachytherapy sources, by carrying out trial irradiations of enriched (80%) samples of Iridium at Dhruva.

Trombay Programmable Logic Controller (TPLC-32) Platform based Electrical Supervisory Control and Data Acquisition (ESCADA) system has been developed for interlocks and monitoring of Electrical Subsystems of Dhruva reactor. The system consists of TPLC-32 based dual redundant nodes in hot-standby configuration, data servers and display stations. Hardware integration and environmental

Dhruva ESCADA Panels undergoing burn-in test

qualification testing has been completed, and all the hardware panels have been dispatched to Dhruva.

Critical Facility (CF)

The Critical Facility of Advanced Heavy Water Reactor was operated 68 times during the year for surveillance, irradiation experiments, neutron activation and testing of Helium detectors. Neutron Activation of 166 samples was done as per desired requirement. Feasibility of 'Approach to Criticality' using Lanthanum Bromide based gamma radiation detectors was evaluated.

High Flux Research Reactor (HFRR)

For establishing the functionality and mechanical efficacy of Fuel Locking System of High Flux Research Reactor, a full-scale mock-up with 9 dummy fuel assemblies (3 x 3 grid) was designed and erected at BARC, Mumbai. Operation of Fuel Locking System is being tested in the mock-up facility. The exercise involving testing of 6 dummy assemblies for 1000 cycles and inspection of the system were completed.

CIRUS

A new remote-operated system was developed and deployed at research reactor CIRUS for ageing assessment program, as part of studies related to material characterization and mechanical property analysis. Operation of Iodine-131 processing facility at CIRUS will be started soon.

I-131 processing facility at CIRUS

ACCELERATORS

At RRCAT, development of Compact 40 kW CW, 505.8 MHz Solid State Power amplifier (SSPA) test stand, has been successfully accomplished. The set up will be used for high power characterization of RF sub systems and components like RF cavity, high power RF circulator, RF loads etc. This is an important development considering future commitments to Fermi lab. Currently, 505.8 MHz RF circulator is being characterized & tested with the help of this SSPA at high power.

Further, the 40 kW, 505.8 MHz solid state power amplifier which was supplied to Fermi lab, USA under Indian Institutions and Fermilab Collaboration (IIFC), has been tested and accepted by the users.

90 kV solid state pulse modulator assembly

Development of 90 kV, 500 Hz solid-state hard switched modulator for electron gun

High voltage pulsed modulator required to bias the electron gun a hard switched solid-state modulator is developed with important specifications 90 kV switched voltage, 2 A peak current, 16 μs pulse-width, and 500 Hz pulse repetition rate. The modulator has been used to test the electron gun.

Commissioning of Horizontal Test Stand (HTS) facility at RRCAT for testing of jacketed superconducting RF cavities at 2K

Horizontal Test Stand (HTS) developed at RRCAT is a unique cryogenic test facility for RF cavities. Commissioning of HTS has been carried out. Various systems related to HTS facility i.e. cryostat, cryogenic distribution system, high power RF system, low level RF control, RF protection & interface, magnetic shield, control & safety system were developed, deployed and operated successfully to test the SCRF cavity at 2K temperature. This achievement completes full cycle of fabrication, processing, tuning, dressing and testing of Superconducting Cavities at RRCAT.

Five cell SCRF cavity with tuner and power Coupler

20 keV, 2 kW thermionic DC strip type electron gun for photon absorber

A 20 keV, 2 kW thermionic DC strip type electron gun-based test set-up was designed and developed at RRCAT for testing of Photon absorbers. These Photon absorbers, also called crotches, are used to absorb unused synchrotron radiation (SR) emanating from bending magnets in Synchrotron Radiation Sources (SRSs). The desired electron beam can be extracted using settable filament and variable powers respectively.

Hybrid Getter Pump

Design, development of first prototype of hybrid getter pump

A prototype hybrid getter pump for Ultra High Vacuum (UHV) has been developed and tested successfully in-house at RRCAT. This advanced technology is essentially required for next generation synchrotron radiation sources; UHV based surface science study instruments and synchrotron beamline mirrors. This technological development is an important import substitute and vital contribution towards Make in India mission.

Design, development and deployment of dual channel Faraday cup electrometer at Agricultural Radiation Processing Facility (ARPF)

In the field of pulsed current measurement for Linac characterisation a state of art Faraday Cup Electrometer (dual channel) has been indigenously

Dual channel Faraday cup electrometer

designed, developed and deployed at Agricultural Radiation Processing Facility, Indore. The Faraday Cup Electrometer Data Acquisition System (FCE-DAS) monitors important parameters in real time. They include charge content per pulse in pC, pulse repetition rate in the range of 1 to 300 Hz, beam current from 1 to 300 mA and the integrated charge in Coulomb for characterization and qualification of the Linac.

RRCAT has developed SCRF (Super Conducting Radio Frequency) related various technologies and infrastructures for future proton accelerators of DAE. Three HB650 cavities have been qualified for assembly in PIP-II (Proton Improvement Program-II) prototype Cryo-Module (pCM) at Fermi lab. Successful integration of 650 MHz cavities in pCM is an important milestone towards development of superconducting technologies for accelerator.

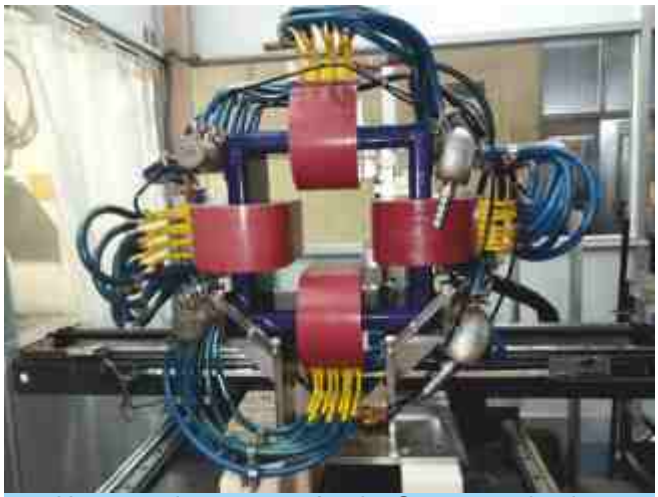
Elliptically shaped 5-cell 650 MHz SCRF bare cavity

String Assembly for pCM of PIP-II with 3 cavities from RRCAT, India and 3 from Fermi lab, USA

High energy (360 MeV @14MHz, 386 MeV@14.5 MHz and 436 MeV @15.4 MHz) Neon (Ne^{6+}) beams and 309 MeV Oxygen (O^{5+}) beam have been successfully accelerated in Super-conducting cyclotron for the first time during this report period. This involved finding optimum operational parameters for three RF systems, main coil and trim coil magnetic fields, two defectors and nine magnetic channels. This beam will be made available to the users soon.

During last year's beam trial significant transmission loss was noticed in the first few meters of the extraction beam line. The reason of the beam loss has been investigated through simulations and a modified layout was proposed. Implementation of this new design is expected to reduce the beam loss considerably.

As a part of the implementation of the design, a new steering magnet has been designed, fabricated and field mapping has been done. The 375 mm effective length magnet is symmetric in horizontal and vertical planes and designed to deflect beam of 2.4 T-m rigidity by 1°. The power supplies (250A @50V) for the magnet have been under fabrication in-house and will be ready soon. The beam line is planned to be taken up for commissioning by this financial year.

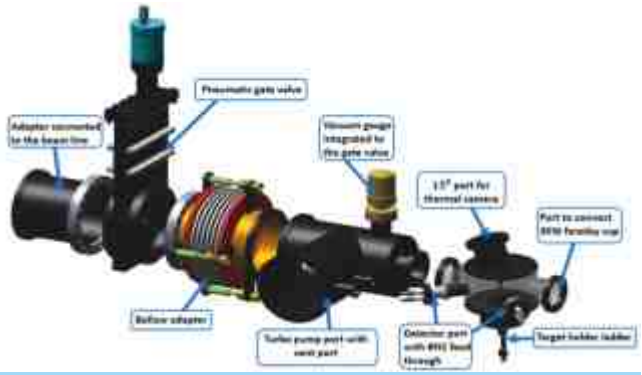


New steering magnet for the Super-conducting cyclotron beam line and measured field profile of the magnet

Induced radioactivity has been estimated in the commonly used materials (Al, Fe & Cu) in proton accelerator facility in the energy ranging from 100 MeV to 1 GeV. The activity generated in the target materials were estimated based on the empirical relations using the cross-section data for the nuclear reaction responsible for the radio-nuclide formation. Data was generated for 8hrs, 40hrs and 2000 h of proton bombardment and 0.1 h cooling period. Results indicate

that the activity from Fe and Cu is almost one order magnitude higher than that of Al.

Facility for Research in low energy Nuclear Astrophysics (FRENA), a high current 0.2-3 MV Tandetron accelerator facility has been commissioned in Saha Institute of Nuclear Physics (SINP), Kolkata. The machine is presently in the trial period of AERB and is delivering proton beams at a maximum current of 100 eμA. FRENA is primarily dedicated for performing experiments related to nuclear astrophysics. Energy calibration is the first and most essential part for this newly installed accelerator facility. This setup will be initially utilized for calibration experiments like 7Li(p,n) reaction. The setup consists of a pneumatic gate valve which isolates the setup part from the accelerator side if the vacuum degrades below a set value.



Different components of setup

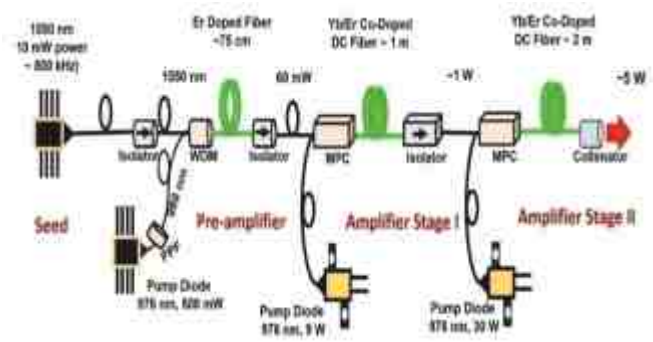
A 152 mm diameter target chamber is coupled, having ports at 50 and 135 for placing silicon detectors. It has provisions for putting bias and extracting the signal. A port at +150 degrees out of the plane will be used for monitoring target heat and beam spot profile using a thermal camera. The bottom flange of the target chamber is assembled with the target ladder. It has provisions for three targets and can be moved vertically to align the target with the beam. Rotational adjustment of the target ladder can also be done. The chamber will be followed by a 3KW faraday cup to dump the beam and make current measurements for thin targets. For thicker targets the beam may stop in the target itself. For such a scenario, a development is also in process to make cooling and the complete target ladder flange electrically isolated from the entire setup. Charge and current information can be collected from the ladder itself. Setup has been already coupled to one of the beamlines of FRENA accelerator.

Setup coupled with one of the beamlines of FRENA

LASER TECHNOLOGY

Following lasers and laser-based systems have been developed for industrial, nuclear applications and applied R&D:

Engineered version of narrow linewidth all fiber amplifier is developed in Master Oscillator Power Amplifier (MOPA) configuration to deliver 5 W output at 1550 nm. Optical to optical conversion efficiency of the system is ~15 %. No significant increase in the linewidth was observed on amplification compared to the seed source where linewidth was measured using delayed self-heterodyne technique.



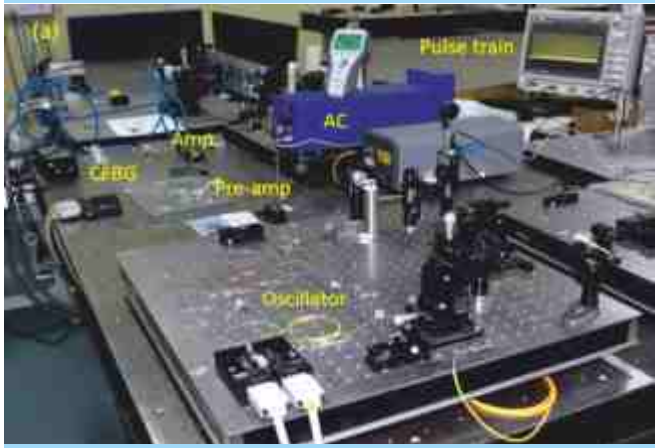
Schematic of all-fiber MOPA

Developed MOPA

A Laser Induced Breakdown Spectroscopy (LIBS) set up has been developed using a 1064 nm, 6 ns, 10 Hz, 450 mJ(max.) laser plasma. The plasma emission is dominated by the continuum emission at the beginning and by the characteristic line emission after a few microseconds. Therefore, the spectrometer signal acquisition was triggered by the laser pulse with some suitable time delay so as to minimise the continuum emission contribution. The setup was used to analyse and differentiate between various metal/alloys samples.

This system uses a calibration free method which is based on the assumptions of stoichiometric laser ablation, optically thin plasma and local thermal equilibrium in plasma, adopted for quantitative analysis of metal/alloys samples. An algorithm is developed to apply the calibration free method to analyse the major components of stainless steel SS 304 and SS 316 and the concentration of Fe, Cr and Ni could be determined with a relative standard deviation of ~1%, 8% and 10%, respectively.

Laser Induced Breakdown Spectroscopy set up

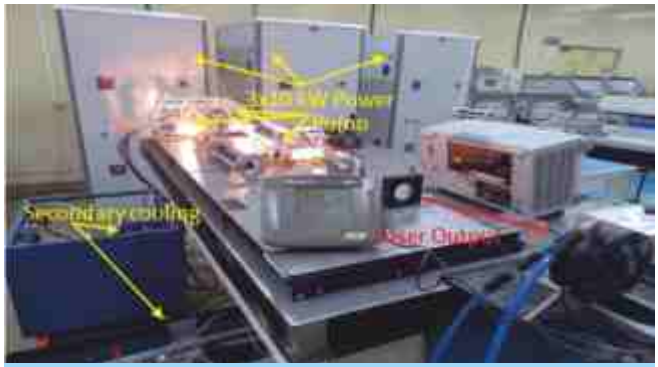


Set up for Mode locked fiber oscillator-amplifier

A Mode Locked Yb doped fiber oscillator-amplifier set-up operating at 1030 nm is developed. The oscillator-amplifier system provided 475 fs duration pulses at 37 MHz repetition rate, ~2W average compressed output power.

Development of an engineered version of 1.5 kW average power and 30 kW peak power long pulse fiber coupled Nd: YAG laser using ceramic reflector based pump chambers has been carried out. This laser will be useful for remote cutting of upto 40 mm thickness of SS and welding up to a depth of 8 mm in SS.

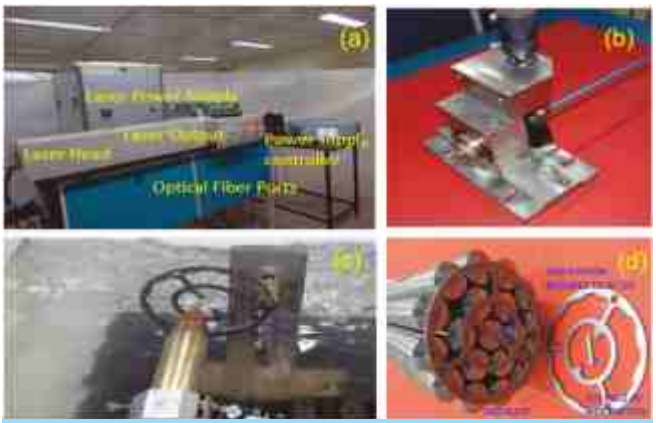
Development of an engineered version of monolithic 1 kW Yb-doped CW fiber laser at 1080 nm with compact packaging and QBH connector interface has been completed. This laser is capable of cutting of up to 8 mm thick Stainless Steel (SS) and welding up to a depth of 4 mm in SS.



1.5 kW/30 kWp Nd:YAG laser for material processing applications

1 kW all-fiber Yb-doped CW fiber laser at 1080 nm

Development of a ceramic reflector and double lamp pump chamber based 500 W average power and 10 kW peak power pulsed Nd: YAG laser has been carried out. An underwater laser cutting tool operable



(a) 500 W/ 10 kWp Nd:YAG laser
(b) laser cutting tool for central Cobalt element,
(c) underwater laser cutting
(d) 19-pin fuel bundle and cut piece of web

remotely from top of 5 m deep spent fuel storage bay water pool has also been developed and underwater cutting of Zircaloy end plates of 19-pin fuel bundle has also been successfully performed during mock trials.

Design and development of a remotely operable laser cutting tool for recirculation loop of TAPS-1&2 reactor has been carried out. The tool can be mounted in a minimum of 150 mm straight section of the pipe. This laser cutting tool and process will be deployed at TAPS-1&2 reactors for cutting and replacement of recirculation loops.

Laser cutting tool and mock trial of 30 mm thick and ~700 mm dia. SS316L tube for cutting of recirculation loop at TAPS-1&2 using 1 kW average power Nd: YAG laser

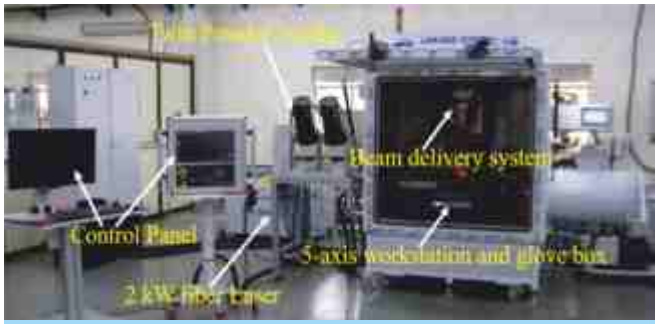
Development of 500 W average power and 10 kW peak power ceramic reflector based fiber coupled pulsed Nd: YAG laser system is completed. There are three fiber ports in each system and welding nozzles have been attached at the exit fiber ends for welding the jobs. The laser system will be used for high performance, leak tight welding applications.

500 W/10 kWp Nd: YAG laser for welding application

Optimization of operation parameters of the Infra-red Free Electron Laser (IR-FEL) have been carried out and tunability of output laser wavelength over 11 to 42 micron has been demonstrated.

Digital Charge Coupled Device (CCD) cameras being utilized for viewing beam profile at IR-FEL go bad frequently in the present set up due to close proximity of radiation exposure from 25 MeV electron beam. To overcome this problem, design and development of a novel Beam Profile Monitor (BPM) for the IR-FEL set up was taken up. A periscopic optical viewing system of 1.75 m length has been designed and developed using metallic mirrors with magnification of ~5X to avoid damage to the cameras and thereby enabling increased life of digital CCD cameras. This periscopic optical viewing system has been deployed in one of the beam-position monitors to record the true measurement of beam size and profile using fluorescence of electron beam in IR-FEL.

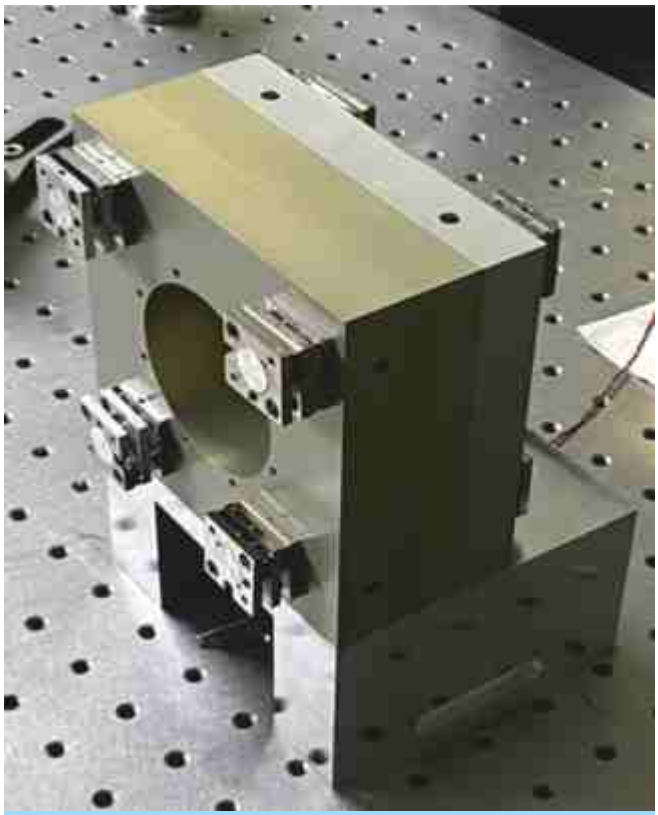
Laser based Directed Energy Deposition System is one of the promising additive manufacturing technologies for the fabrication of functionally graded solid and porous metallic structures having complex geometry. A 2 kW fiber Laser based Additive



2 kW Fiber Laser based Additive Manufacturing System

Manufacturing (LAM) system has been developed. The metallic components with dimensional accuracy within 50 microns have been fabricated. The built volume of the developed system is 400 mm x 400 mm x 300 mm.

A four-stage end-pumped laser amplifier has been developed to scale up the output power of an Non Planar Ring Oscillator (NPRO) laser from 500 mW to 20 W while maintaining the sub-100 Hz line width of the oscillator upto 1 Second. This Laser will find application as a very stable source for precision measurements using laser interferometers.



4-Stage Amplifier

Process development pertinent to the edge cladding of the laser disc has been established on Nd: Glass disc of size 320 mm x 170 mm x 40 mm. The development process included studies on identification of suitable epoxy based adhesives, polishing of Nd: Glass and clad glass discs, cementing of clad glass on large sized Nd: glass disc, testing for stability of the bonded joint under flash lamp irradiation etc. It was found that reflectivity at glass –clad boundary was 10-5 and the Fourier Transformed Infra-Red (FTIR) spectrum was unchanged. The low reflectivity achieved is

Edge clad Nd: Glass disc of size 320 mm x 170 mm x 40 mm

sufficient to suppress the parasitic oscillations within the disc for desired gain of the Nd: glass amplifier.

360 kJ capacitor banks for high energy Nd: glass Laser have been developed which included development of six power supply units with capacitor banks and their charging supplies, flash lamp trigger circuits and PXIe based control system. Resonant converter based scheme has been adopted for charging supply with approximately 250 mA constant current output to charge capacitor banks to maximum 10 kV. The capacitor banks can drive 36 pairs of Xenon filled flash lamps of arc length 400 mm to optically pump Nd: glass laser amplifiers.

360 kJ Pulsed power supplies for Nd: Glass disc amplifiers

Laser Applications

A die with conformal cooling channels is built using Laser Powder Bed Fusion at the optimized parameters of 300 W, 0.08 m/s, 80 μm layer thickness, 0.250 mm hatch spacing. The built component is tested for effective cooling using experiments and simulation.

Conformal Cooling Channel- CAD models for (a) external (b) internal and LAM built parts (c) external (d) internal

Bimetallic structures of IN 625 and SS 304 L with graded interface were fabricated at optimised laser power of 1150 W. The developed bimetallic structures are successfully deformed up to maximum strain of 55% without any crack and delamination at different temperatures. These materials have applications in nuclear industry to meet the extreme environment conditions.

Deposited bimetallic structure of SS304L-IN625 with graded interface

The components used in nuclear industry have very complex geometry and must be manufactured with tight tolerance. Laser Control & Instrumentation Division RRCAT has developed machine vision based non-contact metrology system to inspect dimensions of fuel punches, used for manufacture of nuclear fuel.

Metrology System Photograph

Six Variants of Fuel Punches

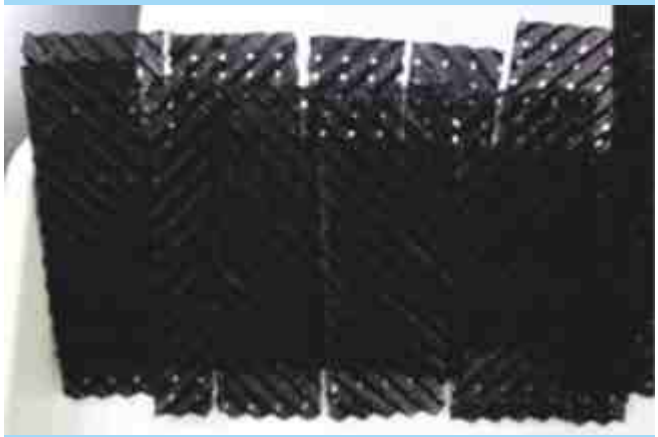
ADVANCED TECHNOLOGIES

A magnetically suspended Turbo-Molecular Pump (TMP) of 400 litres per second capacity has been designed & developed in BARC Trombay. A few prototypes have been deployed for field trials at various DAE units. ANU TURBO – 400 is a totally indigenous development, and is set to serve as import substitute. TMPs find application in various ultra-high and clean vacuum applications in DAE as well as in Indian industry. TMPs are presently not manufactured in India and most of the requirement is being met through imports. India has emerged as 4th country globally to develop magnetically suspended Turbo-molecular Pump.

Magnetically suspended Turbo-molecular Pump ANU TURBO-400

A very high activity liquid phase Hydrogen isotope exchange catalyst has been developed in collaboration with RRCAT, Indore. The novel hydrophobic catalyst on structured packing modules will be useful for hydrogen-water isotope exchange process. In this activity, high activity Platinum on Carbon Aerogel (CA) hydrophobic catalyst (Pt-Carbon Aerogel-PTFE/PFA) was synthesized and coated on stainless steel wire mesh strips for further assembly into structured packing modules. This development will lead to reduction in size and cost of catalytic exchange sections required for large scale heavy water production plants by H_2O-H_2 exchange process. The structured packing modules has been tested for evaluating their

Wire Mesh Strips (before catalyst coating)



Wire Mesh Strips (after catalyst coating)

catalytic performance however long term stability needs to be established for continuous mode operation.

Electronics & Instrumentation

A Prototype Upconversion based Taggant Detection System with response time less than 20 msec has been developed for deployment in operations of Bank Note Press (BNP), Dewas. The system was successfully tested for taggant concentration of up to 0.3% on paper.

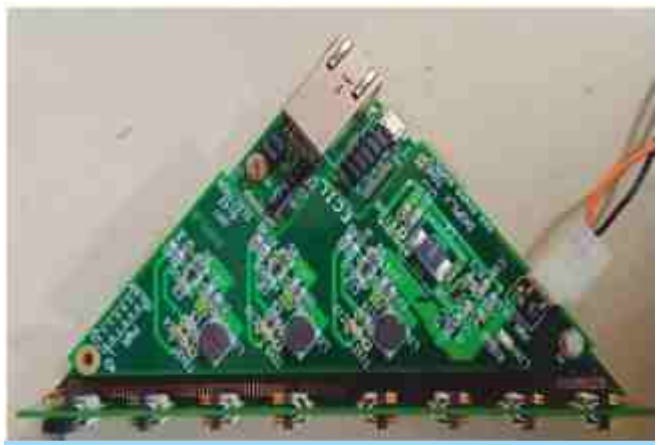
A prototype model of laser-based Fuelling machine Alignment system comprising four probes has been developed and successfully tested at calibration and maintenance facility of TAPS 3&4.

Dual Mach-Zender Interferometer (MZI) based Perimeter Intrusion Detection System (PIDS) Unit has been tested. The system provides exact coordinates of the location of intrusion with an accuracy of better than 200 m for 10 km length of fibre cable.

BARC, ECIL and IGCAR have jointly developed Programmable Logic Controller (PLC) NUCON series 1000 and 2000 as part of development activities to ensure safety and cyber resilience of critical electronic systems. The advantages offered by the newly developed NUCON PLC were presented to potential users, including constituent units of DAE units, Department of Space, Steel, Oil, Gas and Power Sectors. ISRO had deployed NUCON PLC based time critical control systems at its IPRC Mahendragiri facilities.

Launch of Programmable Logic Controller (PLC) and Linux based SCADA Software at a function organized jointly by BARC and ECIL on May 18-20, 2022

A low power, high performance 128-channel Data Acquisition Module (DAM) has been developed for Iron Calorimeter (ICAL) experiment of Indian Neutrino Observatory (INO). The module's FPGA based 128-channel Time-to-Digital Converter (TDC) with 40 μs dynamic range and 84.4 ps resolution facilitates trigger and triggerless data acquisition modes. The module



128-channel DAQ Module

would also be used for high energy physics experiments and muon tomography.

ISOTOPE PROCESSING

The radioisotopes in India are produced in research reactors at Trombay, power reactors of NPCIL and accelerators at VECC. These radioisotopes are processed by BARC, and a vast array of high-quality radioisotope-based products and equipment is commercially produced by BRIT. All these products and services have wide applications in the fields of medicine, agriculture, industry and research.

BRIT handles several Million Curies of Cobalt-60 activity per annum in a safe manner at BRIT-Regional Centre- Kota, also called Rajasthan Atomic Power Plant Cobalt Facility (RAPPCOF), to supply Co-60 sealed sources to healthcare and industrial users in India and abroad.

RAPPCOF facility continued the tasks related with the safe supply of Co-60 for various uses, right from receiving the adjuster rods from various Indian PHWR power reactors (a by-product of neutron regulation), processing of the activity, fabrication of sealed sources, to supply of Co-60 sources (irradiator sources & teletherapy sources), are all carried out.

During 2022-23, Regional Centre, Kota, processed 6.468 Million Curie (MCi) of Cobalt-60 activity. This is mainly used for fabrication of indigenous Cobalt-60 Teletherapy Sources (CTS) and High intensity Multi-Purpose Gamma Irradiator Sources. Successful fabrication of Four hundred and twenty-Four (424) Multi-Purpose Gamma Irradiator Sources and Thirty-one (31) CTS were made during the reported year.

RAPPCOF transported 6.123 MCi of Co-60 sealed source activity to various High intensity Multi-Purpose Gamma Irradiators (used for radiation processing applications such as Medical sterilisation, post-harvest food preservation, sludge hygienisation, etc.) and Radiotherapy Hospitals, both, within the Country as well as abroad. This included Eighty-seven (87) Nos. of W-91 irradiator sources, Four hundred & one (401) Nos. of BC-188 irradiator sources and Six (06) Nos. of CTS.

The Export orders of 2.0 MCi to M/s Nordion, Canada and 1.0 MCi to M/s Ansell, Malyasia are successfully executed after catering the domestic needs, which was ~ 3.5 MCi.

RAPPCOF received 04 Adjuster rods from RAPS-4. Apart from these, 08 adjusters from KGS-1 and 08 adjusters from NAPS-1, are also transported with escort after getting permission from the regulatory board in the financial 2022-23. RAPPCOF trained staff carried out source loading operation in various Multi-Purpose Gamma irradiators plants in the country.

High intensity Cobalt-60 Sealed sources (Cobalt-60 Teletherapy Sources (CTS), W-91 and BC-188 irradiator sources) fabricated at RAPPCOF

Shri. Saeed Anwer Tariq, DGM, RAPPCOF flagged off the M/s NORDION, CANADA export order at RAPPCOF on May 09, 2022

AGRICULTURE

Crop Improvement

Radiations and radioisotopes are used in agricultural research to develop improved varieties for enhancing agricultural productivity to meet challenges like feeding exploding population, climate change and consumer preferences. Towards this, radiation induced mutagenesis along with recombination breeding has

Field view and seeds Trombay Akola Mustard-143 (TAM 108-1)

Field view Trombay Chhattisgarh Vishnubhog Mutant (TCVM)

been used to develop four mustard varieties, Trombay Akola Mustard 108-1 (TAM-108-1) for Maharashtra; Birsa Bhabha Mustard-1 (BBM-1) for Jharkhand; Trombay Him Palam Mustard-1 (THPM-1) for Himachal Pradesh;Trombay Bidhan Mustard-143 (TBM-143) for West Bengal; one groundnut variety, Trombay Akola Groundnut-73 (TAG-73) for Maharashtra; two rice varieties, Trombay Chhattisgarh Sonagathi Mutant (TCSM) and Trombay Chhattisgarh Vishnubhog Mutant (TCVM) have been released and Gazette notified for commercial cultivation by Ministry of Agriculture & Farmers Welfare, Government of India. Towards production of Trombay breeder seeds, 254 quintals of groundnut, 65 quintals of pulses and 80 quintals of rice varieties were produced and distributed to different seed producing agencies for foundation and certified seed production, and for final deployment to the farmers in different states of India. To demonstrate the performance of rice mutant varieties (TCDM-1, Vikram TCR, CG Jawaphool Trombay, TCSM and TCVM) field days were organized in collaboration with IGKV, Raipur. Vikram TCR was cultivated in nearly 200 ha of land by a Farmer's society (Kishan Beej Sahkari Samiti Maryadit", Risda, Bilaspur, Chhattisgarh). In addition, new Trombay pulses and oilseed crop varieties have been produced and distributed to the farmers.

The mutant strain of beneficial microorganism Trichoderma virens based formulation (Tricho BARC)

Trichoderma virens mutant based formulation (TrichoBARC) has been registered with Central Insecticide Board & Registration Committee (CIB&RC)

has been registered with Central Insecticide Board & Registration Committee (CIB&RC), Govt. of India, and is the first mutant micro-organism based biopesticide registered for field applications. Recently, Tricho BARC formulation has been recommended in package of practices by ICAR for seed treatment in chickpea. Pir and Txp40 proteins from symbiotic bacteria PhotorhabdusandXenorhabdus sp. were purified and assessed for insecticidal activity against agriculturally important insect pests and mosquito larvae. The biopesticide formulation based on Bacillus thuringiensis subsp. kenyae ISPC-1 (Btk) was mass produced and evaluated under multi location field trials. This biopesticide has been submitted to ICAR-All India Coordinated Research Project (AICRP) on chickpea to conduct multi-location field trials. An organic formulation of an Actinomycete isolate was found to significantly reduce damping-off disease in vegetable seedlings in pots as well as field conditions. BARC has developed a superabsorbent hydrogel using natural polymer graft-co-polymerised with synthetic precursor using gamma rays. BARC hydrogel can absorb and retain water upto several hundred times of its own weight and releases water upon root demand. BARC, in collaboration with Vasantdada Sugar Institute, Pune, has also developed a versatile bioregulator named "ANU-CHAITANYA" containing gamma-irradiated chitosan which boosts plant growth and activates plant defense mechanisms to tolerate abiotic/biotic stresses. A compact design (25 kg capacity) biogas plant has been commissioned at Dhruva Guest House, New Delhi.

FOOD PROCESSING

India is the biggest producer of mango in the world which is highly valued for their flavor worldwide. To further boost its international trade to USA through sea-route as it offers dual advantage including significantly higher trade volume with lesser (1/10th to 1/8th) freight charges as compared to air-freight, SOP has been developed for this mode of export. During this year, commercial shipment of 16 tons of Kesar mangoes in a controlled atmosphere container has been successfully accomplished by BARC through the involvement of different government as well as private organizations. The processed Kesar mangoes reached the USA after the voyage of 25 days and were successfully marketed in the USA market after the clearance by the US regulatory agencies.

BARC developed protocol for Sea-route shipment of 'Kesar' mangoes to the United States of America

Onion is an important agri-produce that undergoes extensive weight loss, microbial spoilage and sprouting during storage significantly limiting its extended commercial storage. To mitigate these post-harvest issues large scale (15 Tons) commercial trial was undertaken with the prime objective of storing irradiated onions during previous year. The onions were in good physical condition without sprouting with minimal weight loss. The trial was successful with the shelf life of 7.5 months Subsequently, one of the licensees of DAE procured and successfully processed 50 tons Rabi onions as per the SOP developed by BARC. The irradiated onions were stored at commercial storage facility with the shelf life of 7.5 months.

Onions after 7.5 months of storage (external and internal textures)

Sapota (Acharuszapota L.) is popularly known as chiku in India. This is a climacteric fruit which ripens in 7-9 days at ambient temperatures followed by over-ripening, microbial spoilage and rotting within 2 weeks leading to post-harvest losses up to approx. 35%. To address these issues, ripened chiku fruit was converted to a shelf stable 'Chiku Fruit Bites (CFB)' and hygienized using radiation technology. The product is shelf stable at ambient temperature up to 6 months while retaining quality attributes including physical, biochemical, nutritional, health protective (antioxidant and antimutagenic) and organoleptic properties. The developed BARC technology would help farmers and processors of chiku fruit in its preservation and value addition making larger market access.

Packaged and radiation processed chiku fruit bites (Shelf life 6 months)

Strawberry product developed through the BARC technology 'Long Lasting Delicious Strawberry Candy Roll (SCR)' has now been launched at the online portals.

BARC technology 'Long Lasting Delicious Strawberry Candy Roll (SCR)'

BARC has developed a Gluten free (GF) premix using multigrain and radiation processed dietary fibre. This GF premix is cost effective, has better sensory attributes, high in soluble fibre and has a protein content equivalent to regular wheat flour. The product has now been launched at the online portal.

'Gluten Free-Multigrain Premix'

Bombay-duck Fish, locally known as "Bombil" is available in plenty throughout Maharashtra. It is a low-cost and one of the most consumed fish in Maharashtra, Gujarat region in western coast and found in east coast at Andhra Pradesh, Odisha and West Bengal. Bombay duck is rich source of important nutrients including protein, vitamins (especially Vit. A), minerals, poly-unsaturated fatty acids (Ω-3 fatty acids). Nutritious RTE Fish Spread was developed using Bombay duck. The product is shelf stable for 60 days at chilled condition after radiation treatment (5 kGy) with acceptable microbiological and sensory qualities as compared to non-irradiated product (shelf life-8 days). This fish-based spread can be healthy alternative to fat and oil-based breakfast spreads. The technology has been advertised on the BARC website for commercial deployment.

Radiation Processing Services

Radiation Processing Plant (RPP), Vashi

Radiation Processing Plant, Vashi has provided gamma radiation processing services for Spices and allied products to various exporters from all over the country. Forty Seven new customers were registered during the current year. Main products processed were spices (whole & ground both), pet feed, ayurvedic raw materials & healthcare products. Industrial samples like polymer components, electric cables, transmitter, RTDs etc were received from NPCIL vendors & exposed with desired doses of gamma radiation as per qualification test criterion.

During the current financial year, 2022-23, till Dec'22, 2818.68 MT of spices, Ayurvedic raw material, healthcare products and other products were processed. 900 MT of spices & allied products are expected to be processed during Jan-Mar'23.

Surveillance audits for ISO 9001:2015, 22000:2018 and ISO 13485:2016 were got carried out by certifying agency and found in full compliance with the Standard's requirement.

Plant commissioning dosimetry for three radiation processing plants were carried out during the reported Year 2022-23, upto Dec 2022. Dosimetry services was provided during plant recommissioning for medical products sterilization for M/s Nipro, Satara and for Class VI food products, for M/s IFC, Vashi. Dosimetry services for one more radiation processing plant, while its commissioning, would be taken up uptil March 2023.

Production and supply of 2.0 lakhs Ceric-Cerous sulphate dosimeters was made to various gamma irradiators in the country, for absorbed dose measurement. Around 20000 Nos. of dosimeters are expected to be supplied upto March 2023.

Export of 2000 Nos. of Ceric-Cerous sulphate dosimeters were supplied to Atomic Energy Regulatory Board, Sri Lanka, during the reported year 2022-23.

Dose rate certification of Six No's of Blood irradiators (BI-2000) and Three Gamma chamber - 5000 (GC-5000) were completed. Dose rate certifications for two Laboratory Irradiators is expected uptil March 2023.

ISO 9001:2015 Certification was obtained for Dosimeter Production Laboratory, Vashi and recertification of food safety management system (FSMS), ISO 22000:2018 of RPP was done.

Production & supply of 800 Biological Indicators (BI) was done for various customers of RPP.

New MoU for Radiation Processing Plants in Private Sector

Gamma radiation processing plant of M/s Gamma Tech (India) Pvt. Ltd., Tirunelveli, Tamil Nadu and M/s Ansell Sterile Solutions Pvt. Ltd., Coimbatore, Tamil Nadu were commissioned.

Signing of New MoU's for Radiation Processing Plants in Private Sector

During the year, BRIT signed following MoUs:

MoU with M/s Tarsons Products Ltd for setting up a Gamma Radiation Processing Plant in Howrah, West Bengal for treatment of agro products such as spices, herbal products etc. and sterilization applications as permitted by the relevant regulations.

MoU with M/s Q-Line Healthcare Pvt. Ltd., for setting up a Gamma Radiation Processing Plant for treatment of agro products such as spices, herbal products etc. and sterilization applications as permitted by the relevant regulations, in Lucknow, Uttar Pradesh.

MoU with M/s Microwin Sterisolutions Pvt. Ltd., for setting up a Gamma Radiation Processing Plant for treatment of agro products such as spices, herbal products etc. and sterilization applications as permitted by the relevant regulations, in Palakkad, Kerala.

MoU with M/s Vishvesh Agroded Pvt. Ltd., for setting up a Gamma Radiation Processing Plant for treatment of agro products such as spices, herbal products etc. and sterilization applications as permitted by the relevant regulations, in Nagpur, Maharashtra

MoU with M/s Greenrad Ventures Pvt. Ltd., for setting up a Gamma Radiation Processing Plant for treatment of agro products such as spices, herbal products etc. and sterilization applications as permitted by the relevant regulations, in Aurangabad, Maharashtra.

HEALTH

Radioisotope based formulations, techniques and equipment are widely used in the diagnosis and treatment of various diseases. BARC, BRIT, RRCAT and VECC are major contributors in this field.

Radioisotopes are produced, processed and technologies are developed at Trombay for varied applications in the medical field. BARC's Radiation Medicine Centre, a premier centre in the field of radio-diagnosis and radiotherapy in Mumbai, is a regional referral centre of the World Health Organization (WHO) for South East Asia.

BRIT produces and supplies radio-pharmaceuticals for diagnosis and treatment of diseases, teletherapy and brachytherapy sources, radioisotope based kits, various instruments, and radio processing services. Jonaki Laboratory at Hyderabad produces and supplies P-32 labelled nucleotides for research in biology, biotechnology and drug discovery. Jonaki also markets S-35 labelled amino acids produced by labelled compounds at Vashi.

Radioisotopes for medical applications are also manufactured at VECC. The Regional Radiation Medicine Centre in Kolkata meets the radio-diagnostic and radiotherapy requirements of the eastern region of the country.y requirements of the eastern region of the country.

Radiopharmaceuticals

Radiopharmaceuticals are meant for in-vivo use, mainly for diagnostic and therapeutic purposes. Since they are meant for in-vivo use as pharmaceutical grade products, compliance to good manufacturing practices (GMP) is mandatory. In-vitro Radioimmunoassay (RIA) and Immunoradiometric Assay (IRMA) Kits and C-14 Urea capsules are used mainly for diagnostic use. Positron Emitting Tomography (PET) is a powerful imaging agent through which quantitative information on the distribution of positron-emitter labelled radiopharmaceuticals (PET radiopharmaceuticals) in the body can be realized. ^{18}F-FDG is currently the most widely PET radiopharmaceutical in clinical oncology in addition to its clinical applications in cardiology and neurology. The application of PET in clinical oncology is increasing since many molecular targets relevant to cancer can be labelled with positron emitter radiopharmaceuticals and also these products needs to be produced in strict GMP compliance.

Production and supply of the user friendly alumina column based Mo-99/Tc-99m radioisotope generator (COLTECH) to avail Tc-99m at nuclear medicine centres for SPECT based diagnostic imaging of patients continued in 2022. Significant increase in demand for COLTECH generators supplied by BRIT was seen in 2022-23. 1271 COLTECH generators were produced and supplied during the period benefitting more than 2 lakh patients. Solvent extraction generators (TCM-2) were also supplied on demand from the hospitals. A total of 63 consignments of TCM-2 were supplied during the reported period.

Around 53,000 cold kit vials (towards formulation of Technetium-99m, Rhenium-188 and Lutetium- 177 radiopharmaceuticals) were supplied to nuclear medicine centres throughout India. Majority of the cold kits were supplied for preparation of ^{99m}Tc Radiopharmaceuticals towards early disease diagnosis. More than 2.25 Lakh diagnostic procedures were performed using these kits.

About 875 radioimmunoassay (RIA) and immunoradiometric assay (IRMA) kits were supplied to the various nuclear medicine centres, diagnostic laboratories and research institutes throughout India.

Iodine-131 as Na^{131}I is one of the important radiopharmaceuticals supplied to hospitals for management of thyroid disorders including thyroid cancers. This includes oral solution and capsules in different denominations, I-131 labelled mIBG for the diagnosis and treatment of Neuro Endocrine Tumors (NET). Approximately 750 Ci of I-131 products was supplied to nuclear medicine centres all over India during 2022-23.

About 1900 consignments of ready to use injectable radiopharmaceuticals were produced and supplied to NM centers. There was significantly increased demand for ^{177}Lu-DOTA-TATE for treatment of metastatic (somatostatin receptor positive) neuroendocrine tumors & ^{177}Lu-PSMA for the treatment of Prostate Cancer, which was catered to. About 900 patient doses of these products were formulated and supplied to nuclear medicine (NM) centres upto Dec. 2022. Other therapeutic products supplied by BRIT included the ^{90}Y-HA and ^{177}Lu-HA for treatment of rheumatoid arthritis.

The Medical Cyclotron Facility (MCF), Parel, continued the production & supply of Positron Emission Tomography (PET) radiopharmaceuticals, mainly ^{18}F-FDG and ^{18}F-Sodium Fluoride and to a lesser extent the newly launched [F-18]-Fluro Ethyl–L-Tyrosine (FET).

Regular and uninterrupted supply of PET radiopharmaceuticals such as ^{18}F- FDG, ^{18}F-NaF, and ^{18}F-FET to various hospitals, in and around Mumbai, accounting for nearly 176.25 Ci of radioactivity was supplied, during the year 2022-23. More than 12000 patients benefitted with PET investigations in the reported year, upto Dec 2022.

Routine production and supply of cyclotron produced ^{18}F-FDG to different hospitals in Kolkata was carried out during the reported period. The total revenue generated till date is more than 1 core.

Production of ^{68}Ga-PSMA-11 and of ^{68}Ga-DOTA-TATE from ^{68}Ga-Chloride using enriched Zn-68 solid target in Cyclone-30 were produced and supplied to local hospitals in Kolkata.

To prove the clinical efficacy of the ^{68}Ga-PSMA-11 produced by BRIT, PET/CT imaging studies were carried out in an adult male patient to determine prostate metastases. ^{68}Ga-DOTA-TATE was used in Command hospital, Kolkata using GE discovery 690 PET/CT scanner in a patient with a suspected diagnosis of insulinoma. The patient had multiple episodes of hypoglycaemia. The uptake pattern of the tracer was homogeneous and acquired image quality was excellent.

A 30 MeV, 350 μA Medical cyclotron facility is an unique facility under aegis of department of atomic energy which facilitates production of various radioisotopes and basic research simultaneously.

Medical Cyclotron Facility at VECC Kolkata

During the report period the machine availability was satisfactory and it has delivered beam for irradiation of O^{18} to produce F18 and FDG (Fluorodeoxyglocose) which is produced by BRIT. Production was carried out everyday morning for 5 days a week without any major interruption. Two hot cells operated in automatic process for regular production of FDG from medical cyclotron.

Apart from this, beam with different energy was developed and transfered to beamline#1.1 for trial production of Ga67, Th201 and Ga68. Ga68 isotopes were produced using this facility and supplied to local hospitals by BRIT.

Two other beam lines were used for R&D activities related to material science and liquid-metal target study. Irradiation of material sample was started in material science beamline. 16MeV and 20MeV, 50μA beam was transported to material science and delivered to the target. In this period beamline target facilities was developed and various radiation data was obtained for the beamline. Beamline is ready for regular use after regulatory clearnce.

The Radiation Medicine Centre (RMC), a constituent unit of BARC provides nuclear medicine services in India. During April-December 2022, advanced diagnostic services were extended to 8,717 patients using ^{68}Ga-, ^{99m}Tc- and ^{18}F- based radiopharmaceuticals. 1976 patients with thyroid, prostate and neuroendocrine cancer were provided radionuclide therapy. For thyroid cancer patients, radioactive iodine therapy was provided to more than 476 patients. ^{177}Lu- DOTATATE therapy was given to over 378 patients of neuroendocrine cancer. ^{90}Y- DOTATATE therapy was offered to over 08 patients with large progressive disseminated metastatic neuroendocrine tumours.

RMC has started providing treatment using alpha radionuclide therapy using ^{225}Ac-DOTATATE among patients suffering with small single cell neuroendocrine tumours. ^{177}Lu-PSMA therapy was offered to more than 97 prostate cancer patients. Various thyroid function tests (TSH, T_4, fT_4, AMA and Tg) were performed using RIA for 4259 patients. The Medical Cyclotron Facility produced 377 batches of ^{18}F based PET radiopharmaceuticals and these were supplied to 6 Nuclear Medicine Centres across Mumbai. $^{64}CuCl_2$ produced at research reactor Apsara-U was evaluated as a PET radiotracer.

For radioimmunotherapy of non-Hodgkin's lymphoma and breast cancer, ^{177}Lu-DOTA-Rituximab and ^{177}Lu-DOTA-Trastuzumab, respectively were approved by RPC for use in diagnostic and further approval for therapy is expected next year.

A new Nuclear Medicine Facility is coming up within the premises of new DAE Campus at Rajarhat in Kolkata. The facility comprises state-of-art infrastructure for providing various services, including nuclear medicine diagnostics and therapeutics. The development of infrastructure and installation of equipment is in progress.

RMC regularly conducts various academic courses for science graduates. During the year, admissions to M.Sc. program in Nuclear Medicine and Molecular Imaging Technology, Hospital Radiopharmacy as well as MD in Nuclear Medicine were carried out successfully. The affiliation to these courses was granted by Homi Bhabha National Institute.

Radiation Technology Equipment

Radiography Camera

A total of 22 Nos. of Radiography Cameras (ROLI series) were supplied to various NDT users across the country, upto December 2022. Inspection and services were provided for 567 numbers of BRIT and imported radiography cameras.

Blood Irradiator

Two Blood Irradiators-2000 units with Co-60 source have been supplied to hospitals in India during April 2022 to December 2023 and supply of 02 units of BI-2000 is expected to be supplied upto March 2023. One Unit of BI-2000 was reconditioned, Two units were decommissioned, while services was provided for 04 units.

Gamma Chamber 5000

Three units of GC-5000 with Co-60 source were supplied during Apr 2022 to December 2022, and supply of 01 Unit is expected upto March 2023. Source replenishment was done for one unit of GC-5000. One Unit each of GC-1200 & GC-4000A and Three Units each of GC-5000 & GC-900, were decommissioned during the reported year 2022-23, while 01 Unit of GC-5000 & 02 Units of GC-900 would be decommissioned upto March 31, 2023. Inspection & servicing was provided for three units of GC-5000 and two Units of GC-1200.

Treatment Planning System for Bhabhatron II

A new automation-based treatment planning software – DOSAGE – which optimizes important parameters of radiotherapy administered through Bhabhatron-II has been developed in BARC. Phase-I tests for ascertaining the compatibility of DOSAGE software involved several tasks, including multi-planar reconstruction of CT images, contouring tools, plan creation, computation of dose, visualization and validation. Dosimetric performance as per IAEA-TECDOC-1583 on Thorax phantom was validated using measured data as well as commercial TPS. The observed results were found to be acceptable for taking up clinical trials.

Radio Diagnostic & Treatment Services

Regional centres at Delhi, Dibrugarh & Kolkata, Hyderabad (also k/as Jonaki), Bengaluru, and Kota continued their respective services towards the supply of ready-to-use-radiopharmaceuticals to surrounding nuclear medicine hospitals, rendering RIA & IRMA diagnostic services for the benefit of patients in the entire North-Eastern region, PET Radioisotopes production in Cyclotron (VECC), preparation & supply of labelled compounds, radioanalytical certifications and processing of Co-60 sources for their various uses in Engineering Programme of BRIT. Around 3,000 consignments of in-vivo and in-vitro kits were supplied to RCR's for providing extended services to nearby hospitals, research centres, or institutions at and surrounding these cities.

The Radiopharmaceuticals products produce and supplied by BRIT Vashi Complex, are extensively used by the Regional Centre Dibrugarh, for diagnosis & investigation of various diseases. The centre is currently analysing the hormones like T_3, T_4, TSH, Free T_4, Insulin etc. In this period a total of 2165 Nos. of tests are done for almost 2105 Nos of patients.

During the year 2022-23, Technetium cold kits for formulation of ^{99m}Tc-radiopharmaceuticals were supplied to various Nuclear Medicine Hospitals in Kolkata.

Nearly 48.31 Ci of F-18 was produced from CYCLONE-30 at MCF, Kolkata, and RC, Kolkata, produced, duly analysed and supplied ~ 150 batches of ^{18}F-FDG to Nuclear Medicine hospitals in North-Eastern region of India, during this period.

Two PET radiopharmaceuticals, ^{68}Ga-PSMA-11 and of ^{68}Ga-DOTATATE for the diagnosis of prostate cancer & neuroendocrine tumors (NET) from ^{68}Ga-Chloride radiochemical, using enriched Zn-68 solid target in Cyclone-30, were produced, analyzed for quality control before supplying them to local hospitals in Kolkata.

Regular Quality Assuarance (QA) was performed before the batch release of all the RPhs which were supplied through the Centre during the reported period.

During the reported year 2022-23, Regional Centre Bengaluru supplied ready-to-use 162 Ci of 99mTc Pertechnatate to Nuclear Medicine hospitals, along with 1100 TCK cold kits (produced at BRIT Vashi Complex), for the preparation of ^{99m}Tc-radiopharmaceutical formulations.

NABL accredited Radioanalytical testing laboratory (RAL) of Regional Centre, Bengaluru, analyzed and certified ~ 250 samples for residual radioactivity in various commodities such as food items for human & animal consumption, medicine and other miscellaneous items, from April 2022 to December 2022.

Gamma Blood irradiator, commissioned last year at RC, Bengaluru, at Kidwai Memorial Hospital Campus, Bengaluru: Services of gamma irradiation of blood and its components were extended to outside hospitals, other than KMIO, on chargeable basis, since August 2022. Monthly ~ 1200 Nos. of blood and platelets were irradiated at this Centre.

Regional Centre for Radiopharmaceuticals, Delhi, continued the supply of clinical grade, ready to use diagnostic ^{99m}Tc-radiopharmaceuticals injections in compliance with GMP and RPC, COLTECH/GELTECH Generators and TCM-2 (~1.7 Ci) (^{99}Mo Generator kit for Solvent Extraction) ($^{99m}TcO_4^-$), for the nuclear medicine centres in Delhi and NCR regions.

Quality Control of ready-to-use Tc-99m & its labelled RPhs from 48 batches were analyzed during the said period. ~798 Nos. of TCK Cold kits have been supplied from retail outlet of Regional Centre, BRIT, Delhi, to different private and Government Nuclear Medicine Centres in Delhi, NCR & Northern region of India.

Two shielding tong boxes were dismantled and the assembly with lead bricks were safely transported safely to BRIT, Vashi Complex. Fabrication of Stainless Steel furniture is under progress, for the upgradation of the laboratory.

During the period, Regional Centre of BRIT, Hyderabad (Jonaki) supplied ready-to-use Tc-99m as Sodium Pertechnatate to local Nuclear Medicine Centres. It has supplied 798 Nos. of TCK Cold kits (produced at BRIT, Vashi Complex) from retail outlet of Regional Centre, BRIT, Hyderabad.

It has initiated the setting up of Radiopharmaceuticals laboratory for the preparation and supply of ready-to-use Ga-68 formulations to the local Nuclear Medicine Centres, NABL accreditated Radioanalytical testing facility for providing radioanalytical services to the users.

RC, BRIT, Hyderabad, continued the synthesis and supply of ^{32}P-labelled nucleotides (153.5 mCi) and molecular biology reagents such as Taq DNA Polymerase, PCR master mix and enzymes for research in frontier areas of Molecular Biology, Biotechnology, Biomedical and Drug Discovery research of the country.

Labelled Compounds and Diagnostic Kits

Labelled Compounds Programme of BRIT is involved in the synthesis & supply of a variety of ^{14}C, ^{3}H

and ^{35}S-labelled products and various types of Tritium-Filled Self-Luminous sources.

During April to December 2022, Labelled Compounds Programme has supplied 892 Nos. of Tritium Filled Self-luminous (TFS) sources, of various sizes and shapes, to defence establishments and used for illumination of various types of gadgets and instruments.

Tritium gas facility at CIRUS reactor building, BARC, Trombay has been completed. Cold trial experiments were completed successfully, and the report has been submitted to the committees for approval of carrying out the hot trials. Once this facility is ready for operation, the tritium gas handling operation related to Tritium filled light sources (TFS) and tritium labelled compounds production activity will be shifted to CIRUS building.

During the period, EXIT sign board has been designed and fabricated using Gaseous Tritium Filled Light Sources. AERB type approval has been obtained for this product, after successfully completing all prototype tests, as per AERB SS-4 standard.

GTLS 'EXIT' sign board in day light

GTLS 'EXIT' sign board under dark

Custom synthesis and supply of radiolabelled compounds, mainly, C-14 based compounds, is provided to research institutes. These find extensive applications as tracers in the field of biology.

Labelled Compounds Laboratory also continued the production and supply of ^{14}C-Urea Capsules which is used for diagnosis of Helicobacter Pylori infection which causes stomach ulcers.

Another ^{14}C product produced and supplied, during the period, is ^{14}C-planchet source used in environmental studies. This product was supplied to RPAD, BARC.

^{14}C-planchet sources

Radio Analysis

Radioanalytical Laboratory, BRIT Vashi Complex is an NABL accredited laboratory engaged in the measurement and certification of radionuclide content in commodities such as food items meant for human & animal consumption, water samples, metal & metal products, environmental samples such as coal, fly ash, soil, rock phosphate, phosphor-gypsum etc. The laboratory is also empanelled by BIS for the testing of gross alpha and gross beta content in water samples.

During April-December 2022, RAL has carried out more than 5867 tests on export/domestic commodities and water samples. The desk top surveillance audit by NABL was also successfully completed during the period.

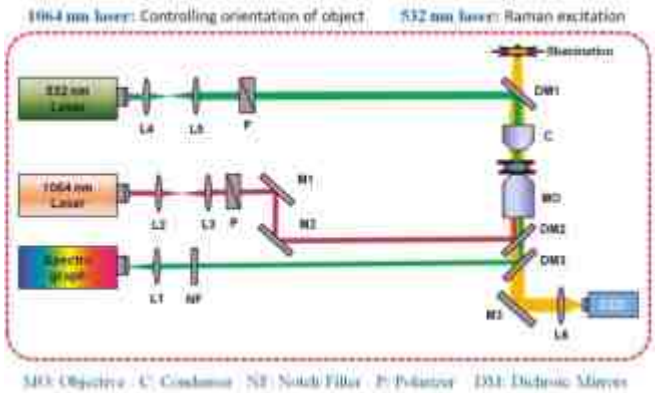
Radiation Sterilization Plant for Medical Products (ISOMED)

Gamma Radiation Processing Plant facility at ISOMED for terminal sterilization of the medical products is being revamped and is under renovation during the reported period 2022-23, after 44 years of impeccable service to the nation.

Biomedical Applications

The possibility of using low intensity and low fluence Antimicrobial Photo Dynamic Therapy (APDT) for inactivation of SARS-CoV-2 using clinically isolated samples has been explored on sixty viral swab samples suspended in viral transport medium at different BSL-2 facilities. For all the samples, RTPCR analysis for expression of the E-gene, open reading frame 1 ab (ORF 1ab) was carried out. To ascertain the effect of APDT, the samples with Ct values > 35 for the two marker genes were considered as negative. The increase in Ct value following APDT suggested damage and inactivation of the virus.

Studies at the single cell level can help in both better diagnosis and comprehension of diseases. Raman spectroscopy in this regard can facilitate such studies with its rich information content and suitability of operation in the native aqueous environment of the cells. However, owing to its extremely weak nature and inherent motility of cells, an optical tweezer is often required to hold on to the cells during the period of observation. An in-house developed resonance Raman optical tweezer has been set-up which can provide an ~100 times enhancement of the Raman optical tweezers signal when used for analysis of single red blood cells.



Raman optical tweezer Schematic

Alternative Applications of Heavy Water

Based on the MoU signed between BRIT and Heavy Water Board, deuterated NMR solvents were dispensed and supplied to various customers. All the solvents that were supplied had >98% Deuterium abundance.

Non-nuclear applications of deuterium in medicinal chemistry/biological field have been progressively taking shape and have become more tangible for Indian industry as well as academics/research institutes.

Field of deuterium applications has broad spectrum and it is difficult for a single organization to cover all the fields of application. It is possible to accelerate the research and industrially scale up the activities in this field with collaborative efforts. HWB takes a lead to catalyze the research and development in this direction by transplanting the concepts to the Indian organizations through collaboration with them.

HWB has issued work order for collaborative project with Faculty of Pharmacy, The Maharaja Sayajirao University (MSU) of Baroda for carrying out the project titled “Synthesis and Biological Evaluation of Deuterated Analogs of some Antineoplastic Drugs”. A work order was issued for collaborative project with Advanced Centre for Treatment, Research and Education in Cancer (ACTREC), Navi Mumbai for carrying out the project “Evaluation of anticancer potential of deuterium depleted water on experimental model systems and clinical trial patients of human breast cancer”.

Proposal has been put up to DAE for entering into agreement with M/s Sigma Aldrich Chemicals Pvt Limited, Bangalore (a subsidiary of M/s Merck KGaA, Germany) for long term bulk supply of heavy water for development of deuterated compounds.

Civil work is being taken up for the project “Augmentation of production of deuterated compounds at HWP, Baroda”.

Besides dispatching small quantities of Heavy Water for R&D purposes, approval has been taken for supply of small quantity Heavy Water for commercial production of deuterated compounds to various users viz. M/s Sigma-Aldrich, M/s Vadilal gases etc. Heavy Water has been supplied to M/s Clearsynth and M/s SyNMR under the existing collaborative agreement with these parties.

Sale order for supply of DDW has been issued to interested parties through tendering process.

^{18}O enriched water in medical diagnostics

HWB is synthesizing ^{18}O enriched water which is a precursor for generation of radiopharmaceutical ^{18}F-FDG in cyclotron. This provides the images of PET scanning by radioactive decay with emission of positron. PET is a diagnostic technique used in oncology, neurology and cardiology. Nuclear grade Heavy Water is used as raw material in first indigenously developed ^{18}O production plant at HWP, Manuguru. The unit remained under steady operation. In the enrichment columns, 95.5% IP ^{18}O enriched liquid was produced in the facility in the financial year.

Cancer Diagnostics and Treatment Services

The Tata Memorial Centre (TMC), an autonomous institution under the administrative control of the Department of Atomic Energy, Government of India. TMC comprises of Tata Memorial Hospital (TMH), the Advance Centre for Training, Research and Education (ACTREC) and the Centre for Cancer Epidemiology (CCE) in addition to new and upcoming cancer centres at Sangrur, Visakhapatnam, Mohali, Varanasi and Guwahati.

There was 20% increase in the total number of new patients' registrations at the TMC hospitals across India. From a figure of over hundred and ten thousand (>110,000) in year 2021, it rose to over hundred and forty thousand (>140,000) in 2022. There was similar increase in the numbers of radiological and of the laboratory investigations performed at all centres across India. The pan India bed strength was just over 1800.

The 60:40 General to Private patients' category ratio was adhered to at all cancer centres and with subsidized cost of drugs for all categories of patients. The investigational & treatment charges were also comparable with those in their habitat.

The commissioning of the Homi Bhabha Cancer Hospital & Research Centre, Mullanpur in Punjab was done by the Honorable Prime Minister of India, Shri Narendra Modi on August 24, 2022.

A new Preventive Oncology Rural service for cancer screening & its early detection was initiated from February 2022 at Khopoli (Raigad district) in Maharashtra,

The one-year 'Cancer Patient Navigation (CPN) Indonesia's training program (International Program) from commenced from November 2022 (21 students enrolled).

The HBCH & the MPMMCC in Varanasi are fully functional and they operated at their optimum capacity & functionalities (>25000 new patients; >4000 surgeries/ >3500 radiotherapy; 30 bone marrow transplants)

The first-year report of the Population-based Cancer Registry of Muzaffarpur, Bihar was published (Cancer Incidence & Mortality in Muzaffarpur State, India: 2018)

The National Cancer Grid (NCG) is the largest cancer network with more than 260 centers all over India.

The first of its kind in the public sector, the latest Hadron (Proton) Beam Therapy facility at ACTREC in Navi Mumbai is expected to get operational by mid 2023.

The physical structure of the Hematolymphoid Women & Children Cancer (HWCC) building & of the Radiological Research Unit (RRU) at ACTREC was completed and are soon to be made operational

TMC continued to provide the online services through TMC-Navya which were availed by over 90,000 patients from across 75 countries.

Big Randomized Controlled Trial (RCT) conducted by TMC proved that injecting local anesthesia around the breast tumor prior to surgery increases the cure rate by 26%. This is expected to save 100,000 lives annually globally.

Large Randomized Clinical Trial (RCT) proved that an inexpensive and commonly available drug, Carboplatin, improves cure rates and response in a highly fatal form of breast cancer.

Large randomized clinical trial proved that Yoga increases the quality-of-life and cure rates in women with breast cancer: A new study by Tata Memorial Hospital, which found 15% relative improvement in Disease-free Survival (DFS) and 14% in Overall Survival (OS) after yoga intervention.

^{60}Co Teletherapy Sources for Cancer Hospitals

RAPPCOF processed a total of nearly 8 MCi of Cobalt-60 activity in 2022-23 financial year, upto December 2022, which included Co-60 sealed sources supply for 424 Gamma Irradiator sources and thirty-one numbers of Cobalt-60 Teletherapy sources (CTS) sealed sources.

Three MCi of Gamma Irradiator Sources were exported to Canada [2 Million Curie (Mci)] and Malaysia (1 MCi). This is in addition to the domestic supply of 3.5 MCi of these irradiator sources, which are used for the radiation processing plants for the disinfestation, shelf-life extension of food products and sterilization applications of healthcare products purposes.

WATER

Water Purification, Desalination of Water & Isotope Hydrology

Under the DAE's Project on “Deployment of water purification technologies rural India”, 1000 point-of-use arsenic decontamination devices of 24 litres per day capacity were deployed in Bihar's Samastipur district. These units are capable of providing arsenic free safe drinking water as per Indian Standard, BIS 10500 from the ground water contaminated with up to 400 ppb of arsenic. Besides, three 2000 litres per hour capacity plants capable of removing fluoride from water were commissioned at Gram Panchayat of Sagargaon, Khordha, Odisha.

Two plants of 12500 litres per hour capacity, equipped with the technology of removing completely salinity in water using Reverse Osmosis process, were commissioned for providing safe drinking water to BSF personnel stationed at Indo-Pak border near Kutch in Gujarat. The plants at Khardoi and Sandeep BOP were implemented as part of Jal Jeevan Mission of Government of India for providing safe drinking water to rural and remote areas in India.

The 12500 litres per hour capacity water treatment unit based on BARC technology commissioned at BSF outpost at Kutch near Indo-Pak border

A 1000 litres per hour capacity community-scale arsenic removal plant with water dispensation facility was installed at Ichhapur-I Village Panchayat, Dist. North 24 Parganas, West Bengal based as part of DAE's Vision-6 Project on “Deployment of Water Purification Technologies in Rural India”. The arsenic concentration was reduced from 400 ppb in feed water to less than 10 ppb in product.

Exploring the hot spring link to fluoride contamination of groundwater in Odisha

The project activity was carried out to identify factors responsible for fluoride contamination in groundwater in the vicinity of hot springs of Khurda, Nayagarh and Ganjam districts of Odisha. Water samples have been collected from the study area in different seasons for two consecutive years. Both thermal (~60°C) and non-thermal (~28°C) waters have been collected from existing wells. Chemical analyses

revealed that the thermal water was richer in Na^+, K^+, and Cl^-, with lower bicarbonate content, whereas non-thermal water is mostly enriched in Na^+, Ca^{2+}, Mg^{2+}, HCO_3-, Cl- and SO_4^{2-}. Around 39% of the groundwater samples showed fluoride concentration > 1 mg/l, higher than the desirable limit specified by the WHO (1.5 mg/L). A strong correlation between fluoride and other major ions could not be found, suggesting that multiple processes are responsible for the high fluoride concentration observed in the study area. The major geochemical processes include dissolution of fluoride-bearing minerals from the rocks, evapotranspiration, agricultural input and mixing of cold groundwater with hot spring water containing high fluoride.

Stable isotope data (d^2H and $d^{18}O$) of the thermal and non-thermal waters both plot on the Global Meteoric Water Line suggesting the source water as meteoric. Environmental tritium data indicate that the non-thermal water is relatively modern, while the thermal waters are older. The modelled radiocarbon age of thermal waters (13.3 – 20.7 Ka) suggests paleo-recharge of the reservoirs during Last Glacial Maxima, characterized by arid climate and low rainfall.

Rejuvenating drying springs in Uttarakhand through isotope technology

Isotope hydrological investigations were carried out with the Dehradun based Himalayan Environmental Studies and Conservation Organization (HESCO) for rejuvenating the drying springs in various locations in Uttarakhand's Uttarkashi and Pauri Garhwal districts. A total of six sets of pre-monsoon and post-monsoon samples were collected for stable isotopes ($d^{18}O$, dD) and environmental tritium analysis during the study period. Rainwater samples were also collected from selected locations in the study area. From the stable isotope values of oxygen and hydrogen ($d^{18}O$, dD) of precipitation samples, the altitude effects were established for different sites. The relation between stable isotopes and altitude was used to estimate the recharge altitudes for different springs.

Environmental tritium of springs was measured to determine the residence time of springs water. The recharge altitudes estimated for 18 different springs of

Geothermal sampling at Atri site in Odisha's Khurda district

Uttarkashi district varied from 1200-2100 meters Above Mean Sea Level (AMSL) whereas recharge altitudes of 8 different springs of Pauri Garhwal district were found to be in the range of 1458-1517 metre AMSL. The residence time of these springs water was found to be 1-6 years. Based on the isotope results, various recharge structures like Gibbon check dams, Gully pluggings, Trenches, Percolation ponds, Dykes (surface and subsurface) and contour bunding were constructed depending upon the geomorphology of the identified zones. Discharge rate of the springs increased from 0.2 to 4.8 times after the construction of recharge structures, which benefitted about 10,000 people residing near these springs.

INDUSTRIAL APPLICATIONS

A Cryo-Irradiator is designed for 400 kCi of Cobalt-60 to irradiate marine product. Major components of the irradiators which were under fabrication has been completed, delivered and installed. Cold run trials of the Cryo-Irradiators are carried out. The plant operated successfully during the cold run. After completion of the cold run, 95 kCi of Co-60 which is approximately 25% of the plant capacity was loaded into the Cryo-Irradiators cask in the IFRT Hot cell. The plant was re-installed after the source loading. The product drive system, ventilation system, loading and unloading conveyors are installed and integrated to the control system. Hot commissioning runs are carried out for both manual modes and auto modes of operation. Blast air unit capable to deliver blast air at -20^{0}C is integrated to the plant. The plant is now ready for commissioning dosimetry.

Installation of Cryo-Irradiator

Cryo-Irradiator Cask with Co-60 Source

ROTEX-I radiography device under 9m drop & 1m punch test

Remotely Operated Tungsten Shielded Exposure Device (ROTEX-1) which is an industrial radiography device is in advance stage of development. Analysis for 9m drop, 1m punch and 800^{o}C fire tests are completed and safety analysis report is submitted to AERB. Fabrications of three numbers of prototypes are completed. As per the AERB recommendation, one prototype of ROTEX-I is dropped from 9m on unyielding target and subsequently drop for 1m on a punch to qualify it as a Type B(U) package. The tests were successfully conducted at Automotive Research Authority of India (ARAI), Pune.

ROTEX-I device hanged at a height of 9m for the drop test

ROTEX-I device hanged at a height of 9m for the drop test (close-up view)

Design approval of Mobile Food Irradiator

Mobile Food Irradiator is a category-II, panoramic, dry storage, batch type gamma irradiator designed to irradiate low and medium dose food products like fresh fruits and vegetables, cereals, pulses etc. The irradiator can be installed on a 40 feet trailer bed and can be moved to different places as per the

irradiation schedule. This makes the irradiator itself capable of reaching to the location of food produce. It is designed for the 3700TBq (100 kCi) of Cobalt-60 radio-isotope. The expected typical throughput of the irradiator is around 9.60 MT/day for mango or 14.40 MT/day for insect disinfection of cereals.

A safety analysis report for the mobile irradiator was prepared and submitted to AERB for the "Design and Construction Approval" of Mobile Food Irradiator. The proposal was discussed in the AERB and the formal approval for the Design and Construction of Mobile Food Irradiator has been accorded. The work contract for the construction of Mobile Food Irradiator is in the advance stage.

Schematic layout of Mobile Food Irradiator

Development of COCAM-A radiography device

Board of Radiation and Isotope Technology (BRIT) has indigenously developed Co-60 based industrial radiography devices COCAM-A. It is a mobile type, category-II radiography device designed for a maximum source capacity of 0.296 TBq (8Ci) of Co-60 radio-isotope. A sectional view of COCAM-A radiography device is shown below.

First prototype of COCAM-A radiography device

There are very few Cobalt-60 (Co-60) based industrial radiography devices available in the Indian market and majority are imported ones. Therefore, Board of Radiation and Isotope Technology (BRIT) has initiated the indigenous development of Co-60 based industrial radiography devices.

COCAM-A is designed and manufactured to meet the requirements of IAEA SSR-6& AERB NFR-TS/SC-1, ISO-3999-1 & AERB RF-IR/SS-1 to qualify it as a Type A transportation package as well as industrial radiography device. The fabrication of first operational prototypes of COCAM-A is completed. The device is checked for its operation, functionality and was found satisfactory. The shielding integrity of the prototypes is also checked by the radiometry test using 2 Ci of Co-60 radio-isotope and observed results were well within acceptable range.

Type B (U) approval of "MTP-1200" Mo-99 Transportation Package

The Molybdenum-99 Transportation Package (MTP-1200) is designed to carry 44.4 TBq (1200 Ci) of

MTP-1200 package during radiometry test

Mo-99 radio-isotope. The package uses tungsten alloy as shielding material to make it compact and light in weight. The package is designed to show its conformance to the type B(U) transportation package requirements as per national and international standards. The fabrication of the first two prototypes of the package is completed. The shielding integrity of the prototypes is also checked by the radiometry test and the package successfully showed its adherence to the standards requirements.

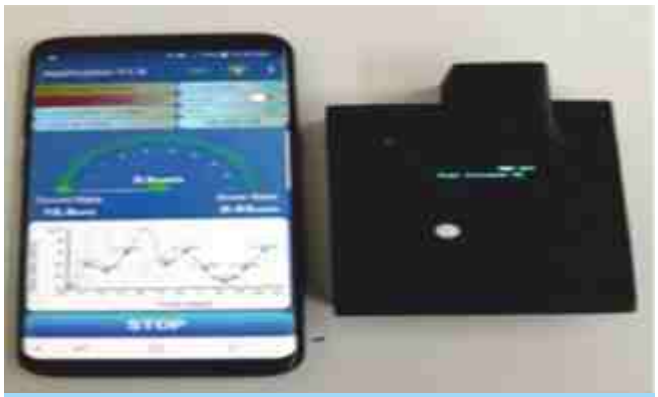
The safety analysis report (SAR)of the package is submitted to AERB for the necessary transportation package approval. based on the SAR, AERB has accorded the Type B(U) transport package approval to the MTP-1200 package.

Design and Development of Cobalt Pin Cask

Cobalt Pin Cask (CoPin-50) is designed to carry a maximum of 50 kCi of Cobalt-60 produced from Co-NU fuel bundle of Indian PHWR to Cobalt handling facility of BRIT at Kota. It is designed as Type B(U) transportation package. Design and fabrication drawings of cask is completed. Finite Element based structural analysis was conducted to assess the structural integrity of the Cask for normal and accident condition of transport. Indent for the fabrication of a prototype of the cask has been processed and is under evaluation.

Development of X-ray Baggage Inspection System (XBIS)

New improvements were made in the X-ray Baggage Inspection System (XBIS) through development of Silicon photodiode-Cesium Iodide based array of 16-pixel X-ray detectors with associated front end, data acquisition and control electronics. The Dual View XBIS software (DVXBIS) on board the system facilitates advanced image processing, better spatial representation and improved detection of contents. The process of evaluation of indigenous XBIS is in advanced stages of completion.



SiPM based hand held Gamma Monitor

Silicon Photomultiplier (SiPM) based hand-held Gamma Monitor

A smart compact gamma monitor using SiPM (3 mm x 3 mm with 50 μm pixel size) coupled to a Cesium Iodide (CsI - TL) scintillation detector has been developed for the detection of gamma radiation. The device can be connected to a PC/ smartphone for obtaining real-time dose-rate.

Radioisotope Sources supplied by BRIT

Industrial Irradiator Sources

Eighty seven (87) nos. of W-91 irradiator sources & Four hundred and one (401) nos. of BC-188 Irradiator sources with total activity of around 6.123 MCi were supplied to various processing plants during the financial year 2022-23.

Co-60 Teletherapy Sources (CTS)

A total of six numbers of Cobalt-60 Teletherapy Sources, in the RMM range of 192-245, were supplied during the Year 2022-23.

^{192}Ir and ^{60}Co Radiography sources

A total of 577 Nos. of Ir-192 & Four Nos. of Co-60 radiography sources with total activity 22858 Ci and 85 Ci respectively were supplied from April 2022 to December 2023. Another 200 sources of ^{192}Ir (activity - 8000 Ci) and one number of ^{60}Co radiography source (50 Ci activity) is expected to be supplied, up to March 2023.

Co-60 and ^{137}Cs CMR sources

About 41 nos. of customized sources of ^{60}Co with total activity 3.714 Ci and Two numbers of ^{137}Cs CMR

sources with 1.57 Ci activity, were supplied up to Dec 2022. Another Five ^{60}Co CMR sources (400 mCi activity) is planned up to March 2023.

Total 90 nos. of devices containing Cs-137 sources were collected from NTPC, Korba. Collection of remaining devices from 3 institutes is planned up to March 2023. Source are to be removed from devices for repatriation to USA.

Around 83 numbers of devices containing various types of radionuclide were handled at RSMS, BARC for safe management of disused sources. Another 50 nos. is expected by March 2023.

Isotope Application Services

Diagnosis of main Fractionator Column (19-C-01) using Gamma Scanning Technique at IOCL, Mathura Refinery

The gamma scanning work at IOCL, Mathura was taken up using 80 mCi of Cobalt-60 as the gamma radiation source and BGO scintillation detector for radiation intensity measurement. The Cobalt-60 source was transported to Mathura Refinery in AERB approved transport package. Marking on the column was done by IOCL as per the internal arrangement of packing and trays. As per the requirement, scaffoldings, temporary shed and passage for source and detector through platforms were provided by IOCL. Both the source and detector collimators have 2.5" outer diameter which are required to pass through between platform and body of the column. Wherever necessary, at some locations specific gratings were removed from the platforms to facilitate the smooth passage of the collimators. Automatic gamma scanning system consisting of source operator and detector operator was kept at suitable location. The source and detector operators were controlled through a control unit and data in form of counts per unit time with respect to column elevation were obtained and recorded in the laptop.

Photographs of scanning arrangements at the site

Gamma scanning was applied successfully to assess the mechanical health as well as hydraulic conditions of the fractionator column. It was very helpful for the refinery engineers to identify the problematic zone and taking important decisions regarding column operation.

Leakage Identification in a Series of Heat Exchangers Using Radiotracer Technique at MRPL, Mangalore Refinery

In the Diesel Hydrotreater (DHDT) unit of Mangalore Refinery and Petrochemicals Limited (MRPL), Mangalore refinery, off spec diesel product was observed. As per the strict environmental norms, it is not permissible. It was suspected that leakage in the Feed/Effluent heat exchangers (EA-33301A/B/C and EA-33302A/B) may be the reason of this contamination. Identification of leaky heat exchanger during operational condition is not possible through conventional techniques such as hydrotesting, pressure drop or sampling etc. MRPL approached BRIT to apply radiotracer technique to identify the leaky heat exchanger, if any, as a possible cause of product contamination.

The above said industrial diagnostic services were able to provide benefits to the industries in terms of taking decisions on shutdown, pinpoint the malfunctions in running condition, minimize the downtime of the plant and avoid the huge financial losses as well as earning a valuable revenue for BRIT.

There were five nos. of heat exchangers connected in series. It was decided to carry out the radiotracer study by single injection of around 1 Ci of Mo-99 in organic phase. The injection device was fabricated and installed upstream of the charge pump by MRPL. Provision of high-pressure nitrogen cylinders were made to inject the radiotracer into the stream. Dummy trials were taken to ensure the performance of the injection device. Finally, Radiotracer was injected by

Radiotracer injection into the system

BRIT officials into the shell side (~ 76 ksc) of the heat exchanger EA-33301C and the leaked radiotracer was monitored towards the tube outlets (~ 65 ksc) of remaining heat exchangers to record the leakage peak, if present.

As per the radiotracer study carried out by BRIT, heat exchanger EA-33301C was found leaky. The leakage was confirmed by the refinery officials during the shutdown. The radiotracer study immensely contributed for the better productivity of the plant.

CHAPTER 5

X-Ray Magnetic Circular Dichroism (XMCD) Beamline BL-20 experimental station has been commissioned at RRCAT

BASIC AND APPLIED RESEARCH

Test Gyrotron at ITER-India lab, IPR

The Department of Atomic Energy has contributed significantly towards strengthening of basic research in India. The Department pursues basic research in its R&D centres that ranges from Mathematics to Computers, Physics to Astronomy and Biology to Cancers. It also provides grants-in-aid to nine institutes of national eminence. Following were the major activities and achievements of DAE in basic research, during the period of report.

MATHEMATICS & COMPUTATIONAL SCIENCES

At the School of Mathematics at TIFR, work was carried out on several questions and problems in Geometric Group Theory, Probability Theory, Complex Analysis, Conformal Dynamics, and Reflection Groups, Geometry and Topology, Lie Groups, Arithmetic Groups and Algebraic Geometry. Univalent polynomials have played an important role in classical complex and functional analysis. A new invariant was defined to study the connectedness of algebraic varieties. This invariant was defined for general rings and was used to study the number of connected pieces that a variety breaks into, for example, a hyperbola. This invariant was used to study projective modules over real affine varieties. It was proved algebraically, using this invariant, that if we remove two points from a circle, we get a disconnected object. Researchers studied First Passage Percolation (FPP) in a Gromov-hyperbolic group G with boundary equipped with the Patterson-Sullivan measure. For every point on the boundary, researchers also showed almost sure coalescence of any two geodesic rays directed towards the point. In another study, researchers introduced the notion of a k-almost-quasifibration. Researchers deduced that the fundamental group of the orbit configuration space of an effective and properly discontinuous action of a discrete group, on an aspherical 2-manifold with isolated fixed points is torsion free.

In the School of technology and Computer Science at TIFR, research work was pursued in the areas of computer science as well as systems science. Markov Decision Processes (MDP) and continuous-time MDP are the fundamental models for nondeterministic systems with probabilistic uncertainty. Mean payoff is one of the classic objectives considered in their context. Researchers provided the first algorithm to compute mean payoff probably approximately correctly in unknown MDP. The algorithm does not require knowledge of the state space, but only a lower bound on the minimum transition probability, which has been advocated in literature. Neural networks have been seen to exhibit simplicity bias, wherein the model learns only the simplest features at the cost of robustness. Researchers formalise this bias mathematically and provide both theoretical and empirical justification for the formalism. It was conjectured that the simplicity can be captured by low-rank structure of the weight matrices learned by the neural network

At the TIFR Centre for Applicable Mathematics, Bengaluru, researchers introduced a concept of dissipative measure-valued martingale solutions to the stochastic compressible Euler equations. Using this concept, they established relative energy inequality for the stochastic compressible Euler equations and, as a corollary, exhibited pathwise weak-strong uniqueness principle. Unique continuation results for ray transforms, momentum ray transforms and transverse ray transforms of symmetric tensor fields were studied. In the ray transform case, it was shown that if the ray transform of a symmetric tensor field vanishes along all lines passing through a non-empty open subset in n-dimensional Euclidean space and if the Saint-Venant operator associated the symmetric tensor field vanishes on the same open set, then the symmetric tensor field is a potential field. Analogous results were proved for momentum as well as for transverse ray transforms.

The central themes of research of the mathematics group at HRI were in the areas of Finite Group Theory, Representation theory and Lie Algebras, Algebraic Geometry, Differential Geometry, Harmonic Analysis, and Number Theory. The report below highlights contributions made to some of these areas over the academic year 2022-2023.

Group theory is a tool in the mathematical study of symmetry and explores general ways of studying it in many different settings. Manoj Kumar Yadav with his collaborators Valeriy G. Bardakov and Mikhail V. Neshchadim continues their work in skew left braces which arise as set-theoretic solutions of the quantum

Yang-Baxter equation, arising in Physics. Specifically, they study a set of left braces called anti-homomorphism on specific infinite groups.

Representation theory is another topic that uses group theory as an integral ingredient. The representation theory of infinite dimensional Lie algebras is of great interest in both mathematics and physics. One of the important questions in this topic is the classification of irreducible integrable modules over these algebras. Punita Batra, in recent work with her student Mr. Santanu Tantubay, has classified irreducible integrable modules for the full Toroidal Lie Algebras co-ordinated by Rational Quantum Torus.

Homological algebra is a tool used in many branches of Mathematics including Algebraic Geometry. Umesh Dubey and his student Gopinath Sahoo continue studying tensor weight structures and t-structures on derived categories of Noetherian schemes. They provided a condition that characterizes those weight structures on a derived category which come from a Thomason filtration on the underlying scheme.

The theory of harmonic manifolds is a crucial area of study in Differential Geometry. In a recent work, Hemangi Shah along with her collaborators continued to study on minimal surfaces of rotations immersed in deformed Hyperbolic Kropina Space.

Fourier integral operators appear very naturally in the construction of fundamental solutions for hyperbolic differential equations and are very useful in many other investigations. P.K. Ratnakumar and his collaborator Ramesh Manna proved the local smoothing estimate for general Fourier integral operators with specific phase functions.

Algebra, Analysis, and Geometry have found many applications in Number theory. Gyan Prakash and Surya Ramana with collaborator Mallesham Kummari explored the representation of integers as monochromatic sums of squares of primes and provided an estimate. Gyan Prakash also conducted a study on thin sum-product bases on a commutative ring with his collaborators F. Hennecart and E. Pramod. On the other hand, R. Thangadurai and A. Pal along with their collaborator V. Kumar continued their study on the growth of trace of powers of algebraic integers and provided a characterization for a non-zero algebraic integer to be a root of unity.

At SINP, the long-range Kitaev (LRK) spin chain has been studied in the context of global quench in the power describing the range of the interactions. The entanglement entropy has been obtained and it has been shown that it can admit both area and volume law depending on the parameter ranges concerned. The OTOC has also been obtained analytically and the numerical conterpart is currently under investigation.

Analytical expressions for exact partition functions of Polychronakos like quantum spin chains associated with the BCN root system have been obtained in the presence of chemical potentials. It has been found that such partition functions can be expressed through some homogeneous multivariate super Rogers-Szego polynomials. Vertex models and transfer matrices related to these Polychronakos like spin chains have been constructed by using their connection with the super Rogers-Szego polynomials.

Integrable properties of local as well as nonlocal vector nonlinear Schrödinger equation with a general cubic nonlinearity in the presence of a linear term, which under certain condition incorporates balanced loss and gain of energy, have been investigated. It has been shown that such nonlinear systems possess Lax pairs and infinite number of conserved quantities. The inverse scattering transformation method is employed and exact soliton solutions are obtained for both the local and nonlocal cases. A new class of two-component nonlocal field models, with different types of continuous or discrete space-time symmetries and infinite number of conserved quantities, have also been constructed.

At IMSc, in Algebraic Number Theory, Sanoli Gun, Olivier Ramare & Jyothsnaa Sivaraman proved a fully explicit generalized Brun-Titchmarsh theorem for an imaginary quadratic field. More precisely, for any finite family of linearly independent linear forms with coefficients in Ø, the authors count the number of integers at which all these linear forms take prime values in Ø.

PHYSICS

At HRI, members of the astrophysics group collaborated with various research centres in India, e.g. Indian Statistical Institute Kolkata, Institute of Mathematical Sciences Chennai and the S N Bose National Centre for Basic Sciences Kolkata. They also have collaborations with various academic institutions outside India (in particular Europe). The group members have been working on accretion physics around large black holes, analogue gravity, non-commutative fluid dynamics, nonlinearity and chaotic behaviours of the light curves from compact objects, and on various other aspects of gravitation and field theory. Work done by the members of the group gets published in various reputed international journals on a regular basis.

Research in condensed matter systems and materials at HRI remained focussed on strongly correlated systems, topological materials, high pressure physics and energy applications through catalysts and solar cells.

HRI have been working on tools to understand nonequilibrium dynamics in correlated electron systems, in particular pump-probe systems. HRI solved the problem of charge-order melting and reconstitution and aim to use the method to develop a better understanding of driven Mott insulators and superconductors.

It continued research themes of materials for alternative, renewable energy and understanding and design of magnetic materials. Therole of water structure in determining the rate of hydrogen evolutionreaction (HER) in alkaline media is explained through a joint experiment-theory work. The work has provided an explanation of why increasing alkaline concentration of the electrolyte decreases HER rate. A battery of Machine Learning models which can select out stable, magnetic materials with large magnetic moment and anisotropy from a given set have been designed by HRI. Efficacy of these models has been tested in subsequent density functional calculations with much success.

Work on the Physics of materials for solar cells and fundamentals behind different catalytic reaction for efficient hydrogen generation and carbon emission have been continued. We have theoretically predicted novel materials for efficient and stable solar cells, where the fundamental electronic and excited state properties are being envisaged. Investigations on Rashba-Dresselhaus and Pseudo-Rashba effect in the promising solar cell materials are on which is arising from the relativistic spin-orbit coupling. Work on high pressure driven phase transformation and exploring the memristive properties from the ion-migration perspective for Neuromorphic computing methods are also being carried out.

The High Energy Phenomenology group of HRI research is focused on searching for signals of beyond the standard model (BSM) physics at present and future colliders, various neutrino physics and dark matter (DM) experiments, and gravitational waves experiments. The group has constructed many novel BSM models predicting the existence of light Z bosons, a light scalar that can induce neutrino self-interaction, and self-interacting and freeze-in DM candidates. New ways of looking for such particles at experiments by making use of multivariate/machine-learning techniques have been put forward. Such cutting-edge data analysis methods have also been used to study the jet substructure of boosted fat W-boson jets and non-standard interaction of the standard model (SM) Higgs boson with bottom quarks at the large hadron collider experiment in CERN. The group has carried out a study analysing the effect of anomalous couplings on the spin-correlations and polarisation of a pair of particles involving the Standard Model heavy fermions and gauge bosons. Also, the impact of BSM physics on muon g-2 anomaly and lepton flavor violating observables has been studied by the group.

The Quantum Information and Computation (QIC) group of HRI conducted fundamental and application driven research in a wide range of areas that include physics, mathematics and computer science. A new faculty member has joined the group, expanding the area of expertise of the group, particularly towards upcoming quantum technologies. The group has received three grants from the QuEST project of the DST, GoI and a SERB (DST) ECR award. Recently, the groupâ€™s research remained focussed in the

following areas: theory of quantum entanglement and quantum correlations, quantum communications, quantum computation, quantum thermodynamics, quantum cryptography, interface of quantum information with quantum many-body physics, etc. Specifically, looking at the effect of noisy environments on the efficiency of the Shor factorization and the Grover search algorithms.

The group has made a proposal for a new a nonlinear measurement-device-independent entanglement witness. Other than that, a small quantum refrigerator in which the working substance is made of a nearest neighbour spin-j quantum XYZ model has been explored.

The string theory group of HRI consists of 3 faculty members, 4 postdocs and 3 Ph.D. students. The group hosts visiting undergraduate students on a regular basis.

String theory is a theoretical framework which can provide us with a unified theory of all the forces observed in nature. We describe some of the directions that have been explored recently. Aspects of the low energy effective action of string theory have been explored by making use of modular graphs and number theoretic methods. Conformal field theories have been studied, novel properties in their structure have been discovered. Quantum field theoretic amplitudes have been studied by making use of on-shell recursion methods. Various studies to connect string theory to cosmology have been made. In this context, some implications of an early universe in the hagedorn phase have been studied.

The Condensed Matter Theory group at the Institute of Physics (IOP) has made well recognized contributions to the non-equilibrium aspects of a higher-order topological insulator, their superconducting phases hosting Majorana modes, their bulk boundary correspondence, quantum transport in Dirac/Weyl materials, twisted bilayer systems, quantum magnetism, strong correlations in a band topological insulators on the Lieb lattice, effect of interaction and disorder in strongly correlated systems in the presence of the magnetic field, aspect of quantum magnetism, organization of bacterial chromosomes, exact dynamical moments for trapped active Brownian particles showing a re-entrant non-equilibrium transition, the emergence of dynamical pattern formation and running waves on spherical membranes due to active cytoskeletal proteins.

The Theoretical Nuclear Physics Group worked mainly on the structure of neutron stars, especially their merger, to estimate the Gravitational Wave Strain. Lots of work is being done to understand the various modes of oscillation of neutron star, cooling of it and Supernovae and the Dark Matter effects. The Nuclear Reaction Dynamics and various exotic structures of finite nuclei are also being studied.

The experimental condensed matter group at IoP remained actively involved in cutting-edge research that focused on Brain-inspired computing, Resistive switching, ion beam-induced self-organized pattern formation and their nanoscale functionalization, photovoltaics, nano-bio glucose sensing, organic and DNA overlayers, novel electronic and magnetic phenomena in atomically engineered thin films/heterostructures, thermoelectric, electronic band structures of advanced materials and understanding of physical properties of atomically thin two dimensional layered materials. The low-energy 3 MV Pelletron accelerator of IOP has been used by different external users to carry out their research.

At TIFR, in Astronomy and Astrophysics, researchers presented design and performance of TANSPEC (TIFR-ARIES Near-infrared Spectrometer), a medium-resolution 0.55-2.5 mm cryogenic spectrometer and imager, now in operation at the 3.6 m Devasthal Optical Telescope (DOT), Nainital, India. 47 Tucanae is one of the richest globular clusters in the Milky Way. Using detailed numerical simulations researchers created a star-by-star model of 47 Tucanae. The study constrained the initial properties of the progenitor of this star cluster and provided strong constraints on its present-day dark remnant populations such as black holes, neutron stars, and white dwarfs. Ultraviolet bright sources were studied in the Galactic globular cluster NGC 4590 using Ultraviolet Imaging Telescope onboard the AstroSat satellite. Using UV-

optical colour-magnitude diagrams, researchers identified and characterized the sources of different evolutionary stages i.e. Blue Horizontal Branch stars (BHBs), Extremely Blue Horizontal Branch stars (EHBs), Blue Straggler Stars (BSs), variable stars, etc. It was found that the massive and younger BSs are concentrated at the centre of the cluster whereas the older and less massive BSs are distributed throughout the cluster.

Scientific ballooning program is a key element for any space science program as it provides frequent and low-cost balloon flight opportunities. The TIFR Balloon Facility, Hyderabad extended its support to national and international user scientists for conducting balloon flights for space research. A plastic balloon designed and fabricated at TIFR Balloon Facility, having a volume of 286,652 cubic metres, was launched on 7th December 2022 at 0545 hrs (IST) from TIFR Balloon Facility, Hyderabad. It was launched with the unmanned HALO Space Exploration Capsule weighing ~620 kg as suspended payload along with telemetry and tele-command packages for two-way communication between the ground station and the capsule and a GPS module for live tracking of the Space Capsule.

Baryonic matter in galaxies is mostly in the form of stars, and neutral atomic and molecular gas. Over a galaxy's lifetime, atomic gas gets converted to molecular gas which then gets converted to stars. A galaxy's baryonic composition is thus an important indicator of its evolutionary stage; the evolution of the baryonic composition of galaxies has long been an open issue in galaxy evolution. Researchers at the National Centre for Radio Astrophysics, TIFR at Pune used the detection of the average HI 21 cm emission signals from high-redshift galaxies and found that galaxies at the epoch of peak star-formation activity in the Universe have a dramatically different baryonic composition from that of nearby galaxies. Unlike the situation today, where stars make up more than half the baryonic mass in galaxies, it was found that atomic gas dominates the baryonic mass of galaxies nine billion years ago, making up ~70% of the baryonic mass, compared with only ~16% in stars. In another study, a robust flux density calibration method for solar observations with the Murchison Widefield Array was devised and verified using multiple different approaches. This work presented the first demonstration of an imaging quality high enough to allow the detection of numerous weak background sources in the vicinity of the Sun, a bit like seeing stars in the daytime. Three millisecond pulsars (MSPs), PSRs J1120-3618, J1646-2142 and J1828+0625 were discovered using the Giant Metrewave Radio Telescope (GMRT) at a frequency of 322 MHz using 32 MHz observing bandwidth. These sources were discovered while conducting the deep observations to search for millisecond radio pulsations in the directions of unidentified Fermi Large Area Telescope (LAT) gamma-ray sources. These MSPs do not have gamma-ray counterparts, indicating that these are not associated with the target Fermi LAT pointing emphasizing the significance of deep blind searches for MSPs.

At TIFR, in High Energy Physics, observations of astrophysical sources with the HAGAR telescope array located at Hanle in Ladakh at an altitude of 4270 m continued, with the aim of studying very high energy gamma-ray emission from these objects, to get insight into emission mechanisms. Several blazar class active galactic nuclei as well as galactic objects like Crab, Geminga pulsar and some of the pulsars detected by Fermi satellite are being observed. A 64-pixel prototype of 256-pixel SiPM-based camera was mounted in the focal plane of the vertex element of the TACTIC telescope at Mt Abu. Test runs were carried out during April-May 2022 demonstrated proper functioning of the prototype. Rate-bias curves were carried out and Cherenkov images of air showers generated by cosmic rays were recorded successfully.

Neutrinos are known to change their identities from one type to another during propagation. If neutrinos are unstable, their propagating states could be different from their decaying states. Researchers of the Theoretical Physics Department of TIFR, pointed out that this “mismatch” is inevitable when these neutrinos pass through the Earth, and oscillation probabilities for such unstable neutrinos were calculated. Two-dimensional lattice models with interacting degrees of freedom are one of the most commonly studied systems in Statistical Physics. In a model of interacting rods on a two-dimensional lattice, researchers showed that there

are infinitely many phases with a varied degree of orientational order. There are essentially two classes of transitions separating these phases. One corresponds to the Ising-type spontaneous symmetry breaking transition and the second belongs to less-studied phase transitions of geometrical origin. The geometrical transition is of novel origin and does not fit the conventional Ehrenfest classification scheme. The results are based on Monte Carlo simulations on a square lattice, and a fixed-point analysis of a functional flow equation on a Bethe lattice.

Ultraintense, femtosecond laser irradiation of a solid produces a dense, hot plasma that has emerged as a test bed for a wide range of phenomena ranging from basic plasma physics through to complex laser-plasma interactions and table-top approximations to astrophysical systems. Researchers of the Department of Nuclear and Atomic physics at TIFR, presented an advance in the measurement of the ultrafast dynamics of the plasma, which enables spatial resolution in the transverse direction. The study obtained spatially resolved velocity maps of the plasma on subpicosecond and picosecond timescales with a few micrometer spatial resolution. The technique thus enables, in combination with simulations, the mapping of the energy flow within the target driven by electron conduction and radiation transport on timescales that are relevant to the laser-plasma interaction and consequent heating. The excited states of odd-odd 154Ho nucleus have been studied by the ^{141}Pr(^{16}O, 3n)^{154}Ho reaction at Elab= 82 MeV utilizing the Indian National Gamma Array (INGA) setup at BARC-TIFR Pelletron facility, TIFR, Mumbai. Data from g–g coincidence, directional correlation (DCO), and polarization measurements have been analyzed to assign and confirm the spins and parities of the levels. The reported level scheme of ^{154}Ho has been improved by including new levels and transitions. Mixing ratios for the mixed transitions extracted from DCO ratios and parity assignments from polarisation data are reported for the first time. The low-lying states in ^{154}Ho, which are mostly collective, characterized by regularity in the excitation spectra, are proposed to be arising from neutron excitation.

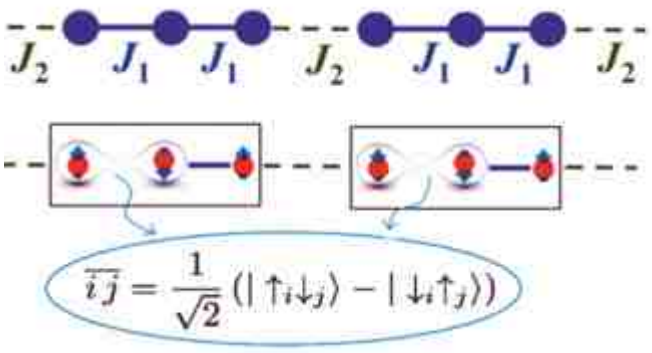
The Pelletron LINAC Facility (PLF), a joint project by TIFR and BARC, continues to be a workhorse for heavy ion research in the country. The LINAC was operated during March 25 to May 22, 2022 for a total of 10 experiments. Additionally, about 30 experiments were completed with the Pelletron beam. The scientific output of the facility continues to be significant and competitive. The programs also include applications like damage study for spacecraft and reactor materials, ion-induced defects in semiconductors, mutations in rice grain for enhancement of the crop yield, etc.

A distinguishing feature of active particles is the nature of the non-equilibrium noise driving their dynamics. Control of these noise properties is, therefore, of both fundamental and applied interest. Researchers of TIFR International Centre for Theoretical Sciences, Bengaluru, demonstrated emergent tuning of the active noise of a granular self-propelled particle by confining it to a quasi-one-dimensional channel. It was found that this particle, moving like an active Brownian particle in two-dimensions, displays run-and-tumble characteristics in confinement. They showed that the dynamics of the relative orientation coordinate of the particle maps to that of a Brownian particle in a periodic potential subject to a constant force, in analogy to the dynamics of a molecular motor. The work illustrates geometry-induced tuning of the active dynamics of self-propelled units, thus suggesting an independent route to harness their internal dynamics. In another study, researchers investigated the effect of a two-dimensional, incompressible, turbulent flow on soft granular particles and showed the emergence of crystalline aggregation due to the interplay of Stokesian drag and short-ranged inter-particle interactions. This was quantitatively demonstrated by the occurrence of a sharp transition between the crystalline and non-crystalline phase as a function of the Stokes number. The nature of preferential concentration, characterised by the correlation dimension, was found to be significantly different from that of particle-laden flows in the absence of repulsive potentials.

The Major Atmospheric Cherenkov Experiment (MACE) telescope has started regular science observations after its commissioning in September 2021. The telescope was deployed for more than 150

hours to monitor high energy gamma-ray emission from galactic and extragalactic sources during the year. Apart from the consistent detection of the standard candle (Crab Nebula) statistically significant gamma-ray photons have been detected from the active galactic nuclei Mrk 501 in a live time of approximately 07 hours with high confidence level. This detection indicates a probable short-term flaring activity in the source.

Quantum entanglement, a phenomenon where the quantum state of a particle in a group is entangled to another spatially separated particle is of special interest for upcoming quantum technologies as well as in fundamental physics. A recent BARC study has demonstrated for the first time the novel quasi-particle excitations of strong spin entangled ground state of a quantum spin-1/2 trimer-chain antiferromagnet. Such a model spin-1/2 trimer-chain antiferromagnet has been achieved in the compound $Na_2Cu_3Ge_4O_{12}$ where the group of three spin-1/2 of Cu^{2+} are strongly coupled to form a spin-trimer, and such trimers are coupled weakly to make a spin-chain. The ground state of such a spin-trimer system involves a quantum entanglement between two spins (out of the three spins at a time) involving the wave function. Most importantly, such entangled states are found to be very stable against temperature and persist up to near room temperature (~250 K), which has a special importance for practical device applications in quantum technologies.



Snapshot of the quantum entangled magnetic ground state of a trimer spin-chain involving the wave function of the entangled state

A new research finding on the non-equilibrium nuclear fission has been reported for the first time from pre-scission multiplicity data recorded at the Pelletron Linac Facility. The observation shows that the pre-scission alpha particle multiplicity makes a changeover from high to a very low value while making a transition from symmetric to relatively asymmetric heavy-ion collisions. This clear signature of non-equilibrium fission has been observed for the first time and has improved our understanding of nuclear fission dynamics and the processes involving super heavy elements synthesis.

The in-house-developed large plastic scintillator Indian Scintillator Matrix for Reactor Antineutrino (ISMRAN) detector installed inside Dhruva reactor hall has been operational round the clock for measurements of antineutrinos through Inverse Beta Decay (IBD) process. The data has been acquired in both reactor-ON and reactor-OFF conditions. The ISMRAN detector provides a tool to monitor the reactor power level in a reliable way. Ongoing data analysis is expected to provide measurements of antineutrino spectra.

At VECC, the effect of weak binding of ^{9}Be on complete fusion has been studied through the emission of intermediate mass fragments (IMFs) from ^{20}Ne + ^{9}Be reaction. The yields of the fragments ^{6,7}Li and ^{7,9}Be emitted from the excited compound nucleus ^{29}Si* have been compared with the respective statistical model predictions. The same fragments emitted from another close-by compound nucleus ^{28}Si* at similar excitation energy, formed by the fusion of two strongly bound nuclei, ^{16}O + ^{12}C, has been studied for comparison. It has been observed that for the reaction ^{16}O + ^{12}C, the yields of ^{6,7}Li and ^{7,9}Be fragments are close to the predictions of the statistical model. However, for the ^{20}Ne + ^{9}Be reaction, although the experimental yield pattern follows the statistical model prediction, there is substantial reduction in yield for all detected fragments. These observations have been attributed to the suppression of complete fusion in ^{20}Ne + ^{9}Be system due to the weak binding of ^{9}Be, a dynamical effect which is not incorporated in the conventional statistical models. It is the first time that a clear signature of the suppression of complete fusion in light systems involving weakly bound nucleus has been observed in IMF emission from fully equilibrated composite produced in fusion well above the barrier.

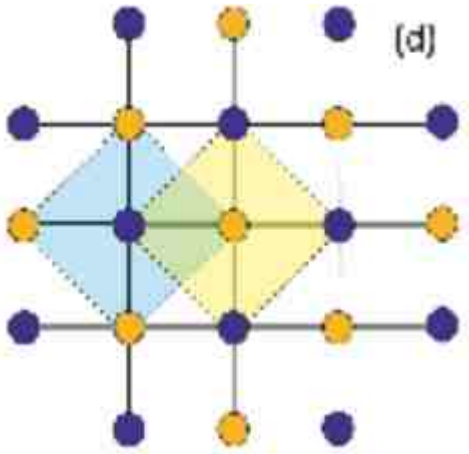
A systematic study has been performed to understand the (N-Z) asymmetry dependence on the nuclear level density by measuring the emitted neutrons from ^{4}He + ^{112,116,124}Sn reactions in the excitation energy range of 25-42 MeV. Statistical model analysis has been performed to test the different phenomenological prescriptions by explicitly studying the dependencies of level density on three key factors: nuclear deformation, neutron-proton asymmetry, and the separation from the most stable isobar. Nuclear level densities determined from the measured neutrons spectra show a reduction for ^{115,127}Te in comparison to that of ^{119}Te, which lies closer to the beta stability line. Such kind of experimental results on isospin dependence of nuclear level density has been unveiled for the first time in a range of isotopes with A>110.

Microscopic interaction from the realistic nuclear equation of state has been successfully implemented in the Canonical Thermodynamical Model of nuclear multifragmentation in order to calculate different fragmentation observables at intermediate energies. Effect of effective mass on mass fractions and average mass of heavy clusters for warm stellar matter has been investigated in the framework of the Nuclear Statistical Model approach. Nuclear collective dynamics has been studied using inputs obtained from the nuclear energy density functional theory.

The density dependent Bag model for quark matter has been implemented to explain the formation of stable hybrid stars in the light of the different astrophysical constraints on the structural properties of compact stars. It is observed that the bag pressure plays a very important role in the emergence of special points on the mass – radius variation of stable hybrid stars in different variants of the Bag Model. Universal (linear) relations emerge in the context of formation of special points between the mass corresponding to the special point and the maximum mass of the hybrid stars with the variation of asymptotic values of bag pressure in the Density Dependent Bag Model as well as in different hadronic models based on Relativistic Mean Field Theory.

The effects of QCD critical point on various observables like spin polarization, transverse momentum spectra, and flow coefficients of hadrons produced in collisions of nuclei at relativistic energies have been investigated. Production and anisotropic flow of thermal photons in collision of A clustered carbon with heavy nuclei have been studied at relativistic energies. The electromagnetic spectral function from chirally imbalanced hot and dense quark matter was derived. The dilepton production rate from such matter has been evaluated.

IPR reported the first observations of a square lattice formation in a 2D dusty plasma crystal, generated during experimentation and corroborated using molecular dynamic simulations. The findings have applications in material science research, where structural transition events are important in understanding soft material systems.



A schematic of square lattice formation

The occurrence of non-equilibrium phase coexistence phenomena in a complex plasma system is experimentally demonstrated for the first time. The initial homogenous crystalline phase becomes unstable and ultimately forms a coexistence of fluid and crystalline phases separated by a sharp interface due to ion-wake induced instability. This system can be used as a model system to study the fundamental problems associated with non-equilibrium phase coexistence, interfacial effects, artificial active matter etc.

A team of researchers at IPR have shown theoretically a significant (>30 fold) enhancement of laser absorption by electrons from a deuterium nano-cluster in presence of ambient magnetic fields Bext

using a simple model of cluster (RSM) and rigorous particle-in-cell (PIC) simulations with a 5-fs broadband laser pulse. This work may ignite new interest for energetic electron generation, particularly with the availability of new generation of broadband lasers and upcoming new magnetic field technology. Moreover, it may improve understanding of the origin of energetic electrons in astrophysical plasmas, e.g., in the environment of neutron stars and pulsars where ambient magnetic fields may range $\approx 10 - 100000$ kT along with a wide range of electromagnetic fields.

The Radar Cross Section (RCS) of an object determines the maximum detection range of potential targets like aircraft, submarines, ships, etc. Reduction in RCS, leading to Stealth systems, can be done by different techniques. R&D at IPR has yielded a broadband (13.42–22.66 GHz), polarization-insensitive, metasurface absorber that provides 20 dB reflection reduction. The work is based on numerical simulations coupled with experiments. Different geometrical shapes of conformal metasurfaces have also been demonstrated both numerically and experimentally.

Conventionally, emission of radiation is understood as a loss mechanism, draining the energy of the physical system. In contrast to this intuitive notion, this work shows that, for a charged particle interacting with a focused electromagnetic wave, in the regime where radiation reaction dominates over the Lorentz force, radiation reaction forces the particle to cross the focal region resulting in enhanced forward energy gain. Studies clearly show that the parameter space for forward energy gain, which is reduced by ponderomotive effects, is compensated by radiation reaction effects. This result is of crucial relevance to present day direct laser acceleration schemes of charged by particles using intense laser beams.

The thermal motions of particles cause fluctuations in local density of a system, which are responsible for transport processes at microscopic scales. A theoretical study of these microscopic fluctuations in density of a strongly coupled system has been performed. The dynamics are described in the framework of Generalized Hydrodynamic (GH) model that incorporates strong coupling effects. An analytical form of Density Autocorrelation Function (DAF) is obtained in terms of transport parameters of the system by using an exactly derived Hydrodynamic matrix. The theoretical results are validated using Molecular Dynamics simulations, and the resulting transport parameters are compared.

At SINP, the behaviour of a noncommutative scalar field in the background of a Reissner-Nordstrom (RN) black hole has been analysed and the entanglement entropy has been obtained within the brick wall formalism. It has been shown that the noncommutative effects appear only in the second order in the deformation parameter.

An alternative derivation of Hawking radiation based on quantum mechanical over-the-barrier reflection from a one-dimensional potential has been explored. The reflection coefficient shows an exponential fall in energy which, on comparison with a Boltzmann probability distribution of a statistical system, yields a temperature. The temperature is the Hawking temperature for spherically symmetric black holes. The derivation gives a local calculation of Hawking temperature.

A new continuous gravitational wave detection pipeline has been developed for searching extremely weak signals from rapidly rotating, deformed neutron stars in the Milky way galaxy. Furthermore, an innovative approach of machine learning based statistical analysis to infer structural and compositional properties of neutron stars have been developed. This will enable us to infer density-pressure relationships in the interior of neutron stars accurately with extremely low latency from gravitational wave events of binary neutron star mergers. The algorithms developed in this machine learning based analysis also have implications for potential practical applications future outside the area of physical science.

In 1967, Bruno Pontecurvo introduced first “sterile neutrino” which can interact only via gravitational interaction and some unknown interaction. Thus, it can be detected through the effects generated by their mixing with active neutrino. SINP scientists have shown direct evidence of the sterile neutrino. An

anomaly has been observed around the endpoint of the measured β-spectrum of second unique forbidden transition of 138La (5+). The data has been analyzed in the light of Fermi-Kurie (FK) plot and an extra component around the endpoint energy has been observed at a 3ε level of statistical significance. The probability of observing that extra component with respect to beta events are same in a number of repeated experiments and the fitted parameters of the extra strength with Gaussian shape around endpoint energy are within the error of 99.7% confidence limit. All possible tentative explanation in the light of atomic, nuclear and neutrino physics have been discussed. A favourable tentative explanation could be existence of the sterile neutrino. The present data analysis provides mass limit, along with active-sterile mixing ratio.

The r-process is responsible for nucleosynthesis of half of the heavy elements. Yet the process is not fully known and various models try to predict the details. One of such models is neutrino driven wind model. In the quest of r-process abundances, according to the neutrino-driven-wind model, light neutron-rich unstable nuclei may play a significant role as seed nuclei that influence the abundance pattern. Hence experimental data for neutron capture cross sections of neutron-rich nuclei are needed. Coulomb dissociation of radioactive ion beams at intermediate energy is a powerful indirect method for inferring capture cross section. As a test case for validation of the indirect method, the neutron capture cross-section (n, γ) for 14C was inferred from the Coulomb dissociation of 15C at intermediate energy (600 MeV). A comparison between different theoretical approaches and experimental results for the reaction is discussed.

A complex system of many interacting particles can be more than the sum of its parts. A classic example that has captured the imagination of physicists for four decades is the Fractional Quantum Hall (FQH) effect: a phenomenon where electrons confined to two dimensions and in strong magnetic fields condense into unusual quantum fluids. In many FQH fluids, by binding together quantized vortices of the magnetic field, electrons transform their identity to that of new particles called composite fermions. When some FQH fluids are taken far out of their equilibrium states, they manifest surprising dynamical behaviour that can no longer be described by composite fermions have been theoretically shown at IMSc.

At sufficiently high energies, the properties of these FQH phases reveal the emergence of a new kind of particle called a parton, which behaves as a fraction of the electron. Similar to quarks in the nucleus, partons can be seen only when a lot of energy is injected into the system. Based on this idea, an experiment to reveal the presence of partons has been proposed which has been described using methods of effective field theory and numerical simulations.

The identification of dynamical signatures of partons illustrates the need for better understanding of nonequilibrium properties of FQH phases. While direct observation of partons remains the key goal for future experiments, on the theory side, the methods developed in this paper may lead to a better understanding of the more fragile FQH phases, including some enigmatic states with properties applicable to quantum information technology.

The School of Physical Sciences, NISER continued to offer the 5-year integrated Master of Science (M. Sc.) program in Physics which included courses from core areas of physics such as Classical Mechanics, Quantum Mechanics, Electromagnetism, Statistical Mechanics and Mathematical Physics. In addition, elective courses based on upcoming areas in physical sciences are also offered for final and pre-final year students. The Ph.D. program included courses from the core-areas of physics such as Classical Mechanics, Quantum Mechanics, Electromagnetism, Statistical Mechanics, particle physics and condensed-matter physics.

CHEMISTRY

A novel family of hydrophobic DES has been synthesized by mixing TOPO and Decanoic Acid in 1:1 mole ratio. A film was prepared using DES, cellulose triacetate (CTA) as a polymeric matrix, and tri-(2-ethylhexyl) phosphate (TEHP) as a plasticizer, which was best suited for the extraction of UO22+ ions in

aqueous samples. DES supported film were equilibrated with uranium (VI) solution and the content of U(VI) after equilibration was measured by spectrophotometer using 2-(5-Bromo-2-pyridylazo)-5-(diethylamino) (Br-PADAP) as a chromophore. Viscometer, Differential Scanning Calorimetry, XRF and FTIR have been employed for characterizing DES and DES supported films.

Cr(VI) has a negative impact on organisms because of its non-degradability and bioaccumulation. Determination of Cr(VI) in aqueous media accurately has important significance for environmental quality control. A membrane has been synthesized using hydrophobic deep eutectic solvent (DES) supported by cellulose triacetate (CTA) for studies involving preconcentration and determination of Cr in aqueous solution.

Laboratory-scale three-step ion exchange separation strategy has been developed for the removal of radionuclides, namely ^{137}Cs, ^{125}Sb and ^{60}Co from irradiated zircaloy. The work was extended to achieve separation of Cesium using ammonium phosphomolybdate (APM) loaded alumina.

In-house reference material of marine sediment was prepared for trace elements, and homogeneity / long-term stability testing was performed to establish the suitability of the prepared material. Four in-house reference conductivity solutions with conductivities of 100, 150, 1000 and 1400 mS/cm have been prepared. In-house calibration standard solutions of Mn and Co were prepared and assayed using nuclear analytical techniques. Marine Sediment in-house reference material was prepared for evaluating the concentrations of trace elements. Atomic absorption spectrometry and inductively coupled plasma optical emission spectrometry were used to assess the impurity profiles in the in-house calibration standard solutions. The values of Co and Mn were assigned according to ISO Guide-80:2014 guidelines. After homogenity and stability assessments, these solutions were used for expediting routine analysis of various samples, calibration of the instruments, and in-house quality assessments.

Large varieties of materials were analyzed for chemical composition, trace constituent concentrations, surface and thermal properties (>3500 samples with ~10000 determinations). The materials include metals/alloys, nuclear materials, environmental, biological, archaeological, industrial, process samples and other miscellaneous materials.

Various materials analyzed under Analytical Services program in BARC

Screening of new synthetic organoselenium compounds for anticancer activity has led to the identification of pyridine based diselenides as potent anticancer agents for lung cancer. DSePA has been demonstrated to show better tumour control in combination to radiation therapy. The regulatory dossier for DSePA has been prepared.

A gelatin composite gel has been fabricated for the topical delivery of curcumin. The gelatin-curcumin composite gel shows efficient wound healing activity in animal models. Further, a biomimic catalytic nitric oxide (NO) generating material has been fabricated by conjugating organodiselenide with gelatin.

A functionalised poly-propylene fabric was developed for selective recovery of gold (III) from aqueous media. The adsorbent was synthesized in two steps - gamma radiation induced grafting of glycidyl methacrylate (GMA) on to PP fabric surface followed by functionalisation with 2-picolyl amine. The maximum sorption capacity towards gold (III) was found to be ~600 mgg-1. The adsorbent also showed very fast kinetics, as it had reached 97% of its saturation sorption capacity within just 5 minutes. Therefore, it can be

deployed as an effective adsorbent for recovery of gold from electronic waste.

Nanocomposites were developed using polymeric materials and sand for the treatment of low-level waste containing radio cesium. The sand-based composites may minimize the health hazard issue due to cesium contamination in groundwater and recovery of radio cesium from radioactive waste streams.

The reactivity of various individual phases as well as red-mud based sacrificial materials were evaluated. The reaction of red-mud brick powder with a mixture of U_3O_8, ZrO_2, SrO, CeO_2, Nd_2O_3, and MoO_3 were studied with progressively increasing temperature. It is observed that all the interactions are initiated only above 1250°C. At 1350°C, red-mud containing these materials undergoes partial melting. It forms stable perovskite type phases with U, Fe/Al and alkali elements, and fluorite type phases with Nd_2O_3, U_3O_8 and CeO_2. In addition, several possible complex oxides containing uranium, alkali and alkaline earth metal ions were prepared from stoichiometric reagents and their stabilities with temperature were investigated.

A simple co-precipitation method was utilized for the synthesis of ZnO and Ni doped ZnO nanoparticles (~ 20 nm). Gas sensing studies of the nanoparticles were carried out in static gas sensing system. Among the tested reducing gases (CO, NH_3, SO_2, H_2S and C_2H_5OH), the sensor showed high selectivity, sensitivity and linear response to only H_2S at an operating temperature of 200°C. Compared to ZnO nanoparticles, 5% Ni doped ZnO exhibited enhanced sensitivity and speed (response and recovery times).

The composites of $LaPO_4$ and Al_2O_3 were explored for developing machinable ceramics for high temperature applications. Sintering behaviour of these two composites as well as mixture having different proportions were studied. Denser ceramic entity could be obtained in all the samples except Al_2O_3 by sintering at 1400°C. It was observed that the composite sample with 50:50 wt % of Al_2O_3:$LaPO_4$ showed good mechanical strength as well as machinability.

A prototype zero-gap diaphragm based electrolyser for TDS removal has been set up at NCCCM, Hyderabad. Commercially available low-cost materials such as graphite anode, stainless steel mesh type cathode and microfiber mesh as diaphragm were used as diaphragm. The operating parameters of electrolysis are: 8-10 A current, 6-7 V of cell potential and 5 mA/cm2 current density for a duration of 8 hrs for 125 L of water. Zero gap is maintained between the electrodes to reduce cell potential and also for removing the TDS efficiently. Total TDS were reduced from 1000 to 550 ppm in 8 hours.

A method was developed for the extraction of gallium from acid leach of 10g coal fly ash. In the acid leaching procedure, HF was replaced with ammonium bi-fluoride to ensure safe handling. A 1:1 ratio of coal fly ash and ammonium bi-fluoride is found to be effective for leaching of gallium. From the acid leach containing ammonium bi fluoride, HCl and H_2O_2 gallium is extracted into 1-octanol, which was extracted into 10% HNO_3. Recovery of gallium came at 90%. The procedure is being scaled higher for 5 kg of coal fly ash.

A micro-procedure was developed for the extraction of Be from effluents of Be plant in which Be was adsorbed onto GO and extracted into 1-octanol. The Be adsorbed GO agglomerates in octanol were coagulated in presence of dilute HNO_3 and Be is back extracted into the dilute HNO_3 for GFAAS analysis. The method is applied to industrial effluents, and ground and seawater samples.

The Charged Particle Activation Analysis (CPAA) methodology using 4 MeV protons was developed and standardized for the determination of carbon in niobium. The method is based on $^{13}C(p,n)^{13}N$ (Eg= 511 keV, $t_{1/2}$ =10 min.) reaction. As the determination involves the measurement of short-lived radionuclide, the relevant beam line was suitably modified to facilitate the commencement of counting (in air) immediately after irradiation with minimum cooling time (in vacuum). The methodology development involved the irradiation of different carbon-bearing targets with 1-4 MeV proton beam and a systematic study of interferences arising from $^{18}O(p,n)^{18}F$, $^{14}N(p,a)^{11}C$ and other reactions producing annihilation radiation. The interference from these reactions can be calculated by simulating the decay curve. The limit of

quantification of the method is about 40 ppm. Niobium samples from NFC were analysed by this method. The determined content of carbon (60±5 ppm) is in good agreement with GDMS measurements.

The efficacy of $^{31}P(a,p)^{34}S$ nuclear resonance reaction (Er= 3640 keV) for depth profiling Phosphorus (P) in materials surfaces was investigated. Thin films of indium phosphide, prepared by physical vapour deposition using bulk indium phosphide as evaporant, were used as targets. The study entailed a comprehensive study of the kinematics of the reaction and the optimization of experimental parameters for the interference free detection of the emitted alpha particles. The method was found suitable for depth profiling of Phosphorus in sub-percentage / percentage levels in surfaces with a depth resolution of 10 nm.

A GD-MS method was developed for the isotopic analysis of Li in different spodumene samples. ^{6}Li concentration was found to be in the range 9- 12%, which is higher than the natural isotope composition. The values obtained are in good agreement with the analysis using ion beam.

The efficacy of arsenil - a covellite based composite developed recently for the removal of arsenic from water - was examined by applying it to the arsenic contaminated groundwater collected from different locations in Raichur, Karnataka. The composite was found to work satisfactorily by reducing the content of As to <5 ppb from 75-400 ppb in the groundwater. Importantly, all parameters standardized in the laboratory using groundwater spiked with As(III) and As(V) were valid for the real as-contaminated groundwater. The remediation experiments were performed with 2L water.

Purification of water using membranes was studied under flow conditions using an in-house fabricated setup having SS pipe covered with membrane at both ends. Two types membranes, namely SulphonatedPolysulfone (SPSf) and Nafion, were tested. The simulated solution containing metal ions $Fe^{2+}/Cu^{2+}/Ni^{2+}/Co^{2+}/Cr^{3+}$ was re-circulated with periodical sample analysis. The diffusion of metal ions through the Nafion membrane was less as compared to that through SPSf. The percentage reduction in the concentration of metal ions in the reservoir in 24 h was ~50% for all the metal ions studied, except Cr^{3+}. The purification rate increased with increase in the flow rate.

Alkylimidazolium ionic liquid [IL] with –hexadecyl side chain [C_{16}MIM][Cl] was found to effectively prevent mono-species biofilm formed by Gram-positive and Gram-negative bacterial strains. Efficacy of this compound was determined on multispecies biofilms in freshwater and seawater. Complete inhibition in biofilm formation in freshwater and seawater required 8 and 125 μM of IL, respectively. Under dynamic flow conditions, complete inhibition in biofilm formation was observed over a test period of 12 days using 100 ᴖM [C_{16}MIM][Cl] in freshwater. However, 250 μM [C16MIM][Cl] was required for complete inhibition of biofilm formation in seawater. These results indicate potential application of [C_{16}MIM][Cl] against natural biofilms, including cooling water systems.

To determine the robustness of bacteria-laden granules for treating biological waste water laden with toxic pollutants, hybrid granular SBRs were inoculated with granules and operated in the presence of oxytetracycline, selenite, tellurite and chromate. Ammonium and phosphorus were efficiently removed even in the presence of toxic concentrations of oxytetracyline, selenite, tellurite and chromate. Ammonium and phosphorus were removed by nitriation-denitritation and enhanced biological phosphorus removal pathways, respectively. The toxic selenite and tellurite were converted to non-toxic elemental Se(0) and Te(0) nanostructures. The Se(0) and Te(0) forms were majorly associated with the granules and retained in the bioreactor. Chromate was reduced to biomass associated Cr(III). Granules performed biological treatment more efficiently than conventional activated sludge in the presence of toxic pollutants. Sewage treatment by biogranules was not inhibited in the presence of ppm concentrations of heavy metals (Zn, Cd, Cu, Pb and Ni). On the contrary, biological treatment of sewage by conventional activated sludge was severely impacted in the presence of heavy metals.

Hybrid granular biofilter comprising biogranules and biofilter in one single unit was investigated as an alternate method for treating greywater and sewage. Hybrid granular biofilter with modified configuration was setup and operated for evaluating treatment parameters. It was found to be working satisfactorily for removing COD, ammonium-nitrogen and phosphorus from synthetic wastewater. Therefore, it was evaluated for treating municipal wastewater. A prototype comprising of treatment unit followed by biofiltration unit with 120 L/d treatment capacity was used for sewage treatment. Effective and sustained treatment of sewage was achieved. The treated wastewater was clear, transparent and without foul smell. The quality of treated wastewater was in line with the existing discharge limits. Therefore, the treated wastewater can be discharged or re-used for gardening without any post-treatment.

(A)Experimental hybrid granular biofiltration unit, (B) morphology of biogranules and (C) sewage water before and after biological treatment

Natural Oxygen is a mixture of three stable isotopes namely, ^{16}O (99.757 %), ^{17}O (0.038%), ^{18}O (0.205%). The enrichment of Oxygen isotopes for production of O-18 labeled water was investigated by cryogenic distillation route. Liquid Oxygen (LOX) obtained from rectification of Air served as the feed for cryogenic distillation cascade. Mathematical model development and simulation was carried out for the process. Based on the model developed, design of a distillation column was carried out for production of ~9 kg/yr O_2^{18} (eq. to 10 kg/yr H_2O^{18}) and its techno-commercial evaluation.

SiOxNy/SiC system is a promising seed for fabricating electronic devices. However, for a practical application, one must have a high-quality interface. Current methods for synthesis of interface such as chemical vapor deposition or epitaxial growth are not free from contamination and are time-consuming. Therefore, we seek a method to fabricate such material by ion implantation. The formation of varying chemical interfaces in Si (100) by implantation of N2+ and CO+ molecular beam from the RIB facility were studied at VECC. This created periodic nano-ripple structures having four different chemical phases and spatially resolved silicon carbide, silicon oxide, silicon nitride, and silicon oxy-nitride patterns on the silicon surface. The different chemical phases at different parts of the ripple were detected experimentally and the mechanism of chemically varying pattern formation were explained.

The study of atomically flat 2D sheets with atomic or molecular thickness is emerging due to their wide application in electronic, optoelectronic, and photonic devices. Muscovite mica [KAl2(Si3Al)O10(OH)2] is a layered, multi-elemental, and insulating material with an atomically flat surface. Techniques, like thermo-luminescence, exfoliation, and swift heavy ion irradiation are not effective in modifying specific selected layer of mica in a controlled manner, whereas using ion-beam one can fine tune the implantation energy and study the modification of the selected layer. Defects were introduced on the top layer of mica by 3 keVAr+ ion bombardment using ion-beams from the RIB facility. X-ray photoelectron spectroscopy measurements of pristine and ion modified mica specify the deficiency of constituent elements, and thus confirmed the vacancy (defect) formation after Ar+ ion irradiation. The measured bandgap of pristine and irradiated mica layers showed good agreement with the theoretical prediction.

Fluorescent chemo-sensors that can detect and image metal ions are valuable tools that can provide insights into metal ion localization and distribution within living systems leading to key mechanistic information. Researchers of the Department of Chemical Science at TIFR, designed a modular synthetic strategy for developing 'turn-on' metal ions sensors. The strategy involved attaching a metal binding scaffold to a fluorescent dye via copper-assisted click reaction. As a proof-of-concept endeavour, researchers applied this strategy to successfully design and synthesize a water-soluble macrocyclic fluorescent sensor for manganese ions. Photocatalytic CO_2 conversion is a promising process for the reduction of CO_2 into useful chemicals

and fuels using solar energy. Researchers synthesized potassium-doped g-C_3N_4 coated over dendritic fibrous nanosilica (K-CN/DFNS) and studied the photocatalytic CO_2 conversion under visible light illumination.

At SINP, the role of grain-boundary and grain size in the electrocatalytic activity of recently synthesized shape-engineered nanomaterials (like, bud-shaped AuNP50 to bloom or flower-shaped AuNP75 to over-bloomed AuNP150) and differential grain-boundary enriched anisotropic flower-like gold nanostructures for the Hydrogen Evolution Reaction (HER) were quantitatively investigated. All the synthesized anisotropic gold nanoparticles and especially the AuNP75 exhibit outstanding catalytic activities toward HER in different pH media compared to that of normal spherical-shaped gold nanoparticles in similar physical conditions. Also, an efficient nanobioconjugate has been developed as electrode coating material by self-assembling the newly reported porous Au-seeded (gold)-Ag nanorod (silver) networks for the early-stage specific detection and quantification of Dengue virus (serotype 2). Despite the structural similarity between virus particles of different dengue serotypes, we can detect the most prevalent DENV-2 specifically by using our nonenzymatic nanobioconjugate assay for the first time through the impedimetric technique. The key achievement of this study lies in its ability in the direct detection of DENV-2 serotype without the aid of an enzyme or antibody in dengue infected blood.

The aim of the School of Chemical Sciences at NISER is to impart high quality undergraduate and postgraduate level of knowledge to students coupled with cutting-edge research activity by the faculty and the students of the school. In addition to traditional organic, inorganic, physical and theoretical chemistry areas, the school embarks on teaching and research activity in the interface areas of Biology, Material Sciences and Medicine. The School of Chemistry continued to offer one of the best integrated M.Sc. and PhD programs and the syllabus was designed not only to teach basic principles but also to have hands on practical experience by research projects as a part of the curriculum.

BIOLOGY

Early adversity is an important risk factor that influences vulnerability to psychopathology and to brain aging. Researchers of the Department of Biological Sciences at TIFR, attempted to uncover the impact of early adversity and the role of specific monoamine neurotransmitters in mediating the consequences of early stress on the rodent brain at distinct epochs of life. It was found that early stress accelerates hallmark features such as mitochondrial dysfunction and oxidative stress, evoking impairments in neuronal bioenergetics. Early adversity also drives neuroinflammatory states, thus cumulatively driving cellular senescence, neuronal and cognitive decline. Nutrition and metabolism have been long known to impact development. A study discovered how nutritional and metabolic variations during development affects adult physiology. This study also delineated the contribution by protein and carbohydrates that differentially encode persistent memory, which ultimately dictates fitness in adult life. These findings provide hitherto unknown phenomenological and mechanistic insights in the field.

At the National Centre for Biological Sciences, Bengaluru, a study investigated the effects of native, leaf-inhabiting bacteria (genus Methylobacterium) on traditionally cultivated rice varieties in a crop field. It was found that inoculation with some bacteria increased rice grain production substantially while a non-native bacterium reduced plant health. Overall, the effect of bacterial inoculation varied across pairs of rice varieties and their native bacteria. Thus, knowledge of evolved associations between specific bacteria hosted by specific rice varieties is necessary to develop ways to increase the yield of traditional rice landraces and preserve these important sources of cultural and genetic diversity. Diverse non-Dipteran insects are known to rely on visual and antennal mechanosensory feedback for flight control. A study showed that in the nocturnal hawkmoth Daphnis nerii, compensatory head movements are mediated by combined visual and antennal mechanosensory feedback. It suggested that head stabilization in moths is mediated primarily by visual feedback during roll movements at lower

frequencies, whereas antennal mechanosensory feedback is required when roll occurs at higher frequency.

Liposomal vaccine for COVID -19, which induces very high titre neutralization antibodies, was evaluated for its in vivo efficacy in viral challenge experiments in hamster model at IISc Bangalore. Data obtained from extensive studies suggested that vaccinated hamsters likely saw protection from SARS-CoV-2 in as compared to control. Further, viral load in vaccinated mice was reduced by more than 4 log units (99.99%) when compared to unvaccinated control. The vaccine is now ready for clinical trials.

As part of efforts for developing a COVID-19 vaccine, RBD gene of SARS-CoV-2 was cloned in BCG to understand the immunogenicity of recombinant BCG, and its effectiveness as a vaccine is being tested on BALB/c mice through heterologous prime boost strategy.

Hepatitis B Virus (HBV) is the leading cause of liver disease ranging from acute and chronic hepatitis to liver cirrhosis and Hepatocellular Carcinoma (HCC). Studies have revealed that HBV infection broadly reprograms the host cellular metabolic processes for viral pathogenesis. Previous reports have shown that glycolysis and gluconeogenesis are among the most deregulated pathways during HBV infection. A novel mechanism of epigenetic reprogramming by HBV have been reported at SINP. Interestingly, Speckled 110 kDa (Sp110) driven regulation during HBV infection was found to promote viral-borne HCC progression. Moreover, Sp110 can be used as a prognostic marker for the hepatitis mediated HCC patients, where high Sp110 expression significantly lowered their survival. Thus, the epigenetic modification protein Sp110 has potential to be a therapeutic target to challenge HBV-induced HCCs.

Hyperthermia inhibits DNA double-strand break (DSB) repair that utilizes homologous recombination (HR) pathway by a poorly defined mechanism(s); however, the mechanisms for this inhibition remain unclear. Hyperthermia decreases an epigenetic modification essential for genome stability and transcription have been reported. Heat-induced reduction in a specific epigenetic modification was detected in humans, Drosophila, and yeast, indicating that this is a highly conserved response. Thus, hyperthermia impacts chromatin organization owing to epigenetic regulation, thus negatively affecting the HR-dependent DSB repair.

Studies are on-going to analyse the metabolic reprogramming associated with stress response in cancer and normal cells. Investigation is also underway to elucidate the role of atypical nutrients in cancer cells. Metabolic profile associated with malnutrition in mouse model and cancer patients are also being studied. Also, metabolic derangements as a result of COVID-19 infection are being investigated.

Mutations in Mitofusin2 (MFN2), a mitochondrial membrane protein is associated with the pathology of the debilitating neuropathy, Charcot–Marie–Tooth type 2A (CMT2A). One such abundant MFN2 mutant results in the generation of elongated, interconnected mitochondria. However, the mechanism leading to this mitochondrial aberration remains poorly understood. A mechanistic insight into mitochondrial hyperfusion has been provided. Such hyperfused mitochondria are also predisposed towards stress and undergo rapid breakage or fission upon induction of mild stress. It has been reported that presence of the MFN2 mutant makes cells susceptible towards stress, thus negatively affecting cellular health.

The School of Biological Sciences (SBS) at NISER promotes scholarly and innovative thinking to conduct cutting edge research in diverse areas ranging from molecular to organismic biology. To facilitate the process, the school offered 5-year integrated MSc program, Ph. D program and Post-Doctoral program to motivate and train students. SBS aims to establish as a centre of excellence with its efforts grown up rapidly and signs of its achievements are being noticed at national and international levels in terms of work and student placements. To further strengthen the SBS research program, an Integrated PhD program initiative is under progress.

CANCER

The link between metabolic rewiring, stemness of cancer cells and chemo-resistance phenotype is being explored to understand metabolism in different cancers, including Lung, Prostate, Thyroid, Liver, Leukemia and Breast. The expression level of embryonic stem (ES) cell marker, Yamanaka factors (Oct3/4, Sox2, Klf4, c-Myc) were evaluated. Work is under way for understanding the levels of Monocarboxylate transporter 1 & 4 (MCT1/4), LDHA, PDK1, PDK3 and different key metabolic inhibitors for better understanding the balance between glycolysis dependent cancer cells and Stem cells.

Autophagic induction and protein level expression of genes associated with the death of the cell were explored using Fo-F1 ATP Synthase inhibitor - Bedaquiline. Studies suggested a simultaneous activation of autophagy and apoptosis in ^{131}Iodine resistant Thyroid cancer cell lines both in vitro and in vivo.

Experiments were carried out to understand transcriptomic, metabolomic and proteomic hallmarks of cancer using Peripheral blood cell and plasma/serum sample for formulating personalized management of non-iodine concentrating poorly differentiated thyroid carcinoma patients. Standardization of isolation of plasma, RNA and peripheral blood cells towards transcriptomic and metabolomic analysis was completed.

Studies on identifying miRNA/s as potential early diagnostic markers for the diagnosis of pancreatic cancer were carried out. The RNA extracted from normal pancreatic and pancreatic cancer cell lines was identified for next-generation sequencing. The data is expected to provide potential clues about the specific miRNA expressed in pancreatic cancer cell line. The pancreatic cancer cell line will further be used to grow tumors in SCID mouse, and the miRNA would be screened at different stages of tumour development.

Studies were carried out with ^{68}Ga-PentixaFor as diagnostic and (^{64}Cu-ATSM) as potential therapeutic radiopharmaceutical for lympho-proliferative carcinoma and hypoxic lesions of cancer respectively, at Radiation Medicine Centre (RMC) of BARC. The ^{68}Ga and ^{64}Cu radio-labelled drugs formulations have undergone preclinical studies proving their potential for diagnosis and treatment of chemo-resistant lymphoma and hypoxia lesions in cancer, respectively.

Antibody based radiotherapy agents, including ^{177}Lu-Trastuzumab and ^{177}Lu-Pertuzumab were developed at RMC for targeting HER2 expressing and ER negative breast carcinomas. Membrane embedded protein Herceptin 2 expressed on different cancers and its feasibility as a tumour-imaging and targeting agent in specific cancer, including ovarian and breast cancer, have been put to use in this project. Pre-clinical evaluation of the developed Her2 targeting RPs was performed for in vitro and in vivo pharmacokinetics and dynamics indicating significant target specificity and stability.

Studies were pursued to evaluate the new Technetium-99m and ^{68}Ga labelled small peptides for prostate-specific membrane antigen and RGD peptides expressed on different cancers and its feasibility as a tumour-imaging agent in specific cancer, including prostate, lung, thyroid and gastrointestinal cancer. Preclinical evaluation of the developed RPs was performed for in vitro and in vivo pharmacokinetics and dynamics indicating significant target specificity and stability.

The research efforts at SINP were aimed at understanding structural basis of enzyme action of L-asparaginase. L-asparaginase is a chemotherapeutic drug approved for childhood leukemia. An understanding of the structure-function-instability of the drug can potentially aid in defining the fate of active drug in the plasma, once it is injected. An enhanced understanding can lead to protein engineering effort(s) to design better version of the existing drug. SINP was involved in probing interactions of the bacterial protein, azurin with cellular partners that may be correlated with the potential anti-cancer activity of the protein.

At the backdrop of cell proliferation that happens in cancer, SINP research follows two avenues: neurodegenerative Alzheimer's Disease (AD) and

demyelinating Neuromyelitis Optica (NMOsd). While the alterations of protein coding genes are well studied in AD, those of the oncogenic non-coding RNA landscape is novel. Works at SINP have been shedding light on the receptor tyrosine kinases (RTKs), their dysregulation and downstream signalling. Evidence to implicate linked sets of RTKs and various oncogenic non-coding RNAs that could possibly change the way we look at AD are being gathered. In the near future, the focus will be on the conclusive proofs of the pathways leading to downstream regulation and their interplay. The roles of specific oncogenic non-coding RNAs in the neurodegenerative disease, AD and develop an axis of correlation between the two are being investigated. In case of NMO, a rare autoimmune disorder that affects the brain and spinal cord, it was shown that upon exposure to NMO sera containing aquaporin, AQP4 auto-antibodies, the glioma cells undergo morphological alterations and shrinkage. To understand the underpinning regulation in a more realistic backdrop, a differentiated glioma disease model has been established and in the immediate future Next Generation Sequencing (NGS) will be done to determine the differential expression profiles of microRNAs.

SYNCHROTRON & THEIR UTILISATION

Synchrotron radiation sources (Indus-1 and Indus-2), the National facility at RRCAT has been operated in round-the-clock mode for 253 days from April to December 2022. At present 7 beam lines in Indus-1 and 18 beam lines in Indus-2 respectively are operational. The availability of synchrotron radiation beam for users has been of the order of 5210 Hrs. (20 hours/day) in Indus-1 and 4327 Hrs. (17 hours/day) in Indus-2 respectively. Over 796 user experiments with around 120 research publications have been accomplished. Pharma industry users have also utilised the facility and for this purpose MoU is signed with each of the industry users. With this performance, the projected beam availability for the year 2022-23 is expected to be ~ 6700 hrs for Indus-1 and ~ 5600 hrs for Indus-2.

Upgradation measures

An Ultra-high vacuum compatible, Fluorescent Screen Monitor (FSM) and a Synchrotron Light Monitor (SLM) have been developed for installation in Indus-1. These will be used to observe the position and spot size of the electron beam and continuous visible SR light at 10° port of dipole chamber DP-4 in the upgraded Indus-1 during the first turn of beam injection.

Ffluorescent screen monitor

Synchrotron Light Monitor

Eight sets of combined function magnets have been developed for performance improvement of Indus-2, these magnets produce sextupole as the main component along with producing skew quadrupole and horizontal & vertical dipole fields respectively.

The Combined function magnet on the measurement bench

Development of power converter cards required for auxiliary coils of Harmonic Sextupole Magnets in Indus-2 has been completed. The bipolar power converter is capable of delivering up to ±50 V DC output voltage, up to ±15 A DC output current, and up to 600 W output power, and is capable of being operated in both the polarities of output voltage and current, with smooth zero cross-over. It is equipped with precision current sensor, electronics and on-board constant-temperature bath that provides output current stability within +/- 100 ppm of the full-scale current.

Power converter card

Batch of power converters

For Indus beamlines some operational enhancements have been carried out as follows:

Beam line (BL-03) Indus-2

An energy dispersive soft X-ray fluorescence measurement setup is designed, installed and commissioned for soft X-ray fluorescence and absorption measurements on soft x-ray reflectivity beamline (BL-03) of Indus-2. The setup can be used to measure K emission line for elements Z=7-14 and L emission line for Z=20-37. This development will further enhance the utilization of the beamline.

Beam Line (BL-16) Indus-2

A vacuum compatible X-ray fluorescence and total reflectance X-ray fluorescence system has been designed, developed and installed on the BL-16 beamline as an additional user facility. This facility is extremely useful for enhancing the capabilities of the beamline by extending the detection capability to low Z elements (Z<17) such as Na, Mg, Al, Si, S, and P in trace amounts, which is important in many fields such as semiconductor, biological and environmental sciences.

Beam Line (BL-20) Indus-2

The X-Ray Magnetic Circular Dichroism (XMCD) Beamline BL-20 has been commissioned. This beamline is developed on an APPLE-II type helical Undulator and is the second insertion device-based beamline to be commissioned at Indus-2. XMCD technique is used to

BL-20 experimental station

determine element specific magnetic properties of materials. Measurements on standard samples have been carried out to calibrate and establish the performance of the beamline.

The electron beam radiation processing facility named ARPF has been offered to industry for terminal sterilization of medical devices (surgical gloves, syringe, I.V. cannula etc). It can sterilize the medical devices in their final packing (without opening boxes), thereby eliminating any chances of re-infection. The facility has FDA licence for radiation processing of Risk Class-B medical devices and AERB license for operation. The facility also has ISO 9001 and ISO 13485 quality management system certifications. This is the first facility of its kind in India for providing e-beam sterilization service to the medical device industry. The sterility test on the irradiated items has confirmed successful achievement of desired sterility assurance level. The facility also caters to gem industry for colour modification of the gems.

RRCAT has developed a 9.5 MeV; 10 kW linac for food irradiation. This linac has maximum electron energy limiting system to meet the regulatory limit of 10 MeV for food irradiation. This linac has been tested for non-stop operation of 32 hours at full rated beam power for food irradiation using volumetric dosimetry on coriander powder and Poha.

An incubation agreement has been signed for tests, trials, and technological scale performance studies in industrial environment.

A new high intensity and high resolution undulator based beamline called Atomic, Molecular and Optical Science (AMOS) beamline has been developed by BARC at Indus-2 Synchrotron source at Raja Ramanna Centre for Advanced Technology in Indore. The beamline can deliver high flux photons (flux $\geq 10^{12}$ photons/sec) in the photon energy range of 6-800 eV at a high resolving power (~10000). After successful installation and testing, first photo-absorption spectrum of Xenon atomic lines has been recorded using synchrotron radiation with a resolution of 2 meV at 8.5 eV. The beamline is a unique facility for advanced research in photophysics and photochemistry involving photo-ionization, photo-fragmentation and photo-dissociation of atoms, molecules and clusters. Basic science involving photochemical processes in the upper atmosphere, astrophysical objects, plasmas, environmental sciences and in high temperature industrial processes can be studied using this beamline.

AMOS beamline at Indus-2

At SINP, the GIXS beamline (BL-13) at Indus-2 is now fully operational and commissioned to the users' operation. All the safety related issues have been cleared and the permission from AERB has been obtained for its regular use. Following this, the beamline is accepting scientific proposal through online portal of Indus-2, RRCAT website and also a few scientists from research institutes and universities have started using this beamline as the regular users. Two post-doctoral researchers have been stationed in the facility to assist the users as well as to carry out their own research work.

CYCLOTRONS & THEIR UTILISATION

The K130 room temperature cyclotron has been operating round the clock and delivering light and heavy ion beams for various types of experiments. The K130 cyclotron has two ion sources (internal PIGIS and external ECRIS) to produce light and heavy ions. Presently PIGIS are in use to produce light ion beams like proton, deuteron and alpha for conducting the research program. For the experimental purpose alpha projectile in the range 26 – 50 MeV and photon in the range of 7 – 14 MeV have been utilised.

The above-mentioned beams are regularly being used to produce isotope production, irradiation, rare ion beam (RIB) production, radiation damage studies, nuclear physics and radio-chemistry experiments etc. The facility has been utilised by the experimentalists of VECC, SINP, ACD/BARC, RCD/BARC, HPU/VECC, Banaras Hindu University, Viswa Bharati University etc.

The K130 cyclotron is regularly fulfilling its target for beam availability. The beam availability was 2262 hours for the period April 01 to December 31, 2022 and the expected beam availability during the financial year 2022-2023 is more than 3000 hrs.

Apart from the regular operation of the K130 cyclotron, a few modifications and maintenance works have been carried out to improve the cyclotron's performance. The six movable panels of the RF resonation system and its eight-gear box assembly have been replaced to resist frequent air and water leaks in the RF resonator tank of the cyclotron.

Electron cloud trapping time extended up to 800s in Room Temperature Penning Trap at VECC

A cloud of electron has been trapped using five electrode cylindrical penning trap with 0.1 Tesla Permanent magnet arrangement. Resonant based detection circuit has acquired induced image current due to oscillation of trapped particle. The electrons for trapping were generated Field Emission Point (FEP) on application of 830V. The primary high energy electrons from FEP collided with the background gases and generated secondary electrons which were eventually confined in the Penning trap. Here, the FEP has been switched on over 400 ms (mili-second) duration and after the beam off, the trapped signal has been detected at different time "T". Initially, trapped voltage kept at 22 Volt to store more energetic secondary emitted electron and it has been ramp down (within time span of 20 ms). During this ramping down, when the trapped voltage is such that the corresponding oscillation frequency is equals to the resonance frequency of detection circuit, then there is a power dip at the amplifier output.

The maximum time T, upto which this trapped signal is observed at a particular vacuum condition is recorded as Trapping time. A strong correlation is observed with the background pressure and trapping time.

Vacuum	Trapping time
2×10^{-7} mbar	<1s
8×10^{-8} mbar	~1 s
2×10^{-8} mbar	4-9 s
7×10^{-9} mbar	24-30s
2×10^{-9} mbar	100-120s
Better than 5×10^{-10} mbar (with liquid Nitrogen jacket)	800s

PLASMA & FUSION TECHNOLOGIES

IPR is developing a 5 Tonnes/day plasma-pyrolysis based biomedical waste disposal plant for deployment at the Homi Bhabha Cancer Hospital,

100kW plasma arc system. Plasma Arc through viewport

Plasma Arc using graphite electrodes

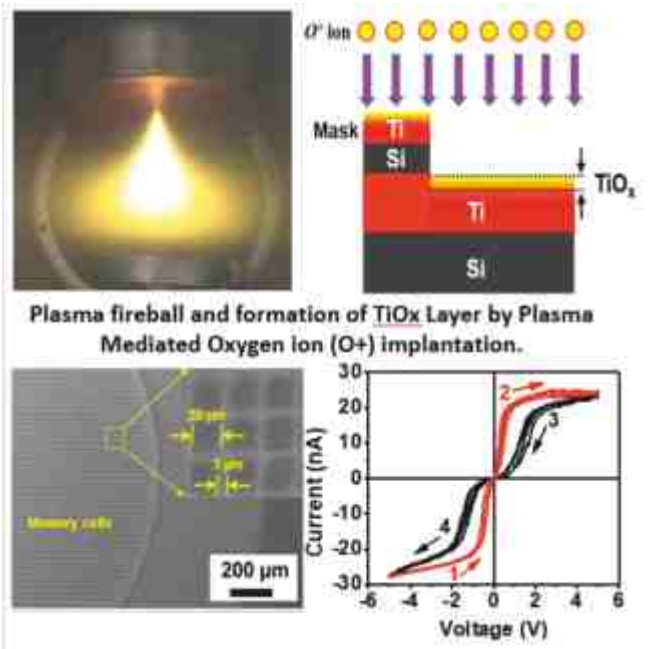
Varanasi using three 100 kilowatt graphite-electrode based plasma arcs. In a major milestone, these arcs and associated power supplies have been tested continuously for 120 hours.

A system has been developed for formation of functionalized coatings at very low pressures using a thermal plasma torch. The technique aims to combine the advantages of physical vapour deposition and atmospheric plasma spray. The supersonic plasma plume has been characterized and the system is ready for spray experiments. Preliminary spray experiments and coatings characterization will be carried out soon.

Supersonic plasma plume

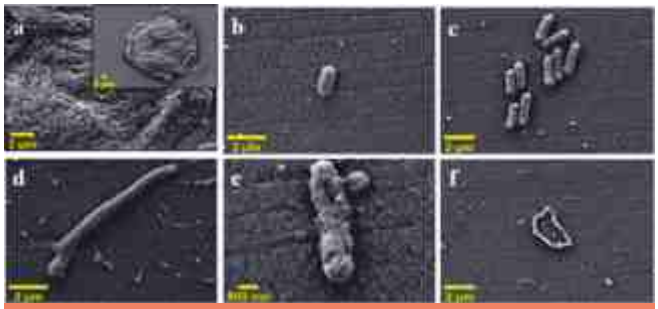
A new, compact, easy-to-handle DC plasma based system has been developed for sterilization of medical equipment and tools. In another development, a microwave-based plasma source has been used for trials and has yielded significant reduction in time scales (almost a factor of 10) for achieving 6-log reduction in the colony forming units of micro-organisms, the norm for sterilization. Preliminary plasma-bio trials have also been conducted that have revealed the effect of plasma on the cell wall / membrane and genetic material. Development of a compact microwave plasma sterilization system and submission of patent are the next steps to be carried out.

Non-volatile memories based on resistive switching are expected to fulfil the requirements of next-generation data-intensive technologies. However, due to the separate growth of functional layer and electrodes in the device, resistive random access memories still suffer from their implementation at a commercial scale. Herein, a single device is used to grow Ti thin film followed by plasma fireball-mediated oxygen ion implantation to transform the top surface of Ti film into a functional TiOx layer to fabricate the device. Large area rapid fabrication of high-density periodic arrays of squared memory cells of different sizes is demonstrated.



FESEM image of a periodic array of TiOx-based memory cells and their I-V curve for showing two-fold erase-write process

Bacteria often try to attach to catheter surfaces and form a complex three-dimensional structure known as biofilm. In our study, we have found that low pressure oxygen plasma treatment is able to reduce bacterial adhesion and biofilm formation on catheter surface significantly (≥ 99 % reduction) without the use of antibiotics / other complex coating and is remains



SEM image of silicon catheter surfaces after plasma modification

efficient up to 30 days after plasma treatment when stored under ambient conditions. Above figure, shows biofilm growth on untreated catheter surface (a) whereas all other images (b – f) show bacterial adhesion on plasma treated catheter surface in which we can observe different phenotype changes in adhered bacterial cells including elongation and death of the cell.

The already matured, commercially-available water electrolysis systems are Alkaline Electrolyzer (AE) and Proton Exchange Membrane (PEM). An emerging technique is Plasma Electrolysis or Contact Glow Discharge Electrolysis (CGDE). IPR has conducted preliminary experiments on plasma electrolysis, the results of which are shown. Initial results are promising, and further R&D is in progress to improve the energy efficiency.

Chemicals like Alcohol, H_2O_2, Chlorine and Chlorine compounds etc. are commonly used as disinfectants. These chemicals can pollute the environment and are relatively costly. Plasma Activated Water (PAW) is an alternate solution. IPR has developed a technology to produce PAW with properties optimized for different applications. In a joint study with a Public Sector agency, PAW was used for sanitization of milk cans, dump tank etc. during dairy operations. A significant reduction in the microbial load was observed when PAW is used for final cleaning of containers. Further, the study reveals that only 25 Litres of PAW would be required to clean milk containers of 5000 L capacity, leading to significant cost saving.

A liquid nitrogen cooled sorption cryopump has been indigenously developed and deployed on the SST-1 Tokamak. It offers a pumping speed of 26,000 litres/s for water vapour and 3,000 l/s for nitrogen. A special

View of installed sorption pump on the radial port of the SST-1 Tokamak

feature is that it operates well even during the baking of the vacuum vessel at 110°C, which leads to a high radiative heat load on the pump.

AGASTYA-400 is a 400 mm opening liquid nitrogen cooled sorption cryopump. The acronym AGASTYA stands for A GAS Trapping YAntra. Gas molecules present in the application vacuum system are trapped on cryopanel surfaces following cryo-condensation, cryo-sorption and cryo-trapping processes. At 77 K, the cryosorption cryopump is capable of pumping nitrogen, water vapor and most of the hydrocarbons when suitable sorbents (activated charcoal) are coated on the cryopanel surfaces. AGASTYA-400 is modular in concept, tested and accepted design and three such systems are in operation at Space Applications Centre (SAC-ISRO), Ahmedabad to evacuate cryovac chambers. It provides ~4000 l/s pumping speed for nitrogen/air and >15000 l/s pumping speed for water vapor for a 400 mm opening. The technology of the cryopump has also been transferred to industry for commercialization.

High pressure leak-tight helium circulators are used in different applications. IPR has indigenously developed a high pressure helium circulator by modifying a locally-available air turbo-blower. It has been successfully tested with operating pressure ranging from 1 to 30 bar with a leak rate of less than 5 x

Indigenously developed high pressure helium circulator

10-5 mbar.l/s. It can provide a pressure head of ~120 mbar. The maximum flow rate of helium (at the maximum operating pressure) is 28 g/s. The cost of the indigenously developed circulator is substantially lower than that of imported circulators, and hence can be a potential import substitute.

Significant progress has been made on R&D for Low and High Temperature Superconducting (LTS and HTS) coil and conductor development for high magnetic field generation. R&D on LTS conductor includes joint development of 14 kA Nb_3Sn Cable In Conduit Conductor (CICC) by IPR and Atomic Fuel Division (AFD) of BARC. A 100 m long Nb_3Sn Cable has been inserted inside a 6m long SS316LN conduit using pull through technique, the conduit ends have then been joined through optimized orbital welding, and final compaction, swaging and spooling have been achieved successfully. HTS developments include the fabrication and testing of a 1 Tesla conduction cooled solenoid magnet, solid Nitrogen cooled system for HTS sample and coil characterization down to 55 K, and a 1m long 3 kA high temperature superconducting cable.

IPR had earlier indigenously developed a 100 kV, 25A Regulated High Voltage Power Supply (RHVPS) for fusion applications. The in-house technology has also been transferred to ECIL for licensed production of RHVPS. Special features of RHVPS include fast dynamics; regulated voltage at 100 kV level and very low short circuit energy imparted to load. A power supply of this class was first delivered to BARC in 2015 for use in driving the LEHIPA (Low Energy High Intensity Proton Accelerator) experiment. LEHIPA is a complex linac that is planned to accelerate proton beams to 20 MeV energy and with high intensity, i.e. 30 mA. Very recently, BARC reported that the Drift-Tube Linac of LEHIPA achieved acceleration level of > 6.8MeV. The remaining 2 stages of IPR's RHVPS are presently being supplied and commissioned by the ECIL team. This achievement has opened a new horizon in independent sourcing of such power systems for the nation.

After completion of preliminary plasma shaping experiments by charging the upper and lower diverter coils in ADITYA-U, a major vessel opening task was carried out in ADITYA-U. This allowed the removal of garland Langmuir probes, the old Thomson scattering system and Normal Incidence Monochromator (NIM) system and for the installation of multiple diagnostics systems such as crystal spectrometer, laser heated emissive probe, Fast reciprocating Langmuir probe, and installation of one diverter tile segment (4 nos. of upper and 4 nos. of lower diverter tiles with flush Langmuir probes). A tungsten coated graphite tile was also installed at the inboard side limiter. Furthermore, a new programmable trigger system hardware and GUI have been installed as well as an upgrade to the real-time horizontal plasma position controller, which now allows GUI-based variable set-points and propositional gain factor at different time-intervals. Standard discharges of Plasma current (IP) ~ 100 kA, duration 100-200 ms at toroidal magnetic field (BT) ~1.07 T has been achieved within just 4 days of operation. Later, the discharge

duration was enhanced to ~300 ms by using extensive wall conditioning and enhancement of Volt-sec using negative converter operation at a toroidal magnetic field (BT) of ~1.2 T.

Studies in other tokamaks have shown sawtooth-induced heat pulse propagation to be faster, with electron heat diffusivity χe^{hp}, enhanced by a factor of 2.5 to 15 as compared to that estimated from the power balance. χe^{pb} A reliable explanation for this is still not available. In ADITYA-U tokamak, we report fast propagation of sawtooth induced heat pulse from core to edge region. Time-lags of 50 – 200 μs have been observed in many plasma discharges with strong MHD activity. In order to track the transient electron heat pulse, ECE measurement were carried out at different radial locations. μs cm^{2}The estimated effective electron heat diffusivity χe^{hp} ~ 50 - 60 m^2/s for plasma discharge with relatively strong MHD activity, as compared to 35-40 m^2/s when MHD activity is weak. This result clearly indicates influence of MHD activity on electron heat transport.

Signatures of coupling between MHD oscillations and fluctuations in edge density (ne) and floating potential (Vf) have been observed in ADITYA-U tokamak. To study this coupling and its effect on turbulence and transport, several sets of Langmuir probes have been installed, separated toroidally and poloidally Systematic analysis of a large discharge database (~100) shows that that these coherent edge fluctuations are triggered by MHD modes. These results indicate that these MHD oscillations might be the origin of GAMs in ADITYA-U tokamak. These kinds of observations are new to the field and have been observed for the first time in any tokamak.

A new indigenous Fast Reciprocating Drive System (FRDS) for probes has been installed in ADITYA-U for radial profile measurement of density (n_{edge}) and temperature (T_{edge}) with high spatial and temporal resolution. Speed and distance to be travelled can be pre-programmed, and can also be varied on a shot-to-shot basis. Data from these probes can provide significant insight into edge density and temperature profile as well as radial electric field (E_r). This can help us understand physical phenomenon such as nature of

A view of Fast Reciprocating Drive System (FRDS)

turbulence, radial structure of zonal flows, effect of gas puff and SMBI on edge parameters and their fluctuations.

Deposition of low Z material on the first wall of a Tokamak significantly reduces radiative losses. Techniques like Boronization and Lithiumization are used to deposit a thin film of Boron/Lithium on plasma-facing surfaces. Li dust injection; ICRF Boronization, Boronization using diborane, and Lithium rod heating for Lithiumization are a few of the techniques used for this purpose. Due to the poisonous nature of Diborane, it becomes necessary to use special equipment for safety. For safe Boronization, a novel dust injector (DI) has been designed for ADITYA-U using the vertical magnetic field as an aid to the system. Preliminary experiments have been carried out. This injector will also allow studies of impurity-induced turbulence suppression and transport.

A new soft X-ray Crystal Spectrometer (XCS) has been designed, developed & installed to provide experimental measurements of plasma rotation, ion temperature, electron temperature and study impurity transport. The spectrometer comprises a cylindrically bent Silicon (111) crystal and a CCD detector to provide measurement of the resonance and satellite line emissions from He-like argon, Ar16+ in the wavelength region of 3.94 – 4.0 Å from the plasma core. The engineering design of the spectrometer has been optimized to address all issues due to port geometry, machine accessibility, adjacent diagnostics etc. After successful lab testing, the optically aligned XCS spectrometer is now fully commissioned on ADITYA-U. Operation during plasma shots has shown preliminary signatures of Ar^{16+} line emission from the plasma during argon gas puffing experiments.

Argon is envisaged to be a crucial candidate for future tokamaks to provide radiative power dissipation by reducing heat load on divertor plates and fine

controllability and compatibility with plasma confinements. In that context, experiments with trace argon impurity injection have been performed for the first time in ADITYA-U tokamak to understand argon impurity transport through high resolution spectroscopic diagnostics by measuring various line emissions in the visible and VUV region. Using a recently upgraded high resolution multi-track visible spectroscopic diagnostic, spatial profile of Ar1+ line emissions has been observed for the first time in Aditya-U plasma.

A radially movable 2-probe Laser Heated Emissive Probe [LHEP] diagnostic system was installed on ADITYA-U, with an aim to study plasma potential and its fluctuations in the edge region, after carrying out a series of both in-situ and in lab experimental iterations. Mechanical structure to support LHEP laser was conceptualized, designed and developed in ADITYA-U having a noteworthy feature of continuous focusing laser beam onto probe surface despite the system's radial movement.

It is observed that the sawtooth oscillation period in Aditya-U Tokamak increases after injection of short pulses of gas, containing 1017-1018 molecules of hydrogen. Maximum increase in period of sawtooth is 1-1.8 ms after each gas pulse injection. It is observed that the increase in the sawtooth period depends on the ratio of the core to edge electron density. After a long sawtooth, period of subsequent sawtooths gradually decreases until the next gas pulse is injected. This may be because modification of current density profile by the short gas pulse injection changes the local shear near the q=1 surface, which stabilises the internal kink mode. Applying a high bias voltage, around or larger than plasma potential, and drawing a large current (~100-300 Amp) from the flux surfaces by an electrode generates an inhomogeneous electric field in the edge region of the tokamak. The sheared radial electric field is responsible for sheared poloidal flow. In Aditya-U, a dedicated electrode bias experiment has been carried out to understand the above phenomenon. Alternative positive and negative pulses are applied by employing the in-house development of an IGBT-based capacitor bank power supply. The experiment has been carried out in a wide range of biasing frequency from 20 Hz to 15 kHz and the maximum voltage applied to the electrode is 400 V. In Aditya-U tokamak, a long-distance coherence mode is confirmed to be zonal flows during biasing improved confinement mode. This study is crucial to understand the role of the sheared radial electric field along with the Zonal Flows (ZFs) on the suppression of turbulence and hence on modification of transport.

To study the dynamics of runaway electrons, a setup is built for hard X-ray diagnostics. This involves NaI (Tl) scintillation detector, Photo Multiplier Tubes (PMT), and the electronics to read out the PMT data. The plan is to measure the hard X-ray radiation only coming from the bulk plasma. Cylindrical collimators, made of lead will be used to get the collimated hard X-ray from the core of the plasma. Another scintillation detector will be collecting hard X-rays coming from bulk plasma as well as from limiters. This way of collecting hard X-ray data coming from these two separate regions of the plasma, the dynamics of runaway electrons will be known.

An indigenously designed, developed, and characterized 100 GHz Heterodyne interferometer system has started providing real-time plasma density measurement. The system has the sensitivity or the noise floor - 69 dBm and dynamic range -65dBm to -10dBm. A new FPGA based density controlled gas injection system has been developed and installed in ADITYA-U. 100 GHz real-time system is used for density feedback to achieve better quality discharges. The

Schematic block diagram and 100 GHz heterodyne system

developed real-time density control system is able to maintain the line integrated plasma density at the desired level.

Till date, visible spectrometers used for plasma diagnostics have all been foreign brands. For the first time, a 0.5 m visible spectrometer, made in India by an Indian optical component manufacturing company in collaboration with IPR, has been procured and installed on ADITYA-U to monitor visible emissions. The spectrometer has three gratings with groove densities of 300, 600 and 1200 grooves/mm and the detector is a linear CCD array having 3648 pixels and one pixel size is 200 mm x 8 mm. The reciprocal linear dispersion of the spectrometer is 1.47 nm/mm with 1200 grooves/mm grating. The spectrometer supplied with software, having all required features for the spectrometer setting and control and also spectrum acquiring capabilities with exposure time setting and background correction. The detector is placed on a computer controlled opto-mechanical platform for easy movement and alignment. It is now in regular operation and is acquiring data during ADITYA-U shots. The performance of this spectrometer is comparable to the results obtained by foreign brands. This development is an important step towards "Aatmanirbhar Bharat".

Visible spectrometer developed at IPR for ADITYA-U tokamak

In SST-1, plasma current of 65 kA for the duration of 650 ms with density 8 x 10^{12} cm^{-3} and temperature 250 eV has been demonstrated. In order to enhance the plasma density & temperature, attempts are going on for the injection of Inductively-driven Pellets of Micro-granules of Lithium Titanate (Li_2TiO_3) powder at a velocity ~ 200m/s, 36-65 MHz and 1.5 kW Ion Cyclotron Resonance Heating (ICRH) , integration of hardware in loop Plasma control system(PCS) for the operation of various systems in loop , Simulation model for vertical field power supply, Linear plasma model simulation, removal of Plasma Facing Components (PFCs), In-situ magnetic field mapping, and installation of In-vessel PF#6 and new VF coils.

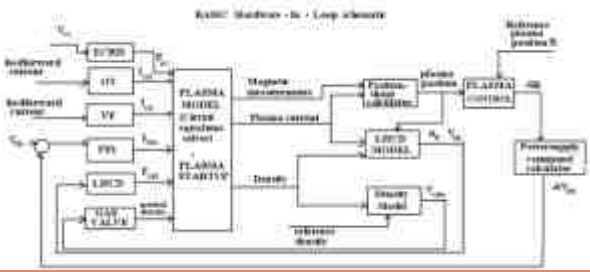
The Hardware-in-loop (HIL) for integrated plasma control system involves operation of various subsystems in a closed loop.

Vertical Field power supply (VFPS) model simulation

MATLAB Simulink based model for VFPS has been implemented, which generates required coil current profile based on expected plasma current profile. The model has been rigorously tested & validated with previous experimental data (within the error tolerance less than 5%) and is under implementation with the hardware so as be available in the upcoming experimental campaign.

Linear Plasma model simulation

Electrical circuit model of the whole tokamak device has been developed. It is being validated against the previous experimental data. Plasma physical parameters and their dynamics are also being incorporated so that it can model the plasma breakdown, current startup and its evolution as observed in the previous experiments.



Schematic of Hardware-in-loop (HIL)

Plasma facing modules were installed earlier for shaped plasma operation in SST-1, Since PF coils cannot be used in SST-1 at the moment due to cryogenic load issues, and shaped plasma cannot be produced, the PFCs are currently redundant. In order to improve diagnostic access to the plasma, a large number of

Inside view of SST-1 vacuum vessel before and after PFCs removal

Plasma Facing Components (PFCs) have been temporarily removed for various technical reasons. The PFCs will be reinstalled when shaped plasma operation again becomes possible. The 29th experimental campaign was the first campaign after the PFC removal and also, a long break for fixing up the vacuum vessel leaks. During this campaign, cryo-stable TF magnet operation at 1.5T for flattop more than 8 hrs. was achieved.

An indigenously-developed R&D program has yielded a Tetrode-based RF source with significant indigenous content (except for the vacuum tube). The entire system was shifted to the SST-1 Hall and re-installed along with required power supplies, water cooling and interconnecting transmission line components. As a part of installation all the control cables have been laid down and handshaking between LCU and various subsystems done and commissioning of the RF source is completed successfully in SST-1 hall and it is operational through LCU remotely for experiments.

View of Installed RF source in SST-1 hall

IPR had earlier developed and supplied a fibre optic-based imaging system to an external User agency for imaging of radioactive waste in a hot cell. As the next step, based on functional requirements proposed by the User, IPR has now developed a prototype remote handling manipulation system for manoeuvring of the optical fibre lens bundle inside the hot cell. The system has an overall diameter of ~175 mm and has a motion range of +/- 70 degree in horizontal & +/- 70 degrees in vertical direction. The system is radiation-compatible as it has been designed with a tendon driven mechanism having all motors/drives placed outside the working environment.

Prototype manipulator for maneuvering the lens bundle

MATERIAL SCIENCE

A correlative methodology has been developed for the quantification of ultrafine Cr rich phase separation in Fe-Cr based alloys, which has significant applications in processes that help understand safe operation of nuclear reactors. High-Cr ferritic / martensitic (F/M) steels or oxide dispersion strengthened (ODS) ferritic steels are deployed in intermediate-to-high temperature (673 to 973 K) operations in reactor core (Generation-IV). To study the phenomenon of embrittlement in these alloys, thermal aging (at 773 K from 1 h to 1000 h) induced change in

micro-hardness is directly correlated with underlying microstructural evolution at nano-scale for high-Cr binary ferritic Fe-20 at.% Cr (model for high Cr F/M or ODS) alloy. The reason for hardening of the alloy is attributed to the decomposition of ferrite phase into the ultrafine Cr-rich a/ phase in the Fe-rich matrix.

A 10 kg steel ingot, comprising 0.23C-2.06 Mn-1.03Ni-1.24Si-0.21Mo-0.38Cr-0.025V(wt.%), was melted and forged at 1200°C for making carbide free nanobainitic steel for applications in reactor pressure vessel (RPV).

A novel Ni-Cr-Mo-Ti based alloy has been developed at Materials Science Division, BARC for structural application in the Indian MSBR. Microstructural characterization showed that the alloy contains prominent carbides of Mo and Ti, many of which are located at the grain boundaries. Although Ni based alloys are known to be generally resistant to corrosive attack by molten halides, it is important to analyze the role of Mo-T carbides in the molten salt interaction. For this purpose, a sample of in-house developed Ni-Cr-Mo-Ti alloy was exposed to molten FLiNaK salt at 700°C for 100 h in the Molten Salt Corrosion Test facility (MSCTF) in BARC. Penetration of salt was observed up to a depth of ~ 50 μm, beyond which, the possible presence of carbide precipitates was noted. This was made clear in the EDS concentration map taken over the same region which revealed the presence of carbides beyond the penetration channels along the same track.

Reactor Pressure Vessel steels are being indigenously developed by BARC. It is important to assess the microstructural and mechanical stability of these materials under irradiation before the final deployment in the reactor. As part of the program to bench-mark the newly developed alloys, proton beam from Variable Energy Cyclotron was used to irradiate microstructure samples (10mm x 10mm x ~125-128 μm thick) and miniature tensile coupons from the RPV steel weld. The irradiation was carried out using 7.5 MeV proton beam after appropriately degrading the energy, so that the Bragg peak occurs at the back-surface of the sample. The microstructure samples were irradiated to a dose of 7.4E17 p/cm^2 which resulted in an average dose of 0.1 dpa from the back-side of the sample in a depth probed by the Co KA- X-ray for the microstructural characterization. The miniature tensile samples were irradiated from both sides so that the gauge length is exposed to an average dose of 0.1 dpa. These samples will be characterized at VECC using XRD and will be sent to BARC for further studies. This is a collaborative study with BARC.

Ni-based alloys, are already being extensively used in nuclear reactor applications due to the high temperature strength and excellent corrosion resistance property. These unique properties have renewed the interest in Ni-alloys as candidate structural materials for applications in molten salt reactors. As a predecessor to the studies on ion irradiation effects on various Ni-based alloys, oxygen ion irradiation was carried out on pure Ni. The weighted energy spectra of recoils formed by irradiation of pure Ni by 160 MeV O^{6+} ion revealed that there is a significant overlap of energetic Ni recoils with the corresponding weighted recoil spectra under fast breeder and fusion reactor neutrons demonstrating that 160 MeV O^{6+} ions can be used as a surrogate to generate similar PKA as the reactor neutrons in pure Ni. The microstructural parameters of 160 MeV O^{6+} irradiated pure Ni were evaluated using detailed X-ray line profile analyses techniques on the data obtained using synchrotron source (BL-12, Indus-2, RRCAT, Indore). Large changes were observed in the domain size, microstrain, stacking fault probability and dislocation density in the material at the first dose of irradiation. At higher irradiation doses all these parameters showed a tendency towards saturation. TEM observations showed that there is formation of stacking fault tetrahedra and dislocation loops in the irradiated samples. Both smaller and larger size loops are formed at higher dose of irradiation. The mechanical properties of the irradiated samples were accessed using microhardness measurements under various loads. The hardness was found to increase with irradiation dose and showed a saturation at higher doses.

The experimental results were supported by carrying out MD simulation of successive cascades using a 2 keV PKA in Ni which could help in understanding the development of defects in a similar

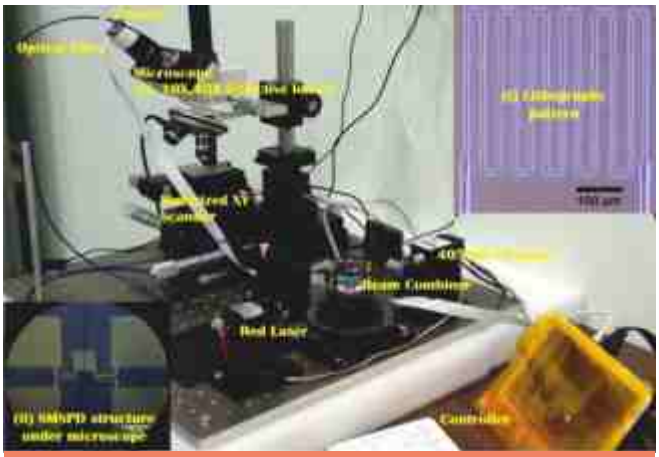
irradiation scenario. The effects of accumulation of dose and pre-existing defects in overlapping cascade events were investigated by analysing the atomic configuration in the sample after every cascade. The concentrations of defects are found to increase rapidly in the beginning at low dpa and then slowly tend towards saturation due to increased recombination and annealing of defects under successive cascades. The dislocation density and the stacking fault probability calculated from the simulation results showed a saturation at high irradiation doses. The observations made in MD simulations are in agreement with the experimentally measured microstructural changes at high doses of irradiation. However, subtle changes observed in the experimental results at the low doses could not be observed in the MD simulation results. This is a collaborative study with RRCAT and IISc, Bengaluru.

Emulation of neutron induced damage of structural materials in reactors using charge particles requires that the ion irradiation be carried out at high temperatures (similar to reactor operating temperatures). In this regard, a target flange has been developed for carrying out ion irradiation at high temperatures up to 300 deg C. Proton irradiation of Alloy 800H has been carried out three different temperatures (200, 250 and 300 deg C) using this setup.

Target flange and its assembly in the beam line at the Cave-1 of the K-130 Cyclotron

The gold–hydrogen analogy, where the chemistry of the gold atom resembles that of a hydrogen atom, is a subject of longstanding debate. To resolve the issues associated with this debate, the electronic and chemical properties of sub-nanometer hydrogen-doped gold clusters were examined systematically. The genetic algorithm coupled with a density functional theory-based method has been used to exhaustively search and identify the energetically low-lying structures of each of the H-doped gold clusters. The lowest energy structures of H-doped and pristine gold clusters are then employed to carry out the calculations of their electronic properties, their stabilities as well as their reactivity towards the adsorption and activation of CO and O_2 molecules. The study showed that in line with the gold-hydrogen analogy, both electronic properties and the adsorption/activation characteristics of H-doped gold clusters remain very similar to those of pristine gold clusters. These findings clearly suggest that the gold-hydrogen analogy is valid for the energetically most stable isomers of $Au_{n-1}H$ (n = 2 – 10) clusters.

A Direct Laser Writer (DLW) -based UV photo-lithography setup with provision for angular and spatial alignment of multiple lithography stages has been developed for patterning thin film structures. MoSi and TiV superconducting alloy thin film patterns for Superconducting Microwire Single Photon Detector (SMSPD) applications have been deposited using this laser writer.

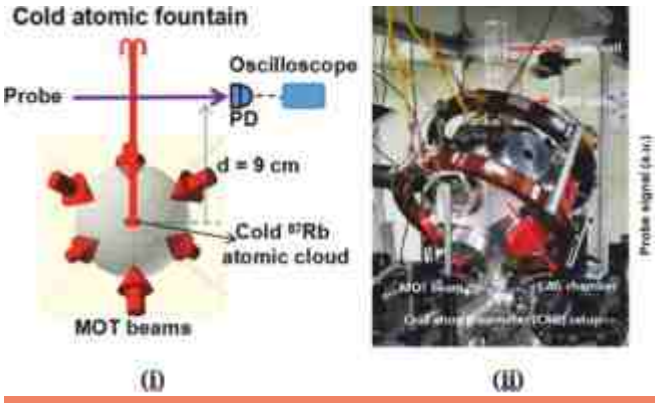


Direct laser writer based photo-lithography unit and deposited patterns

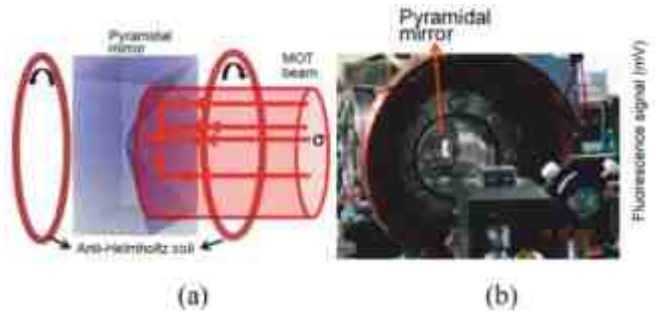
Single crystal of Potassium di-hydrogen Phosphate (KDP) of dimension 160 mm x 155 mm x 120 mm with mass of 5.5 kg was grown using indigenously developed solution crystal growth facility. This is the largest crystal KDP grown in India. Such crystals are required for the high energy laser program and these are commercially not available.

a) Water bath containing 50 L crystallizer; (b) KDP crystal

The working of cold atomic fountain has been improved which is an integral part of a Cold Atom Gravimeter (CAG) setup for precision measurement of earth's gravitational acceleration (g). The source of this atomic fountain is a Magneto-Optical Trap (MOT) of 87Rb atoms which involves three pairs of counter-propagating beams in a three-fold symmetry around the vertical axis. The pressure in the CAG chamber was ~ 3 x 10^{-10} Torr with Rb vapour. The temperature and number of cold atoms in the MOT cloud were ~ 300 ᴍK and ~5 x 10^{7} respectively. The cold atom cloud in the MOT was further cooled to ~ 24 ᴍK in optical molasses. Then, the cold atoms from molasses were launched by increasing the resonance frequency detuning (ΔNlaunch) of upper three cooling beams (directed downwards) while keeping the detuning of lower three cooling beams (directed upwards) unchanged. A probe beam was passed horizontally at the height of 9 cm from MOT centre to detect the cold atoms launched in vertical direction in the fountain. A probe beam, aligned horizontally at fountain height of 9 cm to detect cold atoms in the fountain, showed significant flux of atoms in the fountain at that height.



MOT (i) Schematic of fountain geometry and (ii) experimental setup



MOT setup: (a) Schematic of single laser beam using pyramidal mirror (b) View of pyramidal mirror

A MOT for ^{87}Rb atoms has been developed by using a pyramidal mirror for generating required six laser beams for the MOT. Using the pyramidal mirror, the MOT can be operated by a single input beam without requirement of optics for splitting and polarization purpose.

The surface nucleation kinetics play a vital role in establishing the charge neutral interface for further two-dimensional growth and hence determine the crystalline attributes of polar/non-polar GaP/Si hetero-structures. Taking these into consideration, the influence of different nucleation kinetics on GaP/Si(001) overgrowth layers quality has been assessed in non-destructive and expeditious manner via polar Raman Spectroscopy measurements. The evolution of defect-exposed non-(001) facets is ascertained, and subsequently the best (~525°C) nucleation condition in the given temperature range is determined. These findings established Raman spectroscopy as a quick alternative to other standard techniques for the optimization of pivotal nucleation step and actual epilayer growth.

Gallium arsenide (GaAs) is among the best-suited materials for X-ray photon detection and three-dimensional imaging under direct photon counting mode over a broad energy range. Therefore, GaAs-based detectors are developed and their response in the x-ray region is probed using low brilliance lab-based Cu-kA source and high brilliance synchrotron source. The developed detector is used to measure the characteristic lines of various transition metals such as Mn, Fe, Ni, Cu, and Zr at 6.5, 7.1, 8.3, 8.9, and 17.9 keV, respectively. Higher atomic numbers with greater absorption cross-section open up the possibility of the

GaAs detector

Experimental setup

replacement of Si by GaAs technology for high Z material characterization. Such detectors can find important applications in synchrotron radiation facilities, nuclear reactors, and safeguard applications.

An ultra-narrow band ultra-violet (UV) GaN detector having peak spectral response at 366 nm with only ~ 5 nm width, a UV-visible rejection ratio of $> 2\times10^3$ and detectivity of 1.3×10^{10} Jones at room temperature is developed by an innovative methodology. The device displays three orders of UV-to-visible rejection ratio over a wide temperature range of 150-350 K showing great potential for narrow-band UV detection.

RRCAT has developed a Gas Tungsten Arc Welding (GTAW) process to produce fully austenitic weld metal only by addition of controlled amount of Nitrogen in the shield gas (Argon) while joining austenitic stainless steels. A low-cost industry deployable Binary Gas Mixing System (BGMS) has also been developed so as to fully indigenise the technology.

GTA welding of vacuum chamber using Binary Gas Mixing System (BGMS)

Fabrication of coaxial triple walled discharge tube for development of glass tube based CO_2 laser was carried out at RRCAT.

Full length tube developed for CO_2 Laser

End joint showing Tungsten Electrode

MEMS (Microelectromechanical Systems) based microcantilevers (Mcs), having dimensions in the range of few μm, have attracted much attention in recent times, for various sensing applications, due to their extremely high sensitivity and fast response time. These MCs, fabricated in different geometries / dimensions / materials, offer a miniaturized sensing platform for real-time detection for various physical/chemical/biological sensing and actuation applications. In this work, MCs were systematically investigated for ultrasensitive temperature detection and photon flux measurements,

Experimental setup built for studying photoinduced deflection of Microcantilevers (MCs)

by exposing MCs to photons from a laser source. Apart from sensing applications, the ability of converting light energy into mechanical motion is interesting for realizing micro-actuation devices and opto-mechanical switches. Photoinduced deflection studies were carried out on uncoated and metal coated Si MCs (dimensions: 450×49×2.5 μm3), using an in-house experimental setup shown in figure. Experimentally, by choosing a higher Al thickness, a temperature sensitivity of 24mK/nm, with an equivalent optical power sensitivity of 38pW/$\sqrt{}$ z (~ 40 fJ), with a response time of 1.2 ms was achieved. Experimental results were compared with various theoretical models based on thermal conduction and convection losses. In addition, wavelength dependence of BMC deflection has an inherent advantage of introducing selectivity to MCs which is being pursued for Photo-thermal Deflection Spectroscopy (PDS) applications in mid-IR range for identification of molecules with high sensitivity and selectivity.

Magnetic Tunnel Junctions (MTJ) with ultra-thin multi-layers like ferromagnetic / insulator / ferromagnetic, ferromagnetic / semiconductor / ferromagnetic, ferromagnetic / Graphene / ferromagnetic will show interesting magneto-resistance (MR) properties, which are also sensitive to exposure of ionizing radiation. A recently installed MBE system shown below is used to deposit ultra-thin films of Ni(5nm)/Si(5nm)/Ni(5nm) on Si(100) substrate at RT. SEM and AFM measurements show that films are laterally smooth. Also, films of Ni(5nm) / Graphene / Ni(5nm) are grown on SiC. Presence of a few layer (7 monolayers) graphene is confirmed by Raman spectroscopy. This sample shows island features as the Ni/SiC layer is annealed at 950°C to obtain graphene on Ni. Unique high-resolution RBS measurements in Ni/Si/Ni/Si show smooth surface and interface features, while these features are rough due to islanding in Ni/Graphene/Ni/SiC. MR measurements are carried out in these samples from RT to 4 K by varying magnetic field (B) upto to +/-5 T. The Ni/Si/Ni sample exhibits anisotropic MR (negative MR when B is perpendicular to I and positive MR when the B is parallel to I). MR % at 4K and 300 K for B perpendicular to I is about 0.7 % and decreases drastically to 0.1 % for B parallel to I. This implies that there is ferromagnetic coupling between nickel films separated by Si film. This sample also shows the signatures of anomalous Hall effect in which the Hall resistance saturates at B >0.2 T. Positive RHall for negative B indicates –ve spin polarization in Ni. Low saturation field of 0.2T indicates smooth Ni/Si interface. In contrast to this, Ni/Graphene/Ni/SiC samples show only positive magneto resistance, indicating antiferromagnetic coupling between Ni layers separated by graphene layer, which induces opening of bandgap in semi-insulating graphene with zero bandgap. The bandgap is measured to be around 45 meV from the exponential dependence of resistivity with T.

At TIFR, in Condensed Matter Physics and Materials Science, researchers investigated the superconductivity properties and electronic structure of a full Heusler material, $ScAu_2Al$. From the resistivity and magnetic susceptibility studies, it was found that this compound exhibits a superconducting transition at 5.12 K. This 5.12 K transition is supposedly the highest Tc regime among the Heusler superconductors. From the band structure studies, it was found that this compound exhibits a van Hove singularity near the Fermi level. In continuation with the efforts in investigating the novel physical properties exhibited by Eu-compounds, researchers successfully grew single crystals of EuAl4 by flux method using Al as flux. In the area of Quantum Computing, researchers developed a new multimodal

circuit nicknamed Quantromon, which has two modes: a transmon qubit and a linear LC oscillator coupled to each other via cross-Kerr coupling. This enables the qubit and readout frequencies to be independent of each other, unlike the standard dipolar coupling scenario.

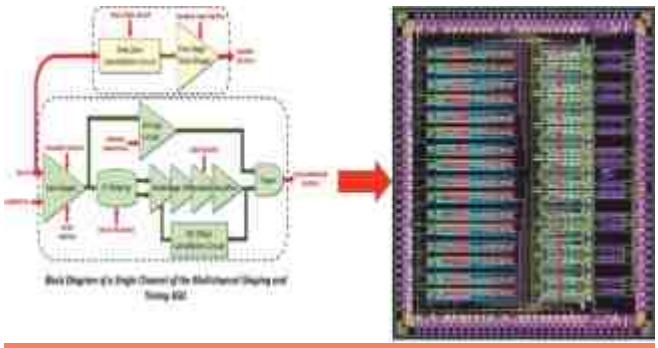
At SINP, activities of the Condensed Matter Physics divisional members comprised of synthesis and studies of various physical properties of a wide range of different materials. Studies include quantum Hall transport, spin-polarized transport, topological properties, magneto-caloric and electro-caloric effect, colossal and giant magneto-resistance, critical phenomena, novel magnetic behavior etc. The members of the Surface Physics division were primarily engaged in understanding and tuning the surfaces and interfaces of low-dimensional systems to achieve desired properties. Some of the research activities were understanding vibronic states and edge-on oriented π-stacking in poly(3-alkylthiophene) thin films; stearic acid mediated growth of edge-on oriented bilayer poly(3-hexylthiophene) Langmuir films; morphology and optical properties of ZnO nanorods and Au-ZnO heterostructures on different seed layers; manipulating edge current in hexagonal boron nitride; transition metal oxide fornon-volatile memory & catalytic applications and coplanar metal-semiconductor-metal structures for visible photo detection.

INTERDISCIPLINARY AREAS

The charged particle detector Array for kinematic reconstruction and analysis developed for intermediate energy (~10– 60MeV/A) nuclear physics experiments is using an imported 16-channel commercial module for first-stage signal processing of the current signal from detector. An indigenous multichannel Application Specific Integrated Circuits (ASIC) has been designed and developed at VECC to replace this imported module and the characterization of the ASIC has been carried out successfully for low power and low noise application. The development of an indigenous module, MCSA-16 using the ASIC has been developed successfully as import substitution.

This successful self-reliant development will not only lead to development of electronics within the department as import substitution in the field of electronics, it will also ensure the development of state-of-the-art electronics for other spin-off technologies using this integrated circuits.

The advantage of using ASIC in multichannel high resolution charged particle reaction and spectroscopy studies relies on its ability to couple it just behind the detector within the vacuum chamber itself which reduces noise introduced from the cable capacitance thus improves resolution. An imported shaping cum timing module is being used presently by the clear physicist for unavailability of any such ASIC. However, the commercial shaping cum timing module introduces additional noise for its inability to reside inside vacuum chamber for huge power dissipation. The tape-out of such an ASIC has been successfully designed and being sent for fabrication.



Block diagram of a single channel of the multichannel shaping and timing ASIC

This ASIC will be packaged using CQFP-120 package and functional testing will be carried out. A generalized NIM module similar to the commercial module mentioned above will also be developed using this ASIC for self-reliance and as import substitute.

The research work continued at the TIFR Centre for Interdisciplinary Sciences, Hyderabad. Cells adopt various mechanisms to fight against stress. A mechanistic understanding of such adaptations is crucial for understanding of biology and diseases, it was observed that the mitochondrial stress caused by defects in LRPPRC, a gene linked to human mitochondrial disease, elicit a mechanism that can segregate healthy and unhealthy mitochondria. This

mechanism was found to be mediated by PINK and Parkin, genes implicated in Parkinson's disease. Further, a novel gene Bendless/UBC13 was found that is required for PINK1 function and thereby for mitochondrial quality control. Achieving room-temperature valley polarization in two-dimensional (2D) atomic layers (2D materials) by substitutional doping opens new avenues of applications. Monolayer MoS_2, when doped with vanadium at low (0.1 atomic %) concentrations, was shown to exhibit high spin-valley coupling, and hence a high degree of valley polarization at room-temperature. The atomic layers of MoS_2 (MS) and V-doped MoS_2 (VMS) were grown via the chemical vapor deposition-assisted method. The formation of new energy states near the valence band was confirmed from band gap calculations and also from the density functional theory–based band structure analyses. This study opened possibilities of room-temperature opto-spintronics using stable 2D materials.

INTERNATIONAL RESEARCH COLLABORATION

The Theoretical High Energy group of the Institute of Physics (IOP) made significant contributions to areas like; formal field theory, string theory, QCD, radiative corrections, neutrino physics, beyond the standard model scenarios and their phenomenology, ultra-relativistic heavy-ion collisions, astro-particle physics, cosmology and quantum information. The experimental high energy group remain actively involved in the collider-based experiments at various international laboratories, such as CMS and ALICE experiments at CERN-LHC, STAR experiment at RHIC, BNL (USA), and the proposed CBM experiment at FAIR, GSI (Germany). The group played a leading role in the development of tau lepton reconstruction and identification techniques in the CMS experiment at CERN as well as in the development of algorithms for the reconstruction of hadrons. Substantial contributions have also been made to various research activities related to the India-based Neutrino observatory.

At IPR, the major activities carried out during April-December 2022 for the LIGO project include two contracts and allied works namely Contract for procurement of integrated vacuum vessel with dimensions 1.24m ID X 20.6m Length, Contract for procurement of 80K Cryopump fabrication and Development of Vacuum Control & Monitoring system for outgassing measurement system. Integrated Vacuum Vessel (IVV) is 1:1 scale in cross-section dimensions of beam tube, while 80K Cryopump is 1:1 scale prototype being fabricated as a technology development and capacity building efforts for LIGO-India project. Operation of IVV and 80K Cryopump will be controlled and monitored centrally and supply of control unit is part of each contract. Two separate contracts were signed with two different vendors after completion of due public tender process.

The first detailed study of exotic decay mode of the neutron-deficient, proton unbound nucleus, 115Cs, close to upper mass limit of the rp-process nuclei, has been studied by SINP. The measurement was performed at ISOLDE (Isotope Separator On Line Device) Decay Station [IDS], CERN by detecting delayed charged particles and rays. The measured delayed-rays are in agreement with bound excited states of daughter nucleus from previous measurement. The properties of proton unbound states at excitation energies from 3.8 MeV to 7.8 MeV were obtained by fitting delayed proton spectrum via _2 minimization and Bayesian method. The measured life time of those protons unbound states are of the order of zeptosecond.

The SINP-CMS group has made significant contributions in Higgs and BSM physics analyses using the 135 fb-1 of pp collision data collected by the CMS experiment during the Run II of the LHC. During the long shutdown period, the group made significant contributions in tracker operations, hadron calorimeter calibration, electron-photon identification, research and development of the upgraded tracker, muon and calorimeter endcap for future high luminosity runs.

International Thermonuclear Experimental Reactor (ITER)

Institute of Plasma Research (IPR), Bhabha Atomic Research Centre (BARC) and Indira Gandhi Centre for Atomic Research (IGCAR) are involved in the design, material development, thermo fluid MHD

analysis and various aspects of Lead Lithium cooled Ceramic Breeder (LLCB) Test Blanket Module (TBM) for ITER.

ITER India continued its steady progress towards fulfilling ITER commitments. While installation work progresses at the ITER France site with the Indian supplies related to cryostat, cooling water system, in-wall shields and the Cryolines, R&D efforts continue in the various labs at ITER India IPR for packages related to ICRH, ECRH, DNB, diagnostics and the power supplies.

Till date ~85 % of work related to various installations at the ITER site has been completed. Dr. Pietro Barabaschi has succeeded as the new Director General of ITER organization following the passing away of former Director General Dr Bernard Bigot.

The following sections provide a brief and pictorial summary of the progress in terms of supplies, manufacturing, technology development and experimentation related to the various packages under the scope of ITER India:

Cryostat

Having successfully completed the deliveries of various sections of the cryostat efforts are now focused to ensure the timely delivery of the ITER Torus Cryopump housing (TCPH) which is also a part of the INDIA scope of supply under cryostat procurement arrangement. TCPH Housing is a penetration located on the Cryostat lower cylinder with main functions to accommodate and support the Torus Cryo-Pump (TCP), connect it to the Vacuum Vessel and provide tritium confinement. The manufacturing contract for TCPH and associated bellows (6 Nos.) has been placed with M/s Vacuum Technique Pvt Ltd., Bangalore.

Half sized mock ups have been fabricated to validate some of the important requirements related to Welding and NDE validation for production that ensures weld configuration with 100% volumetric inspect-ability on full penetration weld joints using GTAW welding process; Assembly sequence to ensure required access suitable for manufacturing including validation of welding shrinkages that controls the distortion during the production; Achievement of critical functional

Half sized TCPH module fabricated, assembled and tested at M/S Vacuum Techniques Bangalore

tolerances (flatness of cryopump flange sitting face machining achieved within 0.12 mm , cryopump bolting hole positions within 0.3-0.8 mm also dowel positions achieved in the range of 2.0-2.4 mm and achieving the desired leak rates of ~ 1.6×10^{-8} mbar l/s.

The above has resulted in establishing the production route of the full sized TCPH assembly. Currently TCPH (3 Nos.) are in assembly stage after component manufacturing. The Mock up configuration of the TCPH assembled and subsequently vacuum tested at the manufacturer's site is shown below.

In addition to the above, prototype activities related to TCPH bellows and 6 signal conditioning cubicles to support ITER Cryostat instrumentation has been completed. The manufacturing of the TCPH bellows is expected to commence soon.

Cooling water system

The Indian scope of supply of the cooling water system at ITER consists of Component Cooling Water System (CCWS), Chilled Water System (CHWS) and Heat Rejection System (HRS). This year marked the completion of the Stage-II of the engineering & procurement contract. A 'Commit to Deliver (C2D)' event was organized by ITER Organization at ITER site on 16th June 2022 to mark the installation and completion of the supply of various equipment's under this procurement.

The meeting was chaired by Dr. Eisuke Tada, Director General (Interim), ITER Organization and attended in person and online by several dignitaries of the council of ITER and members of the participating nations in ITER and worldwide. The Indian delegation was headed by Dr. R.B. Grover. Speaking on the occasion, Dr. Grover, said "This achievement is an example of successful collaborative approach, with DA supplying the equipment and ITER Organization (IO) carrying out site installation." "With the completion of major milestones of Cooling Water Systems, Cryostat, In-Wall Shielding and Cryolines Procurement Arrangements, ITER-India is in the verge of fulfilling the commitments for first plasma", he further added.

In addition to the above, a Task Agreement involving the manufacturing of three safety-important Hydrogen Mitigation System vessels namely, Pool Scrubber Tank (PST), Quench Tank (QEN) and Overflow Tank (OFT) along with the common support frame was completed and the final inspection & acceptance tests (Hydro test of vessels, riboflavin test, lifting test of vessels, helium leak test of vessels, cooling coil pressure drop test, etc.) were successfully completed at the factory and the vessels were delivered at ITER site. The vessels have been accepted by ITER Organization (IO) after successful testing.

Further, as a follow up of the installation, the activities at IO are continuously supported for resolution of any issues in the commissioning of supplied components. Also, as a part of agreement with IO to support the design of CHWS-H1, several design activities have been completed and the remaining are expected to be completed by March 2023.

Pool scrubber tank PST under lifting test and packed for shipping at the manufacturer's site

In wall shields

The in-wall shield blocks supplied by INDA have been installed in the 3 out of 5 vacuum vessel sectors at EUDA and in all the 4 vacuum vessel sectors at KODA to EUDA and KODA continue to be installed in the vacuum vessel segments. The following are some snapshots of such assemblies.

In sequence: IWS lowered for assembly in VV sector, IWS assemble around flexible support housing between outer and inner shells of VV, inspection after assembly to ascertain needed clearance, VV segment view after assembly of IWS and ready for welding the outer shell

Installation of Cryoline and Cryo distribution system

After 100% manufacturing and supply of Cryolines to ITER in March 2022 steady progress continues towards the installation of the Cryolines of various categories at ITER site. Onsite installation of 60% of the X Cryolines, 68% of the Y Cryolines and 73% of the warm lines are completed. An additional 3% of the X Cryolines shall be installed soon. Following are the snapshots of installation of various categories of warm and cold lines under installation at ITER France.

Installation of X, Y cryolines and warmlines at ITER site

Steady progress also continues towards ensuring the manufacturing completion of the Auxiliary Cold Boxes (ACB). The factory acceptance tests of ACB-CP have been completed in Dec 2022. Manufacturing and factory acceptance tests for 3 ACB's is expected to be completed soon. Further, integration with interfaces and acceptance tests of CTCB is underway at the ITER cryoplant cold box building.

Diagnostic neutral beam system

Diagnostic Neutral Beam (DNB) system is based on the roadmap to development encompasses beam production and optimization experiments at the ROBIN and TWIN test beds and several aspects of technology development towards achieving an operation INTF which is a full-scale prototype of the DNB system with some of the components on loan from ITER. Recent experiments in ROBIN source have helped achieve ITER relevant (>30 mA/cm^2 H^- current density beams with an electron/ion ratio of <1) beam parameters at various gas filling pressures. Further experiments on TWIN source with ITER like coil configurations are expected next year to establish matching at RF powers up to 100 kW for two drivers coupled to a 180 kW, 1 MHz RF generator.

Steady progress continues related to the manufacturing of the components and in preparing the INTF test bed for beam operations. Majority of the parts of the DNB beam source have been completed. The manufacturing of the beam line components, the neutralizer, and the electrostatic Residual Ion Dump (RID), has also been completed.

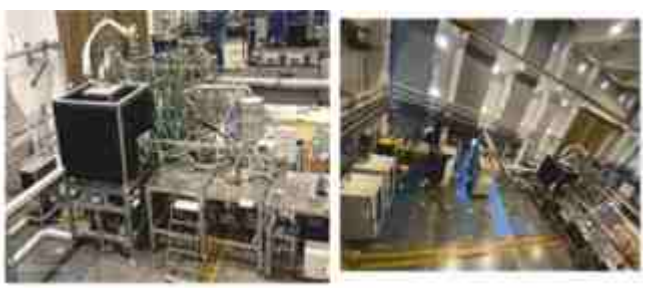
DNB components a) grids of beam source, b) RID panel c) neutralizer under assembly

Ion cyclotron resonance frequency heating sources

After the successful demonstration of the 1.5 MW RF amplifier chain in the recent years, efforts continue towards doing the needful to demonstrate 3MW RF power per source by combining RF outputs from 2 amplifier chains through an indigenously developed combiner circuit. In addition, indigenous developments continue to reduce import dependence to the extent possible. Further development of a 10 kW Solid State Power Amplifier (SSPA) has progressed with the PA1 module fully assembled with a pair of pallets and lumped combiner. In addition to these, water-cooled bleeder circuits for auxiliary power supplies and fast acting series switches for screen grid power supply have been developed and tested.

ECRH system

One of the important developments of this year include successful completion of the site acceptance tests for a 170 MHz 170 MHz Gyrotron unit procured from Russia and integrated with the indigenously developed experimental test bed at ITER India lab. An average peak power of 1 MW for 1000 s at the output of the diamond window and 960 KW at the output of Matching Optic Unit has been achieved for 5 pulses and complies with the specified value for the Gyrotron output power. It is also noted that the output frequency of the Gyrotron, measured using a spectrum analyser setup, is well within the specified range of 170 GHz +/- 0.3 GHz. This is a significant achievement as far as the Indian scenario is concerned. The RF efficiency is estimated at the Gyrotron window output and is found to be compliant with the specified value of 50%. More detailed tests such the reliability tests, modulation tests and some dependency tests etc. have also been carried out within the test facility limitations.



The gyrotron test bed at ITER India laboratory IPR

Power supply systems

A PSM topology based Main High Voltage (55kV, 6MW) Power Supply (MHVPS) has been developed for the Gyrotron test facility of ITER-India, IPR. MHVPS is capable of feeding settable voltage with ±0.5% accuracy from 10kV to 50kV. In-house developed Zynq 702 based controller is deployed for control, regulation and fast switch off; <10μs in case of short circuit. Operation GUI runs on Siemens PLC 1500. MHVPS has been successfully integrated for performing Site acceptance test of 1MW Gyrotron supplied by M/s. Gycom Russia, at ITER-India lab. MHVPS supported conditioning, short pulse requirements and subsequently delivered the required power for 1000seconds operation. Without any interruption, MHVPS supported reliability test (10 successive pulses of 500s) of 1MW Gyrotron including RF power modulation at 1 kHz. The facility at ITER-India lab is among the few where 1MW Gyrotron operations are being conducted.

Integrated operation of HVPS during SST-1 campaign achieved feeding of 1.6 MW power at 60 kV to Klystron of LHCD system. Remote operation was successfully carried out for required power with time synchronisation and load protection. Recently, 3MW HVPS was also utilised for validation, initial operation of integrated IC RF source at SST-1.

Further, 7.2MW, 100kV AGPS supplied by ITER-India has successfully completed 3 years of integrated operation on SPIDER experiments at NBTF, Padua, Italy site with remote support from ITER-India. AGPS is an in-kind supply under ITER package manufactured by M/s. ECIL.

An upscale version of 200kW SSRFG (1MHz) is being developed under contract with M/s. ECIL, where design approval is given for manufacturing of SSRFG.

Diagnostics

Parallel developments continue on several diagnostics to be supplied to ITER France which include systems for XRCS survey diagnostic, XRCS edge diagnostic, CXRS pedestal diagnostic system and the ECE diagnostic system. The developments highlights are design development and testing for X rays and physics design and ray tracing of the Bragg X ray spectrometer and high-resolution X ray spectrometer for the XRCS survey and edge diagnostic systems respectively. Factory testing of the fibre bundle assembly for the CXRS pedestal diagnostic is in progress. The development related to ECE diagnostic systems relates to measurement of the insertion losses for the polarizer splitter, and design of the 170 GHz sensor for stray RF radiation protection system are also being carried out.

ITER India, as a part of its in-kind contribution to the ITER project, has to deliver two high power (1MW/1000 sec) 170 GHz Gyrotron RF source sets. An ITER-India Gyrotron Test Facility (IIGTF) has been established to enable integrated testing and performance demonstration of high power gyrotrons procured for the purpose. This facility hosts indigenously developed high voltage power supplies (55kV, 110A), channel control system and cooling systems (flow and pressure), which are interfaced with the gyrotron assembly during the tests. During a recent acceptance test campaign, a maximum of 650 kW for 1000 s and 860 kW for 260 s at 170 GHz has been delivered into a dummy load for the first time in India.

Test Gyrotron at ITER-India lab, IPR

The achieved performance is at par with similar gyrotron performance demonstrations in Japan and Europe. In addition to this very important demonstration, IIGTF now stands commissioned for testing of high-power long pulse ECRH sources in future.

Lithium ceramics are used as the tritium breeder material in the fusion blanket. ITER, an experimental fusion reactor is under construction in France where these lithium ceramics will be used in the Test Blanket Module (TBM). Breeding blankets in a fusion reactor have to breed the tritium required for D-T reaction and to convert nuclear energy into heat extracted by a coolant. In order to design a breeder blanket, the detail heat transfer phenomena of the pebble bed, both experimental and simulation are essential. Sometimes, experiments and simulations are time and resource consuming. Hence, ANN (Artificial Neural Network) may be used to predict the behavior of the system as a complementary approach of simulation and experimental analysis. ANN Model has been adopted to solve the basic heat transfer problem in Pebbles and its outcome in terms of matching of ANN Model with experimental data has to be spelled out to show that compatibility of ANN Model.

The operation of Pb-Li MHD loop, of interest for IPR's Test Blanket Module design, has been started at IPR. MHD experiments have so far been carried out with a test mock-up having 'U' shaped circular flow geometry in presence of ~1.06 T magnetic field. The stainless steel 'U' shaped circular test mock-up (ID ~ 52.5 mm) was having an effective flow length of ~ 937 mm in the transverse magnetic field region. It was equipped with a large number of potential pins (71) welded on the surface, thermocouples (32 no.) and pressure measurement ports for estimation of important MHD parameters such as liquid metal pressure drop, temperature and velocity profile etc. The loop was continuously operated at a temperature of ~350 oC and Pb-Li flowrate was varied over the range 2-8 kg/s during MHD experiments. For a given pump rotation frequency, Pb-Li flow rate was found to reduce linearly with increasing magnetic field. In the absence of magnetic field, liquid metal pressure drop in the loop was found to vary quadratically, as expected in the case of normal hydrodynamic flow. However, with increasing magnetic

Pb-Li MHD loop at IPR (left) and 'U' shaped circular cross-section test mock up inside the magnet pole gap (right)

field, the pressure drop started following a linear relationship with the magnetic field, clearly indicating the effect of transverse magnetic field on the electrically conducting Pb-Li flow. At B~1.06 T, the MHD pressure drop across the test mock-up was estimated to be ~0.65 bar at the Pb-Li flow rate of ~8 kg/s and this was in good agreement with the pressure drop value obtained from numerical MHD analysis. The sinusoidal distribution of the wall electric potential was also observed which indicates evolution of MHD affected liquid metal flow within the test mock up. The experimentally measured potential values were in good agreement with the numerically estimated values.

CHAPTER 6

Plasma Torch Aerosol Generator commissioned at NATF, IIT, Kanpur

RESEARCH EDUCATION LINKAGES

Faculty Development Programme conducted by ATI at Harish Chandra Research Institute, Prayagraj

The Department of Atomic Energy supports the research education linkages mainly through grants-in-aid to institutes of national eminence, funding of extra-mural research, DAE-UGC consortium for scientific research and others.

The human resource and knowledge management is developed through Homi Bhabha National Institute (HBNI), BARC Training School and the Administrative Training Institute (ATI).

The Board of Research in Nuclear Sciences (BRNS) an advisory body of the Department of Atomic Energy (DAE) provides financial assistance to universities, academic institutions and national laboratories for encouraging and promoting scientific research in the areas of relevance to the mandate of DAE.

The National Board for Higher Mathematics (NBHM) established under the aegis of DAE promotes excellence in higher Mathematics education and research in the country. The Board also provides grants for promotion of activities in pure and applied Mathematics under several schemes including support to research projects, travel grants for participation in workshops, conferences and undertaking collaborative research funds for organizing conferences etc.

HUMAN RESOURCE DEVELOPMENT AND KNOWLEDGE MANAGEMENT

Homi Bhabha National Institute

Homi Bhabha National Institute (HBNI), a Deemed to be University, is a grant-in-aid institute of DAE. It has successfully completed 17 years. During this period, it has established itself as one of the best research universities in the country, encouraging research in various facets of nuclear science and technology including mathematics. HBNI was placed in the 11th position in NIRF-2022, under the research institutions category, based on high-quality publications during the calendar year 2021, in 82 Journals of high impact, the Nature Index 2021 has placed HBNI in the second position, among all institutions in India and in the top position among all institutions with regard to publications in the discipline of physical sciences.

The academic programs of HBNI are leading to human resource development not only in core areas of nuclear sciences and engineering but also in several other areas of societal importance such as medical and health sciences. During the period January to December 2022, HBNI awarded 67 MD degrees; 25 DM and 25 MCh degrees, contributing significantly to the number of specialists in medical oncology in the country. Till December 2022, HBNI has awarded 2208 PhD degrees in a variety of disciplines. HBNI has created an HBNI Industry Linkage Centre (HILC) which helps in the skill development of HBNI students and facilitates their internship in Industry. The cell also facilitated R&D collaboration between Industry and HBNI students/faculty with the aim of scaling up processes, commercializing or incubating new technologies, developing new processes/ products of interest to DAE, etc.

During the year, HBNI organized several value addition courses for HBNI students across the eleven CIs/OCC, viz., Research Methodology, Research and Publication Ethics; An executive management programme for senior executives of DAE organizations in collaboration with IIM, Ahmedabad in May and September, 2022; Advanced Materials Chemistry, and French language for research scholars of IGCAR. HBNI continued the dissemination of knowledge to its research scholars and students across all CIs/OCC through several webinars by eminent scientists/ engineers that were conducted over the WebEx platform.

HBNI organized three day “Discussion Meeting on Basic Sciences (DiMBS - 2022) in April 2022 to commemorate the International Year of Basic Sciences for Sustainable Development with an objective to provide a platform for interaction and catalyze the academic/research collaborations between faculty members and students of different Constituent Institutions (CIs)/Off-Campus Centre (OCC) of HBNI. In continuation, HBNI in association with CIs/OCC conducted a discipline-specific interaction meeting on

"Condensed Matter Physics" at SINP, Kolkata in June, 2022 and on "Life Sciences" at RRCAT in September, 2022.

A Memorial Program in honour of Late Prof. Srikumar Banerjee, Former Chancellor, HBNI, on May 10, 2022, and a Memorial Program in honour of Late Dr. Sekhar Basu, Former Secretary, DAE and Former Chairman, Council of Management, HBNI on September 23, 2022 was organised by HBNI.

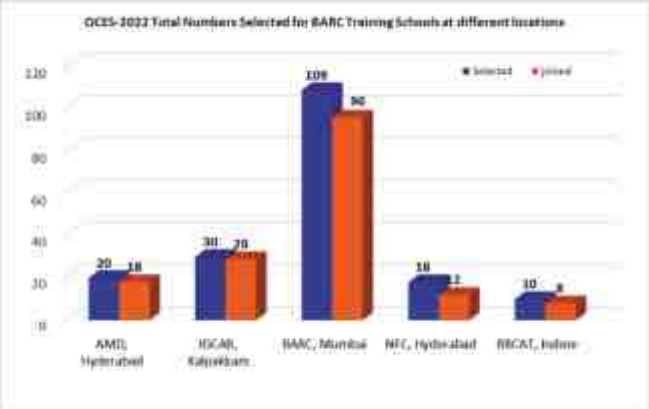
HBNI also organized talks for the popularization/promotion of science in association with four higher educational institutions in and around Mumbai city, viz., Birla College, Kalyan, VG Vaze College, Mulund, Sophia College, Churchgate, and Wilson College, Chowpatty to create awareness among graduate and postgraduate science students regarding the career opportunities in basic sciences, i.e. physics, chemistry and biology in DAE and encouraging them for a research career.

Training School

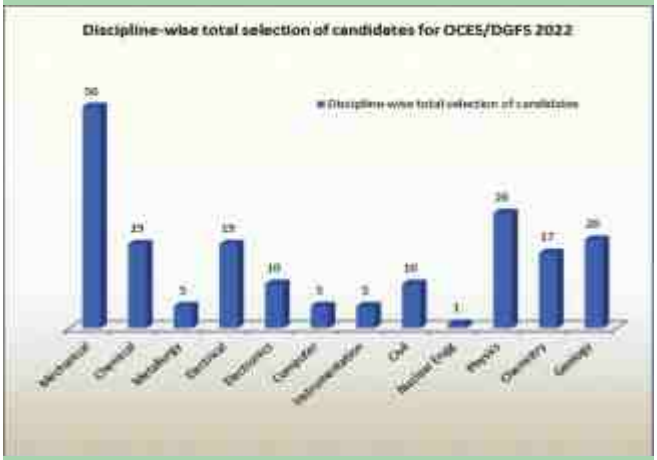
The Human Resources Development Division (HRDD) of BARC provides highly skilled human resources to DAE through two flagship programs, OCES and DGFS. The linkage of BARC Training School programs with HBNI ensures continuous availability of professionally qualified, well trained and motivated scientific and technical manpower for induction into various DAE units.

A total of 101 graduating TSOs of 65th batch of OCES/DGFS-2021 (75 in Engineering, 10 in Physics, 7 in Chemistry, 3 in Biosciences and 6 in Radiological Safety and Environmental Science), after successful completion of training, were placed in various units of DAE. Also, there were 8 Trainee Defence Officers, who passed out with this batch and were assigned to different Divisions/Units for undertaking project for M.Tech under the aegis of HBNI.

While the academic programme of the 65th batch was underway, screening examination for 9 engineering and 3 science disciplines for the 66th batch was organized successfully at 58 venues in 47 cities of India. The number of applicants for OCES/DGFS-2022



Total number of selected and admitted candidates in various BARC Training Schools in the 2022 batch of OCES/DGFS-2022



Discipline-wise total number of selected candidates for OCES/DGFS 2022

was 85,588. Of them, 44,793 candidates appeared in the online examination. A total of 187 candidates were selected for OCES/DGFS-2022 as compared to 198 previous year.

HRDD also conducts the QUEST program under DAE's Continuing Education Programme (CEP). During the year, it offered four advanced courses on Signal Conditioning & Recovery, Advanced Concepts in Finite Element Method, Catalysis and Surface Engineering Chemistry and State-space approach to Reactor Control for PhD students and DAE employees. Certificates were issued to candidates who have secured more than 50 per cent in the passing examination.

HRDD coordinates 1-2 month practical training and also offers up to one-year duration academic projects in BARC for students of BE / Btech

/MTech/ME/MSc/MCA/JRF/SRFs from all over the country for promoting interactions between academia and scientists for wider benefits. HRDD facilitated 719 applicants from outside colleges to perform collaborative research/ project work in BARC.

For upskilling of entry level young graduates, HRDD facilitated enrolment of 78 Trainee Officers of OCES-2021 and 69 TSOs of OCES-2022 of BARC Training School to M.Tech program of HBNI. Under its coordination, M. Tech project work was initiated for 52 officers of OCES-2020 and 45 of OCES-2021. HRDD processed 22 M.Tech theses of OCES-2019 and 16 of OCES-2018 M. Tech degrees from HBNI.

Twenty young trained scientists and engineers (OCES-2021, 16th Batch) have successfully completed their orientation programme at BARC Training School at IGCAR and they have been placed in various units of DAE. At present twenty-nine trainee scientific officers (OCES-2022, 17th batch) are undergoing training. From the current batch (OCES-2022), Seventeen Trainee Scientific Officers from Engineering discipline have enrolled for their M.Tech Programme. Also, one hundred and thirty-six category I & II trainees have successfully completed their training programme and have been placed as Scientific Assistants and Technicians in various group of IGCAR. Recently, 44 Category -I Trainees have been inducted for the Category-I training programme. The programmes of Homi Bhabha National Institute (HBNI) continue to progress satisfactorily. During this period, 15 researchers have submitted their PhD thesis and 11 have been awarded the degrees.

BARC Training School AMD Campus, Hyderabad continued its activity wherein 17 (Geology) Trainee Scientific Officers (TSO) of the 12th batch (OCES-2021) completed induction training on 31st October 2022 and 12 Officers of OCES-2019 batch (Geology:10 and Geophysics: 2) were awarded M.Tech degree by HBNI. In addition, induction training of 16 TSOs of Geology discipline of the 12th batch (OCES-2022) is in progress.

At, RRCAT 14 Trainee Scientific officers (TSOs) from the batch OCES-2021 have completed one-year orientation program and have been placed in RRCAT, BARC and VECC respectively. In the new batch (OCES-2022) 6 TSOs are undergoing the training course.

NPCIL has strong and dedicated workforce of 10727 employees as on December 31, 2022 consisting of Engineers, Technicians and Supervisors, Non-Technical Executives, Staff and Auxiliary support staff who spearhead the activities of the organization. All HR initiatives are directed towards fulfilling the NPCIL's mission and vision by attracting, motivating and retaining the right talent and intellect. While developing the strategic and incremental packages for employees, the individual goals and aspirations are encouraged by way of training culminating in achievement of goals of NPCIL.

NPCIL being a company carrying out special nature of business, the strategic dimensions of its business and the operational flexibility needs to be maintained in every aspect. The trained and skilled Human Resource is an asset of NPCIL. Hence, optimization of manpower is an important strategy towards best utilization of human resource. Accurate and comprehensive manpower optimization models for Construction Projects, Operating Stations, Design & Engineering, including multi-Unit Sites are developed separately in NPCIL. Staffing is done strictly in accordance with these models in NPCIL.

Being a Central Public Sector Enterprise, NPCIL is committed to implement the Presidential Directives and all the Govt. of India orders on reservation, relaxation and concession for SC/ST/OBC/EWS and Persons with Benchmark Disabilities in recruitment and for SC and ST in promotion, wherever applicable.

During the year 2022, as on December 31, 2022, as a part of annual induction programme, 294 young talents were recruited in Group A, B & C through direct recruitment process. Total 12 young talents were recruited through direct recruitment process under Persons with Benchmark Disabilities Category.

Administrative Training Institute

The Administrative Training Institute (ATI) formally came into being on 02.07.2007 which was

CHAPTER 6

earlier known as O&M and Training Division of the Department of Atomic Energy (DAE).

The mandate of ATI is to conduct Department specific induction training programme to the new recruits in the Administrative, Auxiliary and Security cadre of Constituent Units of DAE and orientation courses to the middle level and senior employees of Constituent Units, Public Sector Undertakings (PSU's) and Aided Institutions. The topics covered are on service, legal, financial, vigilance, soft skills, management, computer and development skill. ATI also conducts special programmes to the Scientific, Technical, Medical and Para-medical staff members of DAE on various job-related matters like Intellectual Property Rights, Contract Management, Goods and Services Tax etc. Over the decade, ATI has developed a robust training system to meet the unique requirements of the DAE and has been successfully imparting series of training programmes on behavioural and soft skills, cadre plan, capacity building, faculty development, induction, refresher/orientation courses etc.

ATI continued witnessing new initiatives during the year 2022-2023. A summary of the various activities conducted by ATI were as follows:

Contributed in the field of Training and Development by conducting 47 training programs covering a training population of 1272 with 3807man days till December 2022. Another 20 training programmes are planned during remaining period of the year.

Management Development Programmes (MDP) were conducted in coordination with institute of good repute covering 29 Group A Officers of the Department and a customized programme for AEES Schools Principals/Vice-Principals.

Faculty Development Programme conducted by ATI at Harish Chandra Research Institute, Prayagraj

With the aim of developing in-house faculties for imparting training to the DAE employees, ATI conducted a faculty development programme at Harish Chandra Research Institute, Prayagraj from 5.1.2023 to 10.1.2023.

To commemorate 75 years of Independence, the “Azadi Ka Amrit Mahotsav (AKAM)” programme was conducted showcasing the activities and progress of ATI since its inception and exhibiting the decorative arts/ gifts made by differently abled students of Sausheelya, Anushaktinagar.

Exhibition of decorative arts/ gifts made by differently abled students of Sausheelya, Anushaktinagar during the AKAM

ATI conducted two mandatory induction trainings for administration and auxiliary which covered 94 employees.

An Experience sharing for Official Language Cadre officers was conducted at RRCAT, Indore.

Based on the request received from the Lal Bahadur Shastri National Academy of Administration (LBSNAA), Mussoorie, ATI conducted training

Training programme for employees of Lal Bahadur Shastri National Academy of Administration (LBSNAA), Mussoorie

programme for ministerial staff of LBSNAA. ATI continues to provide customized programme for other Government of India Institutions on need based requests which includes Indian Institute of Geomagnetism (IIG), Panvel.

The ATI is recognized by Central Information Commission (CIC) as Third Party Agency to carry out Transparency Audit for the Department of Atomic Energy Constituent Units, PSU's and Aided Institutions under the Right to Information Act, 2005. Accordingly, for the year 2021-2022, ATI has conducted third party audit of 26 DAE Units, PSUs & AIs. Also, audit of National Institute of Technology, Warangal, and an institute of national importance was conducted by ATI, DAE.

Training programmes on specialized topic such as Risk Management for Board level Officers PSUs was conducted.

Evaluation of Training (EoT) programme was carried out for the first time, in respect of a Refresher Programme conducted for Jr. Store Keeper/Jr. Purchase Assistants. The EoT confirmed the efficacy of the training programme. The report is available on ATI Website.

Government of India has set up the Capacity Building Commission (CBC) with an aim to transform the training ecosystem and make it more focused and create shared knowledge resource under Mission Karmayogi. Towards this direction, Annual Capacity Building Plan (ACBP) for all cadres including Scientific and Technical is under consideration of the Department. A DAE- Capacity Building Unit (DAE-CBU) has been constituted for the same. ATI is actively involved in the program of ACBP for all employees of DAE.

Visit of Capacity Building Commission (CBC) team from Delhi in ATI

ATI continued to carry out Training Need Analysis for DAE. It has been the endeavour of ATI to innovate and adopt the best practices in training with an aim to make it a robust Institute thereby creating a strong, informed and skilled human capital.

SPONSORED RESEARCH

Board of Research in Nuclear Sciences (BRNS)

The Board of Research in Nuclear Sciences (BRNS), of the Department of Atomic Energy (DAE), is providing extramural funding to academic institutions and research laboratories across the nation to pursue Research and Development (R&D) on activities related to the mission of DAE. Post-re-constitution in 2019, BRNS has Nine Committees on DAE Programmes (CDPs) and the involvement of DAE collaborators has been redefined to include the utilization of outcomes from the BRNS-funded projects.

BRNS continued to provide the financial support to the International Science Olympiad Programme, C.V. Raman Lecture Series, Indian Women Scientists' Association, etc. During the Financial Year (FY) 2022-23, some notable activities included the introduction of a new Coordinated Research Project (CRP) Scheme and the completion of “Fast Track Covid-19 Research Projects” which have delivered significant outcomes in diagnostics, therapeutics and novel PPEs.

During the calendar year 2022, 34 Technical Programme Discussion Meetings (TPDMs) were organized in the Hybrid Mode for review of new and on-going relevant research projects submitted to BRNS by project investigators from Indian Universities and National Institutes. A grant of ₹ 11 Crore was released to various Indian academic institutes for 79 new sanctioned projects recommended by the nine BRNS Committees. The total amount of ₹ 28 Crore has been disbursed for ongoing and new research projects, symposia, International Science Olympiad and other schemes. During the year, around 206 new and on-

State wise distribution of 79 new BRNS projects during FY 2022-23

going research projects were evaluated. The closure review of 63 completed research projects was completed by various committees of BRNS. Among the nine committees of BRNS, Basic Research and Science Education (BRE) committee has sanctioned a maximum number of 30 new projects, followed by Food Security (FOS) committee which sanctioned 13 new projects. The following map of India visually indicates the presence of BRNS across the Indian states where 79 new projects were sanctioned this year.

Under the Coordinated Research Projects (CRP-2021) Scheme, review of 47 out of 57 submitted new sub-project proposals was completed by respective BRNS Committees. Sanction and grant of 8 research projects have also been released with a budget of ₹ 172 Lakhs during the year 2022. BRNS has completed the closure review of 29 collaborative research projects in the area of Radon, Thoron and decay products studies. These projects were distributed across 14 states and 1 Union Territory. The focal theme of these projects was to generate the baseline data on concentration profile of Radon, Thoron and their progeny in the environment and associated radiological dose to the member of public. A total of 47 research articles, based on these projects, were published in international journals.

Some of the important and notable outcome arising from BRNS projects that were completed during the year, are as follows:

- Development and design of two potential in-situ sensors (electrochemical mobile based immune-sensor and RT-LAMP integrated CRISPR-Cas12 technique-based sensor) for rapid sensing of SARS-COV-2 and a prototype coverall as Personnel Protective Equipment (PPE).
- Indigenous development of Radon, Thoron, and Progeny Dosimeters and Online Monitoring System. Generation of baseline data on the concentration profile of Radon, Thoron, and their progeny in the environment and associated radiological dose to the member of the public.
- Measurement of neutron-induced reaction cross section up to 18 MeV for advanced reactor design.
- Studies for unravelling heat transfer mechanism in nucleate boiling using multi-scale simulations.
- Investigations on the structural integrity of dome shaped roof slab of future SFRs.
- Validating CFD Simulations of Gas-Liquid STR for different impellers through Radiotracer Based Technology.
- Fundamental Physics in Strong Gravitational field of Neutron Stars.
- Study of Dropwise Condensation on a Plasma Patterned Super - Hydrophobic Metallic Surface for Water Harvesting.

During the FY 2022-23, in all 5 patents were granted for the notable work arising out of BRNS projects.

BRNS provides financial support to fully funded DAE-BRNS Symposia to DAE institutes and partially funded Symposia to non-DAE institutions. During 2022,

98 symposia were supported by BRNS. Among these, 20 were fully funded DAE events and 78 were partially funded by BRNS. Towards celebrating Amritkal Mahotsav, eight Theme Meetings (Tms), organised by DAE researchers on focussed & specific subjects of DAEs interest were supported with a total budget of ₹ 8.7 Lakhs.

BRNS continued the partial financial support to International Physics Olympiad (IPhO) and International Junior Science Olympiad (IJSO) majorly driven by HBCSE, TIFR. In IPhO programme, 368 students from 75 countries participated wherein India bagged 1 Gold and 4 Silver medals, placing at 11th position. In the International Junior Science Olympiad (IJSO) programme, 203 students from 35 countries participated of which 20 gold, 42 silver, and 59 bronze medals were awarded at this programme. India, at the IJSO, has bagged 6 Gold medals, excelling at 1st position in the medals tally. In total, 30 Indian students have participated in the International Science Olympiads and this is the first instance that all Indian students have won some medal (12 Gold, 13 Silver, and 5 Bronze), since 1998.

Current Science is an open-access multidisciplinary journal published by the Current Science Association. BRNS is supporting the Current Science Association with an annual grant of ₹ 10 lakhs.

BRNS supports high-value Research Projects under Memorandums of Understanding (MoUs) mode which are primarily initiated by a DAE institution with the specific objectives requiring participation of academic/research institutions outside DAE. The physical and financial progress of such MoUs is monitored once in six months by an Apex Committee and a Project Implementation Committee (PIC). Progress of 4 ongoing MoUs was reviewed by respective Apex Committees and Project Implementation Committees (PIC). During this year, one of the notable outcomes from BRNS funded MoUs is the development of two rice mutant varieties viz. TCVM (Trombay Chhattisgarh Vishnubhog Mutant) and TCSM (Trombay Chhattisgarh Sonagathi Mutant) which have been notified by Government of India for commercial cultivation.

Plasma Torch Aerosol Generator commissioned at NATF, IIT, Kanpur

Under BRNS-BARC MoU work with IIT Kanpur, a Large-scale nuclear aerosol test facility has been successfully setup at IIT Kanpur for 'Studies on Aerosol Behaviour under Severe Accident Conditions in the Context of Indian Nuclear Reactors'. Pre-commissioning activities, characterization of Plasma Torch Aerosol Generators (PTAG), experimental work on controlling parameters of PTAG and commissioning of the facility have been completed.

Promotion of Mathematics

The National Board of Higher Mathematics (NBHM) was set up by the Government of India under the Department of Atomic Energy (DAE), in the year 1983, to foster development of higher mathematics in the country, to formulate policies for development of mathematics, help in establishment and development of mathematical centres and give financial assistance to research projects and to doctoral and postdoctoral scholars.

Main objectives and functions of NBHM are to continuously evolve and implement policies and programmes for development of mathematics in the country; to help in establishment and development of

mathematical centres; to promote growth of higher mathematics in the country and to coordinate activities for development of mathematics; to assess the nature and extent of mathematical inputs necessary in application and to suggest steps for training adequate personnel, especially in areas where sophisticated mathematics in involved; to give financial assistance to research projects and to doctoral and postdoctoral scholars; to support undergraduate and postgraduate teaching along with research activities in India by offering scholarships, travel support, support to libraries among other things and to determine the funds required for these activities and to administer these funds through suitable machinery set up for this purpose.

During the year DAE allocated ₹ 19.58 Crores for various NBHM schemes for the FY 2022-23. Allocation of funds to various activities was re-worked according to the proportion of actual expenditures in previous years to match the sanctioned amount of ₹ 19.58 Crores.

NBHM has sent the recommendations for sanctions and releasing the grant of ₹ 17 Crores to DAE, and ₹ 16 Crores were disbursed in various schemes by December, 2022. The grants of ₹ 10.51 Crores were disbursed in two months May-July, 2022 in various schemes.

Undergraduate Scholarship for BA/BSc and Postgraduate Scholarship for MA/MSc

The Board has instituted several scholarships for outstanding students with a pronounced aptitude for research, studying for the Master's degree in mathematics or statistics. The selection for awarding these scholarships is done on the basis of written test/interview.

BA/BSc Scholarship

The Board has appointed a liaison committee to consider NBHM funding under the 'Scholarship to Undergraduate (UG) 'BSc (Hons) in Mathematics and Computing' Students for IMA's grant proposal.

MA/MSc Scholarship

The written test for NBHM's Master Scholarship for the Academic year 2021-22 could not be conducted due to the pandemic. The Examinations Committee recommended restoration of the Master's Scholarship Scheme for the year 2022-23 in the 77th Board Meeting. The recommendation for the enhancement of scholarship is proposed.

PhD Scholarship

The budget for PhD fellowships for the FY 2022-23 was ₹ 2.75 crore. The written test for the PhD student was held on June 18, 2022 in 47 centres in 42 cities, including two new centres at Patna and Imphal, which hosted the centres for the first time. Applications were accepted exclusively online. A new online portal has been developed and was used for the first time for this test. Total 2418 applications were received, and 1901 candidates appeared for the test with the 78.5% attendance. Based on the performance on the written test, 88 candidates (15 female) were shortlisted for interviews. The interviews were held online during July 11--13 by five panels consisting of six experts each. Taking into account the performances in the test and the interview, 40 candidates (10 female) have been recommended for grant of the scholarship. The new application portal has a feature where applicants can login with their credentials created at the time of the application and know their own test score (once the scores are uploaded).

Post-Doctoral Fellowship (PDF)

NBHM has been supporting the postdoctoral candidates of the country which gives them an essential lifeline for 3 years after they complete PhD and before they are ready to apply for regular faculty positions. NBHM selects postdoc candidates twice a year - in the month of January and July. Funds of about ₹ 4.51 crore have been disbursed under this scheme during the FY 2021-22. NBHM PDF committee selected 11 candidates out of 45 applications received for 2021 (Part II) and 22 candidates out of 87 applications received for 2022 (Part I) in the year 2022-23. ₹ 4.59 Cr was allocated in BE FY 2022-23 for this scheme, and recommendations for the

amount ₹4 Cr were sent to DAE, and amount of ₹ 3.75 Cr was disbursed until December 2022.

Visiting Professorship

NBHM provides funds to university departments and other institutions for inviting eminent mathematicians from within India or abroad for lectures, joint work and other academic activities. NBHM has allocated ₹ 36 Lakhs at BE stage FY 2022-23 for this scheme and released the grant for two Visiting Professors (@₹ 18 Lakh)

Library Grant

NBHM operates a scheme to extend financial support to the libraries of various Universities and Institutions. There are eight regional centres, and each centre has several libraries falling within its region. The funds are meant for purchase of books and journals. The Board was happy to note that some of the grant-receiving institutes were having devoted corners for NBHM books. The board could not support any Library Grant in December 2022 due to limitation in the funds allocated to NBHM, and has allocated ₹ 4 Cr in its 78th Board Meeting, subject to availability of additional funds at the RE stage beyond ₹ 19.58 Crores, already sanctioned for FY 2022-23.

Book Distribution Scheme

Under this scheme, NBHM supplies selected books to mathematics/statistics departments of universities/institutes/postgraduate centres. Books sent under this scheme are meant for the institutional/ departmental libraries & not for individual collections. If any mathematics department of any university/institute wants to be included in the mailing list of the Complimentary Book Distribution Scheme, they should write a letter to the coordinator of this scheme. NBHM could allocate & disburse payments of ₹ 7,05,320/- under this scheme in the FY 2022-23 due to shortage of funds.

Research Project Grant-in-aid

NBHM provides assistance for Research Projects Proposals (along with JRF/SRG/RA) on the recommendations of its Committee. Due to shortage of funds allocated to NBHM for FY 2022-23, NBHM could extend financial support of about ₹ 1.61 crore to 17 Fresh Research Projects and 30 on-going projects (renewals) this year, based on the recommendations after a close scrutiny by Research Project Committee.

Travel Grant

NBHM provides financial assistance to attend a conference or make a short visit for collaborative work. Total approved budgetary estimate for Travel Grants for the FY 2022-23 was ₹ 50 Lakh. After a strict scrutiny by Travel Grant Committee, recommendations for the amount of ₹ 10 lakh were sent to DAE for the disbursement until December 2022.

Conference Support

NBHM provides financial assistance for holding national and international conferences / workshops / seminars. Total approved budget for Conference Support scheme for was ₹ 50 Lakh for the FY 2022-23. The Board has approved a budget of ₹ 1.50 Cr for FY 2022-23, subject to sanction of additional funds. 20 out of 64 fresh proposals for NBHM Conference Support received till November 2022, were approved by the Chair. Recommendations for the amount of ₹ 70 Lakh under this scheme, were sent to DAE, and amount of ₹ 60 Lakh was disbursed until December 2022.

Mathematical Olympiad & Madhava Mathematics Competition

The Mathematics Olympiad activity was undertaken by NBHM from 1986 onwards and is currently run in collaboration with the Homi Bhabha Centre for Science Education (HBCSE), Mumbai. Main purpose of this activity is to support mathematical talent among high school students in the country. NBHM received a request for a grant of ₹ 117.64 lakh for Mathematical Olympiad and other Programmes (FY 2022-23). NBHM has approved a grant of ₹ 80 Lakh towards Mathematical Olympiad & Related Activities for FY 2022-23, this was released in July 2022. NBHM has appointed representatives for IMO 2022 held in Oslo, Norway during 6-16,2022; Regional Co-ordinators for Arunachal Pradesh and Regional Co-ordinators for Maharashtra & Goa.

Indian Women in Mathematics (IWM)

IWM is a collective of mathematicians that has been in existence since 2009. Its objective over the years has been to encourage more women to pursue higher education in mathematics, and to provide an exposure and environment that enables them to take up careers in mathematics. In its pursuit to fulfil the objective, IWM organizes various workshops and conferences that focus on presentation of original research work and discussion about career opportunities in mathematics. The Board approved the sanction of ₹ 20,88,460/- for FY 2022-23, and the same was released to IWM for the year 2022-23.

Mathematics Training and Talent Search (MTTS), Hyderabad

MTTS Trust established in 1993, holds a large number of cost-effective and immensely useful programmes for promotion of higher mathematics every year. Due to the limited funds available for NBHM's various schemes for FY 2022-23, a grant of ₹ 60 Lakh was allocated as 1st instalment to support MTTS 2022 Camps against the request of ₹ 1.2 crore. DAE released the amount of ₹ 55,23,066/- after adjusting the unspent balance of ₹ 4,76,934/- from the previous year with MTTS. The Board has allocated a total of ₹ 1.2 Crore for FY 2022-23 in 78th Board Meeting, under this head, subject to additional fund being made available at the RE stage.

Support to various Centres of Mathematics during the FY 2022-23

Chennai Mathematical Institute (CMI), Chennai.

NBHM provides major grant-in-aid to CMI on an annual basis. CMI specialises in Mathematics, Computer Science and Physics. CMI faculty are active researchers, comparable to the best in leading institutions in the country. The teaching programmes offered in CMI are BSc Honours in Mathematics and Computer Science, BSc Honours in Mathematics and Physics, MSc in Mathematics, MSc in Computer Science and MSc in Data Sciences. In addition, CMI offers PhD programmes in mathematics, Computer Science and Physics. It makes significant contributions to India's scientific manpower. NBHM, in its 77th Board Meeting discussed the CMI's request of ₹ 14 Crores for FY 2022-23, but could then allocate a grant-in-aid of ₹.6 crore to support CMI for the financial year 2022-23. 1st instalment of ₹ 5 Crore was released by R&D-II (DAE) in July 2022 and 2nd instalment of ₹ 1 Crore was released in December 2022 In FY 2022-23, board re-approved a total sum of ₹ 10 Crores to CMI subjected to availability of additional funds.

Kerala School of Mathematics (KSoM), Kozhikode

KSoM organised an International Conference on Class Groups of Number Fields and Related Topics from October 21-24, 2021. The conference brought together the top Number Theorists and young scholars to present their work. In keeping with the tradition, ICCGNFRT-2021 hosted a handful of Ph.D. scholars and Post-Doctoral Fellows and provided them with opportunities to present their research in front of experts. The Board has approved a grant of ₹ 65 Lakh to KSoM for FY 2022-23. The first instalment of ₹ 30 Lakhs was sanctioned and disbursed to KSOM in July 2022. The remaining funds will be provided subject to the expected allocation of additional funds to NBHM at RE stage. The State Government has set up a Research Council to oversee the activities of KSOM. The Council is presently chaired by Prof. A. J. Parameswaran, and the members of this Council are selected in consultation with NBHM,

Bhaskaracharya Pratishthan (BP), Pune

NBHM has approved a grant-in-aid of ₹ 20 Lakhs to Bhaskaracharya Pratishthan during the FY 2022-23, which was sanctioned and released by in July 2022.

Institute of Mathematics & Applications (IM&A), Bhubaneswar

The Board has appointed a liaison committee to consider NBHM funding under this head and visit IMA to oversee the activities and support to IMA. As a special case, given IMA's role of support to tribal and underprivileged students in the state, the Board has

given approval for support of under graduates of the institute, as proposed, to the extent possible with available funds. NBHM has approved ₹ 65 Lakh for FY-2022-23 and has released the grant of ₹ 30 lakhs to IMA for the present under BE FY 2022-23

National Centre for Mathematics (NCM), IIT-Bombay Campus, Mumbai

Due to the pandemic, NCM could not utilize the grant of ₹ 1 crore in time DAE released during FY 2020-21. NCM has planned several activities, offline workshops and schools and has utilized the funds during FY 2021-22. NCM sent budget estimate of ₹ 406 Lakhs for the FY 2022-23 and requested NBHM for a major part of the same. NBHM had initially approved a grant-in-aid of ₹ 50 Lakhs to support NCM during the FY 2022-23, but due to severe funds restriction, the allocations of ₹ 30 Lakhs to support NCM was made.

NBHM requested DAE to release the first payment of ₹ 30 Lakhs from the NBHM approved budget for NCM for the year 2022-23, and allowed NCM to utilize the unspent amount of ₹ 16.36 Lakhs from previous years. Thus, could make total funding of ₹ 46.36 Lakhs for FY 2022-23 which was closer to the amount of ₹ 50 Lakhs which was initially allocated to NCM.

NBHM has been able to diligently disburse funding at the tune of 86% of its total funding till December 2022, and looking forward to additional funding to fulfil the requirements for suitably support various schemes for promotion of higher mathematics, and also cater to fund some of the schemes which could not be funded due to fund limitations.

GRANTS-IN-AID

Grants to Aided Institutions

The Aided Institutions of the Department of Atomic Energy are an integral part of the Department in as much as there is a growing synergy between these institutions and the Research and Development Units of the Department. Several joint projects have been undertaken between the Units and Aided Institutions and frequent interaction have taken place between the academicians of the Aided Institutions and the Scientists of the R&D Units. The Department has following eleven aided institutions fully funded in terms of their recurring and non-recurring expenditure and they are; Tata Institute of Fundamental Research (TIFR), Mumbai; Tata Memorial Centre (TMC), Mumbai; National Institute of Science, Education & Research (NISER), Bhubaneshwar; Institute of Physics (IoP), Bhubaneshwar; Saha Institute of Nuclear Physics (SINP), Kolkata; Harish-Chandra Research Institute (HRI), Allahabad; Institute of Mathematical Sciences (IMSc), Chennai; Institute of Plasma Research (IPR), Gandhinagar; Atomic Energy Education Society (AEES), Mumbai; Atomic Energy Education Society (AEES), Mumbai; Homi Bhabha National Institute (HBNI), Mumbai and University of Mumbai – Department of Atomic Energy – Centre for Excellence in Basic Sciences (UM-DAE-CBS), Mumbai.

Out of total Budget Provision of ₹ 2121.1 Crore in the year 2022-23, an amount of ₹ 1693.76 Crore has been released as on December 2022 to Aided Institutes towards salaries, Creation of Assets etc.

In addition, there are two Boards the National Board for Higher Mathematics (NBHM) and the Board of Research in Nuclear Sciences (BRNS) set up to encourage study of Mathematics and to encourage scientific research in the country.

Olympiad Programme

The Asian Pacific Mathematics Olympiad (APMO) is a mathematical competition held annually for countries in the Pacific Rim Region. India secured 1 Gold, 2 Silver, 4 Bronze and 3 Honourable Mentions and ranked 6th among 35 countries of the Western Pacific and in Asia in APMO 2022.

INFORMATION TECHNOLOGY APPLICATION DEVELOPMENT

A Certificate Authority (CA) is an electronic entity that issues, stores and revokes Digital Signature Certificates (DSC) to individuals or electronic services, such as a web-service, to reliably identify them in digital space. The identity established through a DSC issued

by a licensed CA is legally valid as per the Indian IT ACT 2000 and a digital signature created using these DSCs are treated on par with hand written signature. Hence, to accelerate the digitization of work-flows with electronic authentication services, IGCAR has established a certified Public Key Infrastructure to issue DSCs to the employees and electronic services of DAE. Hardware Security Modules were procured, configured and commissioned to carry out the cryptographic operations in a secured environment as per the guidelines of Controller of Certifying Authority (CCA), Meity. Necessary hardware with open-source software was installed & configured to perform CA, OCSP (Online Certificate Status Protocol)& Timestamp operations. Registration Authority portal has been developed in-house for certificate enrollment of users. Network traffic was controlled using an IP-based firewall & a reverse proxy was installed to sanitize application level traffic. Necessary physical barriers with biometric authentication were installed to restrict access to the CA facility. 24x7 CCTV monitoring was installed. Identical disaster recovery site was configured and commissioned. Pre-operative audit of the facility was carried out by CCA appointed third-party auditor to verify the strict compliance of CCA guidelines. In-principle approval has been received from the CCA to designate IGCAR as CA and Certificate Signing Request was submitted to the CCA. The DSC services will be made available to all DAE units over Anunet.

A private cloud solution is deployed for IGCAR to provide a reliable, flexible and secure hosting platform for providing service delivery models of Infrastructure as Service (IaaS) and Platform as Service (PaaS)using open-source tools, Openstackand Ceph. The cloud is configured using 7 storage servers, 6 compute servers, 2 controller servers and 2 management servers. Storage servers are configured into a cluster for providing 200 TB of cloud storage. Currently, more than 30 servers offering crucial Intranet / Anunet services are hosted on the cloud. Those includeEmail servers, Archive servers and various Web servers. The cloud facilitates live migration of virtual servers at times of server maintenance or breakdown.The hardware resources (CPU/ Memory/ Disk Space)allocated to a server can be resized as per

Monitoring dashboard showing virtual servers (instances) and resources

requirements. Snapshots of servers are taken at regular intervals, so that in case of an unexpected system error, a working version of the server can be redeployed. All these features have significantly increased the availability of thecritical Intranet services. Servers with various operating systems such as CentOS 7/8/9, Ubuntu 20.04/22.04, Rocky Linux 8/9, Debian 10, Windows 10 and Windows Server 2016/2019 are deployed on the cloud. It also supports deployment and porting of servers with Legacy operating systems (Windows XP / RHEL 5) to overcome hardware obsolescence. The Openstack dashboard provides overview of virtual servers and resources. An open-source monitoring tool, Zabbix is installed and configured to monitor the entire cloud infrastructure.

Outdoor Wireless Sensor Networks have been deployed at IGCAR for different monitoring applications such as water level, radiation, temperature, humidity, etc. To analyse the performance of such wireless networks, an observatory system called Network Analyser Node (NAN) has been developed in-house. It has an in-house developed IEEE 802.15.4 compliant RF transceiver, which works in promiscuous mode to capture network packets. NAN also contains 2nd RF Transceiver for data transmission. It has to be deployed along with the other WSN nodes to capture relevant network parameters during regular network operation. It monitors and stores the data related to the quality of the link between sensor nodes and its neighbouring sites. The collected data is sent to the Base Station, where a map of the link quality between sites can be derived. Four numbers of NANs were deployed in IGCAR with Base Station in WSN lab, Computer Division for assessment of Radiation Monitoring WSN network. NANs have also been deployed for link characterization for Phase-II WSN deployment in Avalanche Site at

Dhundi, Himachal Pradesh for the collaborative project with Defence Geoinformatics Research Establishment, DRDO, Chandigarh sponsored by the Office of Principal Scientific Advisor to Government of India.

At RRCAT, deployment of various software packages for parallel scientific computing applications on Kshitij-5 High Performance Computing Cluster (HPCC) has been completed. Important ones are Comsol 6.0 for Synchrotrons Utilization, Amber version 22.0 for BARC Beam lines, Quantum Espresso with GPU support version 7.1 for Theoretical, Computational Physics and Smilei version 4.7 for Laser Physics Applications, WIEN2k-21, PHONO3py, BoltzTraP2, Xmgrace - 0.26, XCrySDen, Vasp-5.4.4 with wannier 90-2.1.0 and Siesta-4.1.5.

In the ongoing project with ICMR and other hospitals/medical colleges from all zones of India for AI4TB program of India. It is found that large number retrospective data as X-rays are present which can be used for Artificial Intelligence project using AI based DeepCXR for AI4TB program as get digitized. IPR has designed, fabricated and validated X-ray digitizer. The low-cost digitizer digitizes the analog X-Rays and converts it into digital format in highest possible image quality and resolution. The IPR digitizer is modular therefore it can used both by using mobiles and with the customized USB camera with plug and play features. The technology integrates a customized motherboard with inbuilt software features to receive/ capture/ save/ display X-Rays image. The X-Rays generated via analog device can be digitized using the IPR developed X-Ray scanner for tele-consultation and faster diagnosis. This low-cost scanner can be a key to ease out imbalance of experts/radiologists in rural places with helping in fast screening/generation of reports. The digitizers are now being used by the participating hospitals/medical colleges to digitize the retrospective and prospective data (CXR). The data are uploaded in the ICMR central data server. These data is serving towards the CXR image data required for development of AI software for AI4TB program of India.

To cater the need of a general AI software that would work for India a central data server has been rigged up at ICMR Delhi with website https://tb.ai.icmr.org.in/ai4tb/ in collaboration with IPR. The data including CXR images uploaded now covers the geographic differences (rural and urban, plain and plateau etc.), gender, and socio-economic status across 4 zones of India. The data is being used for DeepCXR training/Testing comprises data set from confirmed cases of TB by Gold Standard Test (microbiological or clinical). Total data uploaded (December 2022) is 72630.

The DeepCXR software for Normal/abnormal classification is now installed in ICMR remotely and is being used to test on data being received at ICMR Delhi headquarters from Saharia Tribe, one of the remotest regions in Madhya Pradesh, India. The validation & testing for Normal/abnormal Chest-Xray shows that the specificity & sensitivity is > 94 % on test data set. These test data set from Saharia were not part of the testing data set (unseen dataset fed to AI software) AI software is now being enhanced for identifying further classes of TB e.g. cavitory, pleural diffusion Infiltration, fibrosis with data from all sites. Development to identify NORMAL X-rays with high confidence is also being done. Preparation for validation of DeepCXR with prospective data from all participating sites are being done.

CHAPTER 7

Induction Levitation Melter developed by Bhabha Atomic Research Centre

TECHNOLOGY TRANSFER AND COLLABORATIVE PROGRAMMES

Hydrogen Gas Sensor developed by BARC

The spin-off technologies generated out of the core programmes of the Research and Development organizations of DAE were developed and transferred to industries for commercial exploitation. Over a period of time, a number of technologies have been transferred to industries.

DAE organizations also entered into scientific collaborations with public and private sector organizations. This interaction has given beneficiary organizations a technological edge.

TECHNOLOGY TRANSFER AND COLLABORATIVE PROGRAMMES

Department has inked 178 agreements with small-to-big industry players for transfer of 87 technologies besides renewing licenses for 14 technologies during the year.

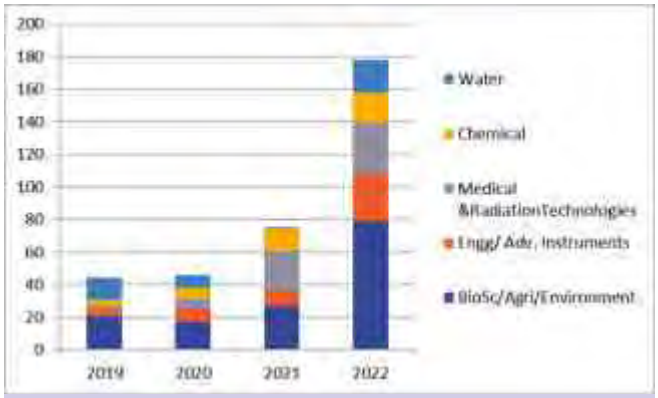
The technologies transferred for commercial use were in the domain of agriculture & bioscience, radiation technology, advanced instrumentation, medical equipment, engineering, environment chemical and water.

Additionally, 26 new technologies have been released into public domain during the year. The new technologies released into public domain are Aluminium Visual Detection Kit (AVDK) for Rapid Detection in Dialysis Fluids and Ground water, developed in NCCCM, a unit of BARC; Tungsten filament based Scanning Electron Microscope (SEM) with imaging resolution of 20nm; Cumulative automatic air moisture collection sampler using Peltier cooling technology; High Coulomb Spark-gap Switch with applications in large charge transfers in high-energy pulsed power systems; Induction Levitation Melter (ILM) for the preparation of experimental quantities (~10 g) of high purity alloys for characterization, Material research and development in Industry & high end research in universities; A process for synthesis of o-Tolylbenzonitrile (OTBN), an advanced intermediate for anti-hypertensive –sartan group of drugs; Environmental Gamma Spectroscopy System (EGSS); Air Plasma Incinerator; Hydrogen gas Sensor which can be used for H2 detection in industries, including heavy water plants, oil refineries, nuclear reactors, research laboratories; DC Accelerator for Radiation Processing Applications; Electron Gun for Linear Accelerator; Scan Magnet and Power Supply for Electron Beam Accelerator; Type IE CRISPR system based microbial gene silencing kit which offers modulation of gene expression in different bacterial strains and species such as Escherichia coli and Salmonella; ANU-CHAITANYA: A versatile bioregulator for sustainable crop production; A novel universal multi-nutrient soil extractant for assessing bio-availability of nutrients in soil; Nutritious Ready-to-Eat (RTE) fish spread; Visual Detection kit for melamine content in adulterated milk; Bonding and Packaging, and Testing Technology of High Power Laser Diode Arrays for Diode Pumped Solid State Laser Module, developed by RRCAT Indore; Laser additive manufacturing system using powder fed Direct Energy Deposition, developed by RRCAT Indore; Process for Synthesis of Poly-Acrylamide-Hydroxamate (PAH) Resin for Recovery of Selective Metal Ions; Isolated Multi-channel DAQ for Multi-cell Stack System; Shelf Stable Luscious and Nutritious Chiku Fruit Bites; Synthesis of High Purity 1, 3-Dioctyloxycalix [4] arene-18-crown-6 (Calix-Crown-6); Process system for cleanup of dissolved oil and salt contaminated waste water; Agni Rakshak - Raman optical fiber based distributed fire sensor system and Naturally Fermented

High Coulomb Spark-gap Switch

Hydrogen gas Sensor

Induction Levitation Melter



Total number of agreements signed in the last 4 years for commercialization of BARC technologies

fibre fortified Rice / Millet Idli using Moong as an alternative to Urad.

Renewal of Technology Licences

Licences for 14 technologies were renewed during the year. These included Nanocomposite Ultrafiltration Membrane Device for Domestic Drinking Water Purification W.R.T. Arsenic, Iron, And Microbial Contaminations; On-line Domestic Water Purifier based on Ultrafiltration Polysulfone Membrane; 70kJ, 25KV Electromagnetic Manufacturing Equipment (EME); Membrane assisted defluoridation process for safe drinking water; Nanocomposite Ultrafiltration Membrane Device For Domestic Drinking Water Purification W.R.T. Arsenic, Iron, And Microbial Contaminations; Membrane assisted defluoridation process for safe drinking water; Preparation of composite polyamide reverse osmosis membrane for brackish water (BWRO) desalination; FDK- Fluoride Detection Kit for Ground Water; Preparation of Composite Polyamide Reverse Osmosis Membrane for Brackish Water (BWRO) Desalination; TLD Badge for Personnel Monitoring; Production of Dysprosium Doped Calcium Sulphate powder and FDK- Fluoride Detection Kit for Ground Water etc.

COLLABORATIVE PORGRAMMES

Department has signed an MoU with the governing body of National Mission for Clean Ganga for carrying out technology demonstration of waste water treatment using electron beam accelerator and associated pre-and -post irradiation solution for water laden with impurities from leather tanning industries. This technology was included for incubation activities.

SOCIETAL INITIATIVES

Through its Advanced Knowledge & Rural Technology Implementation (AKRUTI) program, DAE is propagating deployment of 17 spin-off technologies. During the year, 3 agreements were signed and 9 licences were granted for deployment of AKRUTI technologies in rural and semi-urban areas. The licensed technologies are a Rapid composting technology for decomposition of Dry Leaves, Kitchen

waste and Temple waste; Process for Long Lasting Ready-To-Eat Intermediate Moisture Fruit Cubes; Solar Dryer (25 kg capacity); Foldable Solar Dryer; Banana Tissue Culture; Nisargruna Biogas Plant based on biodegradable waste (one ton per day capacity); Soil Organic Carbon Detection & Testing Kit and Mass Multiplication Medium of Biofungicide Trichoderma spp. At present AKRUTI Centre is operational at BARC.

Four new AKRUTI Centres are coming up at various DAE locations viz., Heavy Water Plant Manuguru, BARC Vizag at Dibbapalem, Institute of Physics at Bhubaneshwar, and Special Material Facility at Chitradurga.

As part of its Corporate Social Responsibility (CSR) program, NPCIL is in the process of setting up AKRUTI Centres for demonstration and deployment of DAE technologies in the vicinity of its nuclear power plants.

Training offered under AKRUTI was organized for ~30 interested entrepreneurs from various parts of India.

Training program in AKRUTI technologies was organized in two phases during 28-29 June and 9-11 November 2022 for 18 resource persons of Punyashlok Ahilyabai Holkar Solapur University.

Senior officers of BARC and trainees of Punyashlok Ahilyabai Holkar Solapur University

At an event held during 24-26 April in Samba Palli Gram Panchayat in Jammu to mark the National Panchayat Raj Day-2022, Team AKRUTI and DAE have jointly organized an exhibition to reach out to local farmers, women self-help groups for potential deployment of BARC technologies. Around 70,000 farmers participated in the event.

Senior officers of BARC and AKRUTI Centre Tarapur interacted with visitors to the DAE-BARC exhibition in Samba Palli in Jammu, India

Team AKRUTI participated in a two-day outreach programme organized jointly by INCAS, BRNS and North Odisha University in Baripada.

BARC AKRUTI and AMD have jointly organized AKRUTI-ARUNODAY event in Arunachal Pradesh's Mushai during 25th August 2022 for the benefit of locals. At the event, various products developed across India using AKRUTI technologies were showcased with the aim of propagating the benefits of BARC technologies to the remotest areas of the country.

INTELLECTUAL PROPERTY RIGHTS

DAE-IPR Cell constituted by the Department, works as a nodal agency for all Intellectual Property Rights (IPR) related matters including filing of patents within India and abroad for all the Units including Public Sector Undertakings and Autonomous Institutions under DAE.

During this period, six DAE-IPR cell meetings were held, where eighteen new patent proposals and three Patent Cooperation Treaty (PCT) international applications were reviewed for filing national phase applications were reviewed.

The following table gives unit wise summary of patents filed and granted during the period:

DAE Unit	Patent Applications			Countries (*in process*)
	Filed (*in process*)	Published	Granted*	
BARC	4	4	5	India, Europe, USA, Australia & South Africa
IGCAR	1 (*2*)	1	1	Europe & USA (*USA & Japan*)
RRCAT	0	0	1	China
IPR	1 (*2*)	1	4	India & Europe (*India & USA*)
TIFR	2 (*2*)	1	2	India (*India*)
SINP	2	2	0	India
CEBS	1	0	0	India
IREL	0	0	2	India & Australia
BRNS	0 (*1*)	0	2	India (*India*)
Total	**11 (7)**	**9**	**17**	
* includes patent applications filed prior to this reporting period				

I. Patent Applications Filed

The following eleven patent applications were filed during this period. This includes seven in India, one each in Australia, Europe, South Africa and USA.

(a) **Compact Hydraulic Pinned Jaw Crusher System with High Size Reduction Ratio** –from BARC (in India, Australia & South Africa – App. No's. 202221026845, 2022215159 and 2022/09557 dated 09-May-2022, 08-Aug-2022 and 26-Aug-2022 respectively).

(b) **Plasmonic Hybrid Nanocatalyst Including Nickel Supported on Plasmonic Colidosomes and Methods Involving the Same** – from TIFR (in India – App. No. 202221026798 dated 09-May-2022).

(c) **A System for Carrying Out Active Microrheology to Probe Viscoelasticity of Protein** – from SINP (in India – App. No. 202231030594 dated 27-May-2022).

(d) **A System and Method for Measurement of Total Hemispherical Emissivity of an Opaque Material** – from IPR (in India – App. No.202221054936 dated 26-Sep-2022).

(e) **System for Executing Nuclear Morphology based Analytics for Accurate Diagnosis / Prognosis of Cancer including Ovarian Cancer** – from SINP (in India – App. No. 202231061023 dated 26-Oct-2022).

(f) **A Portable Device for Estimation of Curcuminoid Content in Turmeric** – from CEBS (in India – App. No. 202221063957 dated 09-Nov-2022).

(g) **Magnesium Nanoparticles to Capture and Convert CO_2 to Methane, Methanol for Formic Acid or Other Fuels or Chemicals** – from TIFR (in India – App. No. 202227065764 dated 16-Nov-2022).

(h) **Annular Centrifugal Extractor with Solid Separation Part to Separate Solid Particles Present in Solvent Extraction Fluid and A Process for the Same** – from IGCAR (PCT National Phase in Europe – App. No. 21851859.5 dated 14-Dec-2022).

(i) **Deuterated-3-3'-Diselenodipropionic Acid (D-DSePA) and its use as an Anticancer or Radioprotective Agent** – from BARC (in USA – App. No. 18/087427 dated 22-Dec-2022).

Seven applications are in various stages of filing and are likely to be filed in the coming months. These include;

(a) **A Plasma based system for generating Antibacterial Coating on Flexible Polymeric Substrates and Process Thereof** – from IPR (in India & USA).

(b) **Annular Centrifugal Extractor with Solid Separation Part to Separate Solid Particles Present in Solvent Extraction Fluid and A Process for the Same** – from IGCAR (in USA & Japan).

(c) **Hydroxy Terminated Nickel Nitride Nanosheets for Plasmonic CO_2 Hydrogenation** – from TIFR (in India).

(d) **Copper Laden Titanium Dioxide Coated Silica Nanospheres as Active and Stable Catalyst for CO_2 to CO Conversion with 99% Selectivity** – from TIFR (in India).

(e) **Synthesis of a unique Beta-Carotenoid Derivative (BCD-III) and its Bio-Medical Applications in the detection and quantification of creatinine in human biofluids** – from BRNS Project between BARC & Madurai Kamaraj University (in India).

II. Patent Applications Published

Among the patent applications that have been filed till date, nine patent applications were published during the year. These include five in India and two each in Europe and USA.

(a) A Method for Diffusion Bonding of Piezoelectric Crystal to Metal Wear Plate – from IGCAR (in USA – App. No. 17/436963 dated 07-Sep-2021).

(b) Plasmonic Hybrid Nanocatalyst Including Nickel Supported on Plasmonic Colidosomes and Methods Involving the Same – from TIFR (in India – App. No. 202221026798 dated 09-May-2022).

(c) Compact Hydraulic Pinned Jaw Crusher System with High Size Reduction Ratio – from BARC (in India – App. No. 202221026845 dated 09-May-2022).

(d) A System for Carrying Out Active Microrheology to Probe Viscoelasticity of Protein – from SINP (in India – App. No. 202231030594 dated 27-May-2022).

(e) A Chlorophyllin Containing Pharmaceutical Composition for Prevention of Pathogenesis of Coronavirus Disease – from BARC (in Europe & USA - App. No. 21162765.8 and 17/214450 dated 16-Mar-2021 and 26-Mar-2021 respectively).

(f) Inductively Driven Pellet Accelerator and Injector – from BARC (in Europe – App. 21172618.7 dated 06-May-2021).

(g) System for Executing Nuclear Morphology based Analytics for Accurate Diagnosis / Prognosis of Cancer including Ovarian Cancer – from SINP (in India – App. 202231061023 dated 26-Oct-2022).

(h) A System and Method for Measurement of Total Hemispherical Emissivity of an Opaque Material – from IPR (in India– App. No. 202221054936 dated 26-Sep-2022).

III. Patents Granted

During this period, seventeen of the previously filed patents were granted to the Department. These include twelve in India, three in Europe and one each in Australia and China.

(a) A Method for making single integrated cut-through artistic design on metallic foil - from BARC (in India, Patent No. 394243).

(b) A Method of Manufacturing Radio Frequency (RF) Coil Multi-Driven RF based Negative Ion Source – from IPR (in Europe, Patent No. 3553797).

(c) A 6-Axis Parallel Kinematic Manipulator – from BARC (in India, Patent No. 395835).

(d) A Method and Apparatus for 'Block Encryption' and 'Synchronous Stream Cipher' (SSC)– from IGCAR (in India, Patent No. 396872).

(e) A Process for Solvent Extraction for Separation of Rare Earth Elements (REE) Through Partial Reflux of Rare Earths in Solvent based on Separation Factor – from IREL (in India, Patent No. 397001).

(f) A liquid Nitrogen based portable refrigeration system for carrying refrigerated goods – RRCAT (in China, Patent No. ZL 201810504018.3).

(g) Human Neural Precursor Cells with Inducible STIM1 Knockdown – from TIFR (in India, Patent

No. 399095).

(h) High Voltage DC Power Supply Circuit – from IPR (in India, Patent No. 403371).

(i) Production of dilute Pb (0.2 to 1.1 wt %) - Li Alloys – from BARC (in Europe, Patent No. 3841231).

(j) Process for Developing Dendritic Plasmonic Colloidosomes as Nano-Heaters and Nano-Catalysts – from TIFR (in India, Patent No. 404105).

(k) An improved Method of Manufacturing Actively Cooled Accelerator Grid with full penetration Weld Configuration – from IPR (in India, Patent No. 3424635).

(l) A process for the Production of Thorium Phosphate from Thorium Oxalate and recovery of Oxalic Acid – from IREL (in Australia, Patent No. 2016210678).

(m) Epoxy Resin based Adhesive and Preparation Method thereof – from BRNS Project by IPR & CIPET (in India, Patent No. 407521).

(n) Escherichia coli Cell Factory for Producing Recombinant Phosphopeptides – from BARC (in India, Patent No. 407999).

(o) A Method of Preparation of Forward Osmosis Membrane using Synthesized Poly(sulfone-co-amide) Polymer – from BARC (in India, Patent No. 408427).

(p) Innovative, inexpensive and viable method for the isolation of novel antioxidant flavonoids from the weed, Coronopus Didymus – from BRNS Project by BARC & Manipal University (in India, Patent No. 410220).

(q) Splitted Plasma Anode Fire-ball based Ion Source for both Nanopatterning and Thin Film deposition – from IPR (in India, Patent No. 413565).

Details of the patents listed in I, II and III above can be accessed from the respective Patent Office websites. Links for the Indian, US and European patent office websites are given below:

1. Indian Patent Office
   http://ipindiaservices.gov.in/PublicSearch/

2. US Patent Office
   https://portal.uspto.gov/pair/PublicPair

3. European Patent Office
https://worldwide.espacenet.com/advancedSearch?locale=en_EP

IV. Technology Transfer of Patents

During the same period, the following seven patented technologies were licensed to nineteen companies in India.

Title of the Technology Transferred	No. of Companies Tech. Transferred
Nitrogen Oxides releasing Wound Dressing	1
Chlorine-dioxide releasing Polymer for Water Disinfection	4
Hybrid granular Sequence Batch Reactor (SBR) for Waste Water Treatment	9
Agastya-400 Cryopump technology	2
Plasma activated Water Generation System	1
Plasma Pyrolysis Technology for Organic Waste	1
Metal Oxide Nano Powder Production Technology	1

V. Patent Applications Referred to DAE u/s 4 and 39 of The Patents Act, 1970

During the year 2022-23, 245 Indian patent applications were referred to the Department by the Controller General of Patent, Designs & Trademarks (Department for Promotion of Industry and Internal Trade, Ministry of Commerce & Industry), under section 4 and section 39 of The Patents Act, 1970. These applications are referred to the department to assess whether the application is related to or useful for atomic energy, under section 20 of Atomic Energy Act, 1962.

CHAPTER 8

Smt. & Shri K. N. Vyas, Chairman, AEC & Secretary, DAE; Smt. & Shri A. K. Mohanty Director, BARC; Smt & Shri B. K. Jain, Director, DCSEM and senior officers of DAE participating in the plantation drive at Anushaktinagar, Mumbai

INFRASTRUCTURE

Dr. R. Chidambaram, Former Chairman, AEC & Former Principal Scientific Adviser, inaugurated the Homi Bhabha Park developed by DCSEM, on the Central Avenue Road, Anushaktinagar, Mumbai on 5th June 2022

CONSTRUCTION, SERVICES & ESTATE MANAGEMENT

Directorate of Construction, Services & Estate Management (DCSEM) is responsible to provide infrastructure support to various Units of Department of Atomic Energy (DAE) including its aided institutions. DCSEM is involved in planning, design & execution of various construction projects for Housing, Schools and Hospitals, Laboratories, Institutional Buildings & Scientific infrastructural facilities to support Scientific & Technological programs of DAE. This Directorate is also responsible for operation and maintenance of various services & Estate Management for the housing colonies of DAE at Mumbai.

Major Highlights / Achievement of DCSEM in FY 2022-23

DCSEM's efforts towards "Clean Green" Anushaktinagar DCSEM has developed various attractive visiting spots along Central Avenue road of Anushaktinagar by developing vacant area and its existing topography & old trees and depicting Glimpses of Dr. Homi Bhabha's life in the form of rock paintings.

Construction of Hostels for Trainees of BARC/HBNI & Extension buildings to VS Bhavan at Anushaktinagar are completed. Getting statutory clearances to occupy the buildings is in process.

Construction of housing projects such as 96 flats of Type IIIC, 208 flats of type IVD at Anushaktinagar are almost completed. Getting statutory clearances to occupy the buildings is in process.

Construction of 312 flats of Type VE at Mandala: Building works are nearing completion. Development works are in progress. Overall physical progress 78% is achieved.

LIGO INDIA PROJECT: Pre Investment Activities for MEGA SCIENCE project of LIGO INDIA Project like land acquisition, Construction of Site Office, geotechnical investigation, fencing, Survey etc. are almost complete. DBR along with BOQ for Civil & MEP Infrastructure for Main project is in advanced stage. Sanction for the Main Project is awaited.

The construction of Diamond Jubilee Guest House for VECC at Rajarhat Campus Kolkata is Completed and inaugurated on 05-04-2022.

Radiation medicine Research centre (RMRC) for cancer therapy & treatment at Rajarhat Kolkata has been completed.

Construction of AMD AERB laboratory building at Kolkata has been completed & handed over to users.

Construction of UGC-DAE building at Rajarhat site Kolkata is nearing completion.

TMC at Vizag: Construction of 100 bedded Cancer hospital is nearing completion.

GCNEP Phase II project: Various facilities such as Construction of Residential building consisting of Type-III-C, Type IV-D and Type V-E ; Central building, New school building; Guest house, dining hall, recreation center; guard house are completed.

RMP Mysore works: Construction of Boundary wall, patrolling road, vehicle parking, storm water drains for RMP Mysore is completed.

SMF Township at Challakere Karnataka: Site grading, development works such as Road, footpath, drains, Nalla, Rain water detention pond, Entrance Guard houses are almost completed. Construction of 48 flats of type IA & IIB is in progress.

Wide array of activities undertaken by DCSEM are executed and managed by six interlinked groups, namely, Planning and Design, Quality Construction, Maintenance, General Services and Estate Management. Together they are responsible for following projects:

Ongoing Constructions Projects

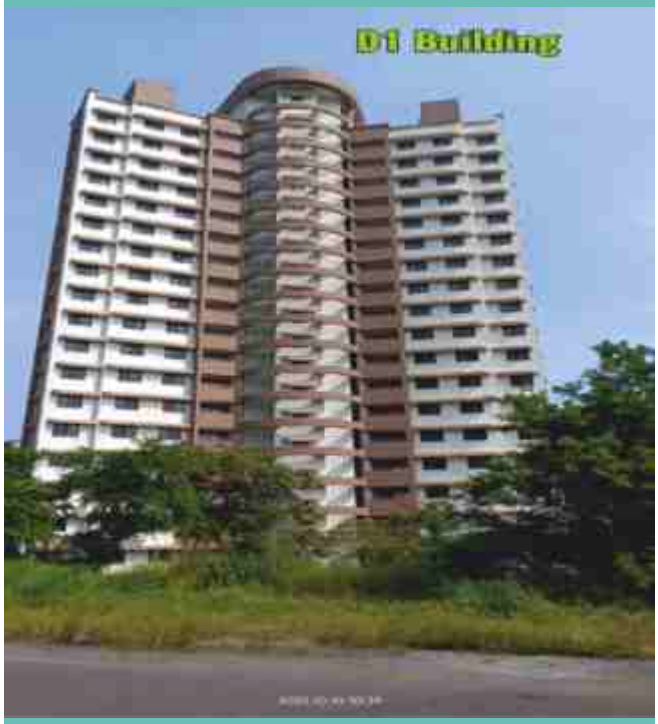
Construction of hostel for Trainees' of HBNI/BARC; Extension of V. S. Bhavan; Construction of 356 flats of various categories at Anushaktinagar; Construction of 100 bedded Hospital for TMC at Vizag;

Construction of 312 flats of type V-E at Anushaktinagar; Upgradation of Elect, PH and Mechanical services; Rajarhat – Kolkata works; Construction of Radiation Medicine Research centre (RMRC) for cancer therapy & treatment; Construction of UGC-DAE-CSR Building; Construction of Diamond Jubilee Guest House cum Hostel – 2021 at Kolkata; GCNEP works at Haryana Phase II; Restoration of old houses –PH-II; Restoration, Renovation & upgradation of residential buildings PH-III; LIGO (India) Project –Pre project works; Boundary wall, patrolling road, vehicle parking works for RMP /BARC at Mysuru, Karnataka; Forty Eight flats of type I & II and Site grading work of SMF/BARC Township Project at Challakere, Karnataka; AERB works -Ph-2 NB-C building; Upgradation of DAE Office-IT infrastructure in OYC; Upgradation of Security related infrastructure works; Augmentation of Waste Management system; Bio Gas Plants and Upgradation of AEES Schools in Mumbai including Sports facility; Building for Fission based Mo^{99} production facility for BRIT at BARC south side and acquisition of land for LIGO-India project at Aundha-Hingoli.

The Radiation Medicine Research Centre (RMRC) building at VECC Rajarhat Campus, Kolkata, was inaugurated by Shri K. N. Vyas, Chairman AEC & Secretary DAE, on 21-11-2022, in the august presence of Dr. A. K. Mohanty Director, BARC, Dr. Sumit Som, Director, VECC, and Shri K. Mahapatra, Director, DCSEM

HBNI Hostel M1 M2 Building

HBNI Hostel Landscaping Between B1-B2 Building View



Type-IV D D1 Building Near Sabarigiri Work Completed

312 V-E Flats at Anushaktinagar, Mumbai

Maintenance Activities

Civil maintenance of 9980 flats, VS Bhavan, AERB, AEES buildings common services at different areas of Mumbai like Anushaktinagar, Chembur, Bandra, Shivaji Park, Ghatkopar, Mulund, Worli, Peddar Road, Malabar Hills, Colaba, OYC, Guest House at New Delhi etc. were continued to be carried out by DCSEM.

Allotment, Enforcement & Vigilance Activities

Allotment of departmental accommodation, monitoring of recovery of license fee & allied charges, management of Departmental Land and properties situated in the city of Mumbai, Navi Mumbai, Bhubaneswar, Delhi i.e., leasing of land and properties from and to outsiders, payment/receipt of lease compensation, payment of service tax, maintenance of land records etc. were carried out by DCSEM.

At GCNEP, the construction work of four major packages including Central Building, School Building-2, Gate House (in campus & township), Guest House Block-B, Residential blocks and Dining & Recreation facilities has been completed. Electrical and mechanical works are in progress. The preparatory works for populating the buildings with essential infrastructure like furnishing, IT/AV facilities, e-Surveillance etc. are being carried out. Residential Infrastructure has been developed in township. Sensor Evaluation Test Bed Facility (SETBF) has been developed and successfully commissioned for testing and evaluation of Physical

Central Building

Integrated PIDS console at SETBF

Protection System (PPS) & Sensors. During this period, around 9 RTIs related to GCNEP have been received, out of which 8 have been successfully answered and 1 will be answered shortly.

DCSEM launched a slew of green initiatives in Anushaktinagar, Mumbai. Aa a Green Tribute to Dr. Homi J. Bhabha, DCSEM developed a Homi Bhabha Park on the Central Avenue Road, Anushaktinagar on 5th June 2022. Dr. R. Chidambaram, Former Chairman, AEC & Former Principal Scientific Adviser, inaugurated the Homi Bhabha Park. The landscaped park and its elements celebrate the life and times of Dr.Bhabha.

Dr. R. Chidambaram, Former Chairman, AEC & Former Principal Scientific Adviser, inaugurated the Homi Bhabha Park developed by DCSEM, on the Central Avenue Road, Anushaktinagar, Mumbai on 5th June 2022

As a DCSEM initiative, a number of saplings of various varieties were planted on the hill side of the western sector using Hydrogel & granules of irradiated sludge for healthier growth. Smt. & Shri K. N. Vyas, Chairman, AEC & Secretary, DAE; Smt. & Shri A. K. Mohanty Director, BARC; Smt & Shri B. K. Jain, Director, DCSEM and senior officers of DAE participated in the plantation drive along with the students of HBNI and

Smt. & Shri K. N. Vyas, Chairman, AEC & Secretary, DAE; Smt. & Shri A. K. Mohanty Director, BARC; Smt & Shri B. K. Jain, Director, DCSEM and senior officers of DAE participating in the drive

BARC Training School and the residents of Anushaktinagar.

PURCHASE & STORES

Directorate of Purchase & Stores (DPS), a service organization of DAE since its inception in 1972 is responsible to carry out the Materials Management function of DAE. The mandate of DPS is procurement of the right material at the right price from the right source at the right time adopting the right procedure and receiving, storing, preserving, issuing the material and disposing surplus and scrap items and also to conclude clearance, Marine insurance, etc.

It played a crucial role in effectively implementing and executing the procurement activities in compliance with the GFR, CVC and Public Procurement Policy of the Government of India and the orders of delegation of financial power issued from time to time. It extended the support of procurement and disposal of goods and explicitly working within the frame work of legal aspects of procurement that are governed by various acts viz, the Indian Contract Act, Sale of Goods Act, Arbitration and Conciliation Act, Completion Act, IT Act and also catering to the disposal of goods.

Services that are consequential to the procurement of goods like receipts, accounting, transportation of material to various units, custom clearance of imports, arranging insurance, export of goods and the storage and inventory management are the other activities were rendered by DPS. This DPS celebrated Golden Jubilee year on 22nd June, 2022 on completion of 50 years since its inception in 1972.

DPS successful made in making 75% (in terms of purchase order placed) of its procurement through GEM portal. DPS has effectively processed 17847 indents and issued 15063 purchase contracts amounting to ₹ 1597.67 crores. This includes 11,379 number of orders worth ₹ 741.15 crores issued through GeM portal. DPS is one amongst the top ten departments to process the tender through CPPP Portal.

In addition, DPS has floated 127 sales tenders and issued 106 e-sales orders. Stores unit have codified 15965 items this year thereby improving its inventory management.

Since HRPSU is also handling the procurement activities of NFC-Kota, HRSU staff were recently deputed to handle the receipts and accounting of NFCStores, Kota that was initially handled by HWP Stores (Kota). It has also implemented Computer Stock card posting discontinuing the Manual mode of accounting.

New Stores are to be set up at AMD Jaipur and Delhi and arrangements to have the stores finalized by March 2023 is in progress.

Vendor meets were organized, one at IRPU, Indore, other at MRPU, Chennai and at CPU, Mumbai to boost participation of more bidders in the tenders and get them acquainted with the recent government policies, government e-market portal and also address their hurdles.

Under Special achievement this directorate was successful in completing the procurement of Desalination plant project at Kutch, Gujarat for BSF personnel and to provide drinking water at Antroli village of Gujarat, 3 villages of Karnataka, 2 villages of Chhattisgarh and one at Maharashtra state.

HRPSU was successful in exporting 97 Drums of Heavy water, ninety-six drums to USA and one to Korea.

DPS administration and accounts have actively started using digital modules for their activities such as processing of pension, nominations and APARs.

GENERAL SERVICES ORGANISATION

General Services Organisation(GSO), Kalpakkam, a Service Unit of DAE, is providing the essential services of housing, health services, water supply, power supply, solid waste management, transport etc. to the employees of IGCAR, MAPS, BARCF, CISF situated at Kalpakkam and their families. There are two residential Townships, one at Kalpakkam and the other at Anupuram. About 4800 families reside at Kalpakkam Township and 2400 families reside at Anupuram Township. The townships are located 10 km apart from each other and approx. 12 kilometers from the DAE Plant Site. There are three Atomic Energy Central Schools, two Kendriya Vidyalayas, three Kindergarten Schools and a school for the specially abled (MEHATVA). Sports and Cultural Facilities are provided through the Nuclear Employees Sports and Cultural Organisation (NESCO).

The Engineering Services Group comprises of the Civil Construction and Maintenance Division, Resources Management & Utilities Division and the Electrical Services Division. The Civil Construction and Maintenance Division designed and constructed residential and public buildings. It also took care of civil maintenance, solid waste management and upkeep of gardens and greenery. The Resource Management & Utilities Division comprising of Planning, Resource Management, Computer, Mechanical Services, Industrial Safety, Telecommunication, and Autoshop Sections, took care of computer networking, e-surveillance, audio-visual system integration and computerization, drinking water distribution, providing telecommunication services and air conditioning systems for the office buildings, hospital and other public buildings in the townships. The Industrial safety requirements in the construction sites of both the townships were also managed by this Division. The Planning Section took care of the budget planning and monitoring. The Autoshop Section took care of maintenance of department transport of IGCAR, BARC Facilities and GSO. The Electrical Services Division designed the total electrical system for new buildings, augmented the sub-stations with all safety features and took care of electrical construction, operation and maintenance of electrical system.

In addition to providing the basic essential services to the residents, the Engineering Services Group supported the five schools in the Townships in terms of Augmentation of Infrastructure, maintenance and solid waste management.

The Medical Group catered to the health care needs of about 30,000 beneficiaries. The 100 bedded DAE Hospital at Kalpakkam and Anupuram provided Emergency/Casualty medical services 24x7.The hospital provide Specialist services to the Out Patients, In patients with Laboratory, Radiology and Physiotherapy services. A new Haemo-Dialysis Centre for Chronic Kidney Disease patients was started at DAE Hospital on 22/9/2021 with MoU and logistics from Apollo Hospital, Chennai. Provision was made for State-of-the-art RO (Reverse Osmosis) water plant at DAE Hospital. Apart from this, the hospital also provide emergency medical aid to the people of the surrounding villages. Each year, the medical officers apart from their regular duties also undertakes case based clinical research which gives insight to the disease profiles of our population and throws light on specific health issues in the community.

All the activities of GSO were supported by Accounts and Administration, who look after Personnel Management, Estate Management, Recruitment, Transport etc.

Some of the significant works carried out in 2022-23 included the followings:

- **Completion and Handing over of Housing Projects -** Two Towers of Type IV-D and Type V-E combination, comprising of 110 Nos IVD and 90 Nos. of VE apartments, were completed at Anupuram Township. Twelve numbers of Scientists' apartments were constructed and handed over at PRP township.

- **Augmentation of infrastructure for essential services –** Construction of mechanical workshop, establishment of fire hydrant system at new hospital building, augmentation of emergency power supply at substation No.8, wheel balancing setup at Autoshop.

- **Township-Security Strengthening Measures-** such as restoration of broken compound wall at Anupuram township, Providing Additional Security Fencing Over Existing Tsunami Compound Wall, implementation of Automatic Number Plate Recognition System at entry/exit gates of Kalpakkam Township etc, were done.

- **Environment Conservation related activities –** Construction of oxidation pond for effluent water, setting up of tertiary treatment plant and recycled water network, installing bio-toilets and installing bio-gas plant-SHESHA, based on technology developed by BARC, were done.

- **Energy Conservation related activities –** setting up of roof top solar power plant, installation of LED fixtures. were carried out.

- **Augmentation of Sports facilities –** Construction of sports complex at Anupuram, renovation of hockey ground at Kalpakkam, renovation of tennis court at Anupuram.

- **Rehabilitation of aged civil structures.**

- **Refurbishment of old apartments** to provide better amenities in line with latest norms of DAE.

- **In-house Development of software** package for online complaints management system.

CHAPTER 9

Dual View X-Ray Baggage Inspection System developed byElectronics Corporation of India Ltd.

PUBLIC SECTOR UNDERTAKINGS

(FINANCIAL PERFORMANCE)

Solid State Cockpit Voice and Data Recorder (SSCVDR) developed by ECIL

Financial performance of DAE's public sector undertakings namely, the Nuclear Power Corporation of India Ltd., Uranium Corporation of India Ltd., Indian Rare Earths Ltd. and Electronics Corporation of India Ltd. are given below. (BHAVINI is yet to commence commercial operations). Operational highlights of these public sector undertakings, except ECIL, have been covered under the relevant major programme heads in chapter 1 and chapter 2 of this report. Gist of the financial performance of these units along with detailed operational performance of ECIL is given here.

NUCLEAR POWER CORPORATION OF INDIA LTD.

The provisional profit after tax (Total Comprehensive Income) up to end December 2022 in current FY 2022-23 is ₹ 3523 crore and the estimated profit for FY 2022-23 is around ₹ 4750 crore. The net profit after tax (Total Comprehensive Income) for previous FY 2021-22 was ₹ 6454 crore. NPCIL Bonds are rated 'AAA' (Highest Safety) by CRISIL, CARE, ICRA and India Rating.

URANIUM CORPORATION OF INDIA LTD.

The performance of all major units of the company during the year 2021-22 remained excellent. The total income of the Company during the year 2021-22 was ₹ 2614.72 Cr as against ₹ 2352.90 Cr during the previous year. The Company has registered a Profit before Tax of ₹ 777.48 Cr in the year 2021-22 as against ₹ 623.21 Cr in the previous year.

INDIAN RARE EARTHS LTD.

During the financial year 2021-22, the company achieved sales turnover of ₹ 1480.00 crore as against ₹.974.13 crore during previous year. The company achieved highest ever Profit Before Tax (PBT) of ₹ 746.68 crore registering growth of 80% as compared to corresponding previous year.

During the period April to December 2022, the company has achieved Sales Turnover of ₹ 1379.88 crore as against ₹ 1019.06 crore achieved during the corresponding period of previous year, registering growth of 35%. The Company achieved Profit Before Tax (PBT) of ₹ 761.47 crore during the period April to Dec, 2022 as against ₹ 451.12 crore during the corresponding period in previous year.

IREL paid dividend amounting to ₹ 166.67 crore for the financial year 2021-22. Based on the half yearly performance during the financial year 2023-23, IREL has paid interim dividend (first installment) of ₹ 118 crore on 22.12.2022.

ELECTRONICS CORPORATION OF INDIA LIMITED

Electronics Corporation of India Limited (ECIL) was established primarily to meet the Control and Instrumentation requirements of India's nuclear power program, ECIL has played a pioneering role in spurring the growth of indigenous electronics industry in the country, ranging from miniature components to complex systems encompassing Instrumentation, Communication and Computer technologies. ECIL is engaged in the Design, Development, Manufacture, Supply and Installation & Commissioning of a wide variety of electronic equipment / systems that cater to the needs of Atomic Energy, Defence, Security, Space, Information Technology and many other user departments in the Government domain. ECIL has been pursuing state-of-the-art technologies and executing projects involving integration of complex and one-of-a-kind systems. The company is organised as 'verticals' to focus primarily on the chosen sectors viz., Nuclear, Aerospace, Defence, Security, IT & e-Governance.

Performance

During the financial year 2021-22, ECIL recorded a turnover of ₹ 1610 crores as compared to ₹ 1504 crores in the previous FY. Revenue from Operations has increased by 7.05% and the corresponding Profit Before Tax (PBT) and Profit After Tax (PAT) have increased by 97.37% and 102.75% respectively in comparison to the previous financial year. Increase in contribution margin and service

revenue resulted in higher profitability during the year. During the year, Nuclear vertical has contributed 17%, Defence vertical 34%, Aerospace vertical 10%, Homeland Security Solutions 9% and IT &e-Governance and others 30% of the company's revenue. In terms of the MoU signed with DAE in accordance with DPE guidelines, the company has been rated 'Very Good' for the FY 21-22.

Outlook for 2022-23 and Performance in FY 2022-23 (up to Dec 22)

The order book position of ECIL as on 01 April 2022 is ₹ 4016 crores. The bulk executable orders comprise of Electronic Voting Machines and VVPATs, Military Radios, electronic Fuzes, Ground based systems for Akash Missiles, ECM Jammers, SATCOM Terminals, Antenna Systems, Ultra Stable High Voltage Power Supplies, Integrated Security Systems, Advanced Radiation Detectors and Monitoring systems. Towards meeting the time bound delivery of the EVM and VVPAT, ECIL has augmented the manufacturing infrastructure. Further, Under the guidance of Technical Expert Committee (TEC) constituted by Election Commission of India (ECI), ECIL has developed and deployed the Secure Manufacturing Facility (SMF 2.0).

DPE has set a target of ₹ 2700 crores for the year Financial Year 2022-23. Against the set target, ECIL has achieved an Income of ₹1092.06 crores till end December 2022.

The sector-wise projects and systems that have contributed towards revenue during the year are as follows:

Nuclear

The major contribution came from supply of

RGMS System

Ultra Stable High-Power Converters

Ultra Stable High-Power Converters to FAIR, ARMS, MPPCS, RGMS and C&I to various nuclear power plants.

ECIL in association with BARC developed 'Safe and Secure' Programmable Logic Controller (PLC) (NUCON PLC). The product was launched along with ECSCADA on 18th May, 2022. The product incorporates safety and security features for applications in strategic sector and has been deployed for applications in space and nuclear sector.

Launch of 'Safe and Secure' Programmable Logic Controller (PLC) (NUCON PLC)

As part of Advanced Radiation Monitoring System, following products for continuous measurement of radioactivity have been indigenously developed for Nuclear Power Plants.

Alpha and Beta Aerosol Monitor

Process Media Monitor

Defence

The major contribution to Defence sector came from supply of Mobile Missile Checkout Facility (MMCF) to BDL, Mobile Squadron Control Center (MSCC) systems to BEL, M7 Radios, Jammers and Garuda Encryption Unit to various Military Organisations, etc.

M7 V/UHF

Radio Mobile System for Missile Checkout Facility

Vehicle Mounted Jammers

ECIL has successfully completed the strategic communication network project (PUSHPAK). The project was formally inaugurated by Chairman, DRDO on 25 June 2022.

Subsystems including in-house designed and manufactured HF and VHF amplifiers for EW system Upgradation project was supplied to the Indian Army.

EW System Upgradation

Aerospace

Major contribution is through supply of Ka Band Antennae, Tri Band Antennae, Stabilisation platform, SATCOM Antennae and Gyros to various organizations.

ECIL has indigenously designed and developed Triband Antenna (S/X/Ka band) feed system with auto-tracking feature in all the 3 bands for high data rate satellite based communication applications in strategic sector.

Antenna Systems

Security

Major contribution is from supply of CCTV and Switches to Delhi Police, AMC services for CCTV, Security equipment for Delhi Police Prisons, Security gadgets to SPG, MHA, UP Vidhan Sabha etc.

ECIL under guidance of Technical Expert Committee (TEC) of Election Commission of India (ECI) has undertaken development and deployment of Secure Manufacturing Facility (SMF 2.0). The facility ensures security, traceability and 4-Sigma quality for manufacture of Strategic Electronic Products.

IT & e-Governance

First Level Checking (FLC) and Sealing, Distribution, Packing and Counting (SDPC) for EVMs to Election Commission of India and State Election

Class Room Jammer

Electronic Voting Machine

Commissions of different states, supply of Class Room Jammer to various Exam Boards and Test Centers, providing Smart lighting, network Infrastructure, Web portal for temple operations, SITC of CCTV systems in Public Health Centers in Telangana State, etc. are some of the contributors in this sector.

R&D Program and New Products

R&D is the driving force in building a growth-oriented company. The focus of R&D at ECIL has been to provide indigenous technology solutions to strategic sectors where technology independence, self-reliance and security are the key drivers. This is steered through the Technology Development Council (TDC) in association with R&D institutes of DAE, DRDO, ISRO and other R&D organisations. Additionally, the corporation also focuses on Industry led R&D to enhance value addition and sharpen its competitive edge in product technology.

Currently, ECIL is working on innovative technologies required primarily for strategic applications. The focus areas include Anti-Drone System ; Design & Development of Light Weight Man Portable HF Set; GIS & GPS based Mine Recording System (GBMRS); Realization of WCS for VL-SRSAM; Indigenous Development of Rugged Computer Hardware for C4I Systems; 7.5m Tri-band (S/X/ka) Antenna for LEO satellite tracking; Seeker for Long Range Anti-Ship Missile(LR-AShM); Ion Chamber Radiation Survey Meter; Advanced Hand-held Survey Meter for Alpha, Beta, Gamma and Neutron; Alarm Annunciation System(AAS) for Nuclear Power Plants; Strong Motion Seismic Instrumentation System; Development of Catalyst with Ceramic substrate to

remove hydrogen and NB-IoT based Asset tracking system within private 4G/LTE Network.

New products and Technologies

Dual View X-Ray Baggage Inspection System

Dual View X-Ray Baggage Inspection System generates two X-Ray scanned images i.e. vertical and horizontal views of a baggage, which is being scanned. A threat object that can otherwise get lost in vertical view of a conventional X-Ray scanner will be clearly visible in horizontal view of scanned image and vice versa. It is designed for real time screening of baggage and is suitable for Aviation hubs, Railway Stations, Government sites, and other security hold areas. It has a tunnel size of 640 mm x 430 mm. ECILs DVXBIS is CE marked and Type approved by AERB.

Dual View X-Ray Baggage Inspection System

Remote Terminal Unit (RTU)

Remote Terminal Unit (RTU) It is a modular, powerful and scalable controller capable of all remote automation and control applications. MODBUS RTU or TCP connection options can be used for simple applications, whilst it can be integrated with SCADAs and PLCs for complex applications. It is integrated with in-house developed ECSCADA as a complete solution from ECIL. It solves the most challenging remote automation requirements for the Oil & Gas industry. The key features of the ECRTU100 include, lowest power consumption, wide operating temperature (range 0 to 70°C), High reliability with well-designed thermal paths, Transient Suppression on every I/O channel & every communication port. It provides a

Remote Terminal Unit (RTU)

powerful IEC 61131-3 programming environment with 5 languages (LD, FBD, ST, IL & SFC) support. It incorporates Power Supply, CPU & Communications redundancy and the IOs are scalable through extender module. It has Flexible communication options with Industry standard protocols of MODBUS & DNP3 towards configuring both as master and slave.

Solid State Cockpit Voice and Data Recorder (SSCVDR)

It records flight parameters like altitude, temperature, rotor speed, acceleration etc. from the sensors mounted on the aircraft and also records voice communication transmitted from or received in the cockpit by radio i.e., communication between the pilot, co-pilot and crew members, external RT and warning tones. The data will be stored in a crash survivable memory, to analyze in the event of crash. It is fitted at the tail end of aircraft/helicopter.

Solid State Cockpit Voice and Data Recorder (SSCVDR)

Missile Control Unit (MCU)

Missile Control Unit (MCU)

It is a Rugged Embedded Small Form Factor Controller unit. The main functions of MCU are issuing launch commands to missiles based on the data received from Central Control Unit (CCU).

RF Receiver & Exciter Unit

It is a subsystem of RF Seeker and consists of three channel RF Front End Receiver, three channels IF Receiver and Exciter. Exciter Module generates the coherent radar signals that are used in transmit and the receiver chain.

RF Receiver & Exciter Unit

New Facilities

Advanced Rear End Development (ARED) Facility

ECIL has successfully completed the setting up of Advanced Rear End Development (ARED) Facility under XII Five Year Plan. These facilities will further enhance indigenous development and manufacturing of Strategic Products. The new facilities set up for manufacturing of Precision components, Carbon Fibre products, Scintillator Crystals, RF Seeker testing and Solid-State RF Power Amplifiers will significantly enhance the capabilities to manufacture niche technology products.

Inauguration of Special Components Manufacturing Facility by Shri K N Vyas, Chairman, AEC & Secretary, DAE

Carbon Fiber Reinforced Polymer Facility (CFRP)

The facility has been set up towards manufacturing the Reflectors of antenna using the Carbon Fiber based material. The facility encompasses Composite Autoclave used for Oven curing the CFRP products, design & analysis software for Composite Design, Static and Dynamic Analysis, Carbon composite Materials and CFRP Layup design software are augmented as part of the facility. Further Laser tracker for all purpose dimensional measurements and Laser Projection System for virtual templating and positioning have been established.

CHAPTER 10

Smt. and Shri K. N. Vyas, Chairman, AEC & Secretary, DAE; Dr. A. K. Mohanty, Director, BARC; Smt. and Shri B. C. Pathak, CMD, NPCIL; and Smt. and Shri B. K. Jain, Director, DCSEM accompanied by the senior officials of the DAE family pedal alongside the cyclists who participated in the "Chain Reaction" Cyclothon which ended at the Gateway of India.

OTHER ACTIVITIES

NUJ journalists being briefed about DAE technologies at the DAE-NUJ workshop held in association with IGCAR at Kalpakkam during May 4-7, 2022

CRISIS MANAGEMENT

The Crisis Management Group (CMG) was created in the Department in 1988 based on the first 'Crisis Management Plan' issued by Cabinet Secretariat, Government of India (GoI) in 1987. The Plan identifies DAE as the nodal ministry/department to deal with any radiation emergency in the country. The CMG of the Department better known as CMG-DAE, draws senior officials from various units of DAE and AERB for overseeing the Department's emergency preparedness for responding to any radiation emergency in the public domain and coordinating response actions with state or national level public officials / agencies.

The emergency response systems of CMG-DAE were checked regularly throughout the year to ensure its efficacy. CMG-DAE continued to function as the contact point of DAE to provide its expertise in the field of nuclear / radiological emergency management at various National and International fora.

Both the Emergency Control Rooms (ECRs) located in Mumbai at two different places kept operating throughout the year on 24 x 7 basis. These control rooms, equipped with diverse means of communication; remained in contact with the various nuclear facilities in the country, the Ministry of Home Affairs (MHA) as well as with the International Atomic Energy Agency (IAEA) in Vienna. The Emergency Control Rooms of DAE are the National Contact Point for nuclear and radiological emergency.

During the year (up to December 2022), India participated in two International Convention Exercises, known as “ConvEx”, conducted by IAEA, which are designed to test various aspects of the international Emergency Preparedness and Response (EPR) framework. As the Competent Authority, CMG-DAE coordinated India's active and satisfactory participation in these exercises.

To ensure that the emergency plans are in high state of readiness, major nuclear facilities like nuclear power stations and heavy water plants had periodically carried out variety of emergency exercises. The number of such exercises monitored / participated by CMG-DAE during the year 2022-23 were as follows:

Description of Exercise	Number of exercises carried out *(Apr - Dec 2022)*	Number of exercises *(Projections for FY 2022-23)*
Communication Exercises	368	464
Fire Emergency Exercises	66	80
Plant Emergency Exercises	34	48
Site Emergency Exercises	15	16
Off-Site Emergency Exercises	03	03
Radiation Emergency Exercises in public domain	02	02

During the stated period, CMG-DAE participated in off-site emergency exercises conducted in 'Integrated Command Control and Response (ICCR)' mode at Kakrapar and Rawatbhata NPP sites. The exercises were found to be effective and satisfactory.

The 'Crisis Management Plan of DAE for Nuclear and Radiological Emergencies' based on the 'Crisis Management Plan-2019' of the Government of India (GoI) was reviewed by Secretary (Security), Cabinet Secretariat and found to be satisfactory.

CMG-DAE has prepared department level Disaster Management Plan (DAE DMP) as per NDMA issued 'National Disaster Management Plan (NDMP)-2019' and the template for different Ministries / Departments of GoI. CMG-DAE has issued guidelines for preparation of DMPs for the various units/entities of DAE. CMG-DAE has also finalized and issued Operating Manual and Procedures for DAE-RERCs (DAE-Radiation Emergency Response Centres); Part-I of which is general for all RERCs and Part-II is specific to individual RERCs.

INTERNATIONAL RELATIONS

India, a founding member of the Board of Governors (BoG) of the International Atomic Energy Agency (IAEA), continued to take active part in policy management and programmes of the IAEA. India was represented by DAE on a number of IAEA Committees, including those on safety, safeguards, nuclear radiation, nuclear engineering and application, nuclear law etc. India hosted several IAEA Workshops, Technical Meetings etc., and offered the services of its experts under the IAEA Technical Cooperation programme in a number of fields. India made contributions towards Innovative Nuclear Reactors and Fuel Cycles (INPRO),

Technical Cooperation Fund (TCF) and Regular Budget of the IAEA.

India's participation in the 66th Annual session of the IAEA General Conference, Vienna during 26-30 September 2022

Considering the primacy of the IAEA General Conference in India's international engagement in the field of Civil Nuclear Energy, Chairman, AEC and Secretary, DAE led the Indian delegation comprising of Director, BARC, Chairman, AERB and Joint Secretary (ER) to the IAEA 66th General Conference which was held at Vienna, Austria from 26-30 September, 2022. In addition to this, the Ambassador and officials from Indian Permanent Mission in Vienna, participated in the event.

Bilateral meetings with our international partners

On the sidelines of the 66th General Conference, Chairman, AEC had bilateral meetings with DG, IAEA and delegations from USA, U.K., Russia, EU, Japan, Argentina, Kazakhstan, INVAP Argentina, Uzbekistan, Canada and Bangladesh. Apart from the above, bilateral meetings were conducted with delegations from France, Canada and Argentina.

The following Agreements and MoUs were signed:

(a) The MoU between Department of Atomic Energy of Government of India and Department for Business Energy and Industrial Strategy (BEIS) of the Government of the United Kingdom of Great Britain and Northern Ireland concerning Cooperation with India's Global Centre for Nuclear Energy Partnership (GCNEP) was signed on 18.04.2022.

The MoU mainly envisages cooperation in research and training in nuclear security, advanced nuclear energy systems studies, radiological safety studies, applications of radio-isotopes & radiation technologies and other mutually agreed topics including providing faculty and fellowships for interested participants from third countries. This MoU will be valid for 5 years.

(b) Memorandum of Understanding between Atomic Energy Regulatory Board (AERB), of the Republic of India and State Committee on Industrial Safety (SCIS) of the Republic of Uzbekistan:

On the sidelines of the 66th General Conference held during September 26-30, 2022, a Memorandum of Understanding between Atomic Energy Regulatory Board (AERB), of the Republic of India and State Committee on Industrial Safety (SCIS) of the Republic of Uzbekistan was signed by Shri G. Nageshwara Rao, Chairman, AERB, India and from the Uzbekistan side by Mr. I.Tashkentbayev, Deputy Chairman, State Committee on Industrial Safety (SCIS) of the republic of Uzbekistan on 27th September, 2022.

A visit of 35 Indian Foreign Service (IFS) Officers Trainees and two Bhutanese Diplomats to DAE, Mumbai was organized from 13-15th June 2022

A visit of 35 IFS Officers Trainees and two Bhutanese Diplomats to DAE, Mumbai was organised from 13-15 June 2022 as a part of ongoing Induction Training programme of Sushma Swaraj Institute of Foreign Services, Ministry of External Affairs.

The officers visited Department of Atomic Energy, Tata Memorial Centre, on 13.06.2022, various facilities in Bhabha Atomic Research Centre, Mumbai on 14.06.2022 and Tarapur Nuclear Power Plant on 14.06.2022 and 15.06.2022. This visit/programme was organised for familiarizing the IFS trainees and foreign diplomats with DAE's Organisation, functioning, objectives, capabilities, achievements etc.

As a part of the programme, Dr. K.N. Vyas, Chairman, Atomic Energy Commission and Secretary, DAE gave a brief introduction on the activities of DAE, its Societal applications etc. followed by an interaction session with the IFS Officers and foreign diplomats. A brief presentation was made by Shri Ranajit Kumar, Head, Nuclear Controls and Planning Wing (NCPW) on DAE and International Atomic Energy Agency (IAEA)

and constituent units/aided institutes and Public Sector Units of the Department.

Global Centre for Nuclear Energy Partnership (GCNEP), the sixth R&D unit under the aegis of Department of Atomic Energy (DAE), is being established at Kheri-Jasaur, Bahadurgarh, Haryana. Phase I of the Centre is operational since April, 2017. The work related to Phase II is in the advanced stage.

During April to December 2022, GCNEP has successfully conducted various technical programmes. “Indo-Vietnam Training Program on Rare Earths” & “Indo-US Technical Exchange on Unmanned Aircraft System (UAS) and Counter UAS technologies” were conducted in online mode; while the other programs were conducted in offline mode such as, “IAEA workshop on Nuclear Security Culture in Practice”, “Indo-US-UK Technical Exchange Program on Secure Transport of Radioactive Materials”, “Indo-US Joint Working Group (JWG) Meeting”, “GCNEP-IAEA Regional Workshop on Advances in the Modelling and Simulation of Thermal Hydraulics in Liquid Metal Cooled Fast Reactor” etc. Follow up and review meetings were held for the on-going activities with other countries using virtual platform. The Centre also expanded its activities for experiments on mutated seed for wheat & mustard with the help of NA&BTD, BARC. In addition, GCNEP has participated in various exhibitions promoting the applications of radio-isotopes and radiation technologies for societal benefits such as Rise in Uttar Pradesh held at Ghaziabad (Uttar Pradesh), International Textile Machinery held at Greater Noida (Uttar Pradesh) and Akash Tattva held in Dehradun (Uttrakhand).

Indo-US Joint Working Group Meeting

In the last quarter of FY 2022-23, Indo-US workshop on “Modeling and Simulation for Improved Nuclear Material Accountancy at facilities” as well as online training courses on societal & industrial application of radioisotopes and radiation technology are scheduled with ITEC partner countries under eITEC platform under Ministry of External Affairs (MEA).

NPCIL is a member of international organizations namely World Association of Nuclear Operators (WANO) and Candu Owner's Group (COG) and is actively participating in their programs for enhancing the safety and reliability of nuclear power plants.

During this year, COG conducted a Candu Chemistry Workshop (virtual) to present and discuss experiences and issues with regard to plant chemistry. NPCIL participated in this information exchange programme of COG.

NPCIL continued to provide information for IAEA-PRIS (Power Reactor Information System) database. IAEA conducted a Meeting on 'Technical Working Group on NPP Operation'. IAEA also conducted a meeting on 'IAEA PRIS on Non Electric Applications of NPPs'.

VIGILANCE

The overall responsibility for vigilance in any unit of the Department of Atomic Energy (DAE) rests with Chief Vigilance Officer (CVO). To ensure effective functioning of the vigilance machinery, a senior level officer in each of the Constituent Units and Aided Institutions of the Department has been designated as part time Vigilance Officer/ Chief Vigilance Officer. In the case of Public Sector Undertakings of the Department, full-time Chief Vigilance Officer discharges these responsibilities.

The activities of Vigilance section of DAE during the year-2022 included; submission of 25 monthly/quarterly/annual returns to various authorities such as Central Vigilance Commission (CVC), Department of Personnel and Training (DoPT), and Central Bureau of Investigation (CBI); Processing of 22 new Disciplinary cases; Total 79 complaints were

downloaded from CVC portal (Including complaints received under PIDPI resolution) and 12 complaints were received through PG Portal. About 141 complaints have been received directly in the Department. Vigilance clearances request received for various purposes were issued to 9327 Group 'A' officers of various Units, Aided Institutions and PSUs as well as staff in the Secretariat. Appointment of Vigilance Officer/ Chief Vigilance Officer of Constituent Units/ Aided Institutes in the Department. Scrutiny of Annual Immovable Property Returns in respect of Officers and staff of DAE Secretariat. Co-ordination between CVC and Units for conducting of CTE (Chief Technical Examiner) examination. A few establishment cases / work orders from DAE Secretariat were verified as a part of preventive vigilance activities.

As per the directives of CVC, "Vigilance Awareness Week (VAW)" is observed every year. Accordingly, "Vigilance Awareness Week 2022" was observed in DAE and its constituent Units/PSUs/Aided Institutions from 31st October, 2022 to 6th November, 2022 on the theme of "Corruption free India for a developed nation"- The week commenced with administering integrity pledge by Joint Secretary (A&A) and Director (Vigilance) to the all employees of DAE Secretariat on 31.10.2022. A few of the important activities held during the week in which officers and staff of DAE actively participated were Quiz Competition, Poster Painting competition, Elocution competition and Patriotic Song Solo singing competition. Prizes for the winners of the respective competitions were also distributed during the valedictory function held on 04.11.2022. Vigilance Awareness Week was also observed in the Constituent Units, Public Sector Undertakings and Aided Institutions of DAE.

NPCIL is on the path of rapid growth towards meeting countries clean energy production. In the process of growth, NPCIL remains vigilant and committed to uphold high standards and integrity at all times. To achieve organizational goals, NPCIL strives to promote integrity, spread awareness and sensitize employees against malpractices and corruption by organizing various Vigilance Awareness Programmes throughout the year. The important activities and events organized to achieve this, during the period April to December 2022 were as follows:

- As part of Preventive Vigilance measures and to spread vigilance awareness amongst the stakeholders, 51 Vigilance Awareness Programmes / Seminars / Meets/ Interactive sessions were organized at HQs & Units.
- Vigilance Officers carried out 146 surprise/regular and 07 Chief Technical Examiner (CTE) type inspections at NPCIL HQs/Units.
- Total 119 complaints were disposed-off, out of which 30 complaints were investigated resulting in issuance of penalties, recoveries and various System Improvements.
- Vigilance Awareness Week (VAW) 2022 with the theme of "Corruption Free India for a developed Nation" was observed with zeal and enthusiasm at NPCIL HQs and all Units to achieve the objective to eliminate corruption in public life.
- Integrity Pledge through mass pledge was administered to the employees at HQs & Units during the opening ceremony of VAW.
- Annual In-house Vigilance Magazine of NPCIL "Chetna" was prepared, published and unveiled during the VAW 2022.
- Various activities/competitions on the recommended theme of vigilance awareness topics viz. Essay Writing, Slogan Writing, Poster/Cartoon Drawing, Quiz Competition/ Online Quiz Competition, Elocution/Speech Competition, Short Film Competition etc. were organized at NPCIL HQ and at its Units for employees, their family members, students, contract workers etc.

RTI COMPLIANCE

The Right to Information (RTI) Act of Government of India which came into force on 12th October 2005 has been implemented at DAE and all its constituent units. The provisions contained in RTI Act,

2005 were fully complied by DAE and its constituent units. The RTI applications and appeals received at DAE and its constituent units were promptly attended.

Total 687 online RTI applications were received at DAE Secretariat during the period from 01.01.2022 to 31.12.2022. The offline RTI applications received during the period from 01.01.2022 to 31.12.2022 were 25. These applications have been transferred to concerned CPIO's in DAE Secretariat and other public authorities in the Department / other ministries for action. A total of 81 RTI appeals were received online during the period 01.01.2022 to 31.12.2022 and the same have been transferred to concerned First Appellate Authority in DAE Secretariat for action.

At UCIL, the number of RTI queries received and replied during the year 2022-23 (up to 31.12.2022) were 120.

DPS answered all the RTI queries and grievances received through CPGRMS portal within the time schedule.

During the year, BHAVINI received a total of 44 applications under RTI and all were replied to. Out of 6 appeals that were received, 5 have been replied to.

At IREL, during the period from 01.04.2022 to 31.12.2022, 207 RTI applications were received, out of which 198 applications have been replied as per RTI Act, 2005.

A total of 28 RTIs were received by BRIT during the year 2022-23. These were effectively dealt and disposed off by the Administration Section of BRIT.

At AMD a total of 327 RTI applications were received out of which 241 applications were replied and 4 applications were transferred to other PIOs.

At NPCIL an elaborate RTI Application management mechanism exists with functional arrangement of 8 CPIOs and 8 APIOs, one at each NPCIL Station/Site along with one CPIO, one APIO and one Appellate Authority at NPCIL Head Quarters, to deal with the requests received under the RTI Act 2005.

The mandatory information required under the Act [section 4(1) (b)] is posted on NPCIL website and the information is updated from time-to-time. Presentations / lectures/Trainings were organized in NPCIL for creating awareness about the importance and ways to implement the Act.

During the FY 2022-23 as on December 31, 2022, about 992 RTI applications and 223 Appeals were received under the RTI Act, 2005 and disposed of. In the case of NPCIL, there were 36 cases (Second Appeal) heard by Central Information Commission, New Delhi.

Department of Personnel & Training (DoPT) RTI online portal is used effectively in NPCIL. The online RTI applications and appeals so received are being disposed through online portal.

A total of 148 numbers of RTI request were received at HWB during the period and out of it, 147 requests were disposed of. One request is pending with CPIO.

At RRCAT, in all 151 new RTI applications were received and 142 have been disposed off.

During the year, upto December 2022, TIFR received 87 RTI queries and all 87 were replied.

SINP received 24 RTI applications during the Financial Year 2022-23 and out of these 21 have been replied till 31.12.2022. Out of 4 RTI appeals that have been received, 3 have been replied.

OFFICIAL LANGUAGE IMPLEMENTATION

The Official language activities towards promotion of use of Official language (OL) Hindi in the various fields of Nuclear Sciences and Technology were carried out in the constituent Units of DAE, its PSUs and Aided Institutions. Some notable efforts are mentioned below:

DAE has carried out 10 OL inspections in the Offices of the Units/PSUs/Aided Institutions. During this period, Hon'ble Parliamentary Committee on Official Language inspected 14 offices viz, AMD, Jaipur; Tarapur

Atomic Power Station, Tarapur; IPR, Gandhinagar; Heavy Water Plant, Baroda; IOP, Bhubaneswar; AMD, Bangalore; ECIL, Bangalore; ECIL, Kolkata and VECC, Kolkata and reviewed implementation of OL status. Action taken of Assurance reports of the inspections carried out earlier were submitted to the committee Secretariat within prescribed time.

The Department of Atomic Energy has been awarded the Rajbhasha Kirti Puraskar for the second position by the Department of OL for the excellent implementation of the official language policy for the year 2021-22. The award was presented to Shri K.N. Vyas, Secretary, DAE by Shri Ajay Kumar Mishra, Minister of State for Home Affairs, on the occasion of the Second All India Official Language Conference held at Surat, Gujarat.

Shri K. N. Vyas, Secretary, DAE receiving "Rajbhasha Kirti Award" from Shri Ajay Mishra, Minister of State for Home Affairs

In compliance with the instructions given in the meeting of the Joint Hindi Advisory Committee of DAE and ISRO, a team of officers of the Hindi Section under the leadership of Joint Secretary (Administration and Accounts) for the purpose of promotion of its activities and science by the Department (1) Science Model Competition (2) Screening of film (3) Lecture on the activities of DAE (4) Quiz based on film and lecture at Atomic Energy Central School at Jaduguda, Narwapahad, Turamdih and its nearby schools during 01.8.2022 to 06.8.2022.

Lecture at Atomic Energy Central School at Jaduguda, Narwapahad, Turamdih and its nearby schools during 01.8.2022 to 06.8.2022

Experience sharing workshop was organized for Official Language Cadre on 08.12.2022 at RRCAT, Indore. Around 35 participants participated in this workshop. Thereafter, a meeting of the Joint Official Language Implementation Committee was held on 09.12.2022 under the Chairmanship of Joint Secretary (A&A), DAE.

A total of 49 offices of the Department have been notified in the Gazette of India under Rule 10(4) of the Official Languages Rules, 1976. Out of total 842 sections under the department, 392 sections have been notified to work in Hindi. Out of total 32,892 computers, 31,021 have the facility to do bilingual work and 1871 computers are connected with scientific work. The Cabinet Notes to be presented to various Committees of Parliament were presented bilingually. Similarly, Annual Reports and various documents, agreements and MoUs were prepared and presented in bilingual form.

A total of 80 seminars and talks were organized on various topics related to nuclear science and technology. The souvenirs of some seminars were also published in Hindi. A total of 118 Hindi workshops were organized for imparting training in "Noting and Drafting" and other subjects in Hindi, in which about 2572 officers and employees were trained. On purchase of Hindi books ₹ 3,43,113/- were spent.

Quarterly meetings of Official Language Implementation Committee (OLIC) in DAE Secretariat were regularly organised under the Chairmanship of Joint Secretary (AA) and progress of Official Language implementation was monitored. Quarterly progress reports and minutes of OLIC meetings of offices of all Units, PSUs and Aided Institutes were reviewed regularly. Hindi Week/Fortnight/Month was celebrated in all the offices of the Department.

Websites of DAE and its 30 establishments are in bilingual and they are being updated regularly. House Magazines/News Letters in the form of soft and printed of various establishments of DAE were published in Hindi/Bilingual. Hindi competitions were organised during “Hindi Fortnight” and “World Hindi Day”.

OLIC chaired by CMD, NPCIL reviewed the progress of implementation at Headquarters as well as its sites/stations/projects/offices. The Committee of Parliament on Official Language inspected the sites during the year and the action taken reports on the assurances were submitted to the Secretariat of the Committee through the Department of Atomic Energy. Hindi e-Workshops, e-Hindi Competitions and Hindi Divas were organized at NPCIL HQ as well as its locations in this financial year following the COVID-19 protocol. For the promotion of Hindi, e-home magazines were published for the promotion of Hindi from all its places including the headquarters.

NPCIL HQ bagged the 2nd prize for Official Language Implementation among 65 PSUs from Mumbai PSU Town Official Language Implementation Committee (TOLIC) for the year 2020-21.

The implementation of Official Language Policy and compliance of instructions/orders issued from time to time by DAE and Government of India have been ensured by NPCIL. The provisions of Annual Programme issued by Department of OL, Ministry of Home Affairs have been taken care of during the year.

The Parliamentary Committee on Official Language carried out inspections of sites during the year.

Hindi workshops were organized. Hindi competitions were organized at NPCIL HQ as well as at its sites. Hindi Day and World Hindi Day Celebration also organized at HQ as well as at all sites/stations/project/offices.

SCIENTIFIC INFORMATION RESOURCE MANAGEMENT

The Home Office Anywhere (HoOA) facility of BARC provides secured remote access to important information resources. Around 100 new members have registered for availing this service during the year.

Digitization of printed copies of proceedings of conferences sponsored by Board of Research in Nuclear Sciences (BRNS) was in full swing in BARC Central Library during the year.

Almost all important documents of BARC have been printed and published in-house in a time-bound manner. These include important scientific literature, newsletters, technology documents and minutes of important official meetings etc.

Five issues of newsletter on important and interesting themes, with articles mostly on research and development work in BARC, were edited and published during the year. These include Waste Management and Reprocessing, Beam Technologies, Astrophysics, and Materials for Sustainable Energy.

BARC has officially published 3 books with ISBN recognition. These books cover R&D work over the years in the field of beam technologies in BARC. Besides, it has assisted Homi Bhabha National Institute in its effort to publish a book on Atomic Energy in India, as part of Azadi ka Amrit Mahotsav (1947-2022) activities.

BARC Newsletter issues published during 2022

BARC activities during the calendar year 2021 were compiled and published in the form of an annual report (BARC VISTA) during the year.

BARC published a special publication in Hindi comprising interesting articles on advancements in nuclear reactor technologies in India. The special issue (Vishisht Sankalan-1) was released officially during a function in BARC to mark 2023 edition of World Hindi Day.

More than 900 articles and 95 doctoral theses pertaining to R&D work in BARC were screened prior to publishing, as part of measures to reflect the originality of scholarly work.

To keep BARC scientific community abreast of latest developments globally, a Nuclear News Web Digest is collated and published regularly every week which covers Nuclear energy related information of credible nature, that are published across several media formats by multiple agencies.

New short-term courses in French and Russian were conducted during the year for the benefit of BARC scientific community. Scientific literature originally published in French, Russian and Spanish has been translated into English based on the requirements of BARC community and constituent units of DAE. 12 issues of monthly Scientific Information Resource Bulletin have been prepared and published in digital form.

Internal, External and Restricted reports were prepared and published during the year. These reports comprised specific scientific and technology outcomes of R&D work in BARC. Pulse - a magazine on hospital practices and clinical procedures - edited and published jointly by BARC and BARC Hospital management - has been released during the year. New standards, databases and codes have been acquired or renewed to meet the requirement of BARC community.

BARC Central Library subscribed to 389 journals in electronic form and 53 print-based journals besides several popular magazines. It is working proactively for the implementation of One Nation One Subscription (ONOS) initiative floated by the Government of India for enhancing the accessibility of wide spectrum of journals. Besides, e-journal gateway J-Gate+ and paid journals repository Lakshya were updated regularly.

PUBLIC AWARENESS

The Department of Atomic Energy (DAE) carried out a gamut of Public Awareness programmes in order to alleviate unwarranted fears, misconceptions and apprehensions harboured against nuclear energy. To keep the public abreast of the latest developments and contributions of atomic energy towards societal welfare, DAE organized a spectrum of events comprising exhibitions, seminars, workshops, essay and quiz contests in different parts of the country which were well received by the targeted audience.

Some of the major events in which DAE and its units participated are mentioned below in detail:

DAE participated in the National Panchayat Raj Day- 2022 held at Palli Village, Samba district, Jammu & Kashmir during April 24-26, 2022. The main focus of the event were Healthy village, Child-friendly, Water sufficient village, Clean & green village, Self-sufficient infrastructure in village, socially secure village, Village with good governance etc. Various Scientific Departments jointly participated in the above event. Vigyan Prasar, an autonomous institute under

Students, Parents and Visitors at the DAE Pavilion at the "National Panchayat Raj Day- 2022" exhibition held at Palli Village, Samba district, Jammu & Kashmir during April 24-26, 2022

Department of Science and Technology organized and coordinated the event. DAE had put up an exhibition on various technologies at the event. It was attended by a large number of gathering.

The Public Awareness Division (PAD) of DAE organized Journalists' Workshop along with the National Union of Journalists (NUJ) at IGCAR, Kalpakkam during May 4-7, 2022. The objective of this workshop was to reach out to the general public through articles, news coverage, magazine articles and press releases by reputed Journalists. At the workshop several talks were given by DAE experts about the safety measures followed in DAE institutions, allay fears about radiation and show the defence in-depth approach adopted by DAE in its Nuclear Power Plants. An exhibition on DAE technologies was also put up for the benefit of Journalists. About 30 NUJ Journalists were invited from all over the country (15 from southern states and the remaining from other parts of the country) along with 5 resource persons of NUJ(I).

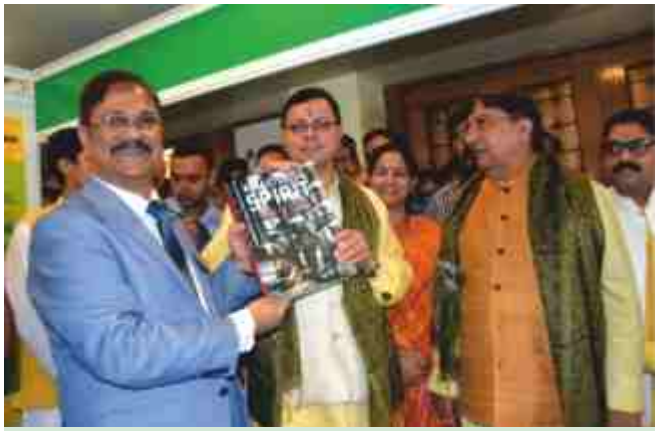
NUJ journalists being briefed about DAE technologies at the DAE-NUJ workshop held in association with IGCAR at Kalpakkam during May 4-7, 2022

DAE participated in the 3rd edition of "Assam Biotech Conclave 2022 Expo" held during May 21-22, 2022 at Guwahati. Leaders from various Government Department addressed the gathering and the event was attended by large number of delegates and global audience of tech enthusiasts. Several exhibits of DAE Biotechnologies/technologies were showcased at the event.

The Indian Women Scientist Association (IWSA) organized an exhibition at IWSA headquarters, Vashi, Navi Mumbai during June 13-14, 2022. DAE participated in this exhibition along with BARC. Students and teachers from various schools participated in this exhibition and were benefited by the event.

School students at the DAE pavilion at The Indian Women Scientist Association (IWSA) exhibition organized at IWSA headquarters, Vashi, Navi Mumbai during June 13-14, 2022

"Rise in Uttaakhand" an exhibition was organised at Dehradun during July 7-9, 2022. DAE participated in the exhibition along with BARC. The event was organized to showcase the schemes, Policies & Initiatives undertaken by the Government in the field of Nuclear Power Technology, Applications of Radiations & Skill Development training programmes for the youth



Chief Minister of Uttarakhand Shri Pushkar Singh Dhami visited DAE-BARC Pavilion during an outreach program in Dehradun in July 2022

and general masses etc. The DAE-BARC exhibition was visited in a big way by students of schools and engineering colleges across the state. The Chief Minister of Uttarakhand Shri Pushkar Singh Dhami and senior cabinet ministers of the state government also visited the stall.

DAE along with VECC participated in the 25th National Science Exhibition held at Central Park Maidan, Salt Lake, Kolkata during August 25-28, 2022 and exhibited DAE technologies. The event was well received by the students, teachers and general public.

PAD in association with AMD, NFC, UCIL and ECIL organised a Journalists' workshop. The workshop was held during July 20-23, 2022 at Hyderabad in co-ordination with the National Union of Journalists (NUJ-I) New Delhi. An exhibition on DAE Technologies was also set up at the workshop. About 40 Journalists from all over the country along with 5 resource persons and a Course Co-ordinator from NUJ (I) were invited. The workshop benefitted the Journalists and various articles of DAE were printed in the local newspapers and also telecast on the Doordarshan and other channels at Hyderabad. An exhibition on DAE technologies was also put up for the benefit of Journalists.

DAE in association with AMD, NFC, UCIL and ECIL organised a Journalists' workshop during July 20-23, 2022 at Hyderabad in co-ordination with the National Union of Journalists (NUJ-I) New Delhi

As a part of Public Awareness Programme the DAE organised the “34th DAE All India Essay Contest” for undergraduate students on topics related to “Nuclear Science & Technology. The students were asked to submit essays on three different topics. The announcement was uploaded on the DAE website for wide publicity. DAE social media channels such as Facebook, Twitter, WhatsApp etc. were also used. Total 30 students were selected for giving oral presentation at DAE headquarters and also, they were taken to visit BARC, BRIT and ACTREC. These prizes were given on the Founder's Day celebration in BARC. The winners were awarded with prize money and certificates. All other students were given consolation prize.

Winners of the 34th DAE All India Essay Contest

The 9th Indian National Exhibition-cum-fair 2022 was organised by Bengal Human Resource Development Foundation on the focal theme of “Self-Reliant India: Sustainable Development” from August 04th – 08th, 2022, at Kolkata Metropolitan Development Authority (KMDA) Ground, Patuli, Kolkata. PAD participated in the exhibition along with VECC and had put up an exhibition in the above event. The exhibition was witnessed by large number of students and other visitors.

The PAD, DAE released two books, an illustrated picture book on Dr. Vikram Sarabhai which

Dr. K.N. Vyas, Chairman, AEC & Secretary, DAE and Dr. A.K. Mohanty, Director, BARC releasing the illustrated picture book on "Dr. Vikram Sarabhai" on 27th August, 2022 at Multipurpose Hall, Training School Hostel, Anushaktinagar, Mumbai

Dr. R. Chidambaram, former Principal Scientific Adviser, Chairman AEC and Secretary, DAE releasing the book "The Story of Uranium in India" written by Dr. R. K. Garg and Dr. D. S. Shukla

was released by Dr. K.N. Vyas, Chairman, AEC & Secretary, DAE and Dr. A.K. Mohanty, Director, BARC and another on "The Story of Uranium in India" written by Dr. R.K. Garg and Dr. D.S. Shukla was released by Dr. R. Chidambaram, former Principal Scientific Adviser, Chairman AEC and Secretary, DAE on 27th August, 2022 at Multipurpose Hall, Training School Hostel, Anushaktinagar, Mumbai. DAE organized this event in association with Atomic Energy Education Society (AEES). Eminent DAE Scientists, AEES teachers & faculties and students attended the event.

DAE participated in the "State S&T Ministers' Conclave" at Science City, Ahmedabad during 10 – 13 September, 2022. The conclave deliberated on some of the key issues like how Centre and States can work proactively to address key challenges and gap areas, strengthen the ecosystem in the States by promoting R&D, innovation and entrepreneurship, assist States in

Students are being educated at the DAE pavilion at the State S&T Ministers' Conclave organised at Science City, Ahmedabad during 10 – 13 September, 2022

formulating State S&T policies apart from various other issues of mutual concerns. On the side lines of the event, an Expo was set up to showcase activities of Departments. The S&T Ministers, Chief Secretaries, Secretaries in charge of the S&T from all the State and UTs, Member Science, NITI Aayog, PSA to the GoI, Secretaries of the Science Departments, Senior officials from GoI, selected Industry leaders, Key officials from all the States etc. participated in the event.

In the month-long event of "Swadeshi Shilp Mahotsav" at Naini Praygraj, Uttar Pradesh organised by Piyush Gramodyog Seva Samiti at Naini Praygraj, Uttar Pradesh, DAE participated for 3 days. DAE participated in this event along with HRI by putting up an exhibition on DAE technologies. The exhibition was attended by large number of students and other visitors.

The National Conference on the Theme 'Akash for Life' was organised at Uttaranchal University Campus, Deharadun during November 04-06, 2022 which was organised by Vijnana Bharti in association with another Scientific Ministries/Department. An exhibition on "Akash Tattva" on November 04-06, 2022 was also organised. The event was based on the concept of panchabhutas, the five elements of nature viz.Prithvi, Jal, Agni, Vayu and Akash associated in Indian thought and tradition with the overall well-being of humanity. DAE was one of the associates of the event and it exhibited its work on the relevant themes/issues and contributed through posters. Eminent academicians, scientists, leaders, scholars, students etc. were the beneficiaries of the conference.

The 81st Ras Utsav and Science Exhibition cum fair 2022 was organised at Jabda, Purba Medinipur, West Bengal during November 04 - 10, 2022. DAE through its unit VECC had put up a stall in the event. Academicians, Scientists, Students etc. attended this exhibition.

DAE participated in the exhibition "Vision Rajasthan 2022" at Jalore Sirohi, Rajasthan during November 01-03, 2022 along with the Institute of Plasma Research (IPR) and had put up an exhibition. "Vision Rajasthan 2022" focused on different segments like Research & Development on Nuclear Energy and its role in the fields of Agriculture, Medicine, Health, Environment, Electricity production and Industry. It also focused on distributing knowledge among the people of Rajasthan regarding various opportunities and innovative schemes launched by Government of India and spread awareness regarding flagship programmes, schemes and initiative in the Nuclear Energy Sector. Large number of students and other visitors got benefitted from the exhibition.

Rise in Uttar Pradesh was organised at Ghaziabad, UP during November 22 – 24, 2022. The event was based on the theme 75th Azadi ka Amrit Mahotsav and highlighted the vision of our honourable Prime Minister regarding Atmanirbhar Bharat and Make in India for promoting skill Development, Training & Education for better employment opportunities in the field of nuclear technology and space sciences etc. DAE participated in this event and exhibited its technologies.

DAE participated in the 57th Annual Adhiveshan of Marathi Vidnyan Parishad 2022 19th, 20th & 21st Nov. 2022 in association with Goa University. The focal theme of the Adhiveshan was "Global Climate Change: Challenges" which was relevant to the activities of the Department particularly the nuclear power program of India. About 300 participants attended the Adiveshan which included eminent scientists.

The "Shining Maharashtra 2022" exhibition was organised from 22-24th December 2022 at Akluj, Maharashtra. The exhibition was organised under the guidance of Shri Ranjeetsingh Naik Nimbalkar, Hon'ble Member of Parliament (Lok Sabha), Madha, Maharashtra, the 'Shining Maharashtra 2022' was focused on spreading knowledge and awareness among visitors, particularly students and scholars about nuclear energy. The event enlightened them with the various Government schemes and programmes in the field of nuclear energy. DAE had put up an exhibition along with BARC in the above event. A large number of students, teachers and the general public visited the exhibition.

Shri Ranjeetsingh Naik Nimbalkar, Hon'ble Member of Parliament (Lok Sabha), Madha, Maharashtra at the 'Shining Maharashtra 2022' exhibition

DAE participated in the 'Shining Madhya Pradesh 2022' held during December 23-25th, 2022 at Ujjain, Madhya Pradesh. The main theme of the event was "Atma nirbhar Bharat" 'Self-reliant' India, to revive the Indian economy and focus on promoting innovation & local products. It showcased the promotion of various flagship programmes of Central and State Government, latest trends, products, services, Research and Development, opportunities and innovations in Agriculture, Research, Power and Energy, Rural Technologies, medium and small enterprises. An exhibition was put up by DAE along with RRCAT on DAE Technologies.

The Acharya Satyendranath Bose Smarak Bijnan "O" Prajukti Mela was held at Hedua Park, Kolkata during January 19 -23, 2023. This Science fair helped the masses to connect with the Science & Technology. DAE participated in the event along with VECC by putting up an exhibition on DAE technologies. The event was a platform for young students to

encourage them to solve real world challenges by applying science and technology.

An International Conference NICSTAR 2023 on "Radiation Technologies: Challenges & Opportunities for Sustainable Development" was organised by National Association for Applications of Radioisotopes and Radiation in Industry (NAARRI) at Lulu Bolgatty International Convention Centre, Kochi, Kerala during January 09-12, 2023. This was a Mega International event wherein various industries from India and abroad participated in the exhibition. It presented an opportunity for DAE to showcase the advancement made by DAE in the field of Isotope and radiation technology. DAE participated in the exhibition and it was witnessed by a large number of Scientists from all over the country.

The 108th Indian Science Congress (ISC) was held during January 03-07, 2023 at Rashtrasant Tukadoji Maharaj Nagpur University Campus, Nagpur. It was inaugurated by the Hon'ble Prime Minister of India, Shri Narendra Modi. The focal theme of ISC was "Science & Technology for Sustainable Development with Women Empowerment. The "Pride of India" (PoI) Expo – a mega Science Exhibition was one of the main attraction of ISC Expo and it showcased the cutting–edge technologies, leading scientific products and services, path breaking R&D initiatives, schemes and achievements of India's foremost and leading public and private sectors, Govt. departments, research labs, educational institutions, corporate defence etc. DAE participated in this mega event along with its units and had setup a grand exhibition on DAE Technologies. A large number of students and general public visited the exhibition.

Principal Scientific Adviser to Prime Minister Dr. A. K. Sood being briefed about DAE activities at the DAE pavilion during the 108th Indian Science Congress

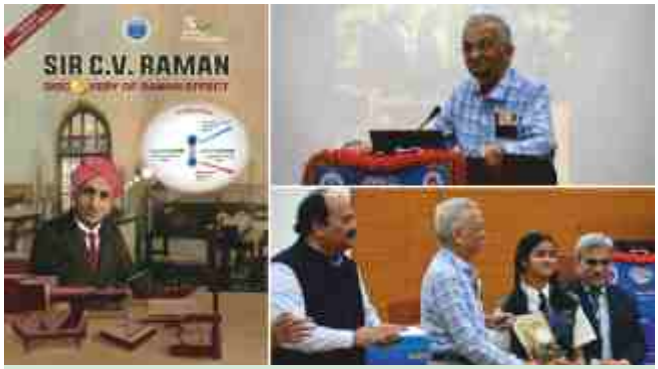
DAE participated in the 5th Innovation Festival held during February 1-3, 2023 at Nehru Science Centre, Mumbai. DAE had put up an exhibition of technologies developed by DAE. A large number of students attended this exhibition.

Students being briefed about DAE activities at the 5th Innovation Festival held during February 1-3, 2023 at Nehru Science Centre, Mumbai

DAE participated in "Alluring Rajathan" at Udaipur, Rajasthan organised by Prayas Exhibition during 23rd to 25th February, 2023.

The Science & Technology Exhibition called "Technovanza", held during February 24-26 was organized by VJTI at its Campus at Mumbai. Technovanza provided a platform for all sectors (Private & Government) to showcase their achievements, innovations, creativity and challenges in the field of Science & Technology. It also aimed to increase awareness and enthusiasm for a large spectrum of audience including school, college and university students. DAE participated in this event by putting up an exhibition showcasing technologies developed by DAE. The programme was well received by one and all. A large number of Engineering students participated in this exhibition.

The National Science Day is celebrated every year on 28th February as Sir C. V. Raman discovered the Raman Effect on this day. PAD, DAE released an "Illustrated picture book on Sir C V Raman" on the occasion of the National Science Day. The book was



Dr. Anil Kakodkar former Chairman, AEC and Secretary, DAE releasing the Illustrated picture book on Sir C. V. Raman

released by Dr. Anil Kakodkar, Chairman, Rajiv Gandhi Science and Technology Commission, Government of Maharashtra, Mumbai and former Chairman, AEC and Secretary, DAE who was the Chief Guest of the programme. AEES school students participated in this event and the topper students were given a copy of the book.

Students of Gujarat along with their teachers visited BARC (June 17-18, 2022) during which they interacted with scientists as well as toured prominent facilities in the centre to gain first-hand knowledge of diversified R&D activities in BARC. The students were presented with certificates of appreciation during their visit. These students have excelled in a state-wide STEM Quiz conducted by the Gujarat State Council of Science and Technology.

Senior officials of BARC visited prominent colleges in the vicinity of Kolkata during April 26-30 as part of outreach activities.

Few glimpses of BARC scientists interacting with the students of pan-India Jawahar Navodaya Vidyalayas in 2022 as part of Parmanu Jyoti Program

DAE has planned, organized and conducted the newly launched Parmanu Jyoti program in which more than 80 young scientists of BARC were deputed to visit pan-India Jawahar Navodaya Vidyalayas (JNVs) in two phases during the year. More than 5000 students from 100 plus schools from 34 states participated in the program.

VECC conducted a few public outreach activities during the year 2022. The VECC Pubic Awareness activities were mainly divided in four broad categories, such as Public Outreach outside VECC, Student's visit in VECC, Participation in Exhibitions and Special Outreach events in VECC. Public Outreach Seminars is a daylong student/public interaction program which was conducted outside by VECC, mainly in remote villages and sub-urban areas to enlighten regarding DAE activities. VECC has conducted six such seminars during the year 2022. VECC accommodated around 400 students and 30 Teaching Staff from various school and colleges during 14 visits in VECC campus throughout the year. VECC represented DAE in three exhibitions in and around Kolkata during the year 2022. Apart from that, VECC has conducted National Science Day in online mode on 1st March, 2022 and more than 60 participants throughout India participated in the event.

The outreach activity of NPCIL in the year 2022-23 up to December, 2022 has reached out 52,13,600 citizens. NPCIL has always reached out to the masses by following a multi-pronged approach. Of the above mentioned outreach figure, during the DAE Iconic Week's Celebrations as a part of the Azadi ka Amrit

CMD, NPCIL launched the official Social Media Pages of NPCIL

Mahotsava from August 22 to 28, public awareness activities were increased exponentially culminating in organizing over 450 events pan India and reaching out to over 15,41,000 citizens during this period alone. The details of the various means of communications and outreach adopted and the number of people benefitted by each of these modes is as given below:

Adoption of social media policy

In order to achieve the net zero target, nuclear power is going to play a major role. It is imperative to enhance outreach to the public at large to get the fullest co-operation. In the present technology scenario, the medium of communication is transforming the way in which people connect with each other and the manner in which information is shared and distributed. Keeping this in view, NPCIL has prepared its social media framework and guidelines and launched Social Media pages on Facebook & Instagram besides a channel on YouTube on December 30th, 2022. These social media platforms which have got wider reach among masses along with the traditional means of communication are expected to have a transformational effect in reaching out to the people who are otherwise not reachable.

Web based public awareness

NPCIL website has been providing large amount of authentic and beneficial information on multiple aspects of nuclear power including significant developments and achievements. Many of the publications have been posted in this regard and two new publications on 'Why Nuclear' and 'Light Water Reactors' have been developed and e-copy published on the website. Regular updates of the web-portal, posting of the information about various developments and answering to the queries raised on the web portal are carried out on the NPCIL Website.

Webinars / online / offline lectures

NPCIL conducted various lecture sessions in both offline and online mode across the nation. A total number of 103 programs were conducted during the period April to December, 2022 out of which 58 programs were conducted during the Iconic week from August 22 to 28, 2022. The total number of people reached out by this mode of communication in the aforesaid period was about 26,595.

Halls of nuclear power

"Halls of Nuclear Power" have been setup at three science centres, located at Mumbai, Delhi and Chennai, where millions of people visit every year to get authentic and correct information on various aspects of nuclear energy and its applications, at a single point. Proposal for setting up of Hall of Nuclear Power at Regional Science Centre and Science Park (RSC&SP), Jaipur is approved and the work is expected to start after signing of MoU. Besides this, MoUs have also been signed for renovation and upgradation of Hall of Nuclear Power at Mumbai and Delhi.

Halls of nuclear power

Miniature nuclear galleries

After the successful fabrication of galleries at various district science centres located at Karwar, Mangalore, Hyderabad, Coimbatore, Vijayawada, Jalandhar, Kota and Bhopal, proposal for setting up of more miniature galleries has been approved and these galleries are planned to be set up at Dharwad, Kalaburagi, Tirchy, Vellore, Pune, Goa, Kalimpong and Dharampur.

Nuclear power plant models

As a part of the public awareness activities, NPCIL is providing 700 MW Nuclear Power Plant Models to various Science Centres & institutions across the country. Six NPP models of 700 MW each have been fabricated, delivered and installed successfully at various science centres located at Egmore, Madurai, Mangalore, Thrissur, Vijayawada and Tatanagar.

The number of persons reached out by means of visits to the Science Centres featuring the Halls of Nuclear Power, Science Centres which display the interactive models of the nuclear power plant and Miniature Nuclear Galleries in the financial year 2022-23 up to December, 2023 is 21,46,213.

Participation in exhibition and seminars

NPCIL participated in many events including exhibition and seminars organized at National level which include Indian Nuclear Business Platform (INBP)-2022 organised in Mumbai, 37th Indian Engineering Congress (IEC) held at Chennai, 5th Asian Congress of Radiation Research-2022 organised by BARC etc. About 36,832 citizens visited the NPCIL pavilion/stalls at 23 exhibitions during the period April - December 2022.

Site visits

During the period April - December 2022, NPCIL organized 661 site visits to different nuclear power plants across the country benefitting 18,342 persons, including students and faculty members from educational institutions, local citizens, various officials and their family members.

Public awareness campaign by means of distribution of printed material

During the period April - December 2022, around more than 2,28,395 publications were distributed with the objective of creating public awareness among the general masses of the country.

Films and Multimedia

MoU was signed with Prasar Bharati (Mumbai Doordarshan) to produce special films on various CSR (Corporate Social Responsibility) activities carried by NPCIL. During the period, production and telecast of 5 innovative CSR films on different themes were done across DD National and other regional channels in Hindi, English and other vernacular languages. The total number of people outreached via this mode was about 14,91,870.

Besides, special documentary film on achievements of Rajasthan Atomic Power Plant and 2 special short films were also produced and telecasted on DD National and other regional channels of Doordarshan on the occasion of Azadi Ka Amrit Mahotsav, during DAE's Iconic Week Celebration. Total outreach through this initiative was about 59,000.

DAE's iconic week celebration under Azadi Ka Amrit Mahotsav (AKAM)

Ministry of Culture had given weekly schedules to all Departments during the Azadi Ka Amrit Mahotsav (AKAM) celebration period. DAE was given an exclusive week during August 22-28, 2022 to upload the activities and achievements. At the DAE headquarters, the DAE Iconic Week was celebrated on 27th and 28th August 2022 during which presentation of DAE's activities and programmes was showcased. Eminent personalities from various State/Central Government Offices, Heads of DAE Units in Mumbai, Joint Secretaries of DAE etc., were invited for the programme.

Senior scientists of Bhabha Atomic Research Centre (BARC) participated in the “Chain Reaction” Cyclothon and they cycled for 1700 km starting from India Gate in Delhi on August 13, 2022. The purpose of the campaign was to spread awareness about nuclear energy as clean, green and safe energy resource. The Cyclothon crisscrossed five states – Delhi, Rajasthan, Madhya Pradesh, Gujarat and Maharashtra and concluded at the iconic Gateway of India on August 23, 2022.

Smt. and Shri K. N. Vyas, Chairman, AEC & Secretary, DAE; Dr. A. K. Mohanty, Director, BARC; Smt. and Shri B. C. Pathak, CMD, NPCIL; and Smt. and Shri B. K. Jain, Director, DCSEM accompanied by the senior officials of the DAE family pedal alongside the cyclists to the Gateway of India.

NPCIL participated in DAE's Iconic Week Celebration, held during August 22-28, 2022 under AKAM. During the entire week long celebration, various public awareness activities and events were organized at all the nuclear power stations / green field sites across the country in association with many professional organizations including Prasar Bharati (Mumbai Doordarshan and All India Radio), Science Centres, officials from Press Information Bureau, Journalists and Media officials from prominent newspapers, Wildlife Institute of India, National Mission for Clean Ganga and Forest Department, Uttar Pradesh. During the entire celebration, NPCIL organized 450 plus events, touching around 1.5 million people across the country.

Emphasizing the role of Nuclear Power as a clean, green and safe source for electricity generation, a “Special Editorial Article” was conceptualized and developed on account of AKAM and was published in all the editions of “Dainik Jagran” News Paper published from 12 prominent cities of UP, Uttaranchal, Jharkhand and Bihar covering millions of readers. Besides, article was also published in all editions of Swadesh, being published from MP and UP, Yashobhumi published from Mumbai and other newspapers, across the nation.

At RRCAT, under DAE Iconic Week celebration, lectures on “Indian Freedom Struggle and Science” and “Satyagraha of Indian Scientists during British Rule” were arranged during the inaugural session. A meeting on DAE incubation program was organized where around 70 representatives from MSME participated.

Awareness camp at Gawali Palasiya, Mhow organised by RRCAT

Another meeting was organized at RRCAT to introduce farmers to the liquid nitrogen based refrigerated transportation technology called as Sheetal Vahak Yantra (SHIVAY) developed at RRCAT. RRCAT awareness team visited different schools in Indore district during DAE Iconic Week to spread scientific and health awareness. More than 1000 school students of 13 schools participated in program. A separate camp was organised in which the photonics based compact and portable cancer screening device “Oncodiagnoscope”, developed at RRCAT was used to screen over 150 individuals.

At RRCAT, under AKAM, a state-of-the-art museum named 'Light Exploratorium' has been set up so as to inspire the students for research in the field of “light science” and to kindle the curiosity of the young minds. It was inaugurated by Padma Vibhushan Dr. Anil Kakodkar, Chancellor, HBNI on Friday, 8th July 2022.

Light Exploratorium inaugurated by Dr. Anil Kakodkar at Sukhniwas Palace, RRCAT, Indore

RRCAT celebrated the National Science Day on 28th February 2022 in an online mode under the “Azadi Ka Amrit Mahotsav”. More than 650 students and teachers participated from 42 schools and 12 colleges in and around Indore through the online program.

A special outreach program for schools was also conducted at the Meghnad Saha Auditorium in VECC-SINP Campus as a part of celebration of AKAM on 25th Aug, 2022. In this daylong program almost 300 students and 30 teachers took part. An open house program was also conducted on 27th Aug, 2022, on the same week to accommodate interested participants from the general public to have a glimpse of major scientific and research facilities in VECC. The response was overwhelming and around 160 participants participated in the event.

HWB enthusiastically took part in the celebrations during the DAE iconic week i.e 22/08/2022 to 28/08/2022. Exhibition was organized at DAE convention center, Anushakti Nagar, Mumbai. Marathon/walkathon race, Short film show and Quiz was conducted at K. J. Institute of Technology, Savali, Vadodara, Anu Bose Institute of Technology, Paloncha, Telangana, Narayani Institute of Engineering and Technology, Angul, Odisha and Holy Cross Engineering College, Tuticorin. There was overwhelming response of participants and general public to the events. National flag was distributed to all the employees of Heavy Water Board under “Har Ghar Tiranga” call given by Government of India.

A webinar series comprising invited talks from eminent scientists honoured with Padma Awards was conducted by Atomic Minerals Directorate for Exploration and Research (AMD) under AKAM on the theme – 'Atmanirbharta in Science' and a Special Commemorative Volume on the proceedings of the webinar series comprising a compilation of transcription of the talks was published by AMD.

At General Service Organization (GSO), as part of AKAM celebrations, a Monolith was inaugurated at the Anupuram Township. Seventy-five fruit tree saplings were planted at Anupuram Township to commemorate seventy-five years of Indian independence.

Interacting with Students on Make in India

During the iconic week, Directorate of Purchase and Stores (DPS) has undertaken various initiatives to reach out to the young minds and create awareness in environmental, social and in health. A tree plantation drive was organized by DPS at Nutan Vidya Mandir School, Mumbai. A talk on "Make in India" policy to secondary school children of NutanVidya Mandir, Mankhurd and a Quiz Competition was arranged to the prospective youngsters. In addition to the above, a skit highlighting the achievements of 75 years since India's Independence invoking a sense of nationalism and Atmanirbharta was enacted.

HBNI organised different activities from August 2021 onwards as part of the celebration of “Azadi Ka Amrit Mahotsav,” a country-wide campaign launched by the Government of India as India completes 75 years of independence. As part of DAE iconic week celebration of “Azadi Ka Amrit Mahotsav”, HBNI organized special lectures by eminent speakers on the current research areas and future challenges for the benefit of students/faculty of educational institutes across all over India during August 22-28, 2022.

SOCIAL WELFARE

Corporate Social Responsibility, Sustainability and Rehabilitation & Resettlement

NPCIL is committed to economic and social development of the local communities around all its sites. CSR programme is implemented at the 14 sites of NPCIL, where either the operating stations or the projects are located. These sites are located mostly in rural and under developed areas. The area within 16 Km

radius from these sites is designated as Local Area for implementation of CSR programme. During the FY 2022- 23, the NPCIL allocated an amount of ₹ 130.55 Crore for implementation of CSR programme. It is a matter of satisfaction that for the last six consecutive years, NPCIL has spent more amount on CSR programme than that was mandated by Companies Act during that year.

The CSR Policy of NPCIL is available at the company website i.e. www.npcil.nic.in Board Sub Committee (BSC) for CSR and Sustainability functions as CSR Committee as defined in the Company (Corporate Social Responsibility Policy) Rule 2014 notified under companies Act 2013. Additionally, Guardian Directors have been assigned to the operating sites of NPCIL to review and assist the CSR programmes of the sites. The effective and expeditious implementation of CSR program is monitored and facilitated at various levels in NPCIL including the Board Sub Committee (BSC) for CSR and Sustainability.

The CSR projects have been taken up in line with Schedule VII of Companies Act, 2013 which falls in the areas of education, healthcare, infrastructure development, skill development, sustainable development.

Education

Under education category the projects like construction of school buildings, class rooms, science laboratories, establishment of smart classes, furniture for schools, deployment of teachers in schools; assistance to schools by providing drinking water, toilets, multipurpose hall, library hall, boundary wall,

Construction of Government Higher Primary School, Bare, Uttar Kannada District, Karnataka

Construction of multipurpose hall at Kasturba Gandhi Girls School, Kumariya, Fatehabad District, Haryana

prayer stage with shed; development of aganwadis, playgrounds and footpath, kitchen shed with store; assistance to students by providing note books, school bags, school kits, sports kit, scholarship and sponsorship, etc. were taken up during this year.

Healthcare

Under healthcare, the CSR projects included running of primary health centre and OPD services at Tarapur Maharashtra Site, Rawatbhata Rajasthan Site, Narora Atomic Power Station, Kakrapar Gujarat Site and Kaiga Generating Station; providing mobile medical van services at Tarapur Maharashtra site, Rawatbhata Rajasthan site, Kakrapar Gujarat Site, Kaiga Generating Station, Gorakhpur Haryana Anu Vidyut Pariyojana and Chutka Madhya Pradesh Atomic Power Project; organising medical, eye and special health care camps; infrastructural facilities for Primary Health Centres

Inauguration of Primary Health Centres (PHCs), Kesar, Bulandshahr District, Uttar Pradesh

Mobile clinic services, Gorakhpur, Fatehabad District, Haryana

(PHCs), ambulance for Primary Health Centres (PHCs), Community Health Centres (CHCs) and for District Hospital Banswara; providing assistive devices to differently abled persons and senior citizens, nutrition supplementation to anganwadi and school children, auto tipper for garbage collection, mobile toilet and cattle catcher; development of drinking water facility, and laying of pipelines, bore wells in remote villages, installation of hand pumps, installation of water coolers and purifiers etc.

Infrastructure Development

Under infrastructure development, the projects like laying of approach roads with drains, footpath and culverts, construction of bridge, installation of paver blocks in streets, resurfacing of damaged roads, development of cremation ground, construction of community hall and gym hall, construction of water tanks, installation of concrete benches, tennis courts,

Construction of Cement Contract Road near Nandpur, Bulandshahr District, Uttar Pradesh

procurement of boats, fire pumps and other items for rescue operation during flood etc. were taken up.

Skill Development

Skill development initiatives were undertaken to acquire skills for income generation for unemployed adults. Skills in tailoring, computers, agriculture, welding and NDT techniques, coaching classes for the local youth aspiring for competitive examinations etc. were focused upon.

Skill development training at CIPET, Valsad District, Gujarat

Sustainable Development

Some sustainable development initiatives were also undertaken this year. These included projects like rainwater harvesting, development of village ponds, ground/ underground natural water bodies, irrigation system, ground water recharge technology, turtle rearing program, establishment of butterfly park, conservation of black bucks, solar street lights etc.

Check dam at Indu village, Tapi District, Gujarat

Interpretation centre and water storage tanks for black bucks, Dhangar, Fatehabad District, Haryana

Projects carried out in Aspirational Districts

As regards CSR projects in Aspirational Districts, purchase of hearse van for aspirational district Nandurbar as well as training, monitoring and assessment of anganwadis at aspirational district Gadchiroli in Maharashtra were carried out. Ambulance at aspirational district Jaisalmer, Complete Blood Count (CBC) machine at aspirational district Baran, establishment of smart class rooms in Government schools at aspirational district Sirohi and Jaisalmer in Rajasthan were provided. Health AHMs (any time health monitoring point of care system) for 5 CHCs at aspirational district Siddarthnagar in Uttar Pradesh were installed. Construction of new block and renovation for Community Health Centre (CHC), Bhagwanpur at aspirational district Haridwar in Uttarakhand is being carried out. Livelihood projects in rural village were provided at aspirational district Ramanathapuram. Construction of new anganwadi centre and toilet facilities in school at aspirational district Virudhunagar in Tamil Nadu was done. Construction of one additional class room building at nine schools at aspirational district Visakhapatnam in Andhra Pradesh and skill development training at aspirational district Damoh in Madhya Pradesh are being carried out.

Oxygen plant, Shorapur, Yadgir District, Karnataka

AKRUTI Programme of DAE

AKRUTI is "Advance Knowledge and RUral Technology Implementation" programme of DAE. It aims to disseminate the technologies developed by DAE for rural sector leading to societal benefits. Under CSR Programme of NPCIL, AKRUTI Technology Demonstration Centres are being developed at Tarapur Maharashtra Site, Kakrapar Gujarat Site, Gorakhpur Haryana Anu Vidyut Pariyojana, Mahi Banswara Rajasthan Atomic Power Project, etc. to create awareness about technologies developed by DAE. NPCIL intends to deploy these technologies for rural development in the field of agriculture, agro-processing, waste management, health and safe drinking water at these sites. Some of the BARC technologies that are being introduced to the people in the nearby villages include nano-technology based water filters, rapid bio-compost facility, solar dryer and Tele ECG machine, etc.

Rapid bio-composting at Tarapur, Palghar District, Maharashtra

Akruti Centre at Tarapur, Palghar District, Maharashtra

Swachha Bharat Mission

Swachhta Pakhwada was introduced in all Central Government Ministries & Departments on the directives of the Hon'ble Prime Minister as a part of the Swachh Bharat Mission. Swachta Pakhwada was observed in DAE Headquarters from 16th - 28th February 2023. The inauguration of the programme was done by Shri Sunil Ganju, Head, ICPD on 16th February. Various competitions such as Swachch Section Competition, Quiz Contest, Essay Contest, Poster Contest, Slogan Contest etc. were organised. The staff members of DAE participated whole heartedly in all these contests. The results of these contests were announced on 28th February, 2023. Prizes were distributed to the winners of the various contests, felicitation of the employees of the department who were selected for their contribution in cleanliness were also done.

Dr. A. K. Nayak, Head, NCPW, DAE handing over the trophy to the winners of the Swachh Section

As part of Swachhata, DPS disposed of about 1973 MT of scrap generating a revenue of ₹ 10.13 Crore.

EMPLOYEES' WELFARE

Employees' Health Care

To provide specialised and personalised health care to its employees and the members of their families even after retirement, the Contributory Health Service Scheme (CHSS) was introduced in the Department in the year 1962. The Revised CHSS scheme came into effect from 01/02/1998.

Health Care is one of the most important social security measures which NPCIL has always focused on. To provide best medical facilities to its employees and their dependant family members, NPCIL continued to follow the Contributory Health Service Scheme (CHSS) of DAE. Under the Scheme, all the eligible employees and their family members were provided with hassle free medical facilities in its established hospitals as well as referral hospitals empanelled by respective Units.

Children's Education

Atomic Energy Education Society (AEES), an autonomous institution under the Department of Atomic Energy (DAE), Govt. of India, was established in the year 1969 with an aim to provide quality education to the children of the employees of the DAE units working at different centres/establishments across the country in an environment in which every student discovers and realizes his/her full potential. AEES currently administers 31 Schools/Junior colleges at 15 centres located all over India and provides education to over 27,000 students. AEES provides education to the economically backward children from the rural/tribal areas around its establishments through its Societal Enrichment and Education Programme (SEEP). This programme is meant for some children, who are identified only from those admitted under the Right to Education Act (RTE) category.

During the year 2022-23, physical classes were resumed with the hope of resuming sport and co-curricular activities in offline mode. AEES planned various sports and co-curricular activities for the students as well as various in-service, training programme for teachers and office staff.

Various events organised by AEES are mentioned as under:

- Junior Science and Mathematics Olympiad enrichment camp for students of Atomic Energy Central Schools (AECS) was organised at AEJC, Mumbai from 6th June to 15th June 2022.

- International Yoga Day was observed in all AEC schools on 21st June 2022.
- DAE Iconic week was celebrated in all AEC schools from 7th August 2022 to 15th August 2022.
- BARC, Mumbai visit was arranged for selected std. X students of AEC schools from all over India centers from 9th August 2022 to 13th August 2022.
- **All India AECS Quiz competition:** Inter-AECS Quiz - 2022 at National level was organised on 25th August 2022 at Dr. Homi Bhabha Hall, AEJC, Mumbai. Four teams i.e. three winner teams of Cluster - I (Rawatbhata), Cluster - II (Hyderabad), Cluster - III (Mumbai) and one guest team participated in the event with great enthusiasm. Teams were named in the honour of Sir Jagdish Chandra Bose, Salim Ali (Ornithologist), Birbal Sahni (Paleontologist), Subramanyan Chandrashekhar (Chandra).
- Teachers' Day was celebrated in all AEC schools and Common function of all AEC schools Mumbai and central office were held at Mumbai on 5th September 2022.
- Hindi Pakhwada was observed in All AEC schools and Central office from 14th September 2022 to 28th September 2022.
- **All India AECS Art competition:** All India AECS art competition was held on 12th October 2022 in all 30 schools of AEES. Large number of students participated in the competition. Competition was held in 7 groups from Prep to standard XII. 1598 best posters were received at the co-ordinating school i.e. AECS-1, Mumbai. Best posters from each school in each group @10% of the participants were sent. A team of distinguished judges selected best five posters in each group. The exhibition of these posters will be held at AEJC, Mumbai on 26th January 2023.
- Ekata Diwas was observed in all AECS schools and Central office on 31st October 2022.
- Vigilance awareness week was celebrated in all AEC schools and Central office from 26th October to 6th November 2022.
- Constitution Day was celebrated in All AECS schools and Central office on 26th November 2022.
- English Debate Competition: Zonal Level English Debate competition was arranged in four zones viz. AECS-4, Mumbai on 16th November 2022; AECS-2, Rawatbhata on 18th November 2022; AECS-2, Kalpakkam on 29th November 2022 and AECS-1, Hyderabad on 2nd December 2022. National Level English Debate Competition were held at AECS-1, Tarapur on 6thJanuary2023.
- Book Exhibition (Rajbhasha) was held in AEJC, Mumbai from 18th – 19th November 2022.
- **All India Inter AECS Cultural Meet**

All India Inter AECS Cultural Meet was held at Narwapahar from 27th – 29th November 2022. Thirty AEES Schools participated in the event. The Meet was inaugurated by Shri V P Venugopalan, Chairman AEES, Smt. Latika Venugopalan, Shri. C K Asnani, CMD UCIL and Smt. Jayshree Asnani.

Inter AECS Cultural meet AECS, Narwapahar

The Inter AECS / JC Cultural meet 2022 at AECS Narwapahar was held from 27th November 2022 to 29th November 2022. With the presentation of over 80 dances of various folk and choreographed forms from different states of India, the programme was like a dance festival in the presence of distinguished guests, the students of the various AEC Schools and Junior colleges of India presented their dances. The event continued for the three days. The function revealed many forms of our folk and theme dances before the audience. Everybody enjoyed the cultural event and highly appreciated the organizers.

All India Inter AECS Sports Meet (Chess & Badminton)

The All India Inter AECS Tournament for Under-14 age-group, in the sports of Badminton & Chess for the year 2022, was conducted from 29 November to 02 December 2022. The Tournament was organized by AECS-2, Mumbai with the Organizing Principal as Shri. B. Venkanna, and Organizing Secretary as Dr. R. Stylemon Pillai. Programme was successful with the efforts of all the teachers and staff of AECS-2, Mumbai and the joint collaboration of all AEC Schools & AEJC, Mumbai.

Inter AECS chess tournament AECS-2, Mumbai

AECS Badminton Tournament, AECS-2, Mumbai

The Tournament was inaugurated by Dr. (Srimati) Balvinder Sapra, Head, Radiological Physics & Advisory Division in the presence of dignitaries' Shri. P.Goverdhan, Secreatary, AEES, Shri. Uday Madhavrao Shinde IFA, NRB & Treasurer, AEES.

The Valedictory function was concluded by Smt. Sushma Taishete Joint Secretary (R&D), DAE as Chief Guest in the presence of dignitaries Dr. V.P.Venugopalan, Chairman AEES, Shri. P.Goverdhan, Secretary, AEES.

In Chess 27 individual players from boys' category & 25 players from girls' category, representing their respective schools participated for the winner place.

In Badminton, all together 103 boys from 26 teams with 04 players per team & 103 girls from 27 teams with 04 players per team took part in the tournament for a place on the podium.

All India Inter AECS Science, Social Sc., Mathematics and teaching aid Exhibition

The Exhibition was organized by AECS-3, Tarapur, Maharashtra. Over 100 chosen projects of Science, Social Science, Mathematics and Teaching aids, from various AEC Schools and Junior colleges across India, were displayed by the Students (Juniors

Inter AECS Science, Social Science & Mathematics exhibition organised at AECS-3, Tarapur

and Seniors) and Teachers. The event was a wonderful display of extremely creative ideas the young generation today has, and a powerful display of what is the potential that the future India holds.

All India Inter AECS Sport Meet (Table Tennis)

Atomic Energy Central School, Kakrapar, was bestowed with the responsibility to conduct the All India Inter AECS Table Tennis Tournament - 2022 for U-14 boys and girls. The much-awaited sports Meet was hosted from 15th - 17th December 2022. The celebrations were held with great pomp to suit the occasion. 18 AEC Schools participated in the tournament. About 134 students and 30 escort teachers (including the host school) took part in this event.

Inter AECS table tennis competition
AECS, Kakrapar

In the inaugural ceremony on December 15th, Shri Sunil Kumar Roy, Site Director, Kakarpar Gujarat Site, and the Chief Guest of the function wished the event all success. More than 100 games were held in 3 days in 7 categories: boys and girls singles, boys' and girls' team, boys and girls' doubles, and mixed doubles. The participating players were encouraged and cheered throughout the matches. The students showcased a great sense of discipline and mastery of skill achieved through months of hard work. The spirit of sportsmanship was in the air. The atmosphere of the event was one of festivity and jubilance.

The International Umpire and Player, Shri B S Vaghela, and his team of 10 officiating referees from the Gujarat State Table Tennis Federation conducted the matches without any dispute. A campfire was arranged on December 16th.

The Chief Guest of the closing ceremony on December 17th, Professor (Dr.) P. Christopher Selvin, Registrar, Homi Bhabha National Institute, Anushaktinagar, Mumbai, in his presidential address, told the students about the origin of table tennis and the importance of games and sports. The culmination of the event witnessed loud cheers during the prize distribution ceremony. The evening ended on a high note with a look of accomplishment and pride on the faces of the students.

Training Programmes

Teachers from various centres attended Olympiad Exposure camp in Biology and Physics at HBCSE, Mumbai. Training on Gem Portal for Officials of Mumbai centre was organised at Central office, Mumbai. Management Development Programme for Principals of all Centres of AEES was organised from 26th to 30th December 2022 at ATI, Mumbai. Training on Service book maintenance for office staff of all centres in online mode was organised. Training on pay fixation for office staff of all centres in online mode was organised.

Recruitment drive

Departmental promotions Examinations and interviews for the post of HM, Vice-Principal and principals were held during 15th to 17th December 2022 at Central Office, Mumbai. CBT for Post of PGT and TGT in various subjects were held at different centres on 21-22 December 2022.

Achievements of students in Activities organised by External Organisations

AECS, Anupuram: N Azwar Aahil Class VIII secured Gold medals at National Level in Silambam (30-35 weight category) and Silambam (Youth Federation at India conducted at Delhi).

AECS-1, Hyderabad: A.Sharanya Class IX, K. Nirvaghna Class V, Arya Singh Class VII participated in State Level Painting Competition organised by the Bureau of Energy Efficiency, Ministry of Power, Govt. of India.

AECS, Jaduguda: Shanti Soren, student of class12th

(2021-22 batch) represented School in 23rd Youth National Volleyball at Rudrapur, Uttrakhand; Nikita Soren participated in National Volleyball tournament held at Jammu; A team of 11girls and 11 boys participated in CBSE Cluster Meet-3 held at DBMS, Kadma. Girls' Team secured 1st Position and Harshika Gupta Class XII won Limca Book of National Record Best Model 2022 award at Alee Club Miss and Mr Teen India competition at New Delhi.

AECS, Kaiga: Sumith Shankar secured 1st Position in Javelin Throw at CBSE, a Cluster VIII level athletic meet, Moodbidri, Uttar Kannada and Arbaz Khan secured 1st Position in Shot Put at CBSE, a Cluster VIII level athletic meet, Moodbidri, Uttar Kannada.

AECS-1, Kalpakkam: AECS-1 KPM, Boys & Girls Team participated in CBSE Cluster Athletic Meet Cluster Level Chennai Region.

AECS, Kudankulam: A Roshan Class X received Certificate of Participation in YUVIKA (Yuva Vigyan Karyakram 2022) organized by ISRO.

AECS, Manuguru: G.Naga Jaswanth secured 3rd Position in CBSE cluster meet VII in long jump.

AECS-1, Mumbai: Arinjit Mahato received Kokino International Karate Organisation Karate Brown Belt.

AECS-2, Mumbai: Riya Hire Class X selected in CBSE Regional Level Science Exhibition. She will participate at National Level.

AECS-4, Mumbai: Vedika Kulkarni Played All India Sub Junior Ranking Tournament at Goa in Main draw (U-15). Her All India Rank is 18. She got More than 5 titles in Singles, Doubles and Mixed double category at state level tournaments and Swati Pattanaik received Talent Search Scholarship for Odissi Dance honoured by the Ministry of Culture, Govt. of India.

Ms. Swati Pattanaik of AECS-4 received Talent Search Scholarship for Odissi Dance

AECS, Mysore: Devdarshan Class IV 'U-9 category' at Srirangapatna Dasara state chess tournament secured 1st Position and a Gold Medal.

AECS, Narora: Humam Ahmed Class XI secured 3rd Position in Central Zone at senior category NFLAT Examination.

AECS, Narwapahar: Habil Pratik Xalxo Class IX secured 2nd Position in shooting 25 meter range in the event held at NCC, Co-Operative College, Jamshedpur.

AECS, OSCOM: Vysyaraju Hansuja and Nadipulli Cellina Achari were the National Winner of Saksham National competition 2022 Quiz by PCRA.

AECS-2, Rawatbhata: Group of Students secured 1st Position in District level Folk and Patriotic song competition organised by Bharat Vikas Parishad. They represented Chittorgarh district and secured 4th Position at State Level Competition held at Kota; Lipika Das, Class VII State Level Painting Competition conducted by Bureau of Energy Efficiency (BEE) under Govt. of India held at Jaipur 3rd Position & cash prize of Rs.20,000 qualified for the National Level and Anusha Yadav Class X was a recipient of Rs.10000 and Certificate for INSPIRE-MANAK Award 2022-23.

AECS-3, Rawatbhata: Shreshth Pant Class XII Kota District Under-19 Cricket category in the Dungarpur Shield Tournament which was held at Udaipur. He is a player on the rolls of Rajasthan Cricket Association.He Took 4 wickets in 2 matches and Chahak Batra Class XII Rajasthan Cricket Association in the recently-concluded Under-19 Women's One Day Tournament which was organised under the aegis of BCCI (Board of Control for Cricket in India).

AECS-Turamdih: Abhinav Kumar Pandit, Vaibhav Kumar, Aneerudh Singh Class IX, Ayush Mahato Class X secured 2nd Position in Science Model Exhibition (National Creativity Olympiad) By Institute of Engineers, Jamshedpur.

DAE SPORTS & CULTURAL ACTIVITIES

DAE Sports and Cultural Council (DAE S&CC) looks after the promotion of sports and cultural activities among DAE employees and their families located at various units all over India. Its office located at the New Community Centre, Anushaktinagar is a demonstration hub of sports and cultural activities established by the Council in 1998. Ever since its inception, for more than thirty-six years, the DAE S&CC has been facilitating promotion of sports, physical fitness, yoga and cultural activities among DAE employees and their family members located at various units all over India. Special emphasis is being put for the overall development of school children and events & activities were also undertaken for the same. Considering that the mandate of sustainable nuclear power needs the inculcation of positive attitude, team work, nurturing of excellence and building up of competitive spirit amongst the employees, DAE S&CC's thrust has been to encourage facilitation of activities towards these themes. In addition, programs are also designed to develop positive health and attitude towards achievement of excellence amongst family members of employees.

The XXXVII Annual DAE Sports and Cultural Meet was conducted in all the sixteen different sports and cultural events (Athletics, Ball Badminton, Cricket, Chess, Cultural, Carrom, Basketball, Volleyball, Football, Lawn Tennis, Bridge, Badminton, Table tennis, Hockey, Swimming and Kabaddi) at various units of DAE at different locations of the country. DAE S&CC nominated observer for each event in order to make sure that the events get conducted as per the guidelines issued by DAE S&CC.

DAE units participated in the different Sports and cultural events through eight groups viz Ajanta, Dwarika Ellora, Golkonda, Konarc, Nagarjama, Pushakar and Rajeshwalru. Inter Unit Selection trials were conducted by the Leader Unit and about 1600 employees participate in the final meets. To conduct these final meets, playing facilities at various units were upgraded so that these DAE events could get conducted in the best traditions of the Department. As per tradition, DAE S & CC decided to give suitable mementoes as token of the Department's appreciation to all participants and volunteers who contributed to the success of this meet. Teams for participation in National events like, Kabbadi, Bridge, Table Tennis, Lawn Tennis, Ball Badminton, Badminton etc. were also selected during the meet.

Ajanta Team, the winner of XXXVII DAE S&C cricket meet

Badminton Meet at IGCAR Kalpakkam

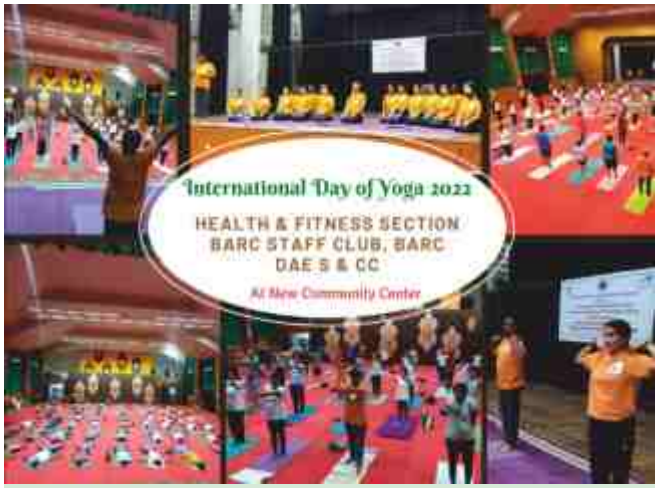
Basketball Meet at RRCAT Indore

Carrom Meet at RAPS, Rawatbhata

Every Year Special Summer Coaching camps are organized jointly by DAE S&CC and Atomic Energy Education Society (AEES) as a regular annual event with more than 1500 children of DAE employees in the age group of 10-14 years receiving entry level coaching in various games and sports like Athletics, Swimming, Cricket, Football, Basketball, Table Tennis, Badminton, Lawn Tennis etc. This is conducted at about 17 AEES centers covering about 30 schools all over India. Based on the camps, advanced coaching scholarship is provided in various games like Badminton, Table Tennis, Lawn Tennis, Cricket, Swimming, Athletics, Handball, Kabbadi etc. This scholarship scheme has been running for more than two decades and has provided excellent results. More than 250 children were benefited from this scheme which was conducted at Mumbai, Anupuram, Kaiga, etc.

Under the Health and Fitness Activities, regular yoga activities as well as camps were organized at different centres at various levels for employees as well as for their family members.

The international yoga day was celebrated on 21st June at various Govt organizations and school and colleges in and around Anushaktinagar as per the protocol AYUSH, Govt. of India. Live demonstration and instruction of yogic posture as per AYUSH protocol were done by senior yoga teachers. Response for the event was overwhelming. Yoga Summer courses were also



The international yoga day was celebrated on 21st June 2022 at Anushaktinagar, Mumbai

organized for the benefit of employees and family members.

Yoga Circle also organized motivational talk by Dr Harish Shetty (Renowned Psychiatrist) at BARC CC Auditorium and also at DAE Convention Centre. He talked on "Work-Life Balance and Managing Performance Pressure as well as on "Building Emotional Wealth & Emotional Equity". Both the talks were interactive in nature with good participation from the employees and family members. Training on CPR in collaboration with BARC Hospital was organized by Yoga Circle.

DAE S&CC and NFC Hyderabad had successfully organised 6th DAE National Yoga workshop on the theme "Yoga for Absolute Fitness-Mind & Body" on 12th and 13th November, 2022. This workshop was organised at Dr Homi Bhabha Convention Centre, Nuclear Fuel Complex, Hyderabad and it was a grand success. About 350 participants attended the workshop from different units of DAE.

Team Girisanchar of DAE S&CC had arranged various Nature & Adventure related activities throughout the year. These includes Himalayan Trekking expeditions, Monsoon treks, Nature & Adventure Camp for school children, Cyclothon, Walkathon, Know Your Trees Walk for school Children etc. Girisanchar-32 (32nd All India DAE Trekking Expedition) was organized in "Bhandardara -Malshej Ghat" region from January 16th 2023 to January 29th 2023.

Twelth All India DAE Himalayan Trekking Expedition (Trek the Himalaya-12) was organised in "Ali-Bedni Bugyal region" of Uttarakhand" from 19th September 2022 to 26th September, 2022 with expedition leaders Shri Nitin Dhoble & Shri Vinod Khanvilkar. Trekking expedition was completed safely and successfully and participants were handed over completion certificate.

12th All India DAE Himalayan Trekking Expedition participants climbing the hill

DAE Sports and Cultural Council in collaboration with BARC Staff Club had successfully conducted Thirty Second All India DAE Trekking Expedition "GIRISANCHAR-32 "during 16th January 2023 to 29th January 2023. This was a week-long trekking activity. The expedition had the prior approval of Indian Mountaineering Foundation, New Delhi. About 225 participants from various units of DAE took part in this event. This event was managed by team Girisanchar comprising of dedicated team of well-trained leaders in a professional manner in collaboration with Nature & Adventure Circle BARC Staff Club. The entire trek route was one of the most fascinating, revealing hidden beauty & treasure of Kalsubai-Harishchandragad WLS of Bhandardara-Malshej ghat region.

32nd All India DAE Trekking Expedition "GIRISANCHAR-32 organised during 16th to 29th January 2023

Outreach Programme during Girisanchar-32 was conducted to reach out to the villages and village schools near the camp sites. Lectures and events were organized for the school students and all these activities were very-well received and appreciated by the local villagers, school children & teachers.

Team Girisanchar and Nature & Adventure Circle, BARC Staff club also organized ten Monsoon treks for the employees at various hills and forts in the vicinity of Mumbai. All the treks were conducted and completed safely and successfully. Children & participants were introduced to the Flora encountered during the treks.

Children's trek at Bhivgad

Nature and Adventure Camp for the children of DAE employees was organised at Van Vihar Camp Site, Ambivali village in Karjat region, during 22nd - 25th December 2022. About 76 children (between age group of 9-13 yrs.) participated in this event. The objective of the camp was to promote the spirit for adventure among the youngsters. Adventure activities inculcate courage, patience, determination, leadership, confidence, team

Participants of Nature & Adventure Camp-2022

spirit and cultivate a love for the environment and respect for nature and infuse a sense of camaraderie in their minds through camping experience. Obstacles, Nature Trail & Introduction to Flora & Fauna, Rock climbing, Rappelling, River Crossing, River Rafting, Burma Bridge Crossing, Jumaring, Star Gazing, Trekking, Fun Games & Introduction to First Aid and Slide shows on various topics were organised. During all these activities utmost care was taken for the safety of the children.

As a part of "Azadi ka Amrit Mahotsav" celebration at BARC, "walkathon-2022" a 6 km walking competition was organized in Anushaktinagar by BARC staff club Nature and Adventure Circle (Team Girisanchar) & DAE Sports & Cultural Council on Sunday 24th July 2022. About 700 participants from various DAE units and their family members participated overwhelmingly in this event.

"Walkathon-2022" flagged off by Dr. A. K. Mohanty, Director, BARC

Participants of 75km Cycling ride at Anushaktinagar

Country-wide celebrations are being undertaken under the 'Azadi ka Amrit Mahotsav' campaign to commemorate the completion of 75 years of India's independence. In view of this, team Girisanchar & Nature and Adventure Circle of BARC Staff Club had organised a 75 km Cycling ride in Anushaktinagar. About 84 participants successfully completed the event. Medals were given to participants on successful completion of the 75km ride.

In order to promote Art, Culture& Cultural activities, DAE Cultural Centre (DCC) had organised various activities like Dance, Drama, Music, Literature, Traditional Art, Films etc. DCC Annual day was

DCC Annual Day Cultural event

Children participating in the Drawing workshop

celebrated on 12th February 2023 and response was overwhelming. DCC had also organized Photography Workshop, Flute & Vocal Concert in collaboration with Bhaktha Rasika Ranjani Sabha, Pottery & Drawing workshops. Students had also appeared for drawing grade examination & in Hindustani Music examination conducted by Akhil Bharatiya Gandharva Mahavidyalaya Mandal.

New community centre is a demonstration hub of DAE Sports and cultural activities established by the Council in 1998. It catered to all the Indoor sports activities for the employees and family members. These activities comprised of Fitness (Aerobic, Power Yoga & Zumba for Ladies, Gymnasium for Ladies & Gents), Badminton, Table Tennis, Chess, Carrom, Snooker, Bridge and Cricket. NCC also conducted Children coaching for Dance, Badminton, Table Tennis, Cricket, Chess, Keyboard and Carrom. Children Cricket Coaching feedback session was arranged and Mumbai Ranaji Team captain Shri A. Tare was the Chief Guest for the session. He encouraged and motivated the young minds.

International Women's day was also celebrated by NCC in a grand way and the response was overwhelming. Walkathon was also organized for women.

New Community Centre under DAE S&CC had organised SPLASH-2022 sports and cultural meet at Anushaktinagar from 30th July to 9th August 2022 as a part of Azadi Ka Amrit Mahotsav Celebration. Current or Ex-DAE Employees, their dependent family members, regular trainees of various DAE units in Mumbai/Navi Mumbai and existing members of NCC participated in this Spalsh-2022 meet and response was overwhelming. Events conducted included Badminton, Bridge, Carrom, Chess, Fitness, Dance, Karaoke Singing, Musical Keboard, Guitar, Rubiks Cube, Snooker and Table Tennis.

DAE Sports & Cultural Council has taken an initiative to start this ambitious pan india movement titled BhaBhaShiS which stands for Bhasha Bharatee Shikhan Sanstha भाभाशीस.Council arrived at this abbreviation after lot of thought as everything in DAE is

Senior officials of DAE attending the first function of "BhaBhaShiS" organised on 4th September 2022 at Anushaktinagar

blessed by Dr. Bhabha. It also has blessings of भाषा भारती or the goddess Saraswati who is the goddess of learning. In a multilingual country like India, language is instrumental in shaping the learning, thinking and identity of people. BhaBhaShiS is one step taken by DAE Sports & Cultural council towards this goal. The first function of this new initiative to learn languages was organised on 4th September 2022 at NCC. The aims is to promote and facilitate learning of all languages to enhance effectiveness of communication among DAE fraternity. Teachers and scholars who had been involved in language teaching, professionally or informally, were invited to participate in the program. The program consisted of showcasing presentations on various languages through projection as well as posters. Guest of honour for the program was Dr Rajagopala Chidambaram, Former Principal Scientific Adviser to the Government of India and former chairman, Atomic Energy commission.

As a part of AKAM celebration in BARC, Anushaktinagar Monsoon Marathon 2022 (AMM 2022) was organized by BARC Staff Club-Athletics Section, on Sunday 28th August 2022 in three categories namely 2.5 Km Fun Run, 5 Km Mini Marathon and 10 Km Anushakti Run. The response was overwhelming and around 1100 participants participated in the event. For accurate time tracking of 10 Km runners, a high-end technology was deployed to provide seamless race experience and set higher race standards for runners.

Dr. R. Chidambaram, Former Chairman, AEC & Secretary, DAE and Dr. A. K. Mohanty, Director, BARC participating in the Anushaktinagar Monsoon Marathon 2022 (AMM 2022) was organized on Sunday 28th August 2022 at Anushaktinagar

Equipment with high functioning RFID antennas was placed along the route.

As a part of celebrations of AKAM, BARC Staff Club Art Section conducted a photography exhibition from February to June 2022. The exhibition was aimed at displaying the splendour and legacy of our country through 20 meticulously chosen topics. Dr. A. K. Mohanty, Director, BARC inaugurated the photography exhibition of the winning entries (87 photographs) at Central Complex Auditorium, BARC on 23rd August 2022.

Photography exhibition organised at Central Complex Auditorium, BARC on 23rd August 2022

As a part of celebration of AKAM, two cultural events entitled “Understanding Chhau, the traditional semiclassical dance of India” were organized on 22.4.2022 (at BARC) and 23.8.2022 (at Anushaktingar, Mumbai) by BARC Staff Club in association with Srikalapith (Seraikelaa). Chhau (छउ) is a semi-classical dance tradition of eastern India that enacts local legends, folklore and episodes from the epics Ramayana, Mahabharata and abstract themes. The most praiseworthy feature of India's Chhau tradition is that it plays an amazing role in bringing people together from diverse socio-economic backgrounds in a festive and religious spirit. In short, Chhau is a people's art involving & uniting the entire community. Chhau performances were performed by Seraikella dance troupe.

Seraikella Dance Troupe performing the Chhau dance performances

The DAE Ball Badminton Team participated in the 68th Senior National Ball-Badminton Championship at Kottarakara, Kerala from 24-12-2022 to 28-12-2022. A team of Players was selected during the 36th Annual DAE Sports & Cultural Meet-2021-22. DAE was in Pool F and it won 6 out of 6 matches and became “Pool F winner”.

Dr. A. K. Mohanty encouraging the DAE Sub-junior Ball Badminton Team boys & girls

The DAE Sub-junior Ball Badminton Team (Girls & Boys) for the first time had participated in the 41st National Sub-Junior Ball-Badminton Championship held at Srirampur, Mancherial, Telangana from 16th to 20th February. To encourage the young talent (10 girls and 10 boys from 9 years to 14 years), Director, BARC distributed game kits to the participating players and interacted with them at the Ballbadminton court at Anushaktinagar. Both teams stood 4th in their respective pools out of seven teams. A very proud moment and a great Achievement. It was a good learning experience for the team members as well as for the accompanying faculty members.

Inter State National Bridge Championship 2022 was held in PYC Hindu Gymkhana, Pune from 14/09/22 to 18/09/22. Even though the event is a contest between top teams of different States, it is a matter of pride that DAE is considered good enough to contest as a state in the Championship and DAE Sports & Cultural Council is an affiliated body of Bridge Federation of India for past many years. Four players of BARC, Trombay represented DAE S&CC in this event and participated in the Team Event & IMP Pairs Event of the Championship. In the team event 28 teams were divided in three groups. DAE was placed 5th out of 10 teams in Group C, which is the best position finish by DAE team during last many years.

AWARDS & PRIZES

TAPS-1&2 received the National Safety Council India (NSCI) Safety Award (Prashansa Patra) for the assessment period of three years 2018-2020 and it also received the National Safety Council (Maharashtra Chapter) awarded plaques (2 Nos.)to TAPS-1&2 for "Factories Working over One Million Man-Hours under two scheme i.e. Scheme-I - Lowest Accident Frequency Rate and Scheme- II - Longest Accident Free Period for the year 2020.

TAPS-3&4 was conferred with Lowest Average Accident Frequency Rate for the year 2019 and Longest Accident Free Period for the year 2019 and 2020 by National Safety Council (NSC) - Maharashtra Chapter. The award trophies (A Plaque) have been received on April 23, 2022 in the Safety Professional Meet NSC-Maharashtra Chapter. It received 'Golden Peacock Occupational Health & Safety Award' for the year 2022 on August 25, 2022 and it also received the Certificate of appreciation from National Safety Council awards for the Year 2021.

Awards received by TAPS-3&4 from NSCI

TAPS-3&4 received Golden peacock Occupational Health & Safety award

MAPS-1&2 received Certificate of appreciation from National Safety Council awards for the Year 2021.

KAPS-1&2 received AERB Fire Safety Award for the year 2020 in production units category-I. AERB Fire Safety Award for the year 2021 in production units category-I. AERB Industrial Safety Award for the year 2021 in production units category-I. and National Safety Council (NSC) conferred "Prashansa Patra" Certificate of appreciation in NSC Safety Awards-2021 in Group-C.

KAPS-3&4 bagged AERB Industrial Safety Award-2021in Construction Units category. It also bagged the prestigious Safety Award "Suraksha Puraskar" from National Safety Council, India for the year 2021.

NPCIL Bagged Second prize shield awarded in PSU category to Tarapur Maharashtra Site (TMS) at district level by TOLIC (Town Official Language Implementation Committee), Thane for best implementation of official language Hindi in a programme organised on August 29, 2022. NPCIL was felicitated for Outstanding Contribution in OL Implementation by "Aashirwad" an NGO working for propagation of Hindi in Mumbai since 1969. This award function was chaired by His Excellency Governor of Maharashtra on 21st September, 2022 at Governor House.

TAPS received second prize shield from TOLIC, Thane

Award for Outstanding Contribution in OL Implementation from Aashirwad

NPCIL was adjudged with Third prize in the category of Best Public Awareness Program by the Public Relations Society of India at the Public Relations Conference on Aatma Nirbhar Bharat: Role of Public Relations held at Bhopal during December 25 - 27, 2022.

Five HRPU staffs were awarded for excellent works/duties discharged in newly introduced GeM portal and 2 HRPU staff awarded with individual award for meritorious performance. Five Employees of HRSU were awarded for the exemplary work carried out in GeM.

ECIL was awarded IEI Industry Excellence Award 2021 for demonstrating a high order of business excellence Rajbhasha Shield and Best Magazine Award by TOLIC Hyderabad for implementation of official language. Telangana Water Conservation Award 2021 in recognition of significant contributions made by ECIL towards Water Conservation.

During the year, IREL conferred various awards which ensured better visibility and enhance its brand value. These awards were "National Safety Award" for Longest Accident Free Period-2019 awarded by Hon'ble Minister of Labour & Employment, Environment, Forest and Climate Change, Govt. of India. IREL, Tamilnadu Unit has also received "Runner in Lowest Injury Frequency Rate-2018 & 19. "9th Greentech CSR Award 2022" for "Outstanding Achievements in Promotion of Healthcare". "Greentech Export Award 2022" for "Outstanding Achievements as Manufacturer Exporter". "Best CMD Corporate Management Innovative Leadership Excellence Award" during the 21st Annual Geomintech International Symposium on New Equipment New Technology Management and Safety in Mines and Mineral based Industries held in Bhubaneswar during 23-24 October 2021.

IREL (India) Limited received many awards namely Violet Diamond HR Excellence, Indigo Brow

Chakra CSR Excellence, Blue Agate Machinery Equipment Maintenance, Green Emerald Environment Excellence, Yellow Sapphire Overall Production Glitter, Orange Crystal Occupational Health & Safety and Red Carpet Swachh Bharat Mission & Pandemic Covid-19 Management Excellence for its excellent performance across all quarters over the past five years. “Leading Director Award 2021" to CMD, IREL during the Leading Directors' conclave conducted by the Greentech Foundation on 27th Aug 2021.

“Outstanding Business Leadership Award 2022” was awarded to CMD, IREL by International Achievers Conference. IREL (India) Limited, Corporate Office has also been awarded with the third prize for the year 2020-21 for “Excellent Official Language Implementation”.

Scientists from TIFR won many prestigious awards during this period. Prof. Vivek Polshettiwar (DCS) was awarded the 2022 CHEMRAWN VII Prize by 'The International Union of Pure and Applied Chemistry (IUPAC)' for developing novel nanomaterials for catalysis, solar energy harvesting, and C02 capture-conversion to tackle 'climate change'. Prof. Vidita A. Vaidya (DBS) and Prof. Nissim Kanekar (NCRA, Pune) have been awarded the Infosys Prize 2022, by the Infosys Science Foundation, for Life Sciences and Physical Sciences, respectively. Prof. Shubha Tole (DBS) received the Bernice Grafstein Award for Outstanding Accomplishments in Mentoring. Prof. Rama Govindarajan (ICTS, Bengaluru) received the IIT Delhi Distinguished Alumni Award in recognition of her outstanding achievements in teaching and research. Prof. Shannon Olsson (NCBS, Bengaluru), was honoured in the 2nd edition of the 'She Is' book series about 75 inspiring Women In STEAM from India. This honour has been given by the Office of the Principal Scientific Advisor to the Government of India in partnership with Red Dot Foundation, British High Commission, and FICCI FLO. Prof. Manas Kulkarni (ICTS, Bengaluru) featured in the book '75 Under 50: Scientists Shaping Today's India', published by the Department of Science and Technology, Government of India. The Zubin Kembhavi Award in the area of 'Observational and Instrumentation Work in Astronomy and Allied Fields' for the year 2021 was awarded to the Team-AstroSat for successful design, build, launch and operations of India's first multi-wavelength space observatory 'AstroSat'.

CHAPTER 11

The Department of Atomic Energy has a mandate to develop peaceful uses of nuclear energy in areas like power generation and basic research in frontier areas of science and technology. In view of the nature of activities carried out by the Scientific and Technical persons in various Research Centres, Public Sector Undertakings, Industrial Units and Aided Institutions of the Department, this Department is not in a position to implement the provisions of reservation of posts fully as required under the "Persons with Disabilities (Equal Opportunities, Protection of Rights and Full Participation) Act, 1995". Therefore, this Department has already sought exemption for the Units like Heavy Water Boards and Nuclear Power Corporation of India Ltd. From the provisions of the said Act. No specific scheme under plan projects for the benefit of persons with disabilities has been introduced in the Department. In-spite of the constraints, all the Units/PSUs/Aided Institutions have attempted to identify posts, where persons with disabilities could be employed without impairing the activities or causing inconvenience.

The sanctioned strength and number of persons with disabilities in various posts in Group A, B, C & D against 3% vacancies to be reserved for them under Section 33 of the said Act is indicated in the pages that follow.

IMPLEMENTATION OF PERSONS WITH DISABILITIES (EQUAL OPPORTUNITIES, PROTECTION OF RIGHTS & FULL PARTICIPATION) ACT, 1995

ANNUAL STATEMENT SHOWING THE REPRESENTATION OF **PERSONS WITH DISABILITIES** AS ON **01.01.2023** AND NUMBER OF APPOINTMENTS MADE DURING THE PRECEDING CALENDAR YEAR **2022** IN RESPECT OF **CONSTITUENT UNITS**

Group	Number of Employees					Direct Recruitment									By Promotion							
						No. of vacancies reserved				No. of appointment made					No. of vacancies reserved			No. of appointment made				
	Total	Category (a)	Category (b)	Category (c)	Category (d&e)	Category (a)	Category (b)	Category (c)	Category (d&e)	Total	VH	HH	OH	D&E	VH	HH	OH	Total	VH	HH	OH
(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)		(9)	(10)	(11)	(12)		(13)	(14)	(15)	(16)	(17)	(18)	(19)
Group A	10311	3	5	54	0	1	1	7	0	130	0	0	1	0	0	0	0	73	0	0	2
Group B	8497	5	12	94	0	3	7	6	0	113	0	0	1	0	0	0	0	393	0	1	7
Group C	8817	10	40	86	0	18	24	23	13	432	0	0	1	0	0	0	0	1278	0	0	2
TOTAL	**27625**	**18**	**57**	**234**	**0**	**22**	**32**	**36**	**13**	**675**	**0**	**0**	**3**	**0**	**0**	**0**	**0**	**1744**	**0**	**1**	**11**

Respective Categories:

(a) Blindness and low vision;

(b) Deaf and hard of hearing;

(c) Locomotor disability including cerebral palsy, leprosy cured, dwarfism, acid attack victims and muscular dystrophy;

(d) Autism, intellectual disability, specific learning disablility and mental illness;

(e) Multiple disabilities from amongst persons under clauses (a) to (d) including deaf-blindness;

ANNUAL STATEMENT SHOWING THE REPRESENTATION OF **PERSONS WITH DISABILITIES** AS **01.01.2023** AND NUMBER OF APPOINTMENTS MADE DURING THE PRECEDING CALENDAR YEAR **2022** IN RESPECT OF **AIDED INSTITUTIONS**

Group	Number of Employees					Direct Recruitment									By Promotion							
						No. of vacancies reserved				No. of appointment made					No. of vacancies reserved				No. of appointment made			
	Total	Category (a)	Category (b)	Category (c)	Category (d&e)	Category (a)	Category (b)	Category (c)	Category (d&e)	Total	VH	HH	OH	D &E	VH	HH	OH	Total	VH	HH	OH
(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)		(9)	(10)	(11)	(12)		(13)	(14)	(15)	(16)	(17)	(18)	(19)	
Group A	1638	3	1	10	1	1	1	2	0	1	0	0	1	0	0	0	0	0	0	0	0	
Group B	3437	3	5	23	1	2	2	9	2	0	0	0	0	0	0	0	0	0	0	0	0	
Group C	2339	6	13	31	2	2	0	3	0	1	1	0	1	0	0	0	0	0	0	0	0	
TOTAL	**7414**	**12**	**19**	**64**	**4**	**5**	**3**	**14**	**2**	**2**	**1**	**0**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	

Respective Categories:

(a) Blindness and low vision;

(b) Deaf and hard of hearing;

(c) Locomotor disability including cerebral palsy, leprosy cured, dwarfism, acid attack victims and muscular dystrophy;

(d) Autism, intellectual disability, specific learning disablility and mental illness;

(e) Multiple disabilities from amongst persons under clauses (a) to (d) including deaf-blindness;

ANNUAL STATEMENT SHOWING THE REPRESENTATION OF **PERSONS WITH DISABILITIES** AS **01.01.2023** AND NUMBER OF APPOINTMENTS MADE DURING THE PRECEDING CALENDAR YEAR **2022** IN RESPECT OF **PUBLIC SECTOR UNDERTAKINGS**

Group	Number of Employees					Direct Recruitment									By Promotion							
						No. of vacancies reserved				No. of appointment made					No. of vacancies reserved				No. of appointment made			
	Total	Category (a)	Category (b)	Category (c)	Category (d&e)	Category (a)	Category (b)	Category (c)	Category (d&e)	Total	VH	HH	OH	D &E	VH	HH	OH	Total	VH	HH	OH
(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)		(9)	(10)	(11)	(12)		(13)	(14)	(15)	(16)	(17)	(18)	(19)
Group A	7703	13	9	71	1	2	3	1	0	266	0	3	2	1	0	0	0	231	1	0	1
Group B	4247	18	11	71	0	2	3	3	0	9	1	0	0	0	0	0	0	28	0	0	0
Group C	3694	7	10	47	0	11	10	10	0	76	2	2	5	0	0	0	0	39	0	0	0
TOTAL	**15644**	**38**	**30**	**189**	**1**	**15**	**16**	**14**	**0**	**351**	**3**	**5**	**7**	**1**	**0**	**0**	**0**	**298**	**1**	**0**	**1**

Respective Categories:

(a) Blindness and low vision;

(b) Deaf and hard of hearing;

(c) Locomotor disability including cerebral palsy, leprosy cured, dwarfism, acid attack victims and muscular dystrophy;

(d) Autism, intellectual disability, specific learning disablility and mental illness;

(e) Multiple disabilities from amongst persons under clauses (a) to (d) including deaf-blindness;

CHAPTER 12

CITIZENS CHARTER

Government of India
Department of Atomic Energy

CITIZENS CHARTER

I) OUR VISION

The vision of the Department of Atomic Energy is to empower India through technology, creation of more wealth and providing better quality of life to its citizen. This is to be achieved by making India energy independent, contributing to provision of sufficient, safe and nutritious food and better health care to our people through development and deployment of nuclear and radiation technologies and their applications.

II) MANDATE

The mandate of the Department, on which its programmes are based, covers :

- Increasing share of nuclear power through deployment of indigenous and other proven technologies, along with development of fast breeder reactors and thorium reactors with associated fuel cycle facilities ;
- Building and operation of research reactors for production of radioisotopes and carrying out radiation technology applications in the field of medicine, agriculture and industry, cancer care, water related technologies, waste management etc.;
- Developing advanced technologies such as accelerators, lasers, supercomputers, advanced materials and instrumentation, and encouraging transfer of technology to industry;
- Support to basic research in nuclear energy and related frontier areas of science; interaction with universities and academic institutions; Support to research and development projects having a bearing in DAE's programmes, and international cooperation in related advanced areas of research, and
- Contribution to national security.

III) OUR ACTIVITIES

- The Department is engaged in the design, construction and operation of nuclear power / research reactors and the supporting nuclear fuel cycle technologies covering exploration, mining and processing of nuclear minerals, production of heavy water, nuclear fuel fabrication, fuel reprocessing and nuclear waste management. It is also developing advanced technologies which contribute to the national prosperity. The human resource developed and technical services being rendered by the Department have been greatly helping the Indian industry.
- The Department is also developing better crop varieties, techniques for control/eradication of insects thus protecting the crops, radiation based post harvest technologies, radiation based techniques for diagnosis and therapy of disease particularly cancer, technologies for safe drinking water, better environment and robust industry.

IV) OUR CLIENTS

- User Ministries/Departments of Central Govt. and State Govt. dealing with energy, agriculture, food, health, education, oil and petroleum, industry, science and technology etc.
- Quasi Govt. Organisations, NGOs, industrial organizations, educational institutes.
- Electricity Boards, Hospitals, Research / Medical / Educational / Academic Institutions, agriculturists etc.

V) LINK TO RTI PORTAL

· Visit the link www.rti.gov.in

VI) WHOM TO CONTACT

I. Nodal Officer and Nodal Appeal Authority for CPGRAMS

Shri E.Ravendiran,
Director(SCS) & Nodal Officer,
Department of Atomic Energy,
Anushakti Bhavan, C.S.M. Marg,
Mumbai – 400 001.
Tel. No.022-2286 2531
Email I.D. – diradmn@dae.gov.in

Shri Sanjay Kumar,
Joint Secretary (A&A) & Nodal Appeal Authority
Department of Atomic Energy,
Anushakti Bhavan, C.S.M. Marg,
Mumbai – 400 001.
Tel. No.022-22840309
Email I.D. – jsaa@dae.gov.in

I. Vigilance Complaints

Shri Sanjay Kumar, Joint Secretary (A&A) &
Chief Vigilance Officer,
Department of Atomic Energy,
Anushakti Bhavan, C.S.M. Marg,
Mumbai – 400 001.
Tel. No.022-22840309
Email I.D. – jsaa@dae.gov.in

II. Nodal Officer / Contact Officer for Citizen's Charter of DAE

Shri Sanjay Kumar, Joint Secretary (A&A) &
Nodal Officer/Contact Officer for Citizen's Charter of DAE
Department of Atomic Energy,
Anushakti Bhavan, C.S.M. Marg,
Mumbai – 400 001.
Tel. No.022-22840309
Email I.D. – jsaa@dae.gov.in

III. Public Relations

Dr. R. K. Vatsa, Head, Public Awareness Division,
Department of Atomic Energy,
Anushakti Bhavan, C.S.M. Marg,
Mumbai – 400 001.
Tel. No. 022-22862505
Email: - rajesh.vatsa@dae.gov.in

Government of India
Department of Atomic Energy
Anushakti Bhavan, C.S.M. Marg,
Mumbai - 400 001

NOTICE

We, the public servants of India do hereby solemnly pledge that we shall continuously strive to bring about integrity and transparency in all spheres of our activities. We also pledge that we shall work unstintingly for eradication of corruption in all spheres of life. We shall remain vigilant and work towards the growth and reputation of our Department. Through our collective efforts, we shall bring pride to our Department and provide value based service to our countrymen. We shall do our duty conscientiously and act without fear or favour.

This office is thus committed to maintaining the highest level of ethics in its working towards achieving the above objective, all are requested:

- Not to pay bribe
- If anybody in this department or its offices asks for bribe : or
- If you have any information on corruption: or if you are a victim of corruption in any of our offices.

You MAY COMPLAIN TO:-

Shri Sanjay Kumar, Joint Secretary (A&A) &
Chief Vigilance Officer,
Department of Atomic Energy,
Anushakti Bhavan, C.S.M. Marg,
Mumbai – 400 001.
Tel. No.022-22840309
Email I.D. – jsaa@dae.gov.in

YOU CAN ALSO COMPLAIN TO THE :-

CENTRAL VIGILANCE COMMISSION,
Satarkta Bhavan, Block 'A',
GPO Complex, INA,
New Delhi – 110 023.
Tel. No. 011-24651084
Fax No. 011-24651010/24651186

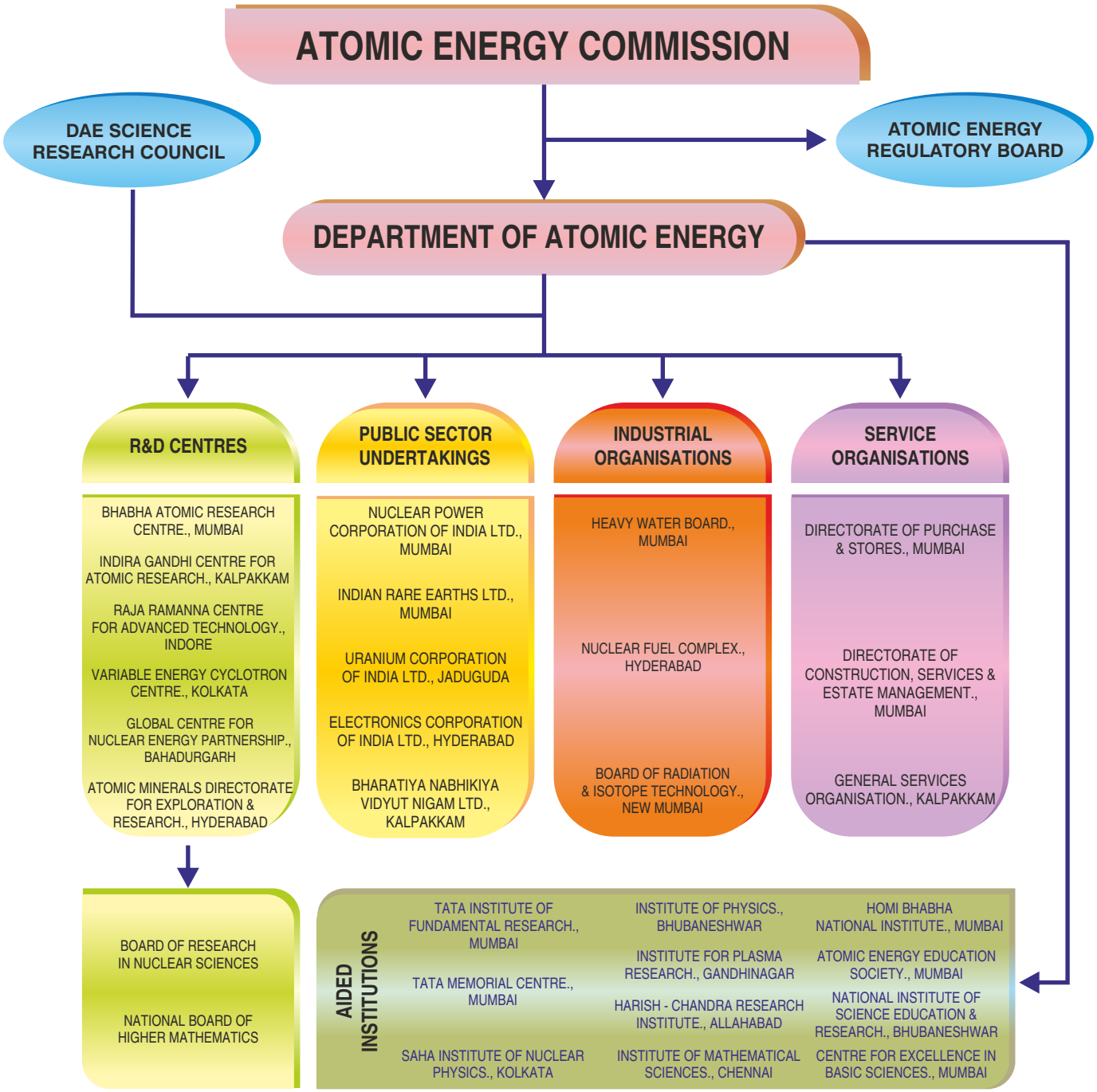
ANNEX-I

THE ORGANISATION

The Department of Atomic Energy (DAE), that came into being on August 3, 1954, has been engaged in the development of nuclear power technology, applications of radiation technologies in the fields of agriculture, medicine, industry, and basic research.

An integrated group of organizations, the Department comprises six Research Centres, three Industrial Organisations, five Public Sector Undertakings and three Service Organisations. It has under its aegis two Boards for promoting and funding extra-mural research in nuclear and allied fields, and mathematics, and a national institute (deemed university).

It also supports Ten institutes of international repute engaged in research in basic sciences, astronomy, astrophysics, cancer research and education, etc., and a society that provides educational facilities to the children of DAE employees.


ATOMIC ENERGY COMMISSION
DAE SCIENCE RESEARCH COUNCIL
ATOMIC ENERGY REGULATORY BOARD
DEPARTMENT OF ATOMIC ENERGY
R&D CENTRES
BHABHA ATOMIC RESEARCH CENTRE., MUMBAI
INDIRA GANDHI CENTRE FOR ATOMIC RESEARCH., KALPAKKAM
RAJA RAMANNA CENTRE FOR ADVANCED TECHNOLOGY., INDORE
VARIABLE ENERGY CYCLOTRON CENTRE., KOLKATA
GLOBAL CENTRE FOR NUCLEAR ENERGY PARTNERSHIP., BAHADURGARH
ATOMIC MINERALS DIRECTORATE FOR EXPLORATION & RESEARCH., HYDERABAD
PUBLIC SECTOR UNDERTAKINGS
NUCLEAR POWER CORPORATION OF INDIA LTD., MUMBAI
INDIAN RARE EARTHS LTD., MUMBAI
URANIUM CORPORATION OF INDIA LTD., JADUGUDA
ELECTRONICS CORPORATION OF INDIA LTD., HYDERABAD
BHARATIYA NABHIKIYA VIDYUT NIGAM LTD., KALPAKKAM
INDUSTRIAL ORGANISATIONS
HEAVY WATER BOARD., MUMBAI
NUCLEAR FUEL COMPLEX., HYDERABAD
BOARD OF RADIATION & ISOTOPE TECHNOLOGY., NEW MUMBAI
SERVICE ORGANISATIONS
DIRECTORATE OF PURCHASE & STORES., MUMBAI
DIRECTORATE OF CONSTRUCTION, SERVICES & ESTATE MANAGEMENT., MUMBAI
GENERAL SERVICES ORGANISATION., KALPAKKAM
BOARD OF RESEARCH IN NUCLEAR SCIENCES
NATIONAL BOARD OF HIGHER MATHEMATICS
AIDED INSTITUTIONS
TATA INSTITUTE OF FUNDAMENTAL RESEARCH., MUMBAI
TATA MEMORIAL CENTRE., MUMBAI
SAHA INSTITUTE OF NUCLEAR PHYSICS., KOLKATA
INSTITUTE OF PHYSICS., BHUBANESHWAR
INSTITUTE FOR PLASMA RESEARCH., GANDHINAGAR
HARISH - CHANDRA RESEARCH INSTITUTE., ALLAHABAD
INSTITUTE OF MATHEMATICAL SCIENCES., CHENNAI
HOMI BHABHA NATIONAL INSTITUTE., MUMBAI
ATOMIC ENERGY EDUCATION SOCIETY., MUMBAI
NATIONAL INSTITUTE OF SCIENCE EDUCATION & RESEARCH., BHUBANESHWAR
CENTRE FOR EXCELLENCE IN BASIC SCIENCES., MUMBAI

ATOMIC ENERGY ESTABLISHMENTS IN INDIA

BRNS : Board of Research in Nuclear Sciences
HBNI : Homi Bhabha National Institute
NBHM : National Board for Higher Mathematics
SSSF : Solid Storage Surveillance Facility
WIP : Waste Immobilisation Plant
AEES : Atomic Energy Education Society
ACTREC : Advanced Centre for Treatment, Research & Education in Cancer
TIFR : Tata Institute of FundamentalResearch
TMC : Tata Memorial Centre
DCS&EM : Directorate of Construction, Services & Estate Management
DPS : Directorate of Purchase & Stores

Research & Development Organisations | Public Sector Undertakings | Industrial Facilities | Grant-in-aid Organisations | Service Organisations

Major Programmes and Sub-Programmes

MP 1		MP 2		MP 3		MP 4		MP 5		MP 6		MP 7	
1.01	PHWR	2.01	Fast Reactors	3.01	Advanced Heavy Water Reactor	4.01	Research Reactors	5.01	Mathematics & Computational Sciences	6.01	Human Resource Development	7.01	Infrastructure
1.02	LWR	2.02	Materials	3.02	Thorium Fuel Cycle	4.02	Isotope Processing	5.02	Physics	6.02	Sponsored Research	7.02	Housing
1.03	Front End Fuel Cycle	2.03	FBR-Front End Fuel Cycle	3.03	Other Thorium Reactor Systems	4.03	Agriculture	5.03	Chemistry	6.03	Prospective Research Fund		
1.04	Back End Fuel Cycle	2.04	FBR-Back End Fuel Cycle	3.04	Accelerator Driven Sub-critical Systems	4.04	Food Processing	5.04	Biology	6.04	Homi Bhabha Centre for Science Education		
1.05	Health, Safety & Environment	2.05	Repair and Inspection Technologies	3.05	Materials	4.05	Health	5.05	Cancer	6.05	Information Technology Application Development		
1.06	Waste Management	2.06	FBR-Health, Safety & Environment	3.06	Hydrogen Energy	4.06	Water	5.06	Synchrotrons & their Utilisation				
				3.07	Fusion Reactor	4.07	Industrial Applications	5.07	Cyclotrons & their Utilisation				
						4.08	Accelerators	5.08	Fusion & Other Plasma Technologies				
						4.09	Lasers	5.09	Material Science				
						4.10	Special Materials	5.10	Interdisciplinary Areas				
						4.11	Advanced Technologies	5.11	International Research Collaborations				
						4.12	Special Programmes						

MAJOR PROGRAMMES

MP-1 : Nuclear Power Programme-Stage-1
MP-2 : Nuclear Power Programme-Stage-2
MP-3 : Nuclear Power Programme-Stage-3 and beyond
MP-4 : Advanced Technologies and Radiation Technologies and their Applications
4A : Advanced Technologies and their Applications (Includes sub-programmes 4.01, 4.08 to 4.12)
4B : Radiation Technologies and their Applications (Includes sub programme 4.02 to 4.07)
MP-5 : Basic Research
MP-6 : Research Education Linkages
MP-7 : Infrastructure & Housing

ANNEX-II

REPLIES TO AUDIT OBSERVATIONS

Report No.2 of 2021 **Financial Audit, Union Government**

Para 3.2 - Short realization of lease rent

Non revision of license fee in accordance with extant Government Orders and non-renewal of expired lease agreements by General Services Organisation, Kalpakkam, resulted in short realization of lease rent of Rs.3.75 crore.

Action taken :

Submission of Initial Action Taken Note is under process.

Para 3.3 - Payment of House Rent Allowance at higher rates

National Institute of Science Education and Research, Bhubaneswar paid House Rent Allowance to its employees at higher rates, which resulted in excess payment of Rs.2.80 crore during the period from July 2015 to February, 2020.

Action taken :

Submission of Revised Action Taken Note is under process.

ANNEX-III

REPRESENTATION OF SCs, STs AND OBCs

ANNUAL STATEMENT SHOWING THE REPRESENTATION OF **SCs, STs AND OBCs** AS ON **01.01.2023** AND NUMBER OF APPOINTMENTS MADE DURING THE PRECEDING CALENDAR YEAR **2022** IN RESPECT OF **CONSTITUENT UNITS**

Groups	Representation of SC/ST/OBC (as on 01.01.2023)				Number of appointments made during the calendar year 2022									
					By Direct Recruitment				By Promotion			By Deputation		
	Total Emp	SC	ST	OBC	Total	SC	ST	OBC	Total	SC	ST	Total	SC	ST
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Group A	10311	752	263	1500	204	8	2	71	608	62	15	4	1	0
Group B	8497	1629	869	3090	175	16	20	92	636	138	39	7	1	0
Group C	8817	1673	821	3428	593	117	33	283	1423	258	126	0	0	0
TOTAL	**27625**	**4054**	**1953**	**8018**	**972**	**141**	**55**	**446**	**2667**	**458**	**180**	**11**	**2**	**0**

ANNUAL STATEMENT SHOWING THE REPRESENTATION OF **SCs, STs AND OBCs** AS ON **01.01.2023** AND NUMBER OF APPOINTMENTS MADE DURING THE PRECEDING CALENDAR YEAR **2022** IN RESPECT OF **AIDED INSTITUTIONS**

Groups	Representation of SC/ST/OBC (as on 01.01.2023)				Number of appointments made during the calendar year 2022									
					By Direct Recruitment				By Promotion			By Deputation		
	Total Emp	SC	ST	OBC	Total	SC	ST	OBC	Total	SC	ST	Total	SC	ST
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Group A	1638	72	14	113	71	2	0	5	1	1	0	0	0	0
Group B	3437	530	186	848	202	40	10	79	1	1	0	0	0	0
Group C	2339	615	155	584	76	13	7	41	0	0	0	0	0	0
TOTAL	**7414**	**1217**	**355**	**1545**	**349**	**55**	**17**	**125**	**2**	**2**	**0**	**0**	**0**	**0**

ANNUAL STATEMENT SHOWING THE REPRESENTATION OF **SCs, STs AND OBCs** AS ON **01.01.2023** AND NUMBER OF APPOINTMENTS MADE DURING THE PRECEDING CALENDAR YEAR **2022** IN RESPECT OF **PUBLIC SECTOR UNDERTAKINGS**

Groups	Representation of SC/ST/OBC (as on 01.01.2023)				Number of appointments made during the calendar year 2022									
					By Direct Recruitment				By Promotion			By Deputation		
	Total Emp	SC	ST	OBC	Total	SC	ST	OBC	Total	SC	ST	Total	SC	ST
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Group A	7703	1013	387	1644	288	50	15	94	469	66	27	0	0	0
Group B	4247	729	405	1380	75	9	3	24	186	45	15	0	0	0
Group C	3694	574	675	990	133	20	19	55	55	11	18	0	0	0
TOTAL	**15644**	**2316**	**1467**	**4014**	**496**	**79**	**37**	**173**	**710**	**122**	**60**	**0**	**0**	**0**

ABBREVIATIONS

ACTREC	Advanced Centre for Treatment, Research and Education in Cancer
AEC	Atomic Energy Commission
AECS	Atomic Energy Central School
AEES	Atomic Energy Educational Society
AERB	Atomic Energy Regulatory Board
AHWR	Advanced Heavy Water Reactor
AKRUTI	Advanced Knowledge & RUral Technology Implementation
ALARA	As Low as Reasonably Achievable
AMD	Atomic Minerals Directorate for Exploration & Research
APO	Alkyl Phosphine Oxide
ATI	Administrative Training Institute
AWE	Alkaline Water Electrolysis
BARC	Bhabha Atomic Research Centre
BHAVINI	Bhartiya Nabhikiya Vidyut Nigam Limited
BNHS	Bombay Natural History Society
BoG	Board of Governors
BRIT	Board of Radiation & Isotope Technology
BRNS	Board of Research in Nuclear Sciences
BWR	Boiling Water Reactor
CCE	Centre for Cancer Epidemiology
CFD	Computational Fluid Dynamics
CHSS	Contributory Health Service Scheme
CMG	Crisis Management Group
CORAL	Compact Reprocessing facility for Advanced fuels of Lead cells
CSR	Corporate Social Responsibility
CVC	Central Vigilance Commission
CVO	Chief Vigilance Officer
DAE	Department of Atomic Energy
DCSEM	Directorate of Construction Services & Estate Management
DEPU	Data Exchange & Procession Unit
DFRP	Demonstration Fast reactor fuel Reprocessing Plant
DFSA	Dummy Fuel Sub-Assemblies
DGFSDAE	Graduate Fellowship Scheme
DPS	Directorate of Purchase & Stores
ECCS	Emergency Core Cooling System
ECFM	Eddy Current Flow Meter
ECIL	Electronic Corporation of India Limited
EDF	Électricité de France
EMS	Environmental Management System
FBR	Fast Breeder Reactor
FBTR	Fast Breeder Test Reactor
FDG	Fluorodeoxyglucose
FMTF	Fuelling Machine Test Facility
FMTR	Fission Moly Tray Rod
FPC	First Pour of Concrete
FRENA	Facilities for Research in Experimental Nuclear Astrophysics
FRFCF	Fast Reactor Fuel Cycle Facility
FSMS	Food Safety Management System
GCNEP	Global Centre for Nuclear Energy Partnership
GFA	General Framework Agreement
GHAVP	Gorakhpur Haryana Anu Vidyut Pariyojana
GRPF	Gamma Radiation Processing Plants
HBCSE	Homi Bhabha Centre for Science Education
HBNI	Homi Bhabha National Institute
HBOSS	Hatch Beam Opening Sealing System
HLLW	High-Level radioactive Liquid Waste
HSCMS	Hydrogen and Steam Concentration Monitoring System
HTS	Hydro- technical structures
HWB	Heavy Water Board
HWP	Heavy Water Plant
IAEA	International Atomic Energy Agency
IDCT	Induced Draught Cooling Tower
IGA	Inter-Governmental Agreement
IGCAR	Indira Gandhi Centre for Atomic Research
ILRT	Integrated Leak Rate Test
IMSBR	Indian Molten Salt Breeder Reactor
IMSc	Institute of Mathematical Science
IOP	Institute of Physics
IPR	Intellectual Property Rights
IPR	Institute for Plasma Research
IREL	Indian Rare Earths Limited
IRMA	Immunoradiometric Assay
ISC	Indian Science Congress
ISI	In-service Inspection
ITER	International Thermonuclear Experimental Reactor
ITSTF	Integrated Top Shield Test Facility
KAMINI	KAlpakkam MINI Reactor
KAPP	Kakrapar Atomic Power Project
KAPS	Kakrapar Atomic Power Station
KGS	Kaiga Generating Station
KKNPP	Kudankulam Nuclear Power Plant
LAM	Laser Additive Manufacturing
LHC	Large Hadron Collider
LIBS	Laser Induced Breakdown Spectroscopy
LWR	Light Water Reactor
MAPS	Madras Atomic Power Station
MCF	Medical Cyclotron Facility
MoEFCC	Ministry of Environment, Forest and Climate Change
MOPA	Master Oscillator Power Amplifier
MoU	Memorandum of Understanding
MRECL	Mixed Rare Earths Chloride
MRTDDF	Magnesium Recycling Technology Development and Demonstration Facility
MZI	Mach-Zender Interferometer
NAPS	Narora Atomic Power Station
NBHM	National Board of Higher Mathematics
NDCT	Natural Draught Cooling Tower
NFC	Nuclear Fuel Complex
NGADU	Nuclear Grade Ammonium Di-Uranate
NISER	National Institute of Science Education & Research
NPCIL	Nuclear Power Corporation of India Limited
NPP	Nuclear Power Plants
NSSS	Nuclear Steam Supply System
NUJ	National Union of Journalists

OCES	Orientation Course for Engineering graduates and Science postgraduates
OHSMS	Occupational Health and Safety Management System
PAT	Profit After Tax
PBT	Profit Before Tax
PCPTF	Primary Coolant Pump Test Facility
PET	Positron Emitting Tomography
PFBR	Prototype Fast Breeder Reactor
PHT	Primary Heat Transport
PHWR	Pressurised Heavy Water Reactors
PIDS	Perimeter Intrusion Detection System
PIE	Post Irradiation Examination
PLC	Programmable Logic Controller
PLF	Plant Load Factor
RAPP	Rajasthan Atomic Power Project
RAPS	Rajasthan Atomic Power Station
REE	Rare Earths Elements
REPS	Reliable Electrical Power Supply System
RHIDS	Remote Handling & ISI Devices Section
RIA	Radioimmunoassay
RMC	Radiation Medicine Centre
RMRE	Rare Metal and Rare Earth
Rph	Radiopharmaceuticals
RPP	Radiation Processing Plant
RPV	Reactor Pressure Vessel
RRCAT	Raja Ramanna Centre for Advanced Technology
RTC	Room Temperature Cyclotron
RTI	Right to Information
SCRF	Superconducting Radio Frequency
SEM	Scanning Electron Microscope
SGDHR	Safety Grade Decay Heat Removal
SGIDS	Steam Generator Inspection Devices Section
SINP	Saha Institute of Nuclear Physics
SLM	Supported Liquid Membrane
SNM	Special Nuclear Materials
SRC	Safety Review Committee
TAPS	Tarapur Atomic Power Station
TBM	Test Blanket Module
TBP	Tributyl Phosphate
THM	Total Heavy Mineral
TIFR	Tata Institute of Fundamental Research
TMC	Tata Memorial Centre
TMH	Tata Memorial Hospital
UCIL	Uranium Corporation of India Limited
UOP	Uranium Oxide Plant
VECC	Variable Energy Cyclotron Centre
WANO	World Association of Nuclear Operators
WEC	Westinghouse Electric Company
WII	Wildlife Institute of India

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