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INDIAN NUCLEAR SOCIETY

INS News Letter

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Contents

Announcement / Appointment

Indian Nuclear Society congratulates Shri Kamlesh Nilkanth Vyas, Secretary to the GOI, Department of Atomic Energy and Chairman Atomic Energy Commission for extension in his service for a period of one year beyond May 3, 2022 *i.e.,* till May 3, 2023.

Indian Nuclear Society congratulates Prof. Ajay Kumar Sood, who has been appointed as the Principal Scientific Advisor to the Government of India for a period of three years. He started his professional career in 1972 in DAE, when he joined 16th batch of BARC Training School and worked in the area of Material Science and Condensed Matter at IGCAR, Kalpakkam till 1988 when he joined IISc, Bengaluru. He was honoured with Padma Shri in 2013.

Obituary

Shri Samir Kumar Chatterjee, Former Managing Director, Nuclear Power Corporation of India Limited (NPCIL), breathed his last on Mahashivratri, Ist March, 2022, at the age of 87 years.

Shri Chatterjee obtained degree in Chemical Engineering from Jadavpur University in 1954. Thereafter he joined Atomic Energy Establishment Trombay (AEET) in the year 1955 and superannuated from NPCIL in 1994.

Notable among his AEET postings was that of Reactor Superintendent, APSARA (India's FIRST Atomic Reactor). Recognizing the potential of Atomic Energy to produce electricity, a separate entity 'Power Projects Engineering Division' (PPED) was carved out of AEET and Shri

Chatterjee was deputed to PPED.

He vindicated the faith reposed by DAE in him. He quickly rose in the hierarchical ladder: Head (PHT), Head (Processes), Chief Engineer (Nuclear), Director (Engineering), and eventually the Managing Director of NPCIL in 1992, a post which he held till his superannuation in 1994.

Shri S.K. Chatterjee had laid a very strong foundation of design discipline within PPED/ NPCIL along with Shri S.L. Kati and others. He was also a keen supporter of development, testing and validation of new concepts and systems. Drawing lessons from his international interactions and experience, he ordered the Peer Review of the various directorates of NPCIL and implemented most of the recommendations of peer reviews, a decision and exercise which stood NPCIL in good stead in later years.

Shri Chatterjee was a Fellow of Indian National Academy of Engineering (INAE), former member Atomic Energy Commission (AEC), and Senior Advisor to the International Atomic Energy Agency (IAEA), Vienna.

He will be remembered as a technocrat, friend, philosopher and guide, great motivator and mentor, imbued with rare qualities of head and heart and above all an excellent human being, never shied away from crediting the success to his deserving younger colleagues. He had tremendous faith in his protéges which he amply demonstrated by fully empowering them. He also had an uncanny knack of diffusing any situation, no matter how hot, thus fully justifying his name SAMIR, (पवन). His ever smiling & unruffled face cannot be easily forgotten.

People like S K Chatterjee, never die. They live forever in the form of their creations, legacy of their ideals and their ever inspiring character. He is survived by wife and a daughter

Indian Nuclear Society prays for the SADGATI of the departed soul.

Obituary

Indian Nuclear Society condoles the sudden demise of **Dr Arun Kumar Bhaduri**, a Distinguished Scientist who passed away at 62 due to heart attack on April 26 afternoon at Kalpakkam. Nuclear and Material Science has lost a luminary and India has lost an institution leader. Born on August 28, 1959, Dr Bhaduri completed his schooling from Calcutta Boys' School in 1978, obtained B.Tech. in 1983 and then joined the 27th batch of the Training school of Bhabha Atomic Research Centre and was awarded the Homi Bhabha Medal for topping the batch. He was awarded Ph.D. in 1992, in Metallurgical Engineering by the Indian Institute of Technology, Kharagpur. He was a Fellow of the prestigious Alexander von Humboldt Foundation and carried out post-doctoral research at University of Stuttgart, Germany from 1994-96.

Dr Bhaduri joined Metallurgy and Materials Group of IGCAR in 1984 . He specialized in the field of welding, hardfacing and materials joining and nurtured an internationally acclaimed group in this area. Apart from steering the centre towards the development of materials and their fabrication technologies for Indian nuclear programme on sodium-cooled fast reactors, he also anchored the development of materials and their fabrication technologies for fusion reactors and advanced ultra supercritical thermal power plants. He worked as Director, IGCAR from July, 2016 to Sept., 2021. He was a recipient of many international and national awards and honours and was also a member of Governing Council of C-MET & Senate Member of NIT Puducherry.

He has to his credit more than 220 journal publications and two international patents. **INS pays homage to it's eminent life member and a Scientist par excellence and prays for peace to the departed soul. May Almighty give strength to the family members to bear this shock.**

From Editor's Desk

World Earth Day is celebrated every year on 22nd April to encourage people to support environmental protection. The pivotal role of nuclear power in environmental protection and meeting the challenge of Net Zero Carbon emission by 2050 is steadily being recognized. Apart from China which is betting big on a nuclear future, aiming to bring over 150 new reactors online over the next 15 years, USA and many European countries are seriously deliberating on rebooting their plans for nuclear power. After four decades, a new nuclear power plant, Olkiluoto 3 EPR was connected to the national grid on 12th March 2022 in Finland. Two nuclear generating units (1114 MWe each) now under construction in Georgia (Vogtle Units 3 and 4) may be connected to grid by 2023 and these will be the first nuclear units to come online in the United States since Tennessee's Watts Bar Unit 2 came online in mid-2016. $6 billion have been allocated by US DOE to prevent the premature retirement of existing nuclear power plants that are certified by the Nuclear Regulatory Commission as safe to continue operations. Earlier Illinois senate sanctioned $694 million to ensure the survival of three nuclear power plants in the state. Unit 3 of the Karachi nuclear power plant in Pakistan, an 1100 MWe Chinese-supplied Hualong One PWR reactor reached 100% capacity for the first time on 31st March, 2022. India's fast breeder test reactor (FBTR) reached its full 40 MWt design power level for the first time on 7th March, 2022 following the installation of a newly designed core containing "few' poison subassemblies. India currently has ten nuclear reactors under construction which includes PHWRs, VVERs and PFBR.

Miniature nuclear reactors have been touted as game-changers as these are regarded to avoid the cost overruns and construction delays that beset a nuclear power sector dominated by large reactors. Microreactors are designed to generate electrical power typically up to 10 MW(e) for remote or disaster-stricken locations. Though the technology has yet to be commercialized, multiple designs are progressing through licensing in North America and Europe, with demonstrations scheduled in the next few years. Oklo, a US-based company, submitted a license application in March 2020 to design and operate a microreactor, with the first reactor expected to start up at Idaho National Laboratory by 2025. The US-based companies Westinghouse, Nu Scale, Ultra Safe Nuclear and Last Energy; Sweden's Lead Cold; a UK consortium led by Urenco and Rolls Royce and Japan's Mitsubishi are developing micro reactors of different designs.

The growing inventory of spent nuclear waste globally is over 450,000 metric tons and is increasing by ~12,000 metric tons each year. There is momentum in recent years to come up with a way to dispose of nuclear waste because of the growing urgency surrounding climate change. In Europe, several deep geologic repositories are under construction. Finland is constructing a permanent nuclear waste disposal at Olkiluoto which is expected to be ready in 2023. Sweden is expected to construct a similar kind of nuclear waste disposal starting sometime in the 2020s at Östhammar and France aims to have its own geologic repository for nuclear waste by the 2030s. Yucca Mountain in Nevada was the front-runner for geologic disposal of spent nuclear fuel in the United States. However, work was suspended in 2010 by Obama administration due to political expediency. Waste Isolation Pilot Plant (WIPP) has been in operation since 1998 in New Mexico to dispose of long lived transuranics nuclear waste from defense activities. A new company, Deep Isolation, is exploring to utilize the directional drilling technology used in the oil and gas industries to dig long, narrow holes (horizontal as well as vertical) and slide canisters of nuclear waste down them.

Fuel Assemblies for PHWRs and BWRs forming the heart of Indian Nuclear Power Reactors have been fabricated for more than fifty years indigenously at Nuclear Fuel Complex, Hyderabad. It has also been supplying the subassemblies for FBTR and PFBR. An overview of the activities of NFC is given by Chief Executive, Dr Dinesh Srivastava and Dr Komal Kapoor in this issue. The phenomenon of radioactivity was discovered in 1896, by Henri Antonine Becquerel. Dr P.R.V. Rao, Vice Chancellor, HBNI presents historical perspective of this epoch-making discovery. A peep into an emerging technology, Robot Assisted Neurosurgery is provided by Shri T.A. Dwarakanath of BARC.

As third wave of COVID showed signs of containment, it was thought prudent to organize INSAC-2022 during 28th - 31st March, 2022 in hybrid mode at DAE Convention Centre, Anushaktinagar. Theme of the conference was "Nuclear Power towards Green Energy in India". Report of the conference is included in INS Round up. Cross word puzzle, DAE News Brief and Nuclear Snippets are regular features of NL . I gratefully acknowledge the complimentary messages and suggestions of members which are an encouragement for Ed Board members . I once again urge members to keep providing their valuable feedback on various features of NL including solution to Cross word puzzle to insvkmeditor@gmail.com.

Vijay Manchanda

DAE News Brief

Major recent Achievements of NPCIL

The excavation of KAIGA 5&6 project commenced on 28th April, 2022. These are the first set of 10 indigenous 700 MWe PHWR reactors sanctioned by GOI to be set up in fleet mode. KAPP-4 PHT System Hydro-test is successfully conducted at a pressure of 159.4 kg/cm2 (g) on 27th April, 2022. It is major milestone achieved towards the successful commissioning of KAPP-4. NPCIL achieved its highest electricity generation ever during the Fiscal Year 2021-22 by generating 47112 million Units (NPCIL's previous highest electricity generation was 46472 MU in FY 2019-20) and thus indirectly avoided release of about 41 million tonnes of CO_2 equivalent in the environment. Sixteen Reactors registered 100% Availability Factor during March, 2022.

FBTR Attained full Power Level

India's fast breeder test reactor (FBTR) reached its full 40 MWt design power level for the first time in March, 2022 following the installation of a newly designed core containing "few" poison subassemblies and after getting AERB clearance. The test reactor, which has an underpinning role in India's preparation for a thorium-based closed fuel cycle, had previously been limited to 32 MWt.

The Hydrogen Gas Sensor:

The sensor has many advantages such as continuous operation, long lifespan, robustness, simple to operate, easy to install and calibrate. It can be used for H_2 detection at industries like heavy water plants, oil refineries, nuclear reactors, research laboratories etc. The sensor comprises of two main parts namely a "Transmitter" and a "Digital Monitor". The transmitter consists of a sensing element comprising of Pt-100 coated with Pd, whose temperature is controlled using a circuit. The temperature at the surface of sensor film changes as a function of H_2 concentration, which is calibrated and displayed directly in volts on a digital monitor. This voltage is properly amplified, calibrated and displayed as the percentage concentration of hydrogen, using 3 1/2-digit DPM. It is developed at BARC and is suitable for detection of H_2 in the 0.5- 4 % range.

Scanning Electron Microscope:

Tungsten filament-based Scanning Electron Microscope (SEM) is a scientific investigative instrument that uses a finely focused beam of electrons for microscopic imaging and microanalysis of specimen. It can image specimen with resolution down to 20nm. SEM's accommodativeness of wide range of samples with minimum sample preparation compared to other electron-microscope variants, has rendered it an indispensable tool for imaging and micro-analysis in various disciplines of science including material science, chemistry, geology, pharmacy and forensics. Indigenously developed SEM by BARC is cost-effective import-substitute for Indian institutions of higher education, research labs and industries etc.

Induction Levitation Melter:

A portable, laboratory scale Induction Levitation Melter comprising of water-cooled segmented crucible, an induction heating power supply unit, a cooling water recirculation loop and a vacuum pumping system was developed indigenously by BARC. The segmented crucible is designed to levitate electrically conducting melt of ~ 10 g. The ILM is powered using MOSFET–based induction heating power supply (20 kW, ~175 kHz). The segmented crucible has eight water-cooled fingers, which are arranged to form a cavity with 20 mm inside diameter. The crucible is fabricated from a single extruded ingot of electrolytic grade copper. The crucible is housed inside a quartz tube for maintaining adequate vacuum (10^{-3} mbar) using a rotary vacuum pump.

Safe and Prolonged Storable 'legume sprouts' and 'sweet corn kernels':

Sprouts and shelled sweet corn kernels are highly nutritious but have severe hygiene and shelf-life issues. The current technology deals with process development to address the issues of safety, short shelf life and poor germination efficiency of seeds during winter season (Temp. < 20°C). BARC developed combination processing ensured microbial safety and extended shelf life up to 15 days for moong sprouts, chickpea sprouts, sweet corn kernels and 10 days in case of alfalfa sprouts when stored at 5±2°C. Processing also maintained the wholesomeness as well as reduced anti-nutritional factors of these products. The developed method could be an effective commercial strategy for ensuring safety and thereby promote its market access.

Environmental Gamma Spectroscopy System (EGSS)

EGSS developed by BARC is a standalone, solar powered, battery operated unit with GSM based online wireless data communication for installation in open field. It has a 2"×2" NaI (Tl) based gamma spectrometer, together with GM tube based gross gamma detectors, the former being automatically switched on when the dose rate detected by the latter increases beyond a pre-set threshold value. The establishment of a network of such field-installed systems with online communication would facilitate the real-time identification of radionuclide releases in case of radiological/nuclear emergencies. This would help in turn to facilitate prompt radionuclide-specific counter measures in case of such incidents.

Industrial Fluoroscope System (IFS)

Industrial Fluoroscope System (IFS) is an indigenously developed, low cost, modern digital radiography system for industrial applications. The system is useful for digital radiography of variety of components & sub-assemblies. This can be used for radiographic inspection of in-process jobs as well as finished components. Film based Radiography testing, which uses penetrating radiation either Gamma or X-Rays, is quite popular and widely accepted as a non-destructive testing (NDT) tool by manufacturing industries because of its capability to reveal the internal detail of a 3 D component as a projected 2 D image, known as a radiograph.

In comparison to conventional film system, digital radiography offers a series of benefits in terms of productivity, sensitivity, low X-Ray dose, environmental aspects, automated acquisition, image processing, image storage, image retrieval and cost reduction. The present IFS combines the benefit of both the real time radiography and the digital radiography. In order to have this cost-effective IFS in the Indian market, the complete manufacturing technology along with testing and validation methods for imaging device (excluding X-ray Source) is made available at BARC. Industrial sectors belonging to manufacturing, nuclear, aerospace, defense, security, automobile and petrochemicals are potential users of IFS for their quality control applications.

^{89}Sr for Cancer Care:

Excruciating metastatic bone pain in cancer patients is the most common pain syndrome encountered, with about 70% of patients with prostrate and breast cancer and 30% of patients with lung and, bladder and thyroid cancers. The pain can be considerably alleviated by selectively targeting the cancer cells in the bones. This is achieved by administrating strontium chloride (with ^{89}Sr isotope which remains in the bones for several weeks) to the patient. Radiations emitted are absorbed almost completely within this area, maximizing the efficacy of the pain palliation treatment. Production of ^{89}Sr radiopharmaceuticals has been achieved at laboratory scale in Fast Reactor at Kalpakkam.

Early Diagnosis of Coronary Heart Disease:

Coronary Heart Disease is caused by the buildup of plaque in the arteries that supply oxygen rich blood to heart. Plaque causes a narrowing or blockage of these arteries, that could result in a heart attack. Single Photon Emission Computer Tomography (SPECT) produces excellent 3-dimensional images which have high sensitivity as well as specificity. However, SPECT studies require ^{201}Tl which is imported. Recently, Thallous Chloride with ^{201}Tl has been produced at VECC-BRIT using the 30 MeV Medical Cyclotron Facility and supplied to Rabindranath Tagore International Institute of Cardiac Sciences, Kolkata for evaluation of its proficiency.

High-level delegation from Argentina visits BARC

A high-level delegation from Argentina headed by Minister Mr. Santiago Andres Cafiero visited Bhabha Atomic Research Centre in Mumbai on Wednesday (April 27, 2022) to review the ongoing bilateral cooperation in the field of nuclear energy. The delegation also explored new areas of cooperation and collaboration . Both the delegations particularly discussed the ongoing collaboration between BRIT, a commercial arm of DAE and Argentinian Company M/s. INVAP for setting up the facility on turnkey basis for the production of High Specific Activity (HSA), Molybdenum-99 (Mo-99) for supply of radioisotope products used in healthcare industry.

BARC and Sher-e-Kashmir University of Agricultural Sciences and Technology in Kashmir (SKUAST-K) Signed an Agreement for Using Radiation Technology in agriculture

An agreement was signed during a recent trip to BARC Mumbai by the SKUAST-K group of scientists, led by Vice-Chancellor Prof Nazir Ahmad Ganai. The radiation technology would be used at SKUAST-K in the agricultural sector to help grow innovative and different classes of crops particularly Kala Zeera, the wild tulip of Kashmir and saffron by using the method of mutation breeding. This technology will also help in prolonging the shelf life of freshly obtained vegetables and fruits and in constructing new crop management technologies for organic agriculture.

Compiled by

Vijay Manchanda and A. Rama Rao

Robot Assisted Neurosurgery

Introduction

Spine, orthopedic and neurosurgeries require high precision surgical practices and the margin of error is small. The availability of facilities and skill are limited and the associated cost is high. The ratio of surgical expertise to patients is very low and it is estimated to decrease in quicker pace over time. The technology to address the scale of the problem and extend affordable high-quality surgical practice is considered in this study. Robotics is a well cited technological solution practiced in various domains of surgery. Da Vinci by far is the highly sophisticated surgical robot and is mostly used for the abdominal and urological surgeries [1]. The literature indicates a paradigm shift towards robot assisted surgical practices to achieve faster healing time and lesser patient time spent in the hospital. The robot-based surgery enhances the option of minimally invasive procedure and helps in doing away with the need for patient to wear bulky reference frame during surgery [2]. Extensive development effort has been devoted to work with frameless reference. The robot-based surgery also automates the manual procedures associated with the frame-less stereotactic neurosurgery for eliminating human errors by utilizing high precision technologies [3]. Robot assisted surgery can optimally utilize the surgical expertise to fill up the gap in providing surgical services in specialized domain of neurosurgery catering to large population spread across the geography.

Robot Assisted Neurosurgical Suite

Four important segments constitute a robot-based neurosurgery. DRHR, BARC in association with Computer Division, BARC has developed all the segments to provide a robot assisted neurosurgical suite. The four important segments of the suite and their characteristics are as follows:

1. Image registration and patient specific 3D model algorithms for surgical planning.
2. High-definition visualization for image guided surgery.
3. Six degrees of freedom surgical robot equipped with Surgical Coordinate Measuring Mechanism (SCMM), Collette for biopsy and telescopic camera.
4. Algorithms, robot software library and integration of real time robot navigation in visualization.

Image registration and patient specific 3D model algorithms for surgical planning:

Image registration is the process to identify the location of the problem (tumour) in the images with respect to the markers in the images. The input for this is the CT/MR images of the patient. Further, the input is taken to build a patient specific 3D model. The problem region is highlighted to show the localization of the spread with respect to the scalp for isolated visualization as shown in **Fig. 1.**

Fig.1: Image Registration & problem Isolation.

The image segmentation, enhancement of regions of interest, dynamic linking of 3D image and cross-sectional images, section normal to the tool axis and passing through the tooltip, digitization of the image, etc. are obtained for accurate patient assessment and surgical planning.

High-definition visualization for image guided surgery:

Visualization involves multi-sectional views and transparent 3D view to provide real time feedback on the progress of the tool insertion. The important aspect is that the virtual SCMM is integrated and the movement of -SCMM is shown in the image and in the patient specific 3D model in real time. High-definition visualization available for the surgeon during the course of neurosurgery is shown in **Fig. 2.**

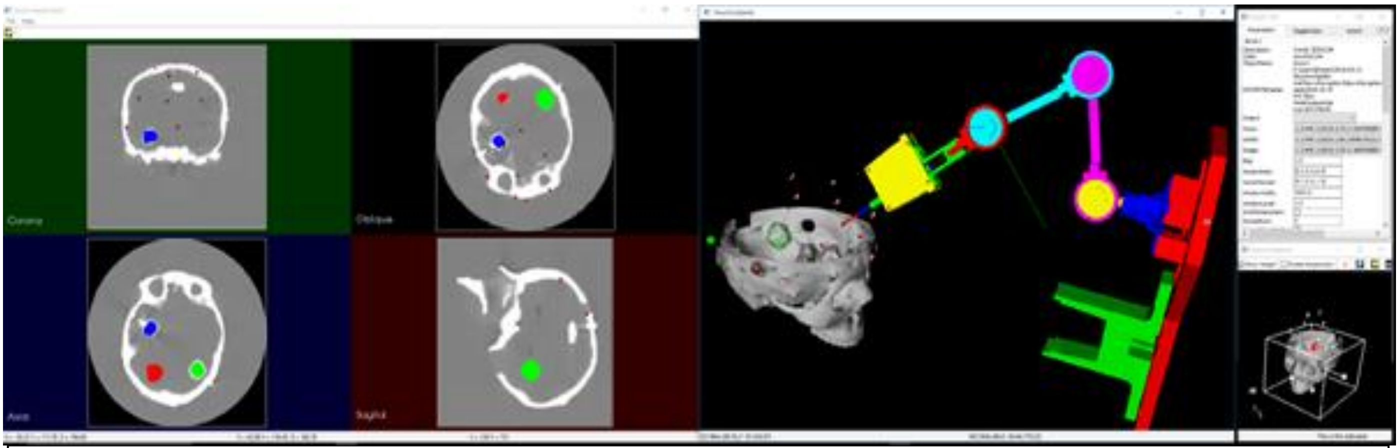

Fig.2: High-definition visualization to enhance the accuracy of neuro-registration and neuronavigation.

Six degree of freedom surgical robot:

A 6 Degrees of Freedom surgical (6D-PKM) robot assists neurosurgery. The 6D-PKM robot is a compact portable system weighing 150 N and it can support and manipulate a payload of 200 N. The repeatability of the robot is 10 µm and absolute accuracy is 60 µm. It has three translational and three rotational DOF, which can approach a point in its workspace from multiple directions or in other words the end effector platform of the robot can be positioned and oriented at any desired posture. The designed drivers, motion control code and safety features are part of the device. The robot in surgical mode, facilitate the biopsy needle to pass through a small burr hole and access the deep target point. The robot based surgical configuration is shown in **Fig.3**. The results pertaining to the accuracy in the surgical mode on various phantoms and vegetable trials forms part of the development.

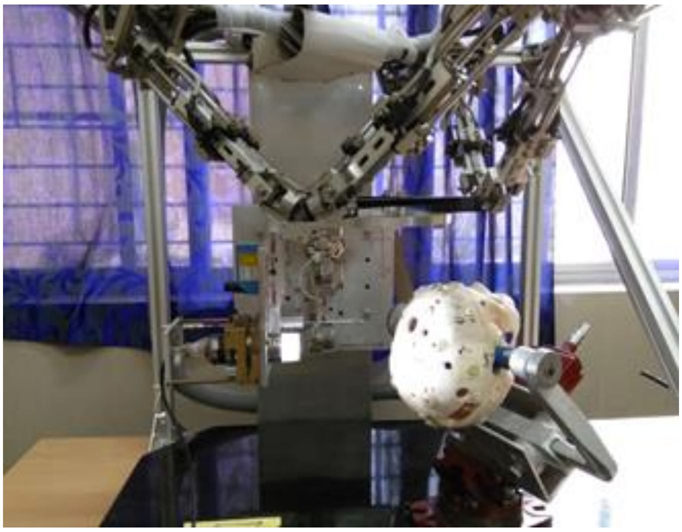

Fig.3: Six DoF Parallel Kinematic Mechanism robot

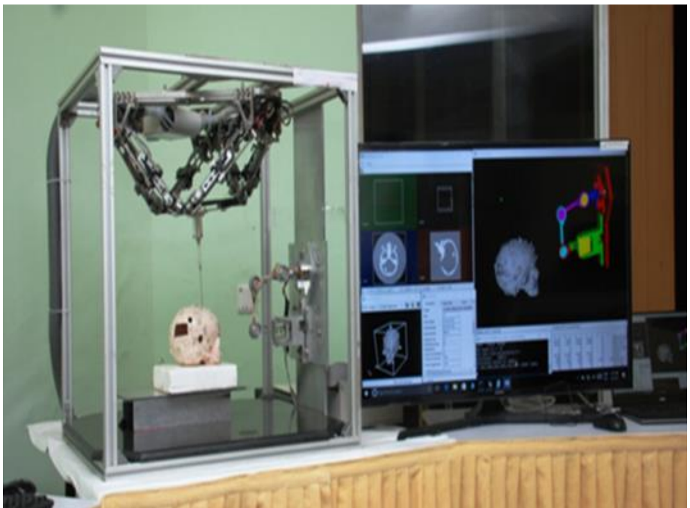

Fig.4: Neurosurgical suite comprising neurosurgical robot, SCMM and visualization.

A Neurosurgical suite comprising the neurosurgical robot, SCMM and visualization is shown in **Fig. 4.** As per the survey of current price scenario, the neurosurgical suite will provide highest affordability on all counts such as the initial cost, training and the involved maintenance.

Clinical trials with recently developed neurosurgical device and Results

Multiple phantoms have been built and successfully registered with respect to the robot and trials were carried out successfully. The robot-based method was demonstrated to practicing surgeons and its

High precision and accuracy:	Biopsy of extremely small, deep rooted tumour can be accessed and extracted.
Integrated Display:	Multi-sectional views and transparent 3D view to provide real time feedback on the progress of the tool insertion.
No line of sight problem:	Ideal for complex manoeuvres which miss camera sight.
Low cost:	Highly affordable compared to imported systems.
Indigenous:	Can be customised to suit local surgical practices.
Minimal footprint:	Lesser space requirement gives surgeons more free space.

several advantages in terms of speed and accuracy were validated. The trials conducted in ACTREC, Navi Mumbai and NIMHANS, Bengaluru. had four targets and four markers for the registration. In all the cases, the Target Registration Error (TRE) and Fiducial Registration Error (FLE) were found to be less than 1 mm and 0.5 mm respectively.

Conclusions

Salient features of the robot assisted suite are summarized above .The results of the experiments show the successful replication of robot-assisted surgical procedures. The same performance values over a large number of experiments reveal high consistency. The case studies are of higher intricacies in terms of trajectory, precision and accuracy than usually practiced for animal and human surgery. The technology can serve many domains of the robot-assisted spine and neurosurgery, especially functional neurosurgery, where high precision and accurate targeting of anatomic landmarks deep within the brain are desired. The robot, method and algorithms in the case studies have met the prescribed guidelines for robot based autonomous neurosurgery for the next stage of experiments on small animals and humans.

Acknowledgement

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Shri T.A. Dwarakanath
(tad@barc.gov.in)
Division of Remote Handling & Robotics
BARC

Discovery of Radioactivity: A Historical Perspective

Introduction:

The phenomenon of radioactivity was discovered in 1896, by Henri Antonine Becquerel, a French scientist. The discovery of the phenomenon of radioactivity came close on the heels of the discovery of X-Rays. The name "radioactivity" was given to the phenomenon by Pierre Curie and Marie Curie in their paper published in 1898. However, there was no clear understanding of the origin of the radiation from uranium and thorium at that time. It was a collaboration between Ernest Rutherford and Frederick Soddy, which in a short period of 2 ½ years (1901-1903), firmly established that radioactivity involved transmutation of the nucleus and expulsion of matter and energy.

The discovery of radioactivity is one of the most important discoveries in science since it forced scientists to radically change their views about atomic structure and finally led to the current understanding of the structure of the atom; it helped to evolve whole new domains of scientific investigations – nuclear physics, nuclear chemistry, nuclear medicine, etc; it led ultimately to the production of nuclear energy; and it resulted in several societal applications including applications of radioisotopes in medicine, food and agriculture.

The Discovery: Serendipity?

Henri Becquerel was born in a family that had a lineage of research. His grandfather, father, Henri himself and his son, occupied the chair of Physics in the Museum of Natural History at Paris continuously for over 100 years! Henry's father Edmond Becquerel was the leading authority of Europe in the subject of phosphorescence of solids; one of his important contributions was that uranic series of salts exhibit phosphorescence, and uranous salts do not. Henri began publishing on phosphorescence as early as 1883.

William Conrod Roentgen discovered X Rays in Nov. 1895, and announced his discovery on 28th Dec. 1895. On 1st January 1896, he circulated information about his discovery among several of his contacts including leading European scientists. Henri Becquerel was a member of the French Academy of Sciences, and attended its weekly meetings. In the meeting on 20th Jan. 1896, mathematician and astronomer Jules Henri Poincare circulated the X Ray photograph that he had received from Roentgen. To a question from Becquerel, Poincare indicated that the invisible radiation seemed to originate from the area of the Crookes tube made fluorescent by the cathode rays. This triggered the interest of Becquerel and he began a series of systematic investigations to find out whether other luminescent materials such as uranium salts can also cause a similar effect.

Henri wrapped a photographic paper in light tight black paper, placed the mineral or chemical on the paper, and kept the kit on the window sill to receive sunshine. At the meeting of Academy on 24th Feb 1896, he reported that potassium uranyl sulphate, on stimulation by sunlight produced radiation that could expose the photographic plate even when covered by black paper. During the following week, he repeated the experiments using thin copper or aluminium plates instead of black paper as cover for the photographic plates. On 26th and 27th February, he prepared several plates as above, but had to postpone the experiment due to overcast skies, so he left the plates and crystals in a table drawer. On Sunday 1st March, he developed these plates and was surprised to find that they were heavily fogged. Thus, 1st March 1896 is associated with the discovery of radioactivity, even though no knowledge of such phenomenon existed at that time.

Becquerel then conducted experiments to find out whether any light stimulation was required at all. Through March 1896 and in several months that followed, Becquerel continued his studies on several phosphorescent uranium compounds and found that even when they were kept in darkness, they were able to fog the photographic plate. Becquerel initially concluded that the observations can be explained by "long lived phosphorescence". However, his subsequent studies showed that even uranium compounds that do not exhibit phosphorescence, e.g., Uranous sulphate, and uranium metal, also caused the fogging of the plates. The uranium metal disc in fact, seemed to emit radiation with an intensity three and a half times that emitted by potassium uranyl sulphate. This made him conclude that rays from uranium were responsible for the fogging phenomenon. He used the term "*Uranic Rays"* in his paper presented to the Academy in Nov. 1896.

The observation of the "Uranic Rays" did not cause the same excitement among researchers or public, as was caused by discovery of X-rays for which several popular applications were quickly identified. This led to a diminution of interest on uranic rays. Becquerel himself published seven papers in 1896, two in 1897 and later moved to other areas of research!

Marie Curie:

Interest on uranic rays was revived by the entry of Marie Curie. The mysterious "Becquerel rays" aroused her curiosity, and she started systematically looking for other materials that could possess properties similar to uranium. In her efforts, the most important difference was that she used a precise and sensitive electrometer that could provide more reliable information on the level of radiation emitted by a material, as compared to a photographic plate. She soon found out that the level of radioactivity associated with different minerals and materials containing uranium was not always proportional to the uranium content. This led her to think that perhaps there were other materials also giving out radiation similar to uranium, and led her to the discovery that thorium gives out radiation like uranium. She also observed that two ores of uranium, pitchblende, and chalcolite were much more active than uranium itself. This observation made her conclude that these minerals may contain an element much more active than uranium.

Marie Curie separated an active substance from pitchblende through various precipitation steps. (This was itself a unique achievement that involved extremely arduous work viz. processing of kilogram quantities of the ore). She announced in her paper in 1898: "We believe therefore that the substance which we have removed from pitchblende contains a metal not yet reported, close to bismuth in its analytical properties. If the existence of this new metal is confirmed, we propose to call it polonium from the name of the country of origin of one of us".

The paper describing this work, published in July 1898, was titled " On a New Radioactive Substance contained in Pitchblende". This was the first instance when the word "Radioactive" was used. Subsequently, she also isolated another new radioactive element, Radium. The Nobel Prize in Physics 1903 was divided, one half to Henri Becquerel, and the other half jointly to Pierre Curie and Marie Curie. Becquerel's Nobel prize lecture was titled "Radioactivity, a New Property of Matter".

Rutherford & Soddy:

The phenomenological understanding came about through the work of Ernest Rutherford and Frederick Soddy. Rutherford showed that the rays had two components – with differing powers for ionisation of gases and penetration through materials; he termed these as "alpha" and "beta" rays. In his studies on activity of thorium, Rutherford observed "emanation" from thorium that was affected by air currents in the laboratory. He also observed that the emanation seemed to cause secondary activity on substances exposed to it. To determine the chemical nature of the emanation, Rutherford invited the collaboration of Frederick Soddy, a gifted young chemist. In the short period of 18 months from Oct. 1901, their collaboration produced 9 journal publications that had a great impact on understanding of radioactivity. The last of these papers titled "Radioactive change" (1903) enunciated the hypothesis of spontaneous atomic disintegration in explanation of the phenomenon of radioactivity.

In due course, the classic experiments on scattering of alpha particles by gold foil carried out by Geiger and Marsden, the delineation of atomic structure by Niels Bohr, discovery of neutron by James Chadwick, the concept of isotopes by Soddy, and artificial radioactivity by Irene and Joliot Curie unravelled the nucleus and opened up new vistas of research, that came to be classified as nuclear physics, nuclear chemistry, etc. The application of radiotracers for the study of biological processes by Hevesy led to the development of nuclear medicine and the discovery of nuclear fission by Otto Hahn opened up new dimensions of nuclear science through the prospect of unleashing the energy from the nucleus.

Conclusion:

Radioisotopes and radiation have found applications in several domains such as agriculture, industry and health. Today, India is a large producer of radioisotopes. DAE is working in close cooperation with other organizations of the Government to widen the reach of radiation technologies for the benefit of the common man. Remarkable progress has been achieved in applications of Radisotopes and Radiation Technology in the areas of nuclear **agriculture, food preservation and industry. Methodologies and** facilities for safe handling of radioactivity have been well established.

Nearly 400 nuclear medicine centres across the country provide succour to patients by deploying radioactivity / radiation for diagnosis or treatment. It is indeed typical of scientific research that what started as a curiosity driven investigation into the nature of radiation emitted by certain materials ultimately led to large scale societal benefits.

Dr. P.R.Vasudeva Rao

(prvasudeva.rao@gmail.com)

VC, Homi Bhabha National Institute, Mumbai and Former Director, IGCAR

Developments and Automation of Nuclear Fuel Processing at NFC

Abstract:

Nuclear Fuel Complex manufactures fuel assemblies required for PHWR and BWR reactors operating in India. NFC also caters to the requirement of core structurals for PHWRs and BWRs, sub-assemblies for FBTR and FBR, special tubes for various nuclear and non nuclear applications. Fuel assemblies mainly consist of UO_2 pellets encapsulated in Zircaloy clad tubes to form fuel elements and these elements are assembled by appendage components and end plates by resistance welding. UO_2 pellets manufacturing involves series of chemical processes, compaction, sintering and grinding. This article elucidates developments and automation in UO_2 powder, pellets manufacturing, welding processes and associated quality systems resulting in substantial increase in productivity and improvement in quality. It also describes various developments in manufacture of core structurals and special tubes.

1.0 Production Activities in NFC:

Nuclear grade natural Uranium Dioxide (UO_2) pellets are produced at NFC by converting variety of raw materials using a well-established conversion processes comprising of different stages like dissolution, solvent extraction, precipitation, calcination & reduction to get UO_2 powder. Subsequently, pellet fabrication is accomplished through granulation, pre-compaction and high temperature sintering of UO_2 powder. The resultant UO_2 pellets are then qualified for physical integrity and chemical purity for encapsulating them into zirconium alloy fuel tubes for fabricating the fuel sub-assemblies. The three types of fuel sub-assemblies (bundles) fabricated in NFC are 19 Element bundle for 220MWe PHWRs, 37 Element bundle for 540/700 MWe PHWRs and 6x6 BWR bundle for 160MWe BWRs and are shown in **Fig-1A to 1C**

Fig 1A - 19Element bundle for 220MWe PHWR

Fig 1B - 37 Element bundle for 540/700 MWe PHWR

Fig. 1C - 6x6 BWR bundle for 160MWe BWR

The production activities of NFC for nuclear and non-nuclear applications are summarized in **Fig-2**. NFC is also responsible for fabrication of core sub-assemblies for Indian Fast Breeder Reactors deployed under 2nd stage of Indian Nuclear Power Program. The facility at NFC presently caters to the requirements of core subassemblies for two reactors namely 13MW(e) Fast Breeder Test Reactor (FBTR) and 500MW(e) Prototype Fast Breeder Reactor (PFBR).

Reactor Grade Zirconium Metal Production:

Reactor Grade Zirconium metal is produced by limiting critical impurity element viz. Hafnium making it suitable for nuclear applications. Zircon sand (Zirconium Silicate) is the raw material for production of Zirconium metal and it contains 67% Zirco-

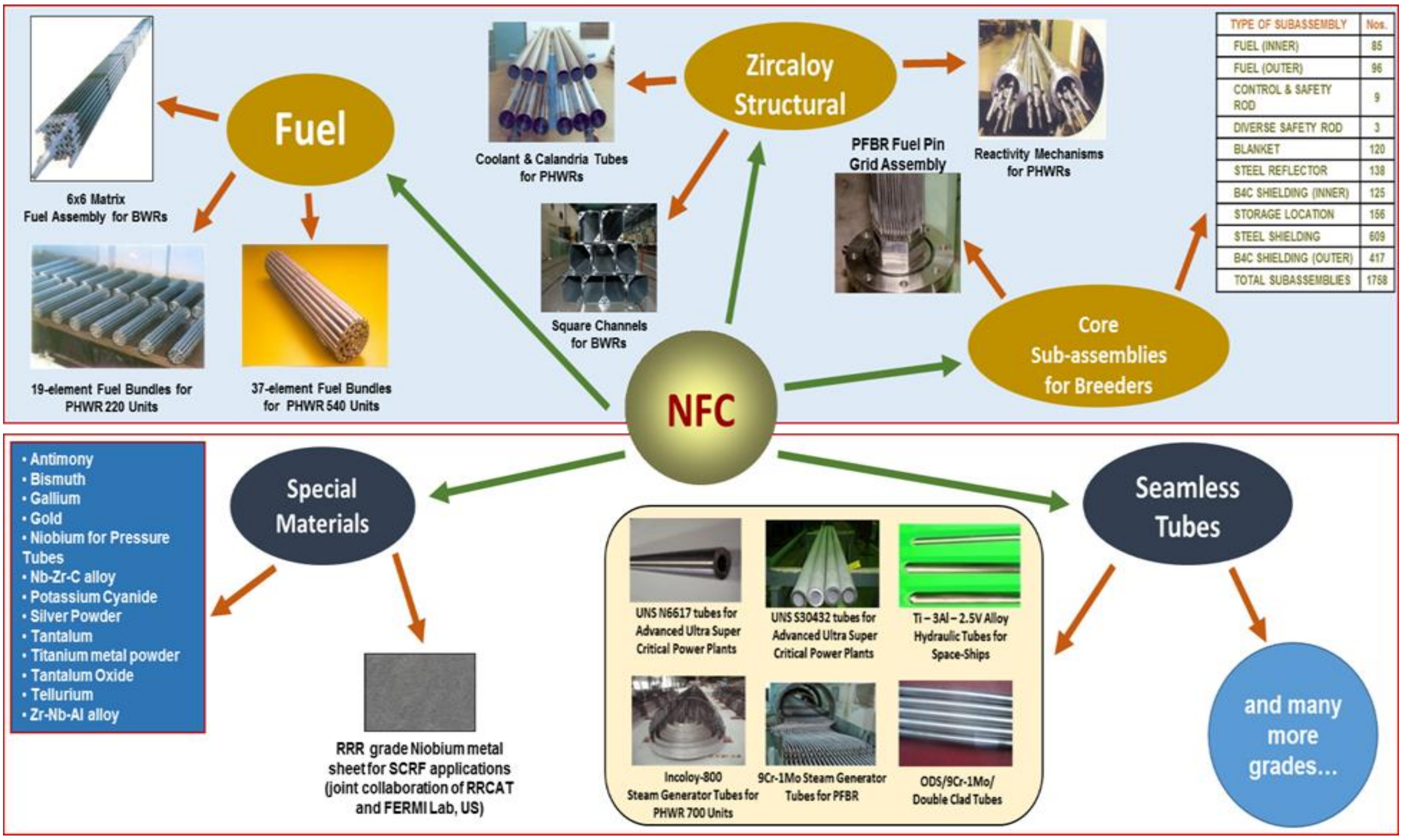

Figure-2: Diversified production activities of NFC

nium and about 2% Hafnium. The first step of removal of Silica involves the treatment of zircon with Caustic Soda. The resulting frit is washed with water to remove water soluble Sodium Silicate. Then Zirconium and Hafnium are brought into solution with Nitric Acid. The separation of Zirconium from Hafnium and other impurities is achieved by solvent extraction using Tri-n-Butyl Phosphate (TBP) in Kerosene as the solvent. Zirconium Hydroxide is precipitated from the pure solution using Ammonia and the Hydroxide is filtered, washed, dried and calcined in a rotary kiln to obtain pure Zirconium Oxide. Hafnium free Zirconium Oxide is converted to Zirconium Tetrachloride ($ZrCl_4$) intermediate through chlorination operation in static bed reactors. Zirconium Tetrachloride is then reduced to Zirconium through magnesio-thermic reduction (Kroll's reduction) operation. The reduced mass of Zirconium after mechanical separation of $MgCl_2$ by-product is subjected to pyro-vacuum distillation operation for removal of entrapped Mg and $MgCl_2$ to get pure Zirconium metal.

Fuel Cladding and Assembly Components production:

Chemically qualified Zirconium sponge is converted into different types of zirconium alloys after addition of required quantity of alloying elements and melting. Zirconium metal and the alloying elements are compacted in hydraulic presses to obtain compacts / briquettes. These compacts are welded by electron beam welding under vacuum to obtain a long cylindrical electrode. These electrodes are melted multiple times by consumable electrode in vacuum arc re-melting furnace in water cooled copper crucibles, with intermediate stage machining for obtaining final ingots. The composition of different Zircaloys is given in **Table-1**. Zircaloy ingots are subjected to 1st stage of extrusion, machining and cutting. After making a hollow billet, it is subjected to beta-quenching, machining and 2nd stage extrusion in order to obtain a hollow blank. This hollow blank is stress relieved in vacuum and passed on for multi-stage pilgering with intermediate vacuum annealing etc. Tube finishing operations like straight-

Table-1: Typical Composition of various Zircaloys

Zirconium Alloy type	Alloying elements (Weight %)				
	Sn	Fe	Cr	Ni	Zr
Zircaloy-2	1.5	0.12	0.1	0.05	Balance
Zircaloy-4	1.5	0.22	0.1	-	Balance

ening, grinding, cutting, etc. are also performed to obtain the requisite stringent quality. For this purpose, fabrication facilities such as extrusion & piercing press, cold rolling mills, vacuum annealing furnaces, special surface finishing and treatment equipment are available to achieve the desired mechanical and metallurgical properties of cladding tubes.

Fuel tubes are resistance welded with components like bearing pads & spacer pads. These tubes are loaded with UO_2 pellets and encapsulated as element by resistance end cap welding. These elements are assembled as bundle by end plate resistance welding.

***Production of Nuclear Reactor Core Structural Components**:*

Seamless tubes of different sizes are being manufactured using alloys of zirconium, titanium and special grade stainless steels. Pressure Tubes (Zr-2.5wt% Nb alloy), Calandria Tubes (Zircaloy-4) and Garter Spring (Zr-2.5wt% Nb-0.5wt% Cu alloy) are the critical core structural of Pressurised Heavy Water Reactors (PHWRs). Square Channels (Zircaloy-4) are used in Boiling Water Reactor (BWRs) and Hardware like Hexcans (SS316/ D9 alloy) are used in Fast Breeder Reactors (FBR). The manufacturing process route for reactor control assemblies required for PHWRs is successfully developed and these are regularly supplied to all the PHWRs. These assemblies are designed for reactor power monitoring, control mechanisms and shut down. These are made of zirconium alloys and require high precision, reliable components and high-quality tubes before welding. For this purpose, advanced welding and machining facilities such as electron beam welding, specialized TIG welding machines, CNC machines, pilger mills, precision roll joint machines, vacuum heat treatment furnaces, special surface finishing and treatment equipment are used.

Stainless Steel and Special Alloy Tubes production:

These are exclusive facilities for development & manufacturing the seamless tubes using various advanced grades of Stainless Steels & Special alloys, Nickel based super alloys, Iron based super alloy, Titanium alloys, Maraging steels for Nuclear, Space and Defence strategic applications. These include state of the art manufacturing facilities like Cold rolling mills (Pilger mills), Tube straightening mills, Draw-bench, Bright Annealing/Vacuum/ Roller Hearth (LPG fired) Annealing furnace, Chemical operations like De-glassing, Pickling, Passivation, Alkaline degreasing, Solvent degreasing and Inspection facilities like Ultrasonic, Eddy Current & Hydrostatic Pressure Testing etc., Manufacturing starts with forged & machined cylindrical billets which are hot extruded to hollow blanks. Extruded blanks undergo series of thermo-mechanical processing to achieve desired properties. Finished tubes are subjected to various Inspection & Tests as per customer requirements. NFC has played a pivotal role in indigenous development & manufacturing of these products as import substitute and is an excellent example for Make in India policy.

2.0 Development and Automation in NFC:

The fuel fabrication involves large no. of chemical, metallurgical & mechanical processes and involves handling of very large no. of intricate components with intensive inspection at every stage of manufacturing/fabrication. Automation is the key and essential to achieving these things. Apart from this, automation benefits in safe handling of radioactive & hazardous materials on large scale and thereby reducing the radiation exposure to working personnel and air born activity levels. Substitution of manual operations with remote/centralized controls & provision of alarms/safety inter-locks enhances the safety in operations. Additionally, it economizes the process by minimizing the failure rates & man power requirements, especially to meet the high demands of production. Automation also improves the Digitization and Documentation.

2.1 Developments in UO_2 Powder Production:

Sinterability and physical integrity of UO_2 pellet is largely dependent on the physical characteristics of the UO_2 powder, which in turn is closely related to powder process parameters, such as dissolution temperature, O/A ratio, uranium concentration, free acidity of uranyl nitrate solution, precipitation temperature, flow rate of the precipitant and temperature profile during heat treatment of the intermediates. It has been observed qualitatively that the effective filtration of uranyl nitrate before precipitation, play crucial role in achieving defects free resultant UO_2 pellets by filtering out various insoluble impurities. For production of UO_2 powder with required characteristics that are acceptable in fuel pellet production, controlling impurity levels in raw materials, process improvements and parameter optimizations have been carried out at various stages of UO_2 powder production process as follows.

a) Increase in dissolution temperature of raw material by 10°C from the existing practice ensured complete elimination of dissolved organics and soluble silica present in the raw material.

b) Use of Uranyl Nitrate feed to the Slurry Extractor at 3rd stage in place of 1st stage reduced the aqueous entrainment in Uranyl Nitrate extract.

c) Increase in Uranyl Nitrate Feed concentration by 75 gpl from the existing concentration helped to decrease the aqueous entrainment in the Uranyl Nitrate Pure Solution (UNPS) extract and resulted in better phase separation during solvent extraction process.

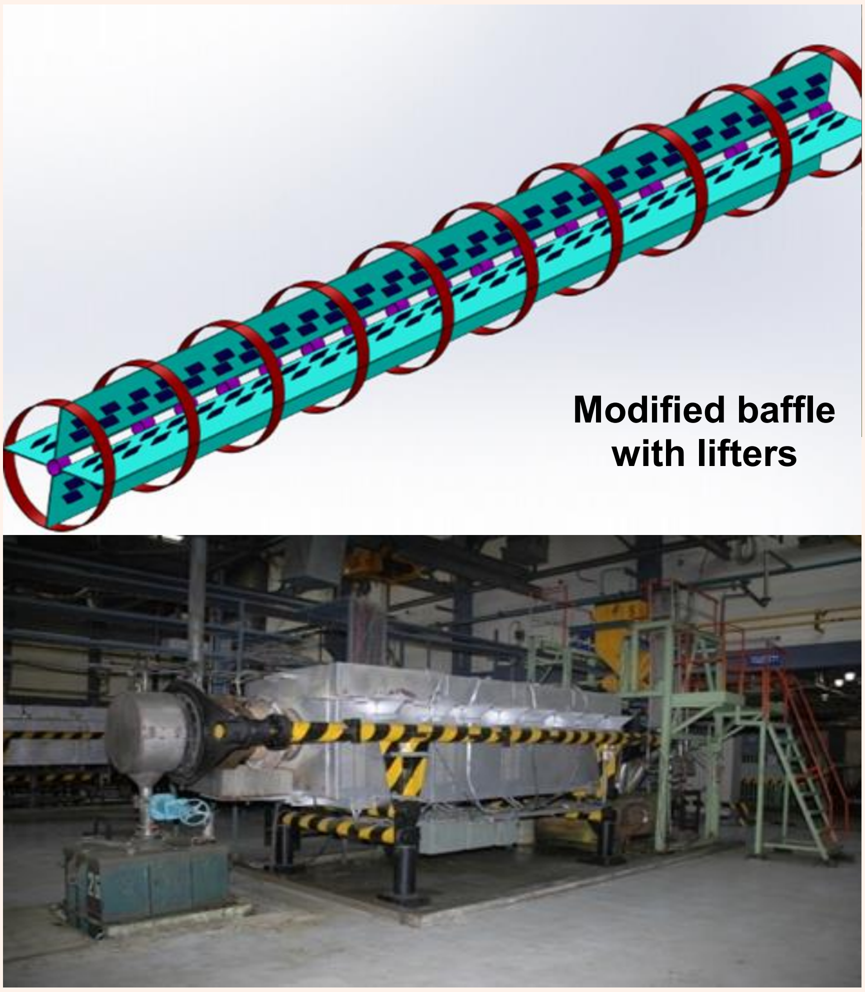

Figure-3: Unique design of baffle cage for rotary furnaces and the picture of calcination furnace

d) Introduction of Vapour Ammonia during precipitation in place of liquid ammonium hydroxide solution helped to get ADU powder with desired size & morphology. Also, the time of precipitation was reduced and minimized the liquid effluent generation as well.

e) Increase in % TBP in solvent extraction process by 3% from the existing condition resulted in increase of U concentration in the extract by 10 gpl which is equivalent to an increase of extract saturation from 90% to 95%.

f) Introduction of modified baffle in the rotary furnaces for calcination, reduction and stabilization operations by a unique design of baffle cage as shown in **Fig- 3** resulted in increased powder lifting and heat transfer to the powder. After the modification, there was a remarkable decrease in calcination temperature by about 20°C with the required powder quality due to the cascading effect realised with the provision of lifters.

g) Modification in AU precipitation by optimization of critical parameters like Ammonia Flow rate, UNPS concentration and precipitation temperature, terminal pH. Using the optimized parameter, the batch precipitation time has been reduced and resulted into more chemically active AU powder (SEM is shown in **Fig-4).** Furthermore, the UO_2 powder produced from this AU powder has resulted in reduction in the temperature of subsequent calcination operation and played a pivotal role in reduction of sintering cycle.

h) Modifications in The Port and the Mechanical Coalescers of Stripping Operation resulted in increase in stripping efficiency by 100%.

2.1.1 Automation in UO_2 Powder Production:

In order to have reliability in process with safety interlocks and reproducible quality in UO_2 power production, automation in powder production following features have been introduced.

(i) Automated operations through PLC Based SCADA

(ii) Automated Radioactive Slurry Transfer System

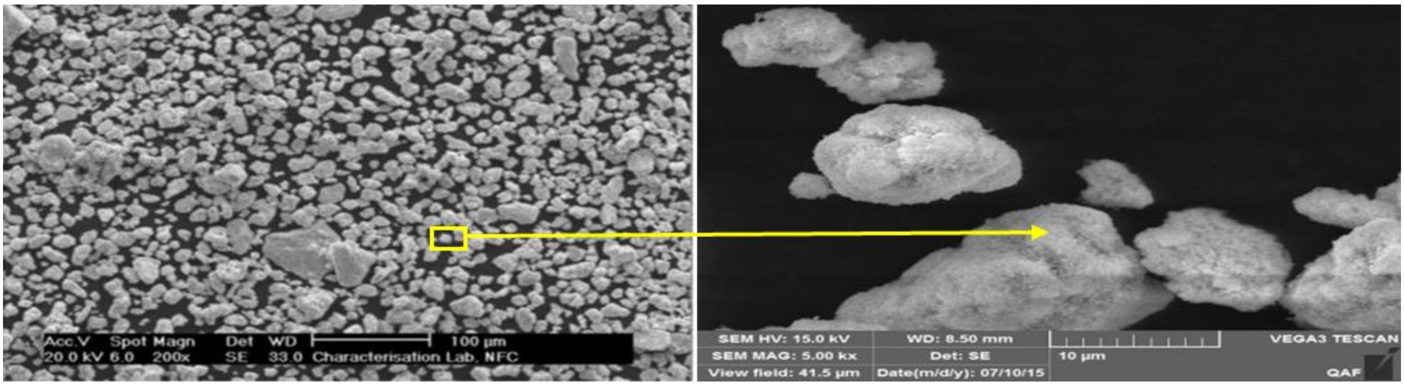

Figure-4: SEM picture of chemically active AU powder

The automation has resulted in an increase of recovery to around 99% (one of the highest recovery worldwide), 20% reduction in process variability, 40% reduction in man shifts, 55% reduction in average air activity.

There has been more than 10-fold increase in the production of UO_2 powder using the existing infrastructure after the process modifications.

Developments in UO_2 Pellet and Fuel Bundle Fabrication:

a) Design and indigenous development of an Advanced 3-D blending machine ensured homogeneity in mixing of UO_2 powder with lubricant. This has reduced the powder blending time drastically from 30 minutes to about 4 minutes and helped in lowering the variations in green pellet density by five times. The 3D Blending Machine has replaced the existing carboy rolling machine.

b) Introduction of Integrated Blending & Granule Transfer System, **Fig.5(a)** and Rotary Compaction Press, **Fig. 5(b)** for final compaction of UO_2 powder resulted in reduction in density variation in green pellets by 50% and two fold increase in the productivity. Also, consistency in sintered density and reduction in handling defects like chips by 3% was achieved by using these systems.

c) Development *of* automatic pellet stacking machine **(Figure 6)** was also carried out. The machine is based on vision technique where the image of unstacked pellets row is captured and is processed to find individual pellet length and its position. An advanced algorithm is developed for selection of pellets from row being stacked and buffer to obtain required stack length (480.68±1.60 mm). A robot is used for interchange of pellets as decided by the algorithm. After stacking, stacked row is verified for stack length by LVDT (Linear Variable Differential Transformer). Machine speed is equivalent to an operator speed. This auto stacking machine provides great ergonomic advantages by eliminating dependence on skilled operator for stacking and it also minimizes radiation exposure to the working personnel.

d) Design & Development of High Capacity Molybdenum Boat with MLR Material resulted in improved sintering quality, thermal life and capacity. The innovative corrugation design at free surfaces

Figure-5 (a): Integrated Blending & Granule Transfer System

Figure-5 (b): Rotary Compaction Press

Figure-6: Automatic pellet stacking machine

has resulted in better heat transfer and sintering. With modified boat, both capacity per boat and Thermal Fatigue Life of the boat has increased by 50%.

e) Automated Green Pellet Charging System shown in **Fig-7(a)** has been integrated with Compaction press.

Figure-7(a) & 7(b): Automated Green Pellet Charging & Sintered Pellet Discharging Systems

f) Automated Sintered Pellet Discharging System shown in **Fig 7(b)** has been developed for discharge of sintered UO_2 pellets from Moly boats into SS rod trays for inspection and grinding. Vision based SCARA Robot processes the image from Area Scan and analyses the position of the pellets to Camera place on SS trays.

(to be continued)

Dr Dinesh Srivastava
(cenfc@nfc.gov.in)
Chief Executive, Nuclear Fuel Complex Hyderabad and Fellow INAE

Dr Komal Kapoor
(kapoork@nfc.gov.in)
DCE, Nuclear Fuel Complex, Hyderabad

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TVA announces new nuclear programme

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Oklo, Argonne to commercialise advanced fuel recycling technology

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A guide to the EU's 'green' taxonomy - and nuclear's place in it

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Fusion energy record at JET 'huge step' forward

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Cameco restarts Canadian uranium operation

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Completion of MBIR reactor brought forward

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Feasibility study for microreactor in Alaska

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US prototype supports microreactor development

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UK regulators approve China's UK HPR1000 design

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South Africa seeks proposals for new research reactor

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Unique fuel facility restarts fabrication

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Initiatives aim to speed fusion deployment

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European Commission presents text of nuclear and gas CDA

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China and Argentina sign nuclear project deal

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West Virginia to remove nuclear construction ban

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Electron beam plan to keep frozen imports COVID-free in China

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Viewpoint: Europe's clean energy dreams should include nuclear

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Ukrainian used fuel storage in commissioning

https://www.world-nuclear-news.org/Articles/Ukrainian-used-fuel-storage-in-commissioning

Vogtle unit to test 6%-enriched fuel

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Swedish government gives go-ahead for used fuel repository

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US, Japanese firms agree to cooperate on fast reactors

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BN-800 running on 60% MOX

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Bruce 7 prepares for isotope production

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Compiled by S.K.Malhotra

INS Round Up

1. INS Head Quarter

1.1 INS organises its Annual Conference INSAC 2022

The conference was organised during March 28 to 31, 2022 in DAE Convention Centre, Anushaktinagar, Mumbai. The theme of the conference was "Nuclear Power towards Green Energy in India". The conference aimed to bring together former and current scientists and engineers to share the new developments, breakthroughs, innovations, updates of the plant performances, challenges and way forward through talks, presentations and panel discussions. The industry partners both from private and public sector who play an important role in pursuing the country's nuclear power programme were invited to share their experiences and suggestions.

The conference was inaugurated by Shri K N Vyas, Chairman, Atomic Energy Commission and Secretary, GOI, Department of Atomic Energy in the presence of Guests of honour Dr A K Mohanty, Director BARC, Shri B C Pathak, C&MD, NPCIL, Dr B Venkatraman, Director, IGCAR and I/C CMD, BHAVINI. In his inaugural address, Shri K N Vyas complimented INS for organising the annual conference with a very important theme. He said, he felt nostalgic in the presence of galaxy of elders and dignitaries present in the audience who had guided the department in the past. He mentioned the challenges he is facing in convincing the government authorities about the need to support nuclear energy as a base load power if India has to meet the target of net zero carbon emission by 2070. In his message to the Unit heads of DAE, he stressed the need to closely collaborate with industry to accelerate manufacture and delivery of critical items in time. He expressed the need to look into production of green hydrogen in the department. He ended his talk with the advice to utilise the excellent talent in DAE to achieve breakthrough in emerging technologies.

Dr A K Mohanty, in his address brought out the importance of hydrogen technologies in meeting the demand for green energy. He briefed about the work being carried out in BARC on several innovative technologies. He also talked about several important developments at BARC in the field of design and validation of high temperature reactors (HTRs). The HTRs are important as source of power in remote and hostile locations and in generation of green hydrogen.

Shri B C Pathak highlighted the important role played by nuclear power in Europe, China and in India in the recent power crisis. He stressed the need to make nuclear power economically competitive by cutting the cost of construction and completing the projects in time. He mentioned that Indian industry has a very vital role in the success of nuclear program. He suggested to industry to better orient its business to suit to the time schedule of nuclear projects and to keep up the schedule of manufacture. He expressed that the annual conference will provide opportunity to discuss and deliberate on collaborative initiative to achieve the department's targets.

Dr B Venkatraman complimented INS for organising the annual conference with a very relevant topic for deliberation in technical sessions and in panel discussions. He particularly appreciated the topics chosen for the panel discussion and said he is looking forwarded for a fruitful outcome.

Shri S K Mehta, in his Presidential address stressed the importance of curbing green house gas emission so that the global average temperature rise can be limited to 1.5 degrees above the pre-industrial times. He said given that the nuclear power plants produce stable energy with low carbon emissions, it would be logical to see that it plays a key role as the Energy (power) source alongside other sustainable sources such as wind, solar and even hydel. For PHWR based NPPs, practically in all aspects there is a self-reliance and their performance matches to international level. Regarding LWRs which are being setup with Russian collaboration, there is a reasonably high level of Indian participation and has been steadily increasing. Higher Public Private sector collaboration shall give better dividends. He thanked large number of senior members of INS, elders and dignitaries who came for the conference. He expressed hope that the deliberations would open up newer initiatives.

Shri S K Malhotra, Secretary INS and Convener of the Conference mentioned about the importance of the theme of the conference and the urgent need to accelerate nuclear program to meet the net zero target by 2070 announced by the Government. With growing demand of electricity, he also stressed the need to accelerate green hydrogen technologies which also need advanced nuclear plants. He said that the technical and panel discussions in the conference will deliberate on accelerating capacity addition of green energy. He thanked EC members for their support, encouragement, participation and guidance in organising the conference.

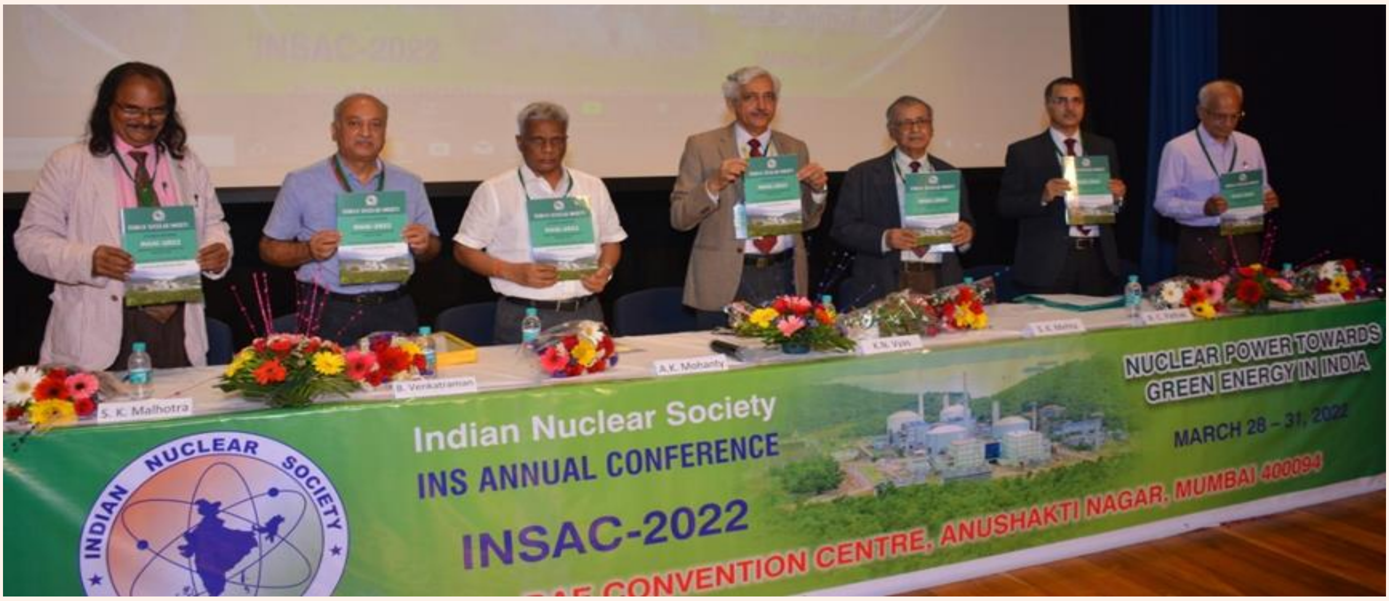
Dr A Rama Rao, Co-Convener of the conference while proposing vote of thanks, thanked all the dignitaries for gracing the function and for their whole hearted support to INS and its activities. He thanked all the session chairs who had agreed to chair respective sessions and panel discussions. He thanked the industry partners who readily agreed to deliver talks and participate in the panel sessions. He thanked BARC, NPCIL and AERB for their support in organizing the conference by providing highly motivated volunteers who took control of executing the conference activities. He thanked EC members for extending moral support and appreciation at every stage.

During the conference, two plenary talks and eleven invited talks were delivered and there were two panel discussions, The conference

28 March, 2022	https://youtu.be/JKQrlOtHVec
29 March, 2022	https://youtu.be/qvJkupjAJ5U
31 March, 2022	https://youtu.be/sEgMrdBlvLg

ended with a round up session of the conference. Members can access the proceedings on you tube link given above.

1.2 **Webinar Series: Following five talks were arranged by the INS .**



15th **INS Webinar** was delivered by Shri Jitendra Srivastava, Chairman & Chief Executive, Heavy Water Board on February 5, 2022 on ‘Saga of Heavy Water Board’.

16th INS Webinar was delivered by Shri Chanchal Manna, GM Mines, UCIL, Jaduguda on February 19, 2022 on ‘Uranium Ore Mining and Processing for Energising the Front – end of Indian Nuclear Fuel Cycle’.

17th INS Webinar was delivered by Dr. D.K. Sinha, Director, AMD, Hyderabad on March 5,2022 on ‘Milestones and Vision for Exploration of Atomic Minerals in India’.

18th INS Webinar was delivered by Prof. Amit Garg, Indian Institute of Management, Ahmedabad on March 19, 2022 on ‘The Role of Nuclear Energy in meeting India’s Net Zero target by 2070’.

19th INS Webinar was delivered by Dr. Manpreet Sethi, Distinguished Fellow, Centre for Air Power Studies on April 2, 2022 on ‘Nuclear Terrorism and Nuclear Security – Challenges and Mitigation Measures’.

2. INS Branches

2.1 **INS Hyderabad Branch**, under its ‘Azadi ka Amrit Mahotsav Webinar Series’ organised following invited talks -

The seventh invited talk was delivered by Padma Shri Prof. Rohini M. Godbole, Centre for High Energy Physics, Indian Institute of Science, Bangalore on 22nd February, 2022 on ”Mega Science Projects: Relevance of and for India”.

The 8th invited talk was delivered by Padma Shri Prof. K. Vijay Raghavan, Principal Scientific Adviser to Government of India on 23rd March, 2022 on “Science and Technology Directions for the Next Three Decades”.

The 9th invited talk was delivered by Padma Shri Prof. R. B. Grover, Member, Atomic Energy Commission on 21st April, 2022 on “The Relationship Between Science and Technology.”

2.2 **INS Rawat bhata Chapter**

The Chapter has been re-activated with constitution of a fresh Executive Committee

Chairman: Shri N.K. Pushpkar, Site Director RR Site, NPCIL

Vice Chairman: Shri K.V. Tale, General

Manager, HWP (Kota)
Shri P.A. Pratap, Project Director, NFC (Kota)

Secretary: Shri Amit Shrivastava, RAPS-3&4

Treasurer: Dr. M.L. Parihar, NFC (Kota)

Members: Shri P.N. Prasad, RR Site, NPCIL
Shri K.K. Jha, RR Site, NPCIL
Shri Harish Kumar Sharma, HWP (Kota)
Shri Vijay Singh, RR Site, NPCIL

3. Programmes organised by other institutions to disseminate information related to nuclear science and technology where INS members actively participated -

3.1 Under the series of webinars being arranged by HBNI as part of celebration of AZADI KA AMRIT MAHOTSAV, Prof. Bikash Sinha, INSA Senior Scientist, former Homi Bhabha Professor, DAE and former Director, VECC & SINP delivered lecture titled "Accelerators & Science of Accelerators in India" on 4th February, 2022.

3.2 AERB, as part of their celebration of AZADI KA AMRIT MAHOTSAV, have started a series of invited talks in physical mode. The first two talks were organised at AERB Auditorium on April 27, 2022. Shri S.K. Malhotra, Former Head, Public Awareness Division spoke on 'Public Risk Perceptions on Nuclear Energy and Radiation Applications'. Dr' A.N. Nandakumar, Former Head, Radiological Safety Division, AERB spoke on 'Societal Applications of Radiation'.

3.3 Dr. Anil Kakodkar was interviewed by Dr. Chris Keefer, Senior Editor and Host at Decouple Media, Canada on topic 'India's Nuclear Past and Future on April 2, 2022. (https://anchor.fm/chris15401/episodes/Indias-Nuclear-Past-and-Future-with-Dr-Anil-Kakodkar-e1g86h4)

3.4 **Women in Nuclear – India (WIN-India),** a new organisation has been created with the specific purpose of providing a platform for women engaged in various fields of nuclear science and technology, security and strategy in India. As part of this effort, a debut Webinar event was held on Saturday 12th March, 2022 on International Women's Day with a specific theme **"Exploring the Myriad Facets of Nuclear Energy".** For more details pl contact Dr Umasankari **<uma_k@barc.gov.in>.**

Compiled by S.K. Malhotra & A. Rama Rao

Do you know?

Barely six weeks after Roentgen's discovery , X rays were used on a Montreal resident Toulson Cunning to facilitate detection and surgery to remove a bullet from his leg. "Never before or since has any scientific discovery moved from bench to patient bedside so quickly."

Biswas and Patro from Institute of Nuclear Physics , University of Calcutta were among the first to measure fission cross section of uranium 235 (526±10 barn) in 1949.The work was however initiated much before the world knew about the nuclear bomb. They used a home-made proportional counter with electrolytic deposited uranium target and neutrons from a Ra-Be source.

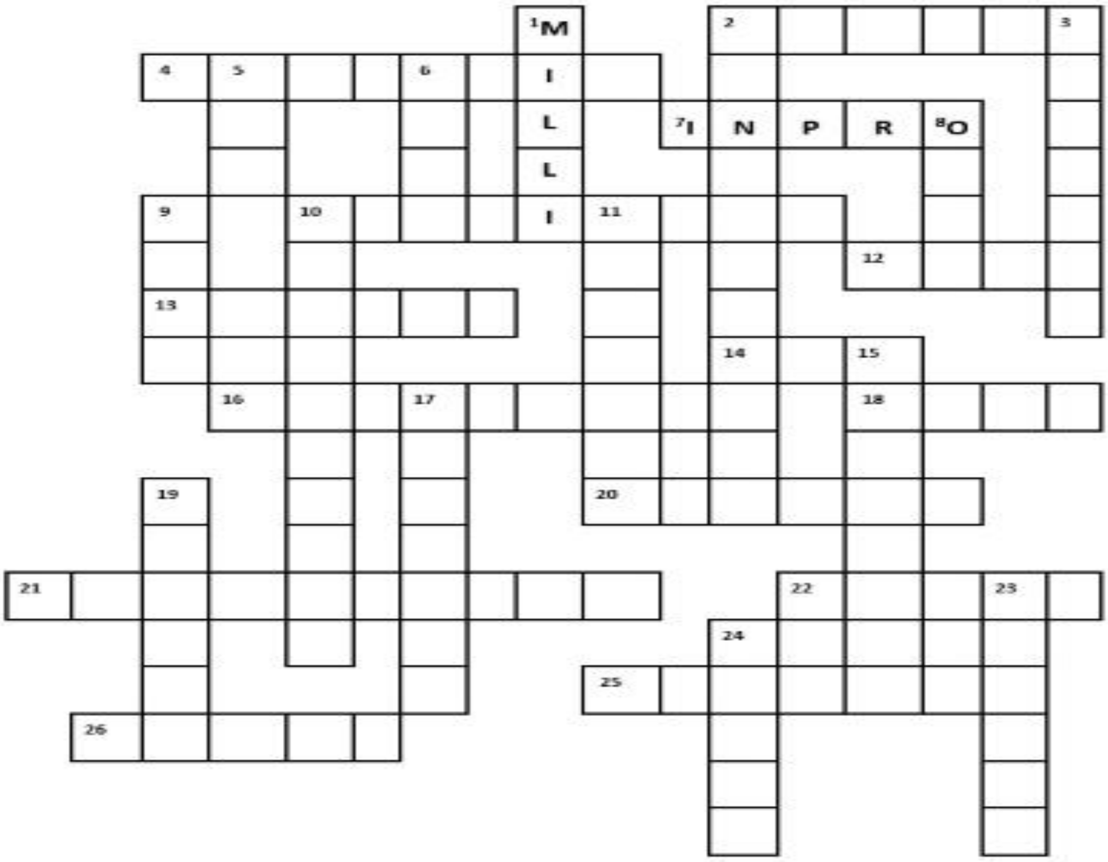
Contributed by K.Tirumalesh and M.R.Iyer

Solution to the Cross word puzzle appeared in INS NL Feb,2022 (Vol 22 Issue 1)

DOWN	ACROSS
1. BDBA	1. BRAGG
2. ISOMER	3. MINOR ACTINIDES
4. CANISTER	6. WIGNER
5. BRACHYTHERAPY	8. BIOASSAY
7. MAXWELLIAN	12. THERMONUCLEAR
10. CHERENKOV	13. RICKOVER
11. BECQUEREL	14. COASTDOWN
14. COW	17. SOMATIC
15. AHWR	18. BURNUP
16. DOSIMETER	

Editor

CROSSWORD



DOWN

1. One thousandth. (5)
2. Process in which isotope exchange between two substances is carried out at a single temperature. (11)
3. To determine concentration of a solute by adding incremental amounts of a reagent of known concentration using an indicator. (7)
5. Square test, a statistical hypothesis test. (3)
6. A facility for interim storage of vitrified high level radioactive waste. (4)
8. Egg shaped sedimentary grain found on the sea floor mostly in tropical shallow seas. (4)
9. This type of water has high mineral content. (4)
10. Dissociation of molecules by ionising radiation due to cleavage of chemical bonds. (10)
11. Latin name of an alkali metal. (7)
15. General term for substance or mixture of substances . (8)
17. Device used to determine number of times an event has occurred. (7)
19. The process used for synthesis of metal oxides from colloidal solutions of their alkoxides. (3-3)
23. Transparent front part of the eye. (6)
24. Total or a dozen of a dozen. (5)

ACROSS

2. Result of alteration of the DNA sequence of the chromosome of a species. (6)
4. ___ waves are a type of energy propagating through a medium by means of adiabatic compression and decompression. (8)
7. International project for long term planning and collaboration on innovations in nuclear reactors, fuel cycles etc. (5)
10. Liquid stream remaining after principal solutes have been removed significantly through contact with an immiscible liquid. (9)
12. A horizontal passage leading into an underground mine.(4)
13. Symbol of a food product having been radiation processed. (6)
14. Computer memory used to store working data and machine code. (3)
16. A synthetic element named after the capital of the country where it was synthesized in 2003. (9)
18. Not a base. (4)
20. The liquid state of a solid at elevated temperature.(6)
21. A medical treatment that reduces pain or symptoms of a disease without providing a cure. (10)
22. Threads per inch is the typical unit of the ___of a screw. (5)
25. 'G' in GS process for manufacturing heavy water stands for___. (7)
26. ___ box is used for safe handling of radioactive materials (5)

The views and opinions expressed by the authors may not necessarily be that of INS

INS News Letter is Published by S. P. Dharne on behalf of Indian Nuclear Society, Project Square, Anushakti Nagar, Mumbai – 400094, E- mail: indiannuclearsociety@gmail.com. Tel: 91-22- 2559 8327,