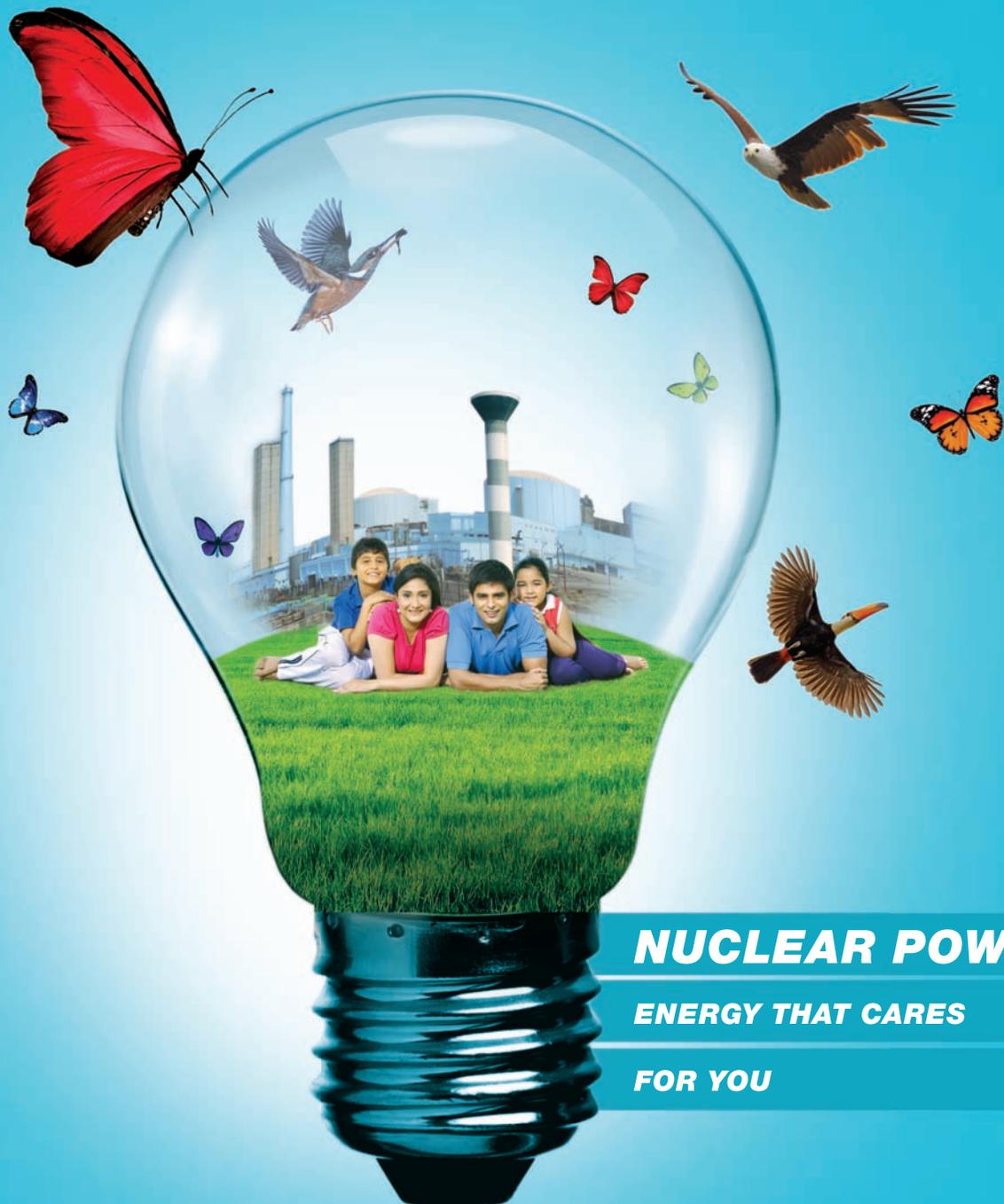


Nu-Power



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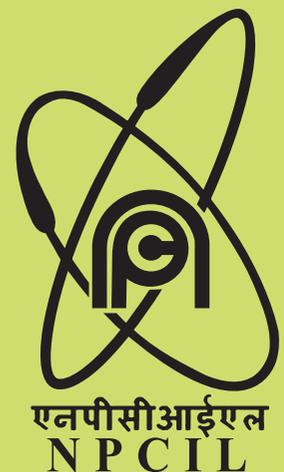
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A Major Fillip to Nuclear Power

It was a moment of achievement, celebration and pride. It was also a reflection of a concerted effort. On March 31, 2017, NPCIL reached a joyous milestone when the 1000-MW Unit-2 of Kudankulam Nuclear Power Plant (KKNPP-2) – the 22nd nuclear power reactor in the country – commenced commercial operation. Its identically specified twin reactor unit KKNPP-1 had commenced commercial operation in December 2014. With a combined power-generating capacity of 2000 MW, the first set of two VVER-type Kudankulam reactors has raised the installed nuclear power generating capacity in the country to 6,780 MW. One great success leads to another. Likewise, the saga of VVERs continues at Kudankulam. With the first pour of concrete, the work has started for the setting up of the next 2 units (KKNPP-3&4) at Kudankulam.

Two more units (units-5&6) have also been launched recently upon receiving the administrative approval and financial sanction from the Government of India, and for these units a 'General Framework Agreement' has been signed with the Russian Federation. Thus, the Kudankulam site will eventually have a tally of six VVERs.

These state-of-the-art VVERs are Pressurised Water Reactors belonging to Light Water Reactor category. With several VVERs deployed globally, these are

With a combined power-generating capacity of 2000 MW, the first set of two VVER-type Kudankulam reactors have raised the installed nuclear power generating capacity in the country to 6,780 MW.

among the safest reactors in the world. With their proven pedigree, these reactors have taken the safety paradigm of nuclear power plants to an even higher level. The Kudankulam VVERs harbour a host of active and passive systems that ensure safe plant operation and safe reactor shutdown.

Each of the two KKNPP reactors is the largest single power-generation unit in India, nuclear or otherwise. KKNPP, a glittering example of Indo-Russian friendship and cooperation, stands tall as a 'temple' of Modern India along with towering historic monuments for which Tamil Nadu is famous globally.

Access to power is linked to countless dreams of citizens for economic growth and social inclusion. Nuclear power helps in realising these dreams in the most benign and environment-friendly

way, providing a proven, viable pathway for ensuring a sustainable future.

Clean energy continues to make strides globally, displacing fossil-fuel-based power plants gradually. Among clean electricity generation technologies, nuclear power occupies a vital place as an earth-friendly mainstream option for emissions-free, 24x7 power generation.

The planet is taking punches from an irrefutable warming that is happening too quickly, even on the scale of human lifespan, and there are already enough distress signs visible. The oceans are absorbing some of the heat. This gives us a false reassurance of a slower global warming than it actually is. This has serious repercussions and we have a very narrow window of time for effective action.

The world must accelerate clean power generation, because

The planet is taking punches from an irrefutable warming that is happening too quickly, even on the scale of human lifespan, and there are already enough distress signs visible.

combating climate change is an imperative and not an option.

India, committed to eco-friendly energy, is reducing emissions substantially. In a recent move, as part of the clean energy push, the government has approved the setting up of 10 more indigenous Pressurised Heavy Water Reactors of 700 MW each in a fleet mode, apart from those already under construction. Upon the progressive completion of the reactors presently under construction and accorded sanction along with those in operation, the total installed nuclear power capacity in the country would reach 22,480 MW. The 10 new PHWRs will be set up by NPCIL in a phased manner. The indigenous 700-MW PHWR reactor design has been developed by NPCIL with support from other units of the Department of Atomic Energy. The setting up of these reactors will further boost the domestic industry in line with the 'Make in India' initiative of Government of India and will generate ample employment in the Indian nuclear industry by augmenting its capacities and capabilities.

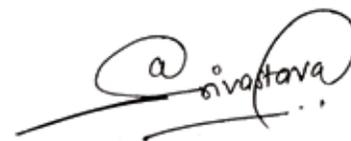
In addition, a series of Light Water Reactors are planned to be installed

in future. This combined approach will speed up clean power generation in the country in the coming years, reflecting our commitment towards building of greener and cleaner nation.

In this issue, we bring you the latest happenings along with regular assortment of news, events and features, as usual.

In a recent move, as part of the clean energy push, the government has approved the setting up of 10 more indigenous Pressurised Heavy Water Reactors of 700 MW each in a fleet mode, apart from those already under construction.

And don't forget to send your feedback to the Editor in case you have any comments or suggestions. Help us replenish Nu-Power with innovative and meaningful stuff to take it to a new level. With this note, I wish you all a very happy & prosperous new year 2018.



Amritesh Srivastava
Editor

KKNPP Unit-2 Begins Commercial Operation

Kudankulam Nuclear Power Project (KKNPP) reached a historic milestone on March 31, 2017, when its second unit, KKNPP Unit-2, of 1000-MW capacity commenced commercial operation. Earlier, the unit was synchronised to the southern grid in August 2016. The electricity generated by the unit will be allocated to the beneficiaries in the southern region, with firm shares to the states of Tamil Nadu, Telangana, Karnataka, Kerala and the Union Territory of Puducherry.



KKNPP-2 is the 22nd nuclear power reactor in the country and its commercial operation has raised the installed capacity of nuclear power generation to 6,780 MW.

The KKNPP Units-1 and 2, of 1000-MW capacity each, are VVER-1000 type reactors set up in technical cooperation with the Russian Federation.

With the electricity that the twin-unit plant generates, it can illuminate up to 20 million homes.

[NPCIL HQ News Desk]

First Pour of Concrete at KKNPP-3&4

The first pouring of structural concrete for two Russian-built VVER reactors, of 1000 MW capacity each was laid on June 29, 2017 at Kudankulam Nuclear Power Project Units-3&4 (KKNPP-3&4). The milestone followed approval by Atomic Energy Regulatory Board on June 19, 2017 for pouring of the first concrete for the units. The units represent the second phase of the Kudankulam project.

Mr. S.K. Sharma, Chairman and Managing Director of NPCIL; Mr. R. S. Sundar, Executive Director (Light Water Reactors); Mr. S. V. Jinna, Site Director, KKNPP; and seniors officials from Atomstroy exports, the Russian firm supplying the VVER reactor technology, were present on the occasion.



[NPCIL HQ News Desk]

First pour of structural concrete underway at KKNPP-3&4

General Framework Agreement and Plant Contracts Signed for Setting Up KKNPP-5&6

A General Framework Agreement was signed between India and Russia for setting up the third pair of VVER reactor units (Units-5&6) at Kudankulam Nuclear Power Plant (KKNPP) site in Tamil Nadu. The two VVER-type Light Water Reactors, each of 1000-MW capacity, represent the state of the art in Pressurised Water Reactor technology. The agreement, covering the design and supply of the main equipment for the new units, was formalised between Nuclear Power Corporation of India Limited (NPCIL) and the ASE Group of the Russian Federation on June 1, 2017. The ASE Group consists of Atomproekt, Atomstroyexport and ASE Joint Stock Engineering Company

(formerly Atomenergoproekt).

Following this, Nuclear Power Corporation of India Ltd (NPCIL) and Atomstroyexport signed contracts on July 31, 2017, covering the design and supply of the main equipment for the new units. NPCIL will be responsible for review of the design and AERB clearances and licensing of the plant; construction of buildings and structures; erection of equipment and systems as well as commissioning and operation of the nuclear power plant.

This marks the commencement of the unfolding of the third stage of the plant. Physical work is already underway for Units-3&4. Recently, the first pour of structural concrete was laid for Unit-3&4.



The signing of agreement at the 18th Annual Russian-Indian Summit, held alongside the St. Petersburg International Economic Forum, by Mr. Valery Limarenko, president ASE Group, and Mr. S.K. Sharma, CMD, NPCIL in the presence of Hon'ble Prime Minister Shri Narendra Modi and the Russian President His Excellency Vladimir Putin.

At the plant site, the first pair of reactors, KKNPP-1&2, with a combined installed capacity of 2,000 MW, are already supplying electricity to the India's southern states of Tamil Nadu, Telangana, Karnataka, Kerala and the Union Territory of Puducherry.

Upon the completion of Units-3 to 6, the KKNPP site will host six VVER reactors, with a combined installed power generation capacity of 6,000 MW.

[NPCIL HQ News Desk]

Mega Impetus for Nuclear Power Cabinet Approves 10 New Indigenous PHWRs

The Government has accorded approval for setting up 10 indigenous 700-MW Pressurised Heavy Water Reactors (PHWRs) in a fleet mode. On the progressive completion of reactors presently under construction and these 10 reactors, the installed nuclear power capacity in the country will reach 22,480 MW.

These 10 PHWRs will be set up by NPCIL. These reactors will be part of India's latest-design 700-MW PHWR fleet with state-of-the-art technology, meeting the the highest standards of safety. The domestic industry, over a period, has developed capabilities to manufacture and supply equipment and components to exacting standards. With manufacturing orders to domestic industry, it will be a major step towards strengthening India's credentials as a major manufacturing partner.

The approval by the government of the 10 PHWRs in fleet mode has generated confidence in the Indian nuclear industry about the continuity of business, as it would bring business for them over a period of time. It would also help the Indian industry evolve and augment its capacities as well as capabilities.

NPCIL humbly acknowledges the strong belief shown by the country in the capability of Indian nuclear scientific community, as brought out in the statement by the Government.

NPCIL will strive to rapidly add nuclear power capacity, providing the country clean baseload power and bolstering efforts to combat climate change.

[NPCIL HQ News Desk]

Structure Construction of Both NDCTs Completed at KAPP-3

The construction of structure of both Natural Draught Cooling Towers (NDCTs), 3A and 3B, has been completed at Kakrapar Atomic Power Plant unit-3 (KAPP-3). NDCT-3A and NDCT-3B were completed on May 11, 2017 and September 4, 2017, respectively.

The Natural Draught Cooling Tower shell has a hyperbolic profile with a

height of 166 m based on thermal design. Each NDCT is designed to dissipate a heat load of 790 MW(t) from Condenser Cooling Water and Auxiliary Service Water systems. The foundation of NDCTs and cold water basin are independent. The foundation for tower shell is continuous annular reinforced concrete structure. The ring raft

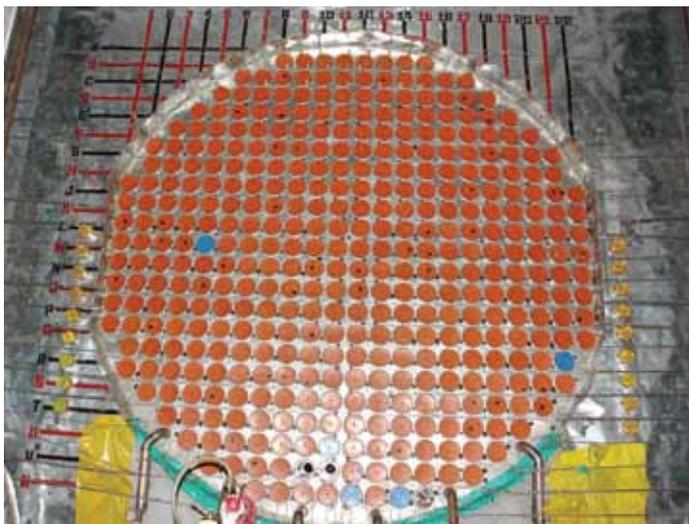


The completed shell structures of both the NDCTs

of each NDCT has a diameter of 142 m. There are 96 Tier-I and Tier-II raker columns as well as 48 rectangular pedestals. The raker columns spanning the air-intake opening transmit the weight of the integral shell as well as seismic and other forces induced in it onto the foundation. The NDCT shell is 1.6 m thick at the bottom, 0.3 m at throat and 0.75 m at the top. NDCT structures were constructed with the help of jump-form shuttering system, which helped in speeding up the construction activities. The tower shell was completed in 107 lifts, with each lift being 1.5 m. The preparatory works, reinforcement, shuttering and concreting of each lift took around 2.5 to 3 days on an average. Cumulatively, 17,200 cu.m of concrete and 2580 metric tonnes of reinforcement were used for the completion of each shell structure. The total surface area of each tower is 90,000 sq.m.

[NPCIL HQ News Desk]

Calandria Tube Rolling Work Completed at KAPP-4



Calandria tube rolling work completed

Kakrapar Atomic Power Project unit-4 (KAPP-4) has successfully achieved the milestone of completion of 'Calandria Tube Installation' on August 30, 2017. KAPP hosts two of India's first indigenously designed 700-MW Pressurised Heavy Water Reactors.

Calandria Tube Installation is one of the major activities on the critical path of the project. The entire work of Calandria Tube installation at KAPP-4 was completed in 42 days. The work involved rolling of 392 Channels Sandwiched joints of Calandria Tube between Inserts and CSTS Bore in each FM Vaults, resulting in a total of 784 rolled joints. All these rolled joints were successfully qualified as per technical specification requirement and met the design intent.

[NPCIL HQ News Desk]

Supply of Components Commences for KKNPP-3&4

As a part of indigenisation (Make in India initiative), NPCIL, along with Indian industry partners, is carrying out the work of design, detailed engineering, material selection, fabrication and supply of Systems, Structures and Components (SSCs) for 2 X 1000 MW units of Kudankulam Nuclear Power Project-3&4 (KKNPP-3&4).

An initial lot of two out of a total of 40 large-diameter stainless steel tanks was dispatched at KKNPP site on July 8, 2017. These tanks will be erected in the lowermost elevation of Reactor Auxiliary Building.

[NPCIL HQ News Desk]



Two large-diameter stainless steel tanks at the manufacturer's premises before dispatch.

First 6.6-kV Load of KAPP-3 Started

On observing all the parameters of Start-Up Transformers (SUTs), all the 6.6-kV Class-IV buses were charged on April 11, 2017 and Class-III bus C-34 was charged on April 25, 2017. These buses are kept in charged condition.

The starting of first 6.6-kV Class-III loads, Service Water Pump Motor-5 & 6 (3-7181-PM-5&6) checks, pre-commissioning checks, including logics, interlocks and protection checks of breaker and motor were carried out. Motor no-load test of Service Water Pumps 3-7181-PM-6 and 3-7181-PM-5 were carried out successfully on April 27, 2017 and May 3, 2017, respectively. After the complete commissioning checks



Commissioning of Service Water Pump-5 at KAPP-3

of Service Water Pump-5 and associated circuits, load test was successfully carried out on May 5, 2017. Service Water Pump was continuously operated for closed-



Induced Draught Cooling Tower-3B charged with Service Water

loop flushing of different circuits of Service Water System and Primary loop flushing of Chilled Water System.

[NPCIL HQ News Desk]



Feeder installation at KAPP-3

Commencement of Feeder Installation at KAPP-3&4

Work on a major milestone on the project critical path has commenced with the installation of Feeders in KAPP-3 recently.

KAPP-3 has 784 Feeders (392 Feeders inside each FM vault) to be installed and grouped into 86 Feeder banks. Mock-up as well as pneumatic and helium-leak testing has already been completed and these Feeders are under installation. As in September 2017, about 35% of the work is completed.

[NPCIL HQ News Desk]

Start-Up Transformers of KAPP-3 Charged



Start-Up Transformer yard of KAPP-3

Start-Up Transformers (SUTs), viz., SUT-3A and 3B (each of 70 MVA capacity, 220 kV/6.9kV/6.9kV), of Kakrapar Atomic Power Project Unit-3 (KAPP-3) were permanently charged on March 22, 2017 from Main Control Room of KAPP-3.

All the requirements and

prerequisites related to electrical system, viz., SUT protection testing and operability checks for circuit breaker and respective isolators were done prior to the charging of the SUTs. A full-scale mock-up test of Fire Water Deluge System for the SUTs was completed successfully and the deluge system kept poised

on permanent basis.

Statutory clearance was obtained from Western Region Load Dispatch Centre (WRLDC) for the charging of the SUTs along with 220-kV cable and respective 220-kV equipment.

[NPCIL HQ News Desk]



Low-Pressure Feed Water Heater (LP-3) at the manufacturer's workshop

Low-Pressure Feed Water Heaters for RAPP-7 Dispatched

Low-Pressure Feed Water Heaters (LP-2 and LP-3) were despatched from manufacturer's workshop for RAPP-7 in March 2017. The equipment is designed and manufactured as per ASME Sec VIII Div. 1, with Quality Surveillance (QS) carried by NPCIL QA Directorate, Mumbai.

[NPCIL HQ News Desk]

PDHRS Heat Exchangers for RAPP-7



PDHRS Heat Exchangers at the manufacturer's workshop

Four Passive Decay Heat Removal System (PDHRS) Heat Exchangers (HXs) were flagged off from the manufacturer's workshop on February 15, 2017 for NPCIL's Rajasthan Atomic Power Project Unit-7 (RAPP-7).

PDHRS is a very important equipment which ensures continued availability and recirculation of secondary side of Steam Generator for decay heat removal during a hypothesised condition of station blackout. These HXs were manufactured as per ASME-SEC-III-NC design section criteria, with seismically-qualified support structure.

[NPCIL HQ News Desk]

India Becomes an Associate Member of CERN



European Organisation for Nuclear Research (CERN)

India becomes an Associate Member of European Organisation for Nuclear Research (CERN) as the agreement signed by Dr. Sekhar Basu, Chairman, Atomic Energy Commission and Secretary, Department Atomic Energy and CERN Director-General Dr. Fabiola Gianotti entered into force on January 16, 2017.

Decades-old continuous participation by India's Department of Atomic Energy and Department of Science & Technology in CERN programmes has earned India

this status of Associate Member. At a brief ceremony held at CERN headquarters, India reiterated its interest in adding two significant dimensions to its existing science and technology collaboration with CERN: industrial participation and education/training, which would allow CERN to directly engage Indian industries and enhance Indian students' participation in various experiments and research activities.

Source: Department of Atomic Energy

NPCIL Wins PRatishtha Awards 2017 for 'Atom on Wheels'



Nuclear Power Corporation of India Limited (NPCIL) clinched the first prize at the first-ever PRatishtha Awards-2017 organised by Public Relations Society of India Limited (Mumbai Chapter), for its innovative campaign 'Atom on Wheels' under 'Best Communication Campaign in Public Sector' category. Amidst

a congregation of eminent PR professionals and communication stalwart, the event was organised on October 6, 2017 at Nehru Centre in the august presence of Mrs. Rajshree Birla, (Director of Aditya Birla Group of Companies) and Mr. Brijesh Singh, IPS and Head (Cyber Security), and DG PR, Maharashtra as chief guests.

The award was accepted by Mr. Amrithesh Srivastava, Sr. Manager (Corporate Communications), on behalf of NPCIL. These awards were conferred in various categories, in which NPCIL was felicitated for its innovative campaign "Atom on Wheels". Under the campaign around 6 lakh villagers of about 1,500 villages of 6 states, namely, Haryana, Gujarat, Madhya Pradesh, Rajasthan, Maharashtra and Andhra Pradesh, were briefed about the various aspects of nuclear energy in a lucid and simple way. The objective of the campaign, under the rural integration programme, was to dispel all the apprehensions about nuclear energy as well as to make people aware of the various positive aspects of nuclear power.

The awards were distributed at at the two-day event of Indian Communication Summit (INDICOM-2017).

[NPCIL HQ News Desk]

Vigilance Excellence Awards



Mr. Prateek Goswami, Chief Vigilance Officer along with Mr. V.K. Gupta, GM (Vigilance) and other NPCIL officers, receiving the award from Mr. K.V. Chowdary, Central Vigilance Commissioner



Mr. N.P. Panchal, DGM (Vigilance), receiving Vigilance Excellence Award (Individual) from Mr. K.V. Chowdary, Central Vigilance Commissioner

Nuclear Power Corporation of India Limited bagged Vigilance Excellence Award for the year 2016-17, established by the Institute of Public Enterprise (IPE), in an award ceremony held at the IPE Auditorium in

Hyderabad. Mr. N.P. Panchal, DGM (Vigilance), NPCIL won the award in 'Individual' category.

[NPCIL HQ News Desk]

NSCI

Safety Awards 2016

The National Safety Council of India (NSCI) Safety Awards are national-level awards in the field of Workplace Safety, Health and Environment and given in recognition of establishing effective Safety Management System and excellent safety and health performance by the organisations in manufacturing, construction and MSME sectors during the relevant assessment periods.

NPCIL's TAPS-3&4 and RAPP-7&8 were bestowed the prestigious NSCI Safety Awards-2016 in a glittering award ceremony held at New Delhi.

Rajasthan Atomic Power Project Units-7&8 (RAPP-7&8) won the first-

'Sarva Shreshtha Suraksha Puraskar' to RAPP-7&8



NPCIL officials from RAPP-7&8 receiving the award from Shri Bandaru Dattatreya, Hon'ble Minister of State for Labour & Employment (Independent Charge), Govt. of India.

level Safety Award Sarva Shreshtha Suraksha Puraskar (Golden Trophy) under Construction Sector category.

Tarapur Atomic Power Station Units-3&4 (TAPS-3&4) won the Safety Award Shreshtha Suraksha

Shreshtha Suraksha Puraskar for TAPS-3&4



On behalf of TAPS-3&4, Mr. Hemant Kumar, Site Director, TMS, receiving the award from the Hon'ble Minister.

Puraskar (Silver Trophy and Certificate) in Group C under the Manufacturing Sector category. The award was conferred in recognition of the efforts in developing and implementing highly effective management systems and procedures in achieving outstanding performance in Occupational Safety & Health (OSH) for the Assessment Period of three year (from 2013-2015).

[NPCIL HQ News Desk]

KGS-3&4 Officers Win at 'DAE Safety & OHP' Meet



Mr. J.R. Deshpande, Station Director, KGS-3&4, felicitating the winners

At the 34th 'Department of Atomic Energy (DAE) Safety & Occupational Health Professional's (OHP) Meet', officers from Kaiga Generating Station-3&4 (KGS-3&4) bagged prizes in four events. The meet was held at Kudankulam Nuclear Power Project during June 28-30, 2017. The meet was jointly organised by Atomic Energy Regulatory Board and Nuclear Power Corporation of India Limited. As part of the meet, safety competitions were organised in all DAE units on the theme 'Key Principles of Human, Organisational and Technical Factors in Safety' and 'Lifestyle Diseases'.

[NPCIL HQ News Desk]

NPCIL Organises 27th Regional Meet of WIPS

NPCIL organised the 27th Regional Meet of Forum of Women in Public Sector (WIPS), Western Region, on the theme “Strong Wings for Bold Dreams – Make it Happen” at NPCIL headquarters, Nabhikiya Urja Bhavan, Mumbai on November 11, 2017. More than three hundred delegates from various public sector units (PSUs) and PSU banks of Western Region participated in the event.

The prime focus of the programme was on motivation. The deliberations at the Meet were on the need for building enthusiasm and passion in life as well as recharging individuals for succeeding on personal as well as professional level.

Mrs. Rajee Guptan, Associate Director (Engg-LWR) & Coordinator, and Mrs. E.T. Vijayarani, Sr. Manager (Human Resources) & Alternate Coordinator, WIPS-NPCIL actively participated in WIPS regional meetings right from conceptualising the theme to finalising the minute-to-minute programme for the meet.

Mr. N. Nagaich, Director (Human Resources), NPCIL addressed the gathering in the inaugural session and emphasised teamwork and gender diversity. He reiterated NPCIL’s continued commitment to support woman employees and further said that women ought to dream big. Ms. Ruby Srivastava, Director (Finance) spoke on financial empowerment of women, stressing upon the need to learn from the management of money by women employees.



Mrs. Rajee Guptan, Associate Director (Engg-LWR) & Coordinator, and Mrs. E.T. Vijayarani, Sr. Manager (Human Resources) & Alternate Coordinator, WIPS-NPCIL alongwith WIPS Cell Members of NPCIL presenting the ‘Best Enterprise Award’ to Mr. S.K. Sharma, Chairman and Managing Director, NPCIL during the NPCIL Pariwar gathering in February 2017.



Mr. N. Nagaich, Director (Human Resources), NPCIL addressing the Meet

Ms. Nirmala Samant Prabhavalkar, Advocate, High Court, Mumbai, Ms. Nazakath, Director (Finance), NFDC, Ms. Jhalal, Director (Finance), IOTIES, Dr. (Ms.) Anonna Guha, Jt. MD, Nityanjali, Dr. Sobha Nair, Consultant Psychiatrist, BARC Hospital and Ms. Harshada Patil, Psychologist shared their views on various topics related to today’s women.

Earlier, WIPS had bestowed on NPCIL the ‘third prize for Best

Enterprise Award – a Tribute to Excellence in Public Enterprise Management’ in recognition of the commendable work done by NPCIL in the area of development of women employees. WIPS Task Force members (NPCIL) presented the award to S.K. Sharma, Chairman and Managing Director, NPCIL, during the NPCIL Pariwar gathering in February 2017.

[NPCIL HQ News Desk]

COP23: Bonn Climate Conference Becomes Launch-Pad for Higher Ambition



Credit: @COP23 Twitter

Momentum Builds With New Financial Commitments on Insurance and Forests to Scaled-Up Climate Action by Governments, Cities and Companies.

Nations agreed at COP23 (November 6-17, 2017) to launch the next steps towards higher climate action ambition before 2020 at the close of the annual UN climate conference held in the German city of Bonn.

Backed by a wide range of positive announcements from governments, cities, states, regions, companies and civil society, delegates from over 190 countries agreed to a 12-month engagement focusing on ‘Where are we, where do we want to go and how do we get there?’

The ‘Talanoa Dialogue’, inspired by the Pacific concept of constructive discussion, debate and story-telling, will set the stage in Poland in 2018 for the revising upwards of national climate action plans needed to put the world on track to meet pre-2020

ambition and the long-term goals of the two-year old Paris Agreement.

The Paris Agreement's central goal is keep the global average temperature rise below 2° Celsius and as close as possible to 1.5—the lower limit is deemed crucial for survival by many small islands and vulnerable countries.

Over one degree of this rise has already occurred since pre-industrial times. The current set of national climate action plans, known as NDCs, are still heading for a path towards 3° Celsius, possibly more.

Frank Bainimarama, President of the COP23 conference and Prime Minister of Fiji, said: “I’m very pleased that COP23 has been such a success, especially given the challenge to the multilateral

consensus for decisive climate action. We have done the job we were given to do, which is to advance the implementation guidelines of the Paris Agreement and prepare for more ambitious action in the Talanoa Dialogue of 2018.”

“We leave Bonn having notched up some notable achievements, including our Ocean Pathway, the historic agreement on agriculture and others on a Gender Action Plan and Indigenous People’s Platform. We have also secured more funding for climate adaptation and launched a global partnership to provide millions of climate-vulnerable people the world over with affordable access to insurance,” said Mr. Bainimarama.

Source: UNFCCC, November 18, 2017 (abridged)

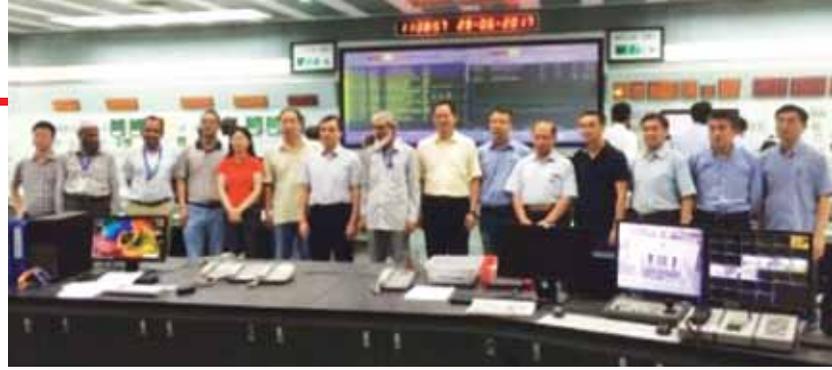
Pakistan's Chashma-4 Connected to Grid

Unit-4 at the Chashma Nuclear Power Plant in Pakistan was connected to the grid on June 29, 2017. The Chinese-supplied pressurised water reactor (PWR) – the country's fifth power reactor – is expected to enter commercial operation soon.

A ceremony was held on July 1, 2017 to mark the unit's grid connection, China National Nuclear Corporation (CNNC) announced today. The ceremony was attended by representatives from the Pakistan Atomic Energy Commission and CNNC.

Construction in unit-3 began in March 2011. It achieved first criticality on October 3, 2016 and was connected to the grid on October 15, 2016.

Construction of Chashma-4 began in late



CNNC and PAEC representatives in Chashma-4's control room (Image: CNNC)

December 2011. The Pakistan Nuclear Regulatory Authority granted permission on February 9, 2017 for fuel to be loaded into the unit, which achieved first criticality on March 15, 2017. CNNC said the unit was connected to the grid at 11.36 am on June 29, 2017.

The Chashma site – also referred to as Chasnupp – is already home to two Chinese-supplied 300 MW PWRs: unit-1, in commercial operation since 2000, and unit 2, in commercial operation since 2011.

Source: WNN (abridged)
(Published: July 3, 2017)

First VVER-1200 Reactor Enters Commercial Operation

Russia has announced the start of commercial operation of its first VVER-1200 reactor, unit-1 of the Novovoronezh-II nuclear power plant.

Also known as Novovoronezh-6, the unit was connected to the network in early August 2016, but Rosatom said that it had officially started commercial operation on February 27, 2017. This followed approval to include power generated by the unit in the country's wholesale electricity market, the state nuclear corporation said.

Novovoronezh-6 is a VVER 1200/392M pressurised water reactor unit with a design net capacity of 1114 MW. It is the first of two such units at Novovoronezh- II – the lead project for the deployment of the AES-2006 design incorporating a Gidropress-designed PWR, an evolutionary development from the VVER-1000. Construction of Novovoronezh-II units-1 and 2 – or



Novovoronezh units 6 and 7 – began in June 2008 and July 2009, respectively. The original Novovoronezh site nearby already hosts three operating reactors.

The unit was "first included in the unified energy system of the country and started the production of electric power on August 5, 2016", Rosatom said.

Source: WNN (abridged)
(Published: March 2, 2017)

Nuclear Construction Reaches 25-Year High

The nuclear industry brought more than 9 GW of new plant on line last year, the largest annual increase in 25 years, according to a new World Nuclear Association report, putting it on track to achieve the Harmony goal of providing 25% of electricity in 2050 using 1000 GW of new capacity.

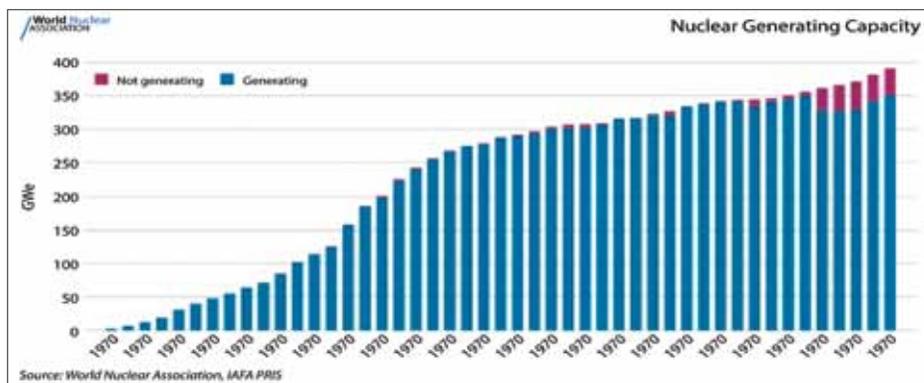
In the World Nuclear Performance Report 2017, the Association detailed power generation and construction achievements for the previous year.

The ten new reactors which came on line in 2016 added 9.1 GW to global capacity and took the total nuclear capacity supplying electricity to the grid past 350 GW for the first time ever. This does not include around 40 GW of operable nuclear plant that remains offline in Japan and is making slow progress towards restart.

Growth in nuclear power is being led by China, where five of the ten new reactors are located. "This trend is likely to continue in the coming years with around a third of reactors currently under construction being located in China," said Ms. Agneta Rising, the Association's Director-General.

Chinese industry constructed its new reactors in 5 years and 9 months on average. Series build is a major factor in this. A case study showed that 912 issues were identified during the construction of Yangjiang 1-3. Successfully addressing these helped unit 4 to be built more than ten months more quickly than unit-1.

Steady performance is a feature of nuclear power plants and this continued across the fleet with a global average capacity factor of 80.5%, down just slightly on last year's 81%. According to the report, 64% of the world's reactors operated at an average of 80% of their full



The global nuclear fleet is growing faster than at any time in the last 25 years. Restarts in Japan would significantly boost output (Source: World Nuclear Association, IAEA PRIS)

potential across the entire year. Only 8% of reactors achieve below 50% of their potential output.

The report states that "there is no significant age-related trend in nuclear reactor performance" with older units achieving the same level of performance as newer ones. It highlights the case of Heysham II-2 in the UK, a reactor that has operated since 1988 and in 2016 completed a record-breaking run of 941 days generating electricity without interruption.

Total nuclear power generated worldwide was up for the fourth year in a row, to 2476 TWh in 2016, which broadly keeps pace with the overall growth of the electricity system. Figures for global electricity of all kinds take longer to compile, but the latest data, for 2014, shows nuclear maintaining a 10.6% share of electricity.

"The world's nuclear power plants have performed well this year, making a significant contribution to meeting the need for clean, reliable and affordable electricity," Ms. Rising said.

Future growth

The build rate of 9 GW per year represents a doubling compared to the

average over the previous 25 years, said the report. Ms. Rising welcomed it as being in line with the needs of the Harmony goal for nuclear power to generate 25% of electricity with 1000 GW of new capacity in 2050. Rising said the path to achieving this needs an average of 10 GW per year of new build now, then a doubling to 25 GW on average from 2021-2025 and a peak construction rate of 33 GW per year on average from 2026. This represents a return to the build rates the industry achieved in the 1980s.

The Association has identified three areas for action to achieve this: establishing a level playing field in electricity markets, building harmonised regulatory processes, and an effective safety paradigm. The latter means considering matters of nuclear safety not just in technical terms, but "from a holistic society perspective," said Ms. Rising.

"The health and environmental benefits of nuclear energy are not valued on an equitable basis with alternative energy sources," she said. Other factors, "such as economics, industrial, social, public health and environment, all need to be considered," she added.

Source: WNN
(Published: June 28, 2017)



International Atomic Energy Agency 61st General Conference, Vienna

September 20, 2017

Statement by Dr. Sekhar Basu

Chairman, Atomic Energy Commission & Secretary, Department of Atomic Energy



Madam President, Excellencies,

Ladies and Gentlemen, Good morning to all of you.

I would take this opportunity to convey on behalf of the people of India, and the Government of India the warmest greetings to the International Atomic Energy Agency and the Member States on the occasion of 61st General Conference.

India has always given primacy to IAEA's role in the promotion of peaceful uses of atomic energy,

both in the area of nuclear power and nuclear applications, while maintaining due support in IAEA's role in safeguards.

Madam President,

I take this opportunity to congratulate you on your election as President of the 61st General Conference. I am sure that the current General Conference will accomplish successfully all the tasks laid before it under your leadership.

We welcome Granada as a new Member to IAEA.

Madam President,

I would like to compliment Dr. Yukiya Amano for his reappointment for the third consecutive term as the Director General of IAEA. Your Excellency, Mr. Amanov, through your tireless effort you have steward the work of the Agency so that it can be better prepared to face the contemporary challenges and also realize the immense opportunities that lie ahead.

India's Minister of State for External Affairs participated in the IAEA

Ministerial Conference on Nuclear Security held in Vienna in December 2016. In the meet, India reiterated its commitment to global nuclear disarmament, non-proliferation and peaceful uses of nuclear energy.

I am happy to inform that we have signed Civil Nuclear Cooperation Agreement with Bangladesh in April this year alongwith two more complementary Agreements.

We are collaborating with our Russian and Bangladeshi partners on establishing Rooppur Nuclear Power Plant in Bangladesh.

India became Associate Member of European Organisation of Nuclear Research (CERN) in November 2016 with whom we have been working for the last five decades.

We have also signed Civil Nuclear Cooperation agreement with Japan and Vietnam.

Madam President,

Let me tell you some of the recent developments in our country in the field of the Nuclear Energy and its applications:

This year we have completed 7 decades of our independence. 70th year of Indian independence has also been an year of exceptional achievements for us in the area of nuclear power, heavy water, nuclear fuel and associated material, uranium mining and milling, rare earth, radio isotopes and cancer care. All our research facilities, including synchrotron, cyclotron and reactors achieved their highest ever performance.

We are making sustained efforts to achieve major growth in our programmes of nuclear energy and nuclear applications.

Recently, Indian Government has approved the construction of 10 Pressurized Heavy Water Reactors in serial mode and also the construction of 2 more reactors at Kudankulam. Apart from the objective of major growth in carbon free electricity production, this step will give major boost to the industries producing the reactor equipment in India.

With these reactors we will now have 21 reactors under construction and 22 reactors in operation. This will increase the capacity to over 22,000 MWe by the end of next decade. We shall continue to add more capacity in future.

To cater to the needs of expansion of nuclear power programme, we are also stepping up our exploration and mining operation for production of uranium. In the Prototype Fast Breeder Reactor front, after completion of construction, the commissioning activities are making steady progress while fulfilling all the safety requirements.

In the Cancer care sector, we have started major expansion by taking up construction/ upgradation of 6 additional facilities throughout our country. This will help us in doubling number of new patients treated from the present figure of 70,000 in the next 4 - 5 years. We have established a cancer grid connecting

over 100 hospitals for diagnostic and therapeutic consultancy. We are also reorganizing ourselves to cater to further expansion in terms of research, education and patient care.

In the frontier science area, we are establishing a small underground research laboratory in one of our uranium mines for pursuing research on dark matter. This will enthuse scientists from all generations.

Madam President,

As part of our celebration of 70 years of independence of our country, we organized a side event at this venue on Global Centre for Nuclear Energy Partnership and I thank all of you who participated in the programme. This Centre will have 5 schools covering safety, security and societal activities. I invite Member States to make use of this facility under the aegis of IAEA.

We thank the city of Vienna, and the people and the Government of Austria, for hosting the IAEA and this event.

India looks forward to IAEA's continued leadership for fostering safe, secure and sustainable use nuclear energy in the future. India will continue to support IAEA in all areas of its endeavor.

We wish the 61st General Conference a grand success.

Thank you.

Performance Improvement of Distillation Columns & Upgrading Plant

M. Venkatachalam, Chief Superintendent, KAPS-3&4 • K.V. Krishnamurthy, Engineer-In-Charge (HW & Ventilation), MAPS
I. Narasimharao, SO/E, Operations, MAPS

Introduction

Heavy water is used in moderator and Primary Heat Transportation (PHT) system in PHWRs. Heavy water escapes from system and gets depleted once it comes in contact with light water. The leakages are mainly collected from fuelling machine vaults, PHT system, boiler room and moderator system. The collected D₂O is a mixture of light water and D₂O.

This depleted D₂O of various concentration (>0.25% to 99.88% w/w) is upgraded to system purity by distillation columns of Madras Atomic Power Station (MAPS) upgrading plant.

Each column consists of 14 tower sections. Each tower section consists of a liquid collector, a distributor and packing material. Liquid collector collects the down coming liquid and the distributor header distributes liquid evenly on the packing consisting of corrugated phosphorous bronze wire mesh coated with copper oxide. The large surface area of the packing facilitates mass transfer between the vapour and liquid phases. A distributor assembly consists of 20 numbers of 17.1-mm-diameter pipes welded on both sides of the header.

There are 304 holes of 1.2-mm diameter in each distributor assembly. If distributor holes are

pH	Chloride	Fe	Cu	Ni
	w/vol of detergent	mg/L of detergent		
8	1.5% w/vol	5.7	1.1	3.6

clogged, water will not flow through distributor but down coming liquid overflows from the holes of wire mesh strainer assembly located above the distributor. Hence; ascending vapor will not come in contact with descending liquid for mass transfer operation. This situation in column is called flooding of tower section.

Column performance is monitored by tracking operating parameters such as temperature and pressure at bottom and top of column, ΔP across the column, checking flooding in tower sections and chemistry of column water.

It has been observed over a period that there was air ingress into system indicated by decrease in pH value of sump water periodically. As per the advice of chemical control laboratory, pH of sump water was maintained by adding lithium hydroxide (LiOH) to sump water. Weekly routine checks revealed major flooding in column-1 tower section. And also minor flooding was observed in column-2 tower sections.

Both columns' performance was not satisfactory due to flooding of tower sections. Performance of column-1

which was operating on PHT mode (prior to shutdown) was very sluggish and response of column while increasing product purity is very slow. Product purity would increase or decrease in steps rather than steadily and constant product purity could not be maintained for longer duration. It was also observed that pH of sump water was decreasing very frequently which indicates air ingress into the system.

Product purity of column-2, which was operating on moderator mode (prior to shutdown) could not be achieved more than 99.89% even after long hours of operation. Product flow rate of 1 to 2 LPH could be maintained at the feed rate of 18 to 20 LPH. To increase product purity, feed purity was increased in steps from 15 to 50% w/w but this resulted in increase in top IP rather than sump purity.

And also, whenever column operated on sump purity > 99.90% w/w, it was observed that top purity would shoot up to 2.0 to 2.50% w/w and water circulating tank purity will increase to 0.40%. This problem was noticed in both the columns.

A brainstorming session was conducted and various possibilities

and proposed actions were deliberated. It was decided to discuss with Heavy Water Board (HWB) and headquarter officials and pool in their expertise.

Accordingly, a sample bottle of kitchen cleaner solution was collected from Wesco laboratory to wash column internals. The following parameters analysed in the MAPS chemical control laboratory are listed in Table-1.

Table-Top Discussion

During December 2014, biennial shut down of unit-1 and PSD of unit-2 were carried out at the same time. Since both units were under shutdown it was decided to utilise the opportunity to carry out column internals inspection and washing internals with water.

A meeting was conducted to discuss and finalise the plan to clean distributors and strainers of all tower sections of both columns.

During the discussion, it was decided that, since steam supply was not available to carryout detergent wash as planned earlier, it was decided to wash distributors and associated fittings with demineralised (DM) water and also carryout needle prick of distributor holes.

Conduct air-hold and vacuum-hold test after completion of assembly work of tower internals.

Use available in-house expertise for dismantling and assembling of tower section internals.

Explore various possibilities to reduce internal uptake due to

tritium such as wearing PPE's and adopting time, distance, decay and shielding methods.

Following guidelines were issued by OS during the meeting.

Measuring DAC values inside and outside of column after removing manhole cover flange.

Use of Air line respirators and bottle respirators to reduce internal uptake.

Only required occupancy need to be maintained while removing and assembling the tower section internals to avoid internal uptake.

Operate the vacuum pump once a while to ensure that tritium does not spread out.

Radiological survey and contamination levels need to be measured.

Activities Performed

I. Cleaning of Tower Section Internals (See Annexure-1 of this report)

1. Established rubber station in tower section.
2. Arrangement of air line respirators in the tower sections.
3. Radiological survey of all tower sections.
4. DAC values of tower sections (Outside and inside column).
5. Removal of tower section manhole cover.

6. Removal of strainer and its wire mesh from distributor pipe.
7. Removal of connecting rod from distributor.
8. Removal of three pieces of distributor.
9. Shifting all parts of distributor to decontamination area of UGP.
10. Washing wire mesh, bottom and top support ring of tower section with DM water.
11. Covering tower section manhole with polythene sheet.
12. Removing clogs from distributor holes.
13. Cleaning wire mesh of strainer.
14. Assembling tower internals.
15. Closing tower section with manhole flange.

II. Maintenance Carried out in the System

1. Maintenance on steam lines.
2. Calibration of main steam line RV.
3. Replacement of various diaphragms of pumps and lines to utilise the opportunity of plant shut down.

III. Normalisation, Startup, Monitoring Performance of Column

1. Air-hold test of column
2. Vacuum-hold test of column
3. Normalisation of system and charging column with water

Table-2					
Feed		Product		Reject	
IP% W/W	Rate LPH	IP% W/W	Rate LPH	IP% W/W	Rate LPH
9 to 27	29 to 46	99.10 to 99.25	1 to 6	0.01 to 0.20	28 to 40

Annexure-1



Removal of manhole cover of tower section



Covering manhole cover with polythene sheet



Placing bunk inside the manhole



Vacuum of 200 mm of Hg was maintained after placing bunk



Removing distributor parts from column



Shifting removed distributor parts for cleaning



Cleaning distributor parts

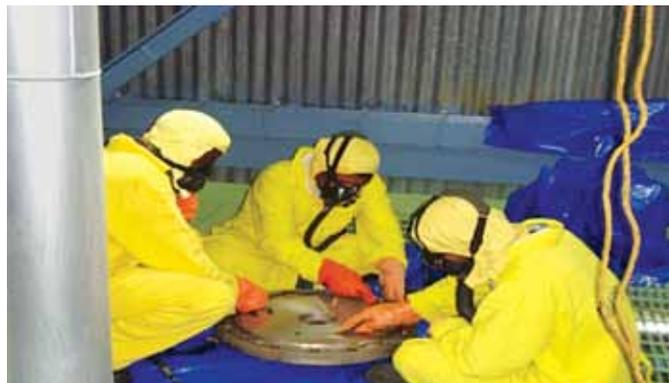


Cleaning strainer mesh with Alph-3, Citric acid and DM water

Annexure-1 (Contd.)



After removing clogs from distributor holes



Cleaning faces of manhole cover flange



Inside the tower section



Assembling distributor parts



After assembling distributor parts



Aligning manhole cover flange with column



Tightening manhole cover flange



The team after completion of the task

4. Startup of column, total reflux operation, starting feed, product and reject take-off
5. Observing column performance

Brief Description of Activities Performed

After shutting down the column, vacuum pump, process water booster pump and chilled water

Temporary rubber station was formed at tower sections. The flange joints of all tower sections were removed. All tower section Distributors of Column-1&2 were removed from column and clogs were removed from holes of distributors and cleaned with DM water (internals were taken out one tower section at a time).

After installing tower section internal and manhole flange, replacing defective gaskets and diaphragms of leaky joints, vacuum hold test was conducted. Vacuum drop was found to be 8mm of Hg in 24 hrs corresponding to chilled water temperature of 11.50 °C. (As per design 6 mm of Hg drop in 24 hrs is specified). Maximum 710 mm of Hg vacuum was achieved at chilled water temperature of 11.50 °C.

Feed		Product		Reject	
IP% W/W	Rate LPH	IP% W/W	Rate LPH	IP% W/W	Rate LPH
10 to 50	18 to 20	99.82 to 99.89	1 to 2	6 to 50	17 to 18

booster pump were operated for 24 hours in order to reduce column temperature. After the temperature of column sump got reduced to <52° C, water was transferred to feed tanks.

Radiological survey was done at tower sections to be cleaned and following were the details.

External radiation: 0.1 to 0.4 µSv/hour

Tritium DAC level: 0. 1 DAC.

Contamination: Nil

Column-1

Column was producing PHT grade water before shutdown and operating flow rates are listed in Table-2.

Before opening the tower section manhole covers, vacuum hold test was done and found vacuum drop of 40 mm of Hg per hour. Air-hold test conducted at 0.50 kg/cm² and leak check was done with soap solution by QA staff and leaky points were identified.

Column Packing was washed with DM water. The manhole of tower section openings were covered with polythene sheets and the vacuum pump was operated to maintain column vacuum at 200 mm of Hg. The packing in all the removed sections was inspected and found to be in good condition.

DM water jetting through distributor holes was checked before clearing the blocked holes. Clogs of distributor holes were removed with sharp edge needles. After cleaning the distributor, DM water was charged again into distributor, water jetting was checked through all holes and ensured they are free from clogs.

Conical shape wire mesh strainers of distributors were also found choked. These strainers were soaked for 1 hour with citric acid after adjusting the pH with ammonia to 8.0 to 9.0. Cleaned distributors were assembled in the respective tower sections and manhole covers were closed.

Hence, air ingress into column got reduced considerably after carrying out maintenance works. Since, air ingress into column was arrested and also all tower section internals were serviced, it was decided to operate column on moderator/ultra purification mode (prior to shut down column was operated on PHT mode).

After carrying out distributor cleaning, column was started and taken into service. Start-up performance of column was good and feed take off could be started after 70 hours of total reflux hours and column enrichment could be completed as intended. Product purity of moderator column has been achieved 99.94% w/w and maintained at that purity level continuously. At feed purity of 25% w/w, feed flow rate of 28 LPH, the product flow of 4 LPH could be maintained constantly.

Column feed purity was increased up to 50% w/w and found that top purity was not shooting up and it was fully under control due to which higher product purity and flow rates could be maintained. Top

takeoff Tritium was also significantly maintained at lower value, i.e., less than 2 Ci/l (for 100% equivalent). This top take off water was used to feed PHT column. Air ingress into system was arrested, pH of column sump has not decreased since after starting column.

Column-2

Column was producing moderator grade water before shutdown and operating flow rates are noted in the table listed in Table-3.

Before opening the tower section manhole covers, vacuum hold test was done and found vacuum drop 100 mm of Hg of per hour.

Temporary rubber station was formed at tower sections. The flange joints of all tower sections were removed. All tower section Distributors of column-1&2 were removed from column and clogs were removed from holes of distributors and cleaned with DM water (internals were taken out one tower section at a time). Column Packing was washed with DM water. The manhole of tower section openings were covered with polythene sheets and the vacuum pump was operated to maintain column vacuum at 200 mm of Hg. The packing in all the removed sections has been inspected and found to be in good condition.

DM water jetting through distributor holes was checked before clearing the blocked holes. Clogs of distributor holes was removed with sharp-edge needles. After cleaning the distributor, DM water was charged into distributor, water

jetting was checked through all holes and ensured they were free from clogs.

Conical shape wire mesh strainers of distributors were also found choked. These strainers were soaked for 1 hour with citric acid after adjusting the pH with ammonia to 8.0 to 9.0. Cleaned distributors were assembled in the respective tower sections and manhole covers were closed.

It is expected that inside column DAC levels would be high since Column was operated on moderator mode before shutting down column for distributors cleaning. After removing manhole flange of tower section, DAC level was measured and it was 500. Opening of manhole cover would cause a significant raise in area Tritium DAC. A bunk to cover the manhole was devised and installed. Further vacuum was pulled in the column. By this innovative method developed by the team, complete activity was carried out without any significant internal uptake.

After installing tower section internal and manhole flange, replacing defective gaskets and diaphragms of leaky joints vacuum hold test was conducted. Vacuum drop was found to be 40 mm of Hg in 24 hours corresponding to chilled water temperature of 11.5°C. On investigation, air ingress through reboiler flange was found and it was well within the capacity of vacuum pump.

After carrying out distributor cleaning, it was decided to operate

column on PHT mode since required product purity is 99.25 %w/w. Start up performance of column with low purity water was good and feed take off could be started after total reflux hours and column enrichment could be completed as intended.

Air ingress into system completely could not be arrested and pH of column sump is decreasing since starting the column. Arresting air ingress into system through reboiler top flange is planned to be attended in the next available opportunity. After carrying out distributor cleaning, the product take off rate could be increased smoothly and steadily up to 6 to 8 LPH. Product purity of PHT column has been achieved 99.64% at feed IP of 15 to 18% and feed rate of 40 to 45 LPH. Also low Reject purity between 0.02 to 0.06 % w/w could be maintained.

Conclusion

Distillations columns were continuously operated without interruption to upgrade downgraded water to 99.25% for PHT grade water and 99.94% w/w for moderator grade water. To produce high purity moderator grade water, columns need to be operated beyond designed product purity of 99.80% w/w and reject purity of 0.50% w/w. Enriching column to the purity of 99.94% and simultaneously limiting top purity to designed purity of 0.5% w/w is very difficult. To achieve product IP of 99.94% study was done by feeding various IP water from 10 to 50% In This study it has been found that Feed purity of 25% with feed and

product flow rate of 28 and 4 LPH respectively was optimum to reach IP of 99.94% and simultaneously top water of lower tritium water was produced.

Earlier it was found that, performance was sluggish during start up and operation. This decrease in column performance was indicated by lower feed and product flow rates, decreasing pH of column sump water due to air ingress into the system. Brainstorming was conducted to explore various options to be carried out to improve performance of columns. One of best option evolved during the brainstorming was to carry out

detergent wash and cleaning of distributors of tower sections. But detergent wash and cleaning of distributors of tower sections could not be carried out since there was continuous demand for reactor grade water for moderator and PHT system addition due to which the columns could not be shut down.

BSD of unit-1 and PSD of unit-2 were carried out during December 2014. Since both units were under shutdown this opportunity was utilised to shut down columns to wash distributors and associated fittings with DM water and also carryout needle prick of distributor holes. Air hold test and vacuum hold

test of column was carried out and columns were taken into service. After carrying out distributor, cleaning performance of columns were improved during start up and operation of columns. Product purity of moderator column was attained 99.94% and maintained at that purity level continuously. At feed purity of 25% w/w, feed flow rate of 28 LPH, the product flow of 4 LPH could be maintained constantly. And Product purity of PHT column was achieved 99.64% at feed IP of 15 to 18% and feed rate of 40 to 45 LPH. Also low reject purity between 0.02 to 0.06% w/w could be maintained.



M. Venkatachalam, Mechanical Engineer, joined 31st batch of BARC training school in the year 1987 and after the completion of training, he joined MAPS in the year 1988 in Operation Section. In Operation Section, he has worked in various capacities. He is also a BIS-certified Energy Auditor and Manager as well as Chairman of Energy Conservation Committee. He has contributed to upgrading column performance improvements and is a recipient of NPCIL meritorious service award. Presently, he is Chief Superintendent, KAPS-3&4.



K.V. Krishnamurthy is a Mechanical Engineer. He is from the 1st batch of NPCIL. He joined Operation Section at MAPS in the year 1990. He held different positions and presently working as Engineer-In-Charge (HW & Ventilation). He has been awarded NPCIL's Special Contribution and Group awards.



I. Narasimharao is a Mechanical Engineer. He joined MAPS in the year 1987. He has worked as field Engineer in Heavy Water Upgrading Plant and Operation Section. Presently, he is working as Senior Engineer in Heavy Water Upgrading Plant. He was accorded with NPCIL's High Performance group award in the year 2011 and Special Contribution award in the year 2013.

Radiation is our constant companion. We are all constantly exposed to radiation that is present in nature everywhere, all the time

Adding Dimensions to Radiation Protection Programme

Umed Yadav, Addl. Chief Engineer, NPCIL Headquarters

Introduction

A well-laid Radiation Protection (RP) programme in a nuclear power plant (NPP) clearly outlines its prime objective to ensure that in all operational states, radiation exposure within the installation or due to any planned release of radioactive material from the installation is kept below stipulated limits and As Low As Reasonably Achievable (ALARA). It also ensures mitigation of radiological consequences arising out of any off-normal condition, however low its probability may be.

All this necessitates implementation of all reasonably practicable measures to ensure that the aforementioned objectives are objectively met with a high level of confidence. To begin with, in an objective manner, optimisation of radiation protection provisions entailing a set of protective measures, remote assessments, timely information acquisition and dissemination, etc. alongside other conventional methods entitles a utility an additional edge.

Effective radiation protection is a combination of well-laid design, high-quality construction and good operation with well-laid provisions to meet the RP requirements. Optimisation of such provisions is an important aspect, which can be met with appropriate indigenisation and effective utilisation of available

resources and limiting or avoiding re-work, to achieve them. The provisions intended should have a long-lasting net benefit to the organisation and society at large, offsetting the efforts involved.

Associative with the above cause is a well-informed personnel, who can contribute suitably to the cause of the utility in the service of nation. Accordingly, extensive efforts in strengthening communication aspects have always been a focus area at any utility.

These dimensions are the guiding elements in this effort-taking exercise at any NPP during its pre-operational and operational phase. It is these features which continually help utility in setting up safe operation benchmark and its RP objectives in an effective manner.

While establishing an RP programme at a utility, the following noticeable aspects are to be given due consideration:

- a) Operating experience sharing within and beyond organisation
- b) Identifying requirements beforehand to prevent re-work at the construction/commissioning stage itself
- c) Incorporating new methodologies/concepts and technological upgrades in the system through indigenous developments and/or utilisation

of available resources effectively

- d) Addressing areas which may have a tangible impact or otherwise on RP programme in the longer run of the nuclear facility
- e) The overall developed setup should become an integral and important asset, supporting continual improvement of utility's work culture

This article covers one such NPP, i.e., Rajasthan Atomic Power Station Unit-5&6 (RAPS-5&6). Even though RAPS-5&6 are the last in the fleet of its kind (i.e., Indian PHWR of 220 MW capacity), the requirement of radiation protection front were equally demanding. With this thought in mind, efforts were taken in various areas to establish an RP programme which provided an added dimension beyond the conventional. In line with the expectations, many such developments were carried out indigenously. Some of the prominent features of this establishment are presented in the following sections.

Access management

- Access to the operating island of the utility is regulated through a single entry/exit point of Central Alarm Station (CAS). The entry/exit pathways remain under electronic surveillance continuously.

- On a similar note, the entry/exit for controlled areas (within operating island) are also managed through a single access point, with distinguished routes. The inward movement requires electronic authentication of an individual. Only individuals with authorisation for access to controlled areas are allowed to enter the system. On the other hand, while moving outwards, individuals have to mandatorily undergo a check for whole-body contamination. Only if an individual is found free from contamination, he/she is permitted to leave from the final exit point after his/her authentication. This methodology helps in identification of personnel contamination, if any, followed by necessary corrective action.
- Personnel movement is also regulated on similar lines at 'Zone-3 to Zone-2' interface. This is implemented as a good practice to pre-identify potential cases of personnel contamination, thereby limiting the probability of contamination spreading to relatively contamination-free areas.
- Apart from these physical barriers, control on access of an individual is also exercised by Health Physics Unit (HPU) officials through their Dose Management System (DMS) services. Any individual access can be regulated in controlled areas by setting an administrative constraint against him/her. With this facility, such constraints can be invoked at times and for reasons which are



Electronic surveillance and access control at CAS



Access control and monitoring final exit

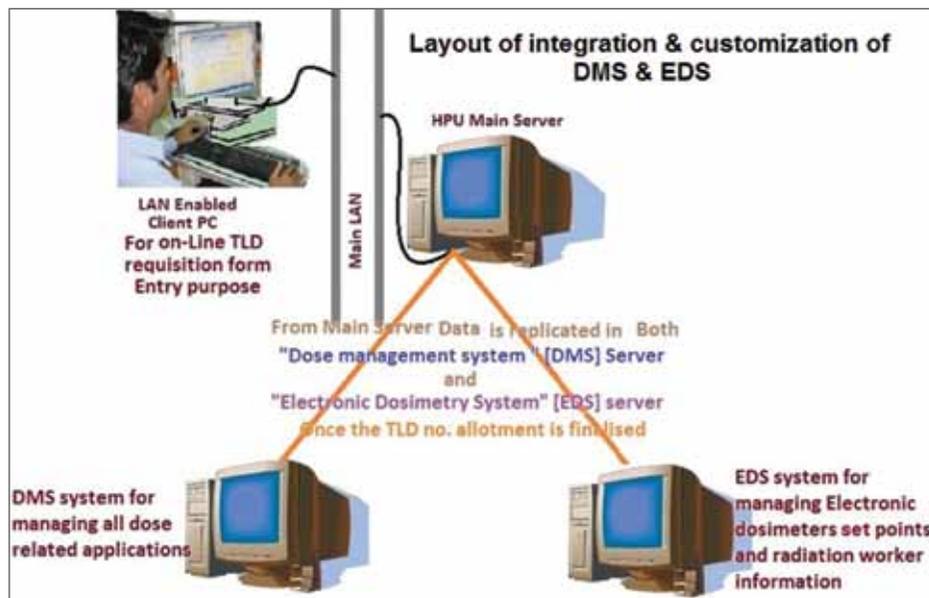
either administrative in nature or involve dynamic in-house decisions which are otherwise difficult to manage.

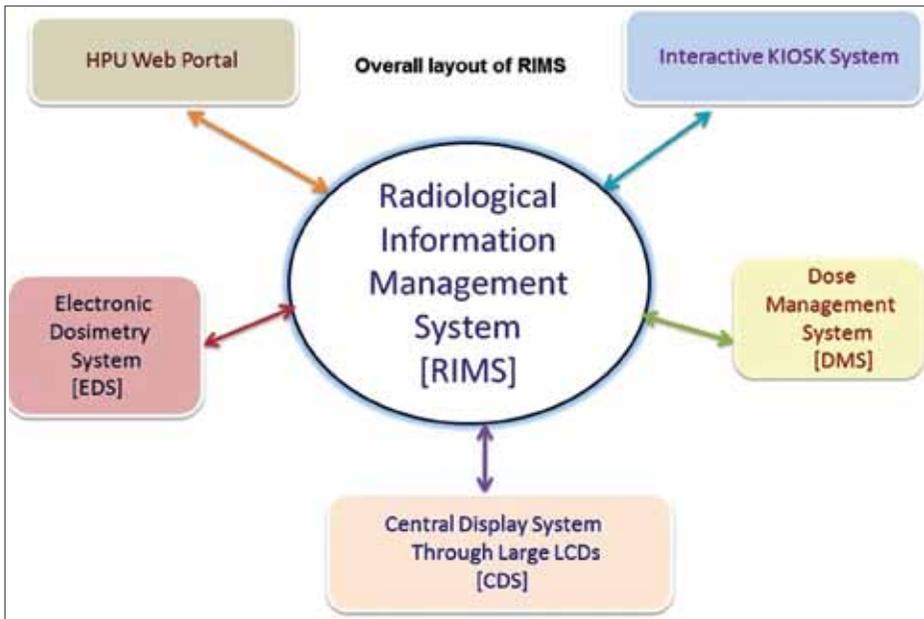
- Movement of vehicles/materials is managed using a well-established online key management system in conjunction with Normal/

Conditional Release Permit system. Accordingly, all such movement happens after due monitoring by officials of HPU and their subsequent clearance.

Information acquisition mechanism

- Several software modules have been indigenously designed, developed and maintained to effectively manage large volumes of information. In order to maintain a high-level of consistency within these modules/sub-systems and to minimise human-related entry errors, a system of 'four ones' is adopted. Accordingly, all modules/sub-systems are seamlessly integrated and one





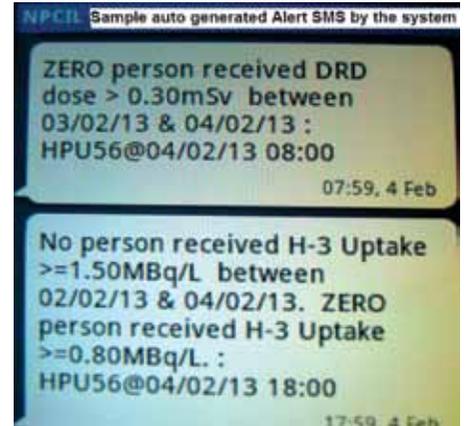
data/information fed through one system by one individual at one time after due validation and verification is made available through all the connected systems instantly.

- The systems through which information acquisition primarily takes place includes DMS, Electronic Dosimetry System (EDS), kiosk services, Radiation Data Acquisition System

(RADAS), Radiation Monitoring systems and HPU web portal services.

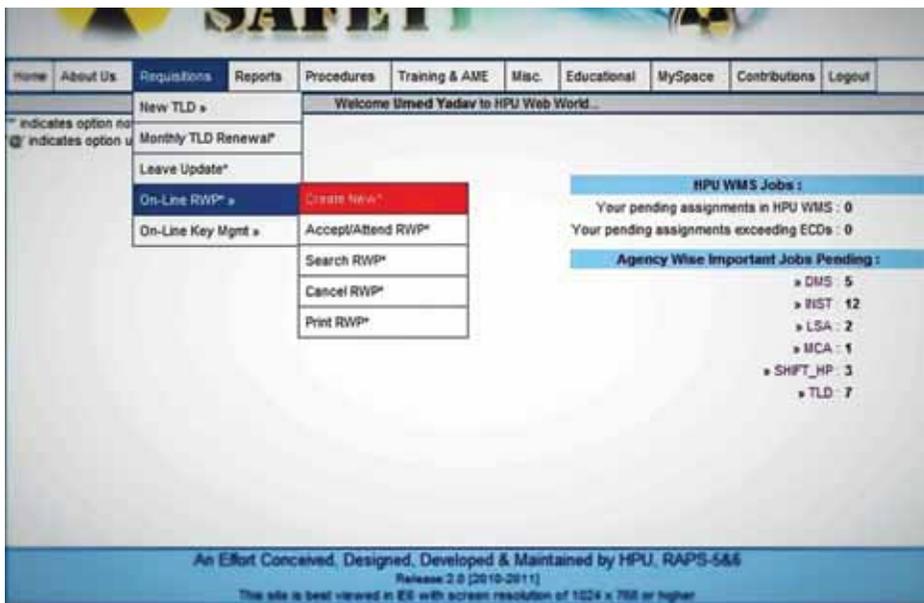
Information dissemination methodology

- HPU web portal services are equipped with plenty of interactive features, viz., dynamic/flexi reports, trending facility on various parameters/data, bioassay compliance,



work management system and exhaustive training/educational material for improved learning.

- A virtual tour of Reactor Buildings (RBs) of the utility enables an individual to view the latest radiological status superimposed in a nearly 360° real photographed area for superior job planning and execution.
- An individual can access his/her data online in addition to other relevant information through a Personnel Identification Number (PIN) system, which enhances security of personal data. Online e-Radiological Work Permit (e-RWP) and e-Whole Body Counting (e-WBC) management are add-on features.
- Availability of a Centralised Display System (CDS) at radiologically significant areas



HPU web services portal

Home Page LOGOUT **On-Line Radiological Work Permit (RWP) Requisition (SAMPLE)**

Issuer TLDNo: 50 Issuer Name: UMED YADAV Section: HPU Planned Dose: 0.50 P-mSv RWP No.: 25134

RWP Job Details

Unit: Unit-6 Unit Power Status: Full Power Building: RB Elev (m): 100

Location: 100M_South Passage Gen Remark(s): Normal

Job Type: Surveillance Section: HPU USI No: 67870 Description: RADIATION MEASURING EQUIPMENT--GENE

Fill Equipment Details: Select Equipment Type: Others Equipment No.: 0

Radiological Conditions May Change During Job? If Yes, Select Reason: Shielding Breach

ALARA Meeting Done.(Tick if yes) If Yes Fill- Select Type: Section Computer No.: 01 Date(dd/mm/yyyy): 01/01/2000

Job Description: This is a test RWP for demonstration only. Issuer Contact No.: 45974

Add RWP Crew Details TLD No. Add To Crew

SNo.	TLD No.	Name	Dose Status (mSv)				Tritium Uptake		Category	Criteria	NOPE Dose(mSv)
			D	M	Q	Y	Date	(MBq/l)			
1	50	UMED YADAV	0.00	0.00	0.00	0.00	13/02/13	BRL	Normal	Normal	
2	53	AMAN DEEP KAKKAR	0.00	0.00	0.00	0.00	14/02/13	BRL	Normal	Normal	
3	55	PRADEEP KUMAR UPADHYAYA	0.01	0.01	0.02	0.02	17/02/13	BRL	Normal	Normal	

Send To HPU

Report - Windows Internet Explorer
 http://10.24.2.12/...
 ALARA Meeting Minutes Details
 Registration number: RAPS-55M/ALARA(Section)/Unit-5/HPU/2011/1
 Date of ALARA meeting: 01/02/2011



KIOSK Terminal SAFETY

Welcome To Radiological Information Management System(RIMS), Health Physics Unit, RAPS-5&6

Message(s)

Intro -

Bioassay Weeks? .ADOPT & SUPPORT ALARA PRACTICES
 .Now you can use online eWBC request for faster Whole Body Counting procedure.
 .Submit timely bioassay sample.

Bioassay Category?

PIN System? **Submit Bioassay Sample Login Now...**

Misc - Fully. Do Not Press Screen Hard Or With Wet/Dirty Hands. Help Us Serve You

कृपया गीते ऊपरवा मन्दे हातो से स्क्रीन को ना छुवे।
 Please do not touch screen with wet or dirty hands, Thanks for your cooperation.

mSv/h : RAPS-6 Hot Spots (mSv/h) : 91M PHTLC Tanks[RAPS-6] : 10.00- 20.00

makes dissemination of up-to-date information, status and instructions simple and accessible to all concerned.

- Two advanced widescreen kiosk systems connected through Local Area Network (LAN) and HPU web system have been installed in controlled areas. A radiation worker has full access to his/her details, dose, compliance, e-RWP, personal details, etc. The kiosk also serves miscellaneous functions, viz., PIN change, e-RWP view/print, up-to-date hotspot listing,

RAPS-5 & Common		Rajasthan Atomic Power Station-5&6 Health Physics Unit		RAPS-6	
Eqpt. Radn. Field Location	mSv/h	Eqpt. Radn. Field Location	mSv/h	Eqpt. Radn. Field Location	mSv/h
91M_PHTLC Tanks	3-6	91M_PHTLC Tanks	7-10	91M_PHTLC Tanks	0.01-0.03
91M_3496 Tank	-	91M_3496 Tank	-	100M_ESCS Lines	0.03-0.05
100M_ESCS Lines	0.03-0.05	100M_ESCS Lines	0.03-0.05	100M_FM Valve Stn (R)	0.07-0.15
100M_FM Valve Stn (R)	0.1-0.2	100M_FM Valve Stn (R)	0.07-0.15	100M_S5S Tanks	0.05-0.15
100M_S5S Tanks	0.07-0.15	100M_FM Valve Stn (S)	0.07-0.15	100M_FM Valve Stn (S)	0.03-0.07
100M_FM Valve Stn (S)	0.07-0.15	100M_Mod. Sampling Station	0.03-0.07	100M_Mod. Sampling Station	0.03-0.07
100M_Mod. Sampling Station	0.03-0.07	103M_FM Pumps (F-1/F-2)	0.03-0.05	103M_FM Pumps (F-1/F-2)	0.05-0.07
103M_FM Pumps (F-1/F-2)	0.03-0.05	103M_Gland Filter (F-1/F-2)	0.05-0.07	103M_Gland Filter (F-1/F-2)	0.07-0.1
103M_Gland Filter (F-1/F-2)	0.05-0.07	103M_Purification Lines	-	103M_Purification Lines	-
103M_Purification Lines	-	103M_3525 HX-1	0.1-0.2	103M_3525 HX-1	0.1-0.2
103M_3525 HX-1	0.1-0.2	103M_Strainer-1	0.1-0.3	103M_Strainer-1	0.1-0.3
103M_Strainer-1	0.1-0.3	107M_PHT Sampling Cabinet	0.02-0.03	107M_PHT Sampling Cabinet	0.02-0.03
107M_PHT Sampling Cabinet	0.02-0.03	107M_Bunch of PHT Lines	0.05-0.1	107M_Bunch of PHT Lines	0.05-0.1
107M_Bunch of PHT Lines	0.1-0.3	107M_He Gas Blower-1 (1/2)	0.07-0.1	107M_He Gas Blower-1 (1/2)	0.07-0.1
107M_He Gas Blower-1 (1/2)	0.1-0.2	107M_OSU - H	0.05-0.07	107M_OSU - H	0.05-0.07
107M_OSU - H	0.05-0.07				

!!! सावधान / CAUTION !!!
 Areas, 95mE1
 Ion Chamber Area at 103 mE1

(mSv/h) 91M PHTLC Tanks[RAPS-5] : 3.00-

Centralised Display System (CDS)

informatory messages and instructions from HPU.

- Seamless integration of DMS, EDS, CDS, web portal and kiosks has proven to be highly efficient, error-free, user-friendly and replicable/backup to one another. The entire setup is collectively known as Radiological Information Management System (RIMS).

Realignment, reorientation and relocation of facilities

- With the purpose of providing ease of access, optimised utilisation of resources, meeting time constraints in execution of tasks etc., a step forward was taken to realign and relocate some of the facilities pertaining to various agencies. In this context, Chemical Control Laboratories (CCL) of Zone-2&3 were aligned, while Health Physics Laboratory (HPL) and Control Maintenance Workshop, situated in Zone-3 but at different elevations in Service Building, were swapped.
- Some of the inter-zonal access paths were changed and, subsequently, the freed space thus resulted was reallocated for office space/store.
- The widely used clothing crib counter's orientation was changed to facilitate ease of access to the crib by personnel visiting controlled areas besides reducing the superfluous occupancy in the much-used walkway.
- While doing so, radiological zoning integrity was ensured. The access ways, ventilation



Reactor building virtual tour with up-to-date radiological status



Health Physics Unit Shift Office & Laboratory and Chemical Control Laboratory, Zone-3 are located side by side



Wide Range Gamma Monitors located outside Main Air Lock, Flasher & Hooter inside working areas

and drainage facilities were accordingly modified. This resulted in preventing intermittent crossover of zones while moving horizontally or vertically (at different elevations) in the controlled areas.

- These changes were brought in beforehand prior to the start of actual work at site during construction phase itself. Thus, re-work and loss of resources thereon could be avoided.

Reformed area/workplace radiation monitoring system

- Area radiation monitors installed for workplace monitoring play a very important role in providing on-the-spot radiation levels at a given instance. To make this

installation more effective, their schedule were changed. The detector and hooter units of the installed area radiation monitors were reviewed and relocated with due consideration to the (potentially) hot equipment and personnel occupancy in the area based on the work history and experience gained elsewhere. Also, the monitors of these detectors have been shifted at the respective entry points of accessible areas for effective dose control. Thus, individual working at a place or likely to visit a place remains informed about any significant change in radiation level in the area resulting in enhanced exposure control.

- As far as areas which do not fall in the vicinity of ‘installed area radiation monitors’ but holds hot equipment where activities like maintenance can be planned, use of portable programmable gamma alarm stations is encouraged. These programmable alarm stations work as installed area



Electronic alarming dosimeter, its wearing pattern, Electronic Dosimetry System, portable radiation survey monitors

monitors during the jobs having (potentially) high radiological concerns.

- Additional area monitors were installed for implementation at locations which had high radiological concerns, e.g., on Fuel Handling System, Active Maintenance Shop, Radioactive Source Storage Facility, Active Waste Transit Facility, etc.

Introduction of advanced dosimetry systems

- RAPS-5&6 became the first nuclear power plant having introduced a full-fledged electronic alarming programmable dosimeter setup in the country. This EDS has been customised indigenously and integrated in a manner that works seamlessly with the main DMS/HPU web system.
- The features of EDS have been incorporated such that it stores the critical information as a backup to the main DMS/HPU web system.
- A loop-along-loop networking methodology is implemented in a manner that allows the EDS to work independently even in the event of non-availability of main network on which DMS/HPU web system is hosted. The vice-versa also equally holds good.
- Every radiation worker's dose and dose rate limits are individually set in the dosimeter before it is issued to an individual, depending on his/her work requirements. Thus, a dose control at an individual level is exercised.

- If a worker observed to have received more than expected radiation dose, his/her detailed record is retrieved on time scale to identify possible location of actual work where he/she might have consumed this component of dose. As a follow-up action, this suspected area is critically evaluated and a probable hotspot is identified and subsequently addressed.

Enhanced communication provisions

- The station RP programme encompasses enhanced means to communicate with the concerned officials in time. To facilitate this, a web-based service involving automatic generation of pre-formatted e-mails with latest updated information to the authorised officials of the station is implemented.
- In addition, an intelligent automatic SMS service provides prompt availability of significant information/data for effective decision-making. This involves specific and important reminders, effluent status, technical specification-related concerns, significant event involving radiological protection, etc.
- All radioactive jobs are conducted with the electronic e-RWP system. As a consequence, e-RWP has become an important tool of communication among different partaking agencies. All communications, duly time-stamped between agencies, get recorded in the form of a



Indigenously prepared audio/video training aids on RP procedures / ALARA practices

chat within e-RWP system for anytime reference.

- The content of e-RWP can be accessed by authorised/concerned persons online through web portal and Kiosks or from a print copy.

Training and operating experience sharing advantage

- Floor shop discussions, ALARA workshops, walk-and-talk kind of sessions and group discussions on specifics are additional concepts introduced besides the well-established training programme.



Ram-B Drive test facility, Separator test facility and D₂O MVD test facility



Valve test facility, Snubber test facility and Steam Generator mock-up setup

- Operating experience from own, other Indian nuclear facilities and from nuclear fraternity at large around the world is being consistently utilised for continual improvement. A few examples meant for controlled areas includes: Station instruction on entry in Spent Fuel Transfer Duct (SFTD) and annular space, permanent erection of platforms at identified locations, placing of temporary shields, relocation and shielding of Annulus Gas Monitoring System (AGMS) tank, shielding of SFTDs, etc.
- A number of indigenously prepared audio/video short films on radiation protection aspects highlighting various "Dos and Don'ts" are prepared and integrated in various training programmes. Furthermore, these films are

being run automatically on the Centralised Display System (CDS) across the station and serves as a good procedural reminder.

Test and mock-up facilities lead

- Various test facilities are in place for conducting tests, validation and corrective actions thereof, for example, Valve test facility, Oil MVD test facility, D₂O MVD test facility, RV test facility, Separator test facility, Ram-B Drive test facility and Snubber test facility
- A number of mock-up facilities have been devised and put to use especially for convoluted and critical jobs that involves working on important systems in quite high radiation background. Such activities may require high

level of accuracy above and beyond low time expenditure in such high radiation background. These mock-up facilities allows a worker obtain expertise in much field like conditions, assess (likely) constraints during execution of work, sort out alternate and better ways of execution.

Improved personnel safety gears

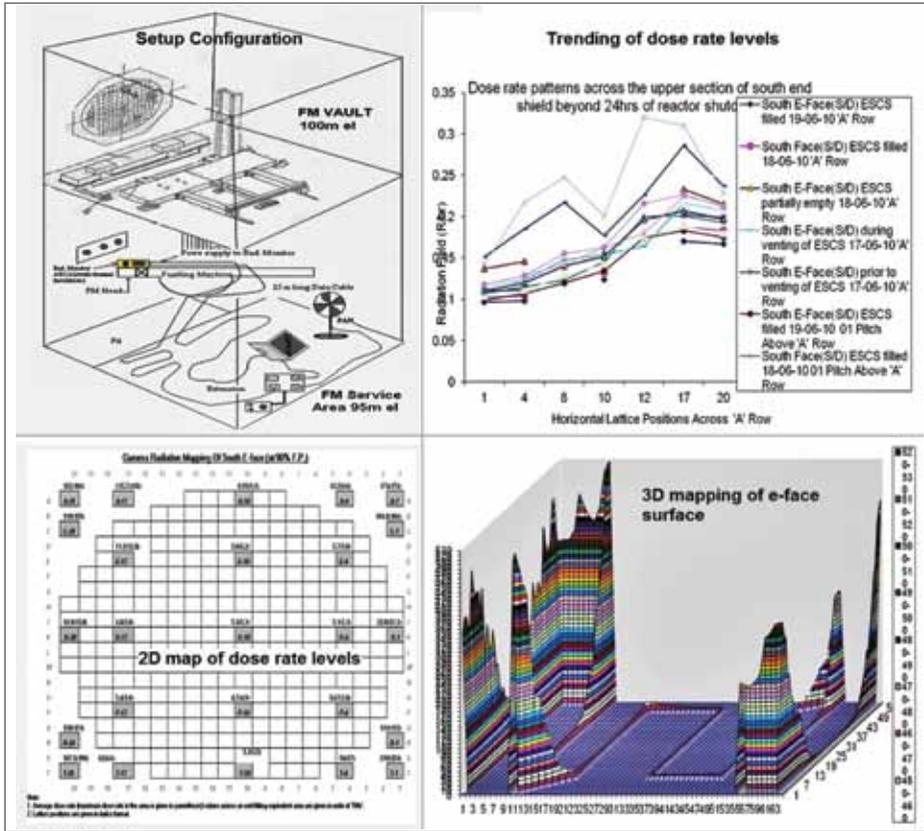
- Safety helmets with add-on ear muffs have been introduced for carrying out jobs inside operating island of the utility. The helmets have been colour coded for their distinguished usage in different areas, viz., controlled and other than controlled areas. Thus, industrial safety with effective contamination control measure could be ensured.

- Modified full face ventilated suits have been introduced, especially for jobs like welding

works in radiologically significant areas, where conventional ventilated plastic

suits cannot be used.

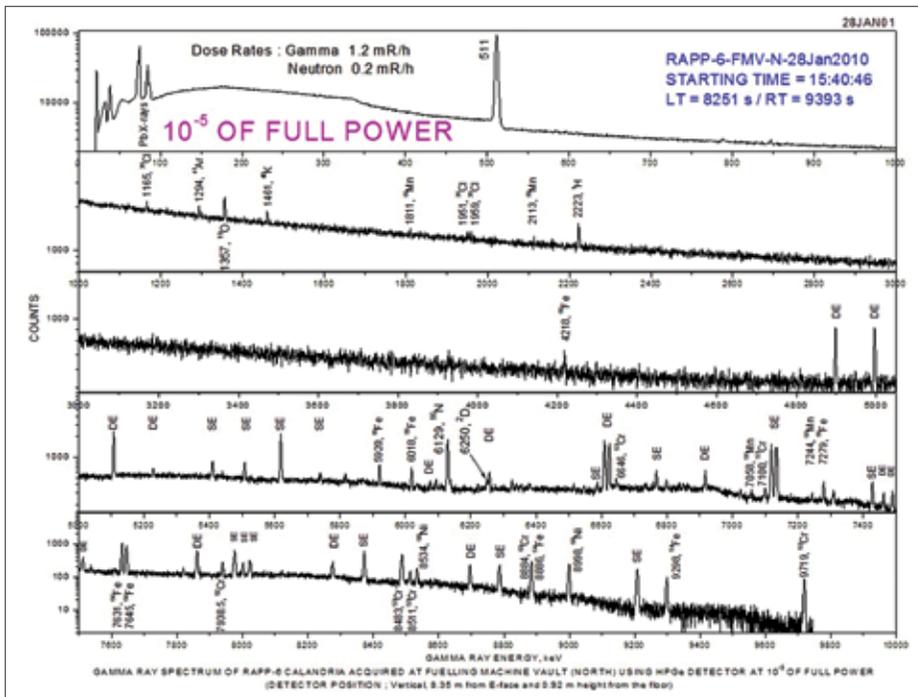
- Two piece ventilated plastic suits were also introduced as protective gear for works which require more of flexibility and moderate work time in tritium prone controlled areas.
- Moreover, fresh air supplied full face hoods were also used for low tritium areas requiring significant occupancy. This is in addition to airline, oronasal, tritium bottle and cartridge respirators.



Remote radiological mapping of e-face

Miscellaneous supplemental aspects

- Customisation of portable radiation monitoring systems was done to yield computerised setups for conducting remote measurements. These setups proved as accurate and effective gamma mapping tools for surfaces/equipment for remote measurements e.g. e-face mapping at different reactor power levels, SFT duct during spent fuel transfer, etc. The data thus obtained was 2D/3D mapped for assessment of shielding effectiveness. With this setup, shielding effectiveness was assessed and gaps, if any were augmented in time.
- An exhaustive exercise was carried out in co-ordination with Radio Chemistry Division, Bhabha Atomic Research Centre to measure the passive gammas originating from reactor core prior to initial criticality and prompt gammas originating from reactor core during various stages of boron



Sample prompt gamma ray spectrum acquired at 10^{-5} Full Power of RAPS, Unit-6



Enclosed D_2O valve stations, exhaust hood in cleaning area, enclosed sample collection chamber and dedicated fume hoods for handling D_2O samples.

removal till first approach to criticality of the reactor. About seventeen gamma spectrums of reactor core of RAPS Unit-6 were acquired with the help of a customised Gamma Spectrometry setup specially designed to meet this objective.

- This exhaustive field experiment provided vital information on reactor core behavior, which can be useful for validating computer models, shielding considerations/calculations and by designers for use in upcoming nuclear plants/facilities.
- Sub-micron filters in Primary Heat Transport (PHT) circuit have been installed for filtering out small suspended contaminants in the system to improve chemistry and to reduce the radioactive contaminants.
- Dedicated enclosures, sampling stations, demarcation of areas, residual D_2O collection arrangements, dedicated exhaust provisions, etc. have been highly useful in managing (potential) tritium sources.
- Identification of minor D_2O leaks (which are otherwise not visible) by using methods of D_2O sniffing and tritium mapping

arrangement is being put into use.

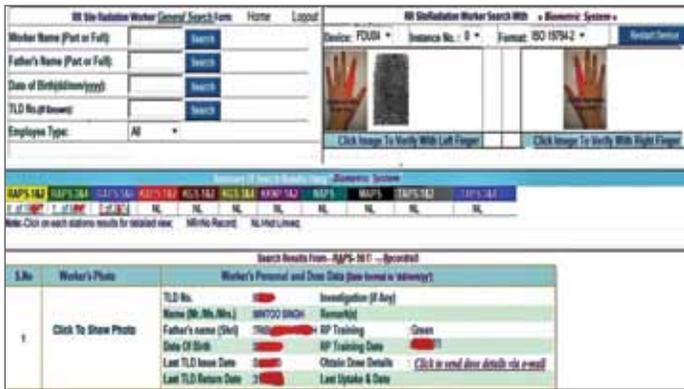
- An exhaustive radiological surveillance, be it periodic or special, has led to identification of hot spots. A detailed Hot Spot management system exists at the utility. Temporary Shielding Management System (TSMS) is one such supporting tool. The identified hotspots which either could not be removed/



Temporary shielding arrangement on identified hot equipment

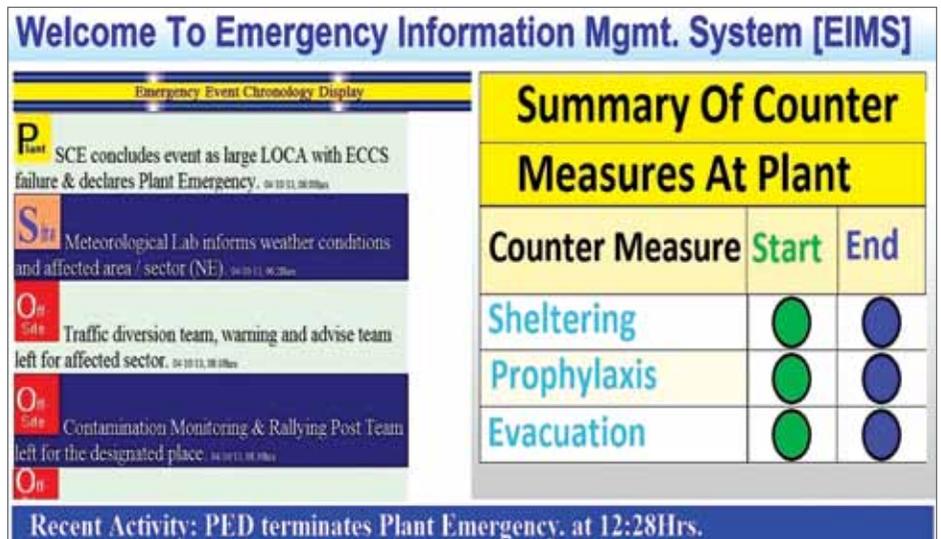
flushed or which requires a time delay for their addressal, are temporarily shielded through TSMS.

- With the fast growing nuclear industry in the country and frequent movement of occupational radiation workers (especially those engaged through award of contract) from one station to another, prompt and correct identification of a radiation worker with respect to his/her earlier assignments in the industry is posing new challenges. An indigenous effective tool titled 'Inter-Station Radiation Worker Search Engine' was developed that identifies workers based on biometric information and/or personnel details. Once a person is identified across various stations, his/her radiation dose history is automatically obtained through a secured channel from respective station(s) before he/she is permitted to work in radioactive areas. This system integrates itself with any existing dose management system and works seamlessly thereby eliminating the potential errors and delays in communications.
- With the intention of managing off-normal/emergency conditions, availability of information



Inter-station radiation worker search engine with biometric and generic search features

in time has a significant importance. To meet this requirement of effectively managing compound information being received during such conditions, HPU at RAPS-5&6 has conceived, designed, developed and implemented a comprehensive integrated network based system, named 'Emergency Information Management System (EIMS)'. This system is scalable and addresses requirements pertinent to plant, site and offsite emergencies of a station/site. It is highly helpful in organising, monitoring information in an orderly manner so as to help in handling, re-evaluation and reinforcing steps to mitigate the consequences and ensure optimum utilisation of resources during off-normal situations. This system can be integrated with a Decision Support System (DSS) for further enhancement of its capabilities.



EIMS comprehensive master display screen

Conclusion

The achievements of the aforesaid accomplishments are in terms of reduced individual and station's radiation exposure expenditure, effective utilisation of resources, minimisation of waiting time between relevant activities, reduced efforts and superior error prevention ability. Additionally, the

outcome is also in terms of a better informed workforce, equipped with resources facilitating improved work and safety culture of the utility in the time ahead. However, this can be considered only as an initiative which must propagate generously beyond the boundary of the utility and it is needless to state that it will continue to evolve.



Umed Yadav has served the organisation for about two-and-a-half decades in the capacity of Health Physicist, Station Health Physicist and Radiological Safety Officer at KAPS-1&2, NAPS and RAPS-5&6. He has worked in the areas of Dose Management Systems (DMS), Radiological Information Management System, Dosimetry systems, introduction of new/improvement of the existing radiation measuring field and laboratory instruments and introduction of biometrics in DMS as well as development of Emergency Information Management System. Presently, he is Additional Chief Engineer at NPCIL Headquarters.

Indian Scenario of Co-60 Production and Its Requirements

Dr. A.K. Kohli, Former Chief Executive, Board of Radiation & Isotope Technology

Introduction

Board of Radiation & Isotope Technology (BRIT) is a unit of Department of Atomic Energy (DAE), Government of India. BRIT is engaged in promotion of various non-power applications of radiation and radioisotopes in the country. This includes setting up of cobalt-60 (Co-60) based radiation processing plants for both food and sterilisation of disposable medical products. Co-60 based irradiators are in use for other applications such as municipal sludge hygienisation, vulcanisation of natural rubber, microbial load reduction in pet feed, colour enhancement in semi precious stones etc. BRIT is the only organisation in the country

involved in production and supply of Co-60 sealed radiation sources for such irradiators.

Requirements of Co-60 in India

India has at present 18 industrial irradiators which are carrying out sterilisation of medical products, radiation processing of food and other allied products. In addition, one plant for sewage sludge hygienisation is also there. The yearly Co-60 requirement is 2-2.5 MCi. This is expected to go up to 6 MCi in 2020 when it is estimated that 50 such irradiators will be there in the country. The additional irradiators are expected to be set up more for food irradiation than other applications. It is expected that there will be demand for irradiators

for dry sludge hygienisation also. After 2020, the availability of indigenous low cost accelerator based systems and improved availability of power situation in the country may result in slowing down the pace of setting up of gamma irradiators. However, by 2025, 75 such irradiation facilities may exist with total Co-60 requirement from these at 7-8 MCi/year.

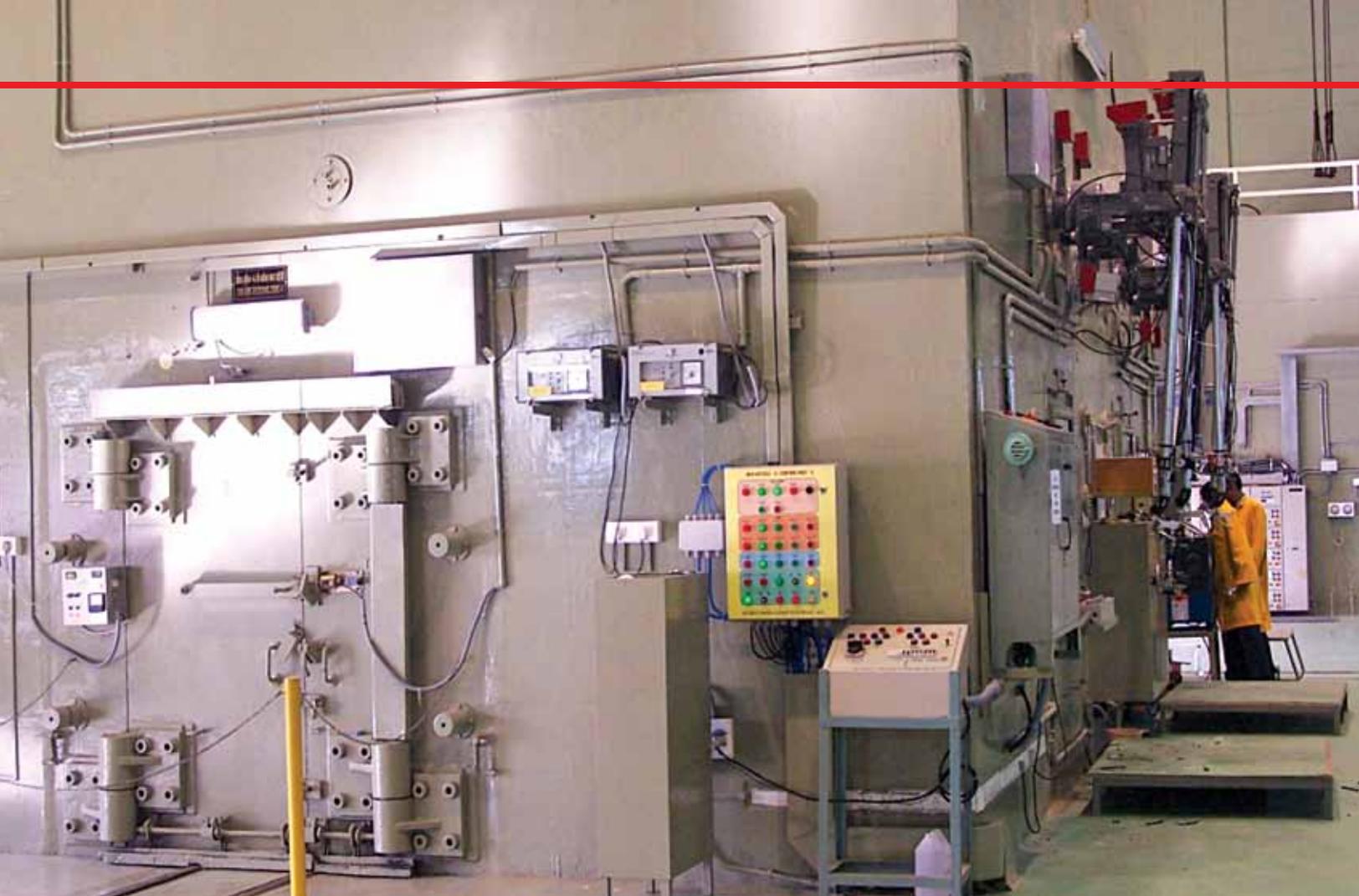
Apart from irradiators, Co-60 is being used for production of teletherapy sources and in laboratory irradiators like gamma chambers and blood irradiators. Also a very small amount of Co-60 is used in production of radiography sources. There are about 250 teletherapy machines in India and this number may remain more or less same because of decommissioning of old machines and introduction of Bhabhatrons keeping in view the introduction of indigenous medical LINACs. The requirement of telecobalt will remain small at about 250 kCi/year with specific activity of >160 Ci/gm. The requirement of Co-60 for other applications as described above is not expected to be more than 50 kCi per year. As such, all such requirements do not alter the overall requirement scenario of Co-60 and it will continue to be dominated by requirements from industrial irradiators in India.

Production of Co-60 Pellets/Slugs

Pressurised Heavy Water Reactors (PHWRs) of Nuclear Power



RAPPCCOF Facility, Rawatbhata



Hotcell in the RAPPCOF facility

Corporation of India (NPCIL), another unit of DAE are being employed for neutron irradiation of Co-59 slugs or pellets. Regulating and absorber rod assemblies are used to control reactivity inside the reactor core under different operating conditions. Reactivity control is achieved by inserting or withdrawing these neutron absorbing elements into the core thereby changing the neutron flux. The regulating rod and absorber rod assemblies are mounted vertically and arranged in a symmetrical pattern. The absorbing elements travel into and out of the reactor core in vertical columns in between the calandria tubes. Each location has two independently acting absorbing assemblies. The assemblies are housed in zircaloy inner and outer

flow tubes. Each flow tube has an absorbing element. The two flow tubes move telescopically on a common vertical axis inside the reactor core, thereby providing vertical motion to absorbing assemblies. The absorbers can be simply made out of stainless steel in which case those will last the full reactor life. For Co-60 production, Stainless Steel is replaced with Cobalt in the absorber rods.

In India, Co-60 production started on 220-MW reactors which use 2-m-long absorbers. After 220-MW reactors, NPCIL had introduced 540 MW reactors in which Co-60 production was not envisaged. These reactors have 4-m long absorbers. However, in the next generation 700-MW PHWRs,

provisions have been made for Co-60 production with introduction of features which will facilitate easier recovery of Co-60 pencils. For ease of handling, 10 of the 17 locations are selected for loading the cobalt absorbers. The length of absorbers is reduced by about 0.5 m to facilitate easier handling. Out of 10 absorbers, 4 are 3.5 m long and 6 are 2.8 m long. Provision to separate the absorber holding cable from the absorber assembly and separation of assembly in spent fuel bay into individual bundles have also been incorporated. This facilitates ease of transfer of assembly from top of reactor to the spent fuel bay.

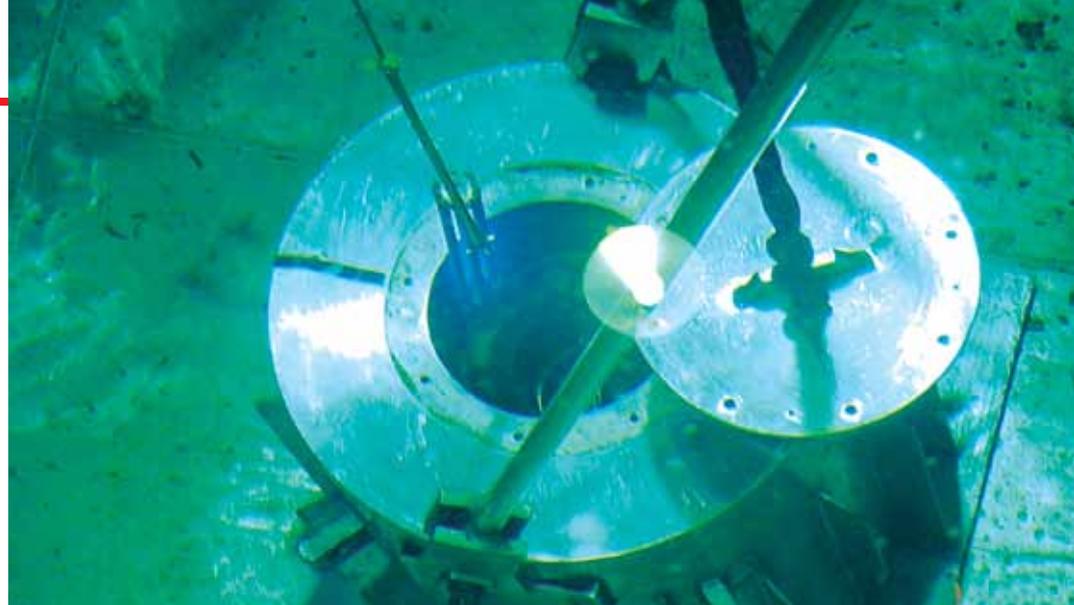
BRIT has one facility at Rawatbhatta, Rajasthan called RAPPCOF, which is used for recovery of Co-60 from

the absorber rods. This facility was originally designed with a view to accept absorber rods from 220 MW reactors. For handling the heavier transportation flask required for the longer absorber rods of these reactors and additional water pool needed for storage for absorber rod sub-assemblies, the facility at RAPP COF is being upgraded.

The loading of Co-59 pellets and slugs in reactors has been planned considering the present and future requirements of both irradiator as well as teletherapy cobalt. At present cobalt is loaded in 10 numbers of 220 MW reactors which includes 5 reactors at Rawatbhata, 2 at Narora, 2 at Kakrapar and 1 at Kaiga. It is planned to put cobalt absorbers in the 700 MW RAPS-7&8 reactors under construction at Rawatbhata. By 2020, it is planned to discharge out all the absorbers from the existing non-Rawatbhata reactors and load the absorbers into RAPS-7&8. This will result in all the reactors at Rawatbhata site – 5 of 220 MW and 2 of 700 MW – irradiating for Co-60. These 7 reactors are expected to meet the bulk of the demand for Co-60 in India.

Absorber rod sub-assemblies under water

In making the selection of reactors for loading of Co-59, security and transportation of long and heavy Cobalt Absorber Transportation Flask, particularly in public domain



Underwater handling of Absorber Flask at RAPP COF

Concluding Remarks

Table-1: The Co-60 requirements from domestic users and anticipated production rates

Year	Number of Plants				Installed Capacity MCI	Co-60 Requirement MCI/Year
	Medical and Food	Food	Sludge	Total		
2015	14	3	1	18	15	2 - 2.5
2020	25	20	5	50	30	4 - 6
2025	30	35	10	75	60	7 - 8

has been kept in mind. Location of RAPP COF and more number of PHWRs at Rawatbhata site results in meeting that objective effectively.

The policy on production of Co-60 is focussed at keeping pace with the growing requirements from domestic radiation processing plants. Targets for production of Co-60 are, however, kept somewhat higher to ensure that no shortages are faced. The timing of discharge of absorber rods from the reactor is coincided with normal reactor maintenance shutdown by NPCIL.

Only surplus Co-60 available at any point of time with BRIT will be meant for exports.

Possibilities for increasing the production rate are available and the loading of cobalt absorbers in the different reactors will continued to be done in association with NPCIL keeping in view any envisaged changes in the requirement. To sum up, BRIT in association with NPCIL is fully geared up to meet the current and future requirements of Co-60 in the country for all the different societal applications.



Dr. A.K. Kohli, former Chief Executive of BRIT and a Raja Ramanna Fellow, started his career at Reactor Engineering Division, BARC after graduating from BARC Training School in 1975. He has done his post-graduation and Ph.D from IIT Delhi. He was involved in indigenous development of refueling equipment for PHWRs and PFBR. He has been instrumental in bringing up of large number of industrial-scale radiation processing plants in the private sector in India. His sustained efforts have resulted in introduction of new products suitable for industrial irradiators in the country. He has comprehensive knowledge of radiation and radioisotope technologies and has taken several new initiatives to enhance the performance of BRIT. Currently, he is President of National Association for Applications of Radiation and Radioisotopes in Industry (NAARRI).

Nitrogen Blanketing of Steam Generator and Chemistry Control to Prevent Antimony Excursion in PHT System

B.S. Sahu, Station Chemist, KAPS • A.L.V. Vikram Reddy, STE (Nuclear), KGS - 1 to 4

Introduction

Kaiga Generating Station (KGS) is committed to generating power with minimum radiation exposure to working personnel as well as general public. In Indian Pressurised Heavy Water Reactors (PHWRs), Primary Heat Transport (PHT) system is filled with heavy water and it takes heat away from uranium fuel and transports it to Steam Generator for production of steam for power generation. PHT system contains activation products (formed by interaction of atoms with neutron) and fission products which have the potential to cause radiation exposure to working personnel. The activation products generally observed in PHT system are manganese-56, zirconium-95, niobium-95, cobalt-60, iron-54 and antimony-124. In PHWRs, the generation and deposition of above-mentioned gamma-emitting activation products is minimised over time by selecting superior construction materials and stringent chemistry control. In-Service Inspection (ISI), maintenance and overhauling during plant shutdowns are major contributing factors to the overall dose exposure to personnel. Preventing and minimising the release at source and enhancing the removal of radioactive activation products are important

steps in reducing overall collective dose exposure. Reappearance of antimony whenever the PHT system is exposed to oxidizing environment during ISI/maintenance activities during biennial shutdowns (BSDs) is still an enigma to nuclear engineers and chemists. This causes significant contribution of collective dose to personnel. This article explains various steps taken in Units-3&4 of Kaiga Generating Station (KGS-3&4) during a shutdown, to minimise the release of antimony by innovative technique of nitrogen blanketing of PHT system during system draining, maintaining reducing environment by chemical addition and removal of antimony, in case of any release from the system before plating out of the same on the system pipelines.

History, probable sources and deposition mechanism

Excursions of antimony (Sb-124) activity during maintenance outages of PHT system is a perennial problem in Pressurised Water Reactors (PWRs) and PHWRs worldwide. The sources of antimony in these reactors are the Main Primary Circulating Pump seals and carbon bearings. Antimony is commonly used as filler in seals and gaskets for high-temperature fluid applications. Antimony is impregnated in bearings, seal faces, gaskets, etc. to improve strength, wear resistance

and thermal conductivity. Antimony present in these components enters the reactor core due to wear and tear and gets activated. Release of antimony from failed fuel bundles also adds to the inventory even though its contribution is not significant. In KGS-3&4 and other new-generation Indian PHWRs, antimony-impregnated bearings and seals are not used but still some release of antimony was observed during the shutdown.

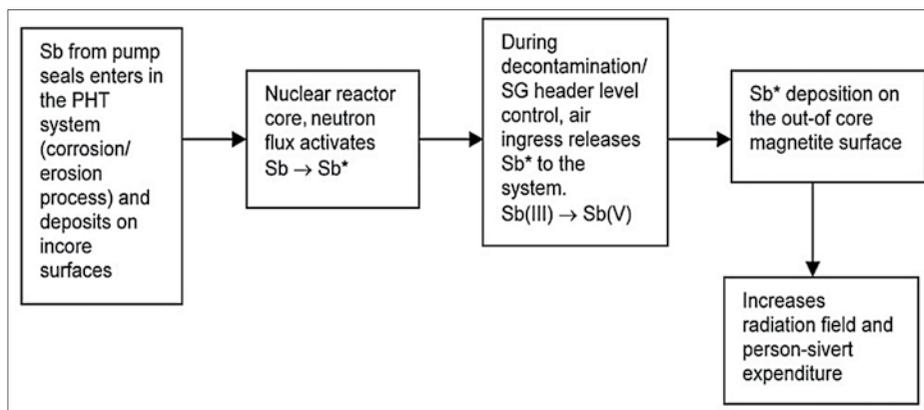
Natural antimony consists of Sb-121 (abundance 57.36%, neutron absorption cross section 5.9 barns) and Sb-123 (abundance 42.64%, neutron absorption cross section 4.1 barns), which under the influence of neutron field form Sb-122 and Sb-124, respectively. Sb-122, with a half life of 2.7 days, emits gamma rays of energies 546 and 693 keV and Sb-124, with a half life of 60.2 days, emits gamma rays of energies 603 and 1691 keV.

Antimony is present in water in anionic form. It is removed by using strong base anion exchange column. Due to long half life and high gamma energy of Sb-124, it has much effect on radiation dose compared to Sb-122. During normal operating conditions of reactor, reducing environment is maintained in the PHT system to minimise corrosion of system

materials. In this condition, any antimony entering water as a result of erosion/corrosion will be present in the highly insoluble reduced form [elemental Sb and Sb (III) form]. It will be trapped in the protective magnetite layer on the carbon steel surface and in-core zirconium oxide layer. During maintenance outages, as the system is opened, air ingress occurs in the system, which creates oxidative environment in PHT. Under oxidising conditions, antimony converts from reduced form to more thermodynamically stable and soluble Sb (V) form. The soluble, activated oxides of antimony get dissolved in water under oxidising conditions and redeposit on out-of-core surface of the system pipelines, where system temperature is less during unit shutdown.

Atomic Research Centre In-service Inspection System (BARCIS) activities. During these activities, there are chances of air ingress into the system. In KGS-3, increase in antimony was observed for the first time during a planned shutdown in the year-2010. Sb-124 activity increased to 222 $\mu\text{Ci/l}$ from 1.0 $\mu\text{Ci/l}$. During this period, shutdown purification was isolated for maintenance. Shutdown purification ion-exchange (IX) columns was taken in service and Sb-124 was brought down from 222 $\mu\text{Ci/l}$ to 2.1 $\mu\text{Ci/l}$. Due to increase in the antimony activity in PHT system, the radiation field increased 2.5 times on system lines. This caused higher man-rem consumption and delay in the execution of some of the shutdown activities.

on the principle of converting insoluble and reduced antimony to highly soluble pentavalent antimony. Dissolved antimony is removed using ion-exchange columns exclusively earmarked for this purpose. It is employed in PWRs for the decontamination of antimony before the systems are opened for maintenance. But in PHWRs, this method has yielded partial success. The presence of magnetite layer in PHWRs compared to the ferrite layer of PWRs, pH range of PHWRs, plating out of antimony at different temperature ranges and generation of radioactive waste in the form of ion-exchange columns are the limiting factors. Large quantities of H_2O_2 are required for maintaining the requisite dissolved oxygen concentration, as the magnetite layer consumes the dissolved oxygen. It can also damage the magnetite layer and can subsequently lead to crud release. The other decontamination techniques using mild acids under reduced conditions are also of not much use, as Sb (III) is found to redeposit on magnetite layer. Moreover, carrying out decontamination prior to every biennial shutdown (BSD) is not pragmatic, as it is time-consuming and can cause more radiation dose exposure. The addition of decontamination chemicals can also cause significant changes in the Heat Transport System chemistry, particularly with respect to isotopic purity.



Experience at KGS-3&4

In KGS-3&4, the bearings and pump seals are free from antimony. However, antimony activity was observed in KGS-3&4. Increase in antimony was observed in PHT of both units during Relief Valve replacement, during header level control and during Bhabha

Antimony removal techniques employed in different NPPs

One of the methods employed is to decontaminate the system before commencement of shutdown activities. For decontamination, hydrogen peroxide (H_2O_2) is dosed into the system after shutdown to create an oxygen-rich environment to release antimony. This is based

Nitrogen blanketing during header level control of PHT system

From past experiences, it is observed that antimony is released

bulk draining was 13.8 $\mu\text{Ci/l}$. Further, the bulk draining rate was kept at 1.5 tonne/hour and chemical addition was done as recommended by chemical lab.

Antimony control by nitrogen blanketing was implemented for the first time in June 2011 during the BSD of KGS-3. Being a first-time measure, exhaustive discussions were held considering the merits and demerits on the methodology. As the first-time implementation was successful, in all subsequent shutdowns of both units of KGS-3&4, nitrogen blanketing was implemented satisfactorily during header level control operation.

Nitrogen blanketing is a unique innovative idea implemented for successful prevention of antimony during header level control. Though antimony excursion can be prevented by nitrogen blanketing during system draining and establishment of header level control, ingress of air into the system during subsequent stages can also cause antimony release, e.g., during first BSD of KGS-3, while carrying out maintenance on ECCS valve and PCP casing vent valve, antimony activity was observed. This was due to the fact that while providing isolation for working on these valves, the loop vent valves were kept open (air ingress took place due to loop going under slight vacuum) as per standard practice and air ingress took place. Hence, the following measures are also taken so that antimony activity can be controlled throughout the shutdown.

- Hydrogen is added twice per week to control oxygen during plant operation when system is hot and pressurised. But in shutdown, dissolved oxygen cannot be controlled by hydrogen addition. However, just prior to a planned shutdown, 50 psi pressure drop of hydrogen is added in the PHT system to ensure reducing conditions in the initial few days of shutdown.
- During shutdown, hydrazine is added in PHT system to control oxygen during header level control and other works in which there are possibilities of air ingress into the system. But hydrazine converts to ammonia after a few hours of addition in the system due to radiation field. Ammonia slowly converts into dissolved hydrogen and reduces oxygen in radiation field. As hydrazine converts to ammonia, fast ingress of air cannot be controlled by hydrazine addition.
- It is observed that rate of depressurisation of PHT system and draining of system for header level control also influence antimony release. PHT system is depressurised at the rate of 1 kg/per minute to minimise the crud release in the system. PHT system draining rate is maintained < 1.5 tonne/hour.

Table-1: PHT Chemistry Regime during Unit-4 BSD

Date	pH	SP. Conductivity ($\mu\text{S/cm}$)	Dissolved D_2 (ml/kg)	Dissolved oxygen (ppb)
28-July-2015	10.28	19.5	2.05	5
30-Jul-2015	10.28	22.1		
1-Aug-2015	10.46	22.2		5
3-Aug-2015	10.43	23.5		
6-Aug-2015	10.48	23.9	4.50	10
09-Aug-2015	10.45	24.5		
12-Aug-2015	10.47	25.2		
15-Aug-2015	10.63	36.2	5.90	10
18-Aug-2015	10.67	38.9		
21-Aug-2015	10.50	30.1	8.6	
24-Aug-2015	10.58	40.5		10
27-Aug-2015	10.53	37.1	4.40	
31-Aug-2015	10.31	34.3		10
1-Sep-2015	10.22	22.7	2.85	

Table-2

S. No	Date	Main Activity	Specific Activity With Potential for Antimony Excursion in Chronological Order	Hydrazine added (litre) (ppm)	Hydrazine	Ammonia (ppm) (ppb) ($\mu\text{Ci/l}$)	Dissolved oxygen Sb-124	Sb-124 ($\mu\text{Ci/l}$)
1.0	28/07/15	System shutdown	---	0	BDL	0.15	5	<0.5
2.0	30/07/15	System depressurised	<ul style="list-style-type: none"> • Normal purification isolated • Anion column taken into service 	1	0.8	3.8	5	<0.5
3.0	03/08/15 – 15/08/15	BARCIS of 16 coolant channel	<ul style="list-style-type: none"> • BARCIS of 16 channels • D_2O pump out rate from 3525 TK1 to PHT storage tank during BARCIS was approximately 20 tonne per day 	2	0.12	5.6	5	0.7
4.0	15/08/15 - 16/08/15	Bulk transfer of D_2O	<ul style="list-style-type: none"> • Shutdown purification stopped • D_2O transfer • N_2 admitted through SG manhole vent from ECCS tank after transferring 10 tonnes of water • Bulk transfer completed by transferring 36 tonnes • Header level achieved. 	5	0.58	40.0	10	<0.5
5.0	17/08/15 - 26/08/15	Maintenance of SG ISI and ECCS MV	<ul style="list-style-type: none"> • SG 1&2 hot/cold leg manhole opened and nozzle dam installed • SG 1&2 hot leg ISI and ECCS MV7 maintenance completed • SG 1&2 cold leg ISI and ECCS MV 2, 10 in progress • SG 1&2 cold leg ISI completed • SG 3&4 ISI in progress. ECCS MV 2, 10 reinstalled • PHT storage tank 3333-RV-27 calibration • 3334-RV-63 calibration (PPP discharge) • Plugging of thinned tubes in SG 1-4. • S/D MV 2&4 ISI and S/D MV4 maintenance is done 	2.5	0.30	92.0	10	<0.5
6.0	27/08/15	PHT refilling	<ul style="list-style-type: none"> • PHT filling and venting done • S/D purification taken into service 	0	0.15	24.0	10	<0.5
7.0	29/08/15 – 31/08/15	PHT system normalisation	<ul style="list-style-type: none"> • PHT pressurised • Two diagonal PCPs started • Normal purification taken into service. 	0	0.07	9.0	10	<0.5



B.S. Sahu passed his M. Sc. from Bihar University. He is from 34th batch of BARC Training School. He joined Kakrapar Atomic Power Station (KAPS) in 1991, where he and was associated with chemistry control of various systems of the station. He has contributed to the standardisation of a method for carrying out chemical cleaning of condenser tubes at KAPS, which has significantly improved the performance of the systems, and also in the development of unique and novel method for identification of the leaky steam generators in PHWRs. Presently, he is Station Chemist at KAPS.



A.L.V. Vikram Reddy presently Sr. Technical Engineer-Nuclear Systems, KGS-1 to 4, is a Mechanical Engineer from REC, Warangal and from the 36th batch of BARC (NPC-IV). He started his career from KAPS in 1994 and has contributed to the commissioning of PHT system and Auxilliary system in KGS-1&2 and KGS-3&4 together with engineered safety features associated with Containment systems. He has contributed to the implementation of nitrogen blanketing of steam generators as well as in endeavours towards reducing man-rem by introducing innovative control measures during shutdowns.

Construction of Breakwater Dyke and Shore Protection Bund Structures at KKNPP-1&2

R.R. Kamath, Addl. Chief Engineer (Projects-LWR), NPCIL Headquarters

1.0 Introduction

Breakwater dykes are the structures constructed by placing huge masses of stones on the seabed away from the shore to protect harbour facilities and offshore facilities from hostile forces of ocean waves and to provide tranquil conditions for safe operation of such facilities. They are also widely used while constructing structures in the sea, such as intake structures.

Depending upon the method of construction, breakwaters can be grouped as rigid, semi-rigid and flexible. The flexible rubble mound structures are most commonly used type in India. They are constructed by first placing large stones of various sizes, layer by layer, comprising a bedding layer core, secondary layer protected by an armour layer and a toe to prevent slippage of armour units. The armour layer consists of quarry stones, if available, in required size and quantity, or may consist of specially designed concrete armour units.

The stability of rubble mound structures under wave attack is the most important aspect in their design. It depends on factors such as stability of individual armour units on its seaward slope, weight of the armour units, shape, interlocking,

specific weight, slope of structure, number of layers, packing density, location, type of waves, etc.

Several empirical formulae such as Hudson's formula and Van der Meer formula are widely used in the design of breakwater structures.

2.0 Design Of Rubble Mound Structure

Following are the typical stages in the design of breakwater structures:

1. Specification of design conditions
2. Determination of armour unit size/type and under layer requirements
3. Development of toe structure and filter or bedding layer
4. Analysis of foundation settlement, bearing capacity and stability

3.0 Breakwater Dyke at KKNPP-1&2

A breakwater dyke at KKNPP-1&2 has been provided to protect the intake and fish protection structures located at the northern end of it by providing a tranquil pool of water without any sea disturbance as well as to locate the seawater intake pipeline (caissons) at its southern end, which facilitates for drawing of

water at 1.2 km from shore as per design requirement.

The breakwater at KKNPP-1&2 is a rock-fill structure located at a distance of 270 m from the shore. The plan dimensions of the structures at the centre line are approximately 900 m x 250 m. The bottom sea level is varied from -4.00 m to -13.00 m with respect to mean sea level (MSL). The dyke has a top elevation of +8.0 m with side slopes of 1:2. This is a common structure for both units.

The breakwater dyke at KKNPP-1&2 had two cross sections, namely:

1. Sheet pile section
2. Non-sheet pile section

In sheet pile section, the breakwater cross section was built as two separate bunds, namely, inner bund and outer bund, leaving the area between the two for sheet pile driving. In the non-sheet pile section, breakwater cross section is built as a single bund.

Breakwater dyke was built in two stages:

1. In the first stage, the straight portion of the East and West arms from 440 S (from temporary dyke junction) to 1090 S (near to breakwater dyke mouth) was constructed.
2. In the second stage, after

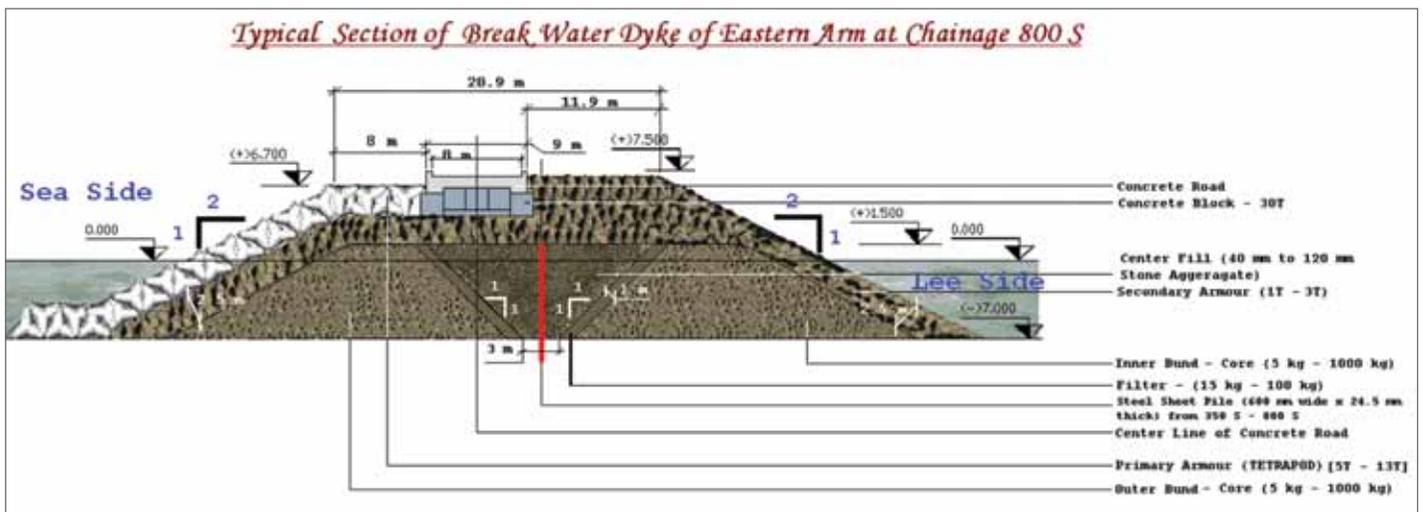


Fig. 1: Typical cross section of breakwater dyke of Eastern arm at Ch. 800 S (sheet pile section)

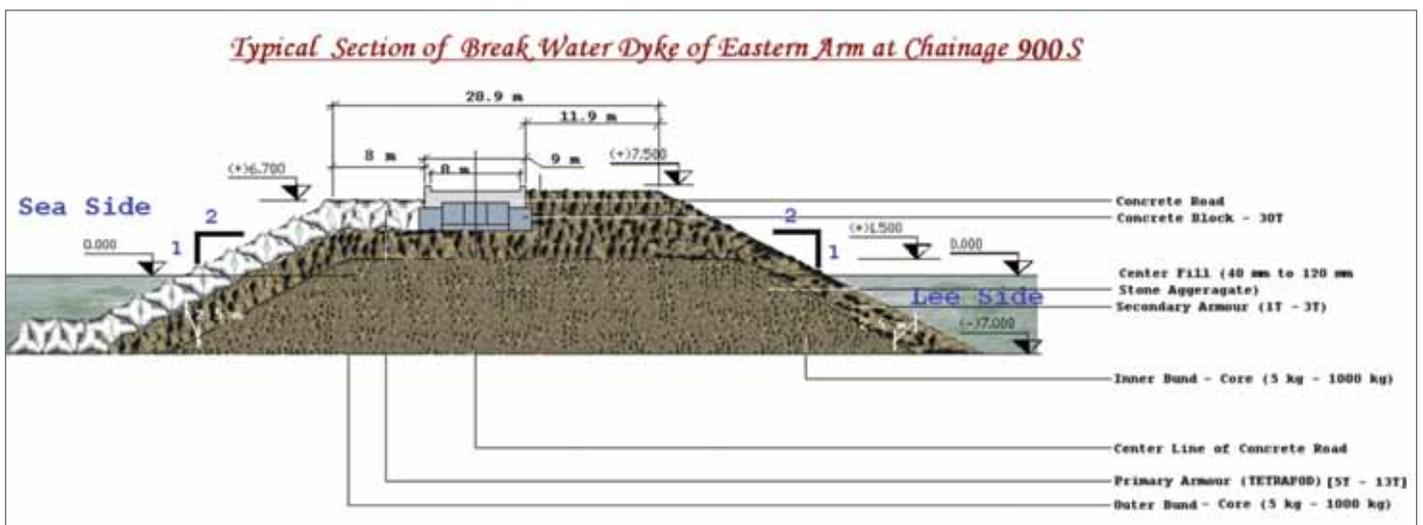


Fig. 2: Typical cross section of breakwater dyke of Eastern arm at Ch. 900 S (non-sheet pile section)

breach of temporary dyke, and after towing and positioning of caissons, the curved closing arms on the northern end and southern end was built.

The breakwater dyke cross section consisted of following materials:

a. Core

Quarry stone forming the main body of the structure. Weight of stone varying from 5–1000 kg

b. Filter – A

Quarry stone of 15–100 kg forming

the filter layer in the sheet pile portion

c. Filter – B

Crushed stone of 40–120 mm forming the central filling for sheet pile driving at the center of the two (Outer and inner) bunds.

d. Secondary Armour

Layers of rock laid over the core and made of stone mass 1000–3000 kg

e. Primary Armour

Outer protective layer of armouring

consisting of individual concrete tetrapods interlocked to the required density of weights 5, 13 and 20 metric tonnes, depending upon the depth of water.

A typical cross section at the sheet pile section and non-sheet pile section is given in Fig.1, 2.

4.0 Production of Rock Materials

Rock materials were obtained from two quarries namely Irukkanthurai quarry at a distance of about 12 km

Table-1: Fractional Composition of Stone Category

Stone Category	5–1000 kg	15–100 kg	1000–3000 kg
	Content (in % of the total quantity) per fractions		
< 5 kg	3-7	< 2	-
15–16 kg	-	40-60	-
60–100 kg	-	40-60	-
5–100 kg	20-33	-	-
100–400 kg	35-50	< 3	-
400–800 kg	10-30	-	-
800–1000 kg	10-15	-	-
1000–2000 kg	-	-	40-60
2000–3000 kg	-	-	40-60

and Vijayapathy quarry at a distance of about 10 km from the plant site. These were pit quarries. Blasting was carried out using fourth generation explosives (emulsion cartridges). Various blasting patterns were tried to get the required fragmentation for obtaining core and armour materials to satisfy required gradations.

Gradations were specified in the drawing for different grade of rock materials to be used in break water dyke as given in Table-1.

4.1 Acceptance Beyond Specified Minimum and Maximum Weight

A small proportion of rocks lighter than the lower limit and higher than the upper limit could be present during production. However, the percentage and weight of stones below the lower specified weight (ELCL) and above the higher specified limit (EUCL) were restricted within specified acceptance limits as given Table-2.

Each class limit is a particular weight for which the cumulative percentage passing by weight must fall within the specified range.

For 5–1000 kg (Core) and 1000–3000 kg (Armour):

- ELCL – 0.65 LCL
- EUCL – 1.5 UCL

For 15–100 kg (Filter):

- ELCL – 0.5 LCL
- EUCL – 1.5 UCL

4.2 Acceptance Below Specified Limit

The limiting values are given in Table-3.

To ensure proper gradation of the stones, trained spotters were deployed for inspection of the material at quarry before loading. Spotters were also deployed at the placing point in breakwater dyke. To aid the visual identification, samples of stones with correct blend of weights were kept at strategic locations with display boards. Further, individual stones of difference weights with their actual weight painted on the stone were also displayed to help the spotters.

Table-2: Acceptance Limits for Stones

ELC L	Extreme lower class limit	
LCL	Lower class limit	To define standard grading classes
UCL	Upper class limit	
EUCL	Extreme Upper class limit	

Table-3: Limiting Values of Stone Category

	Minimum Wt	Maximum %	Maximum Wt.	Maximum %
5–1000 kg	---	---	1500 kg	3%
1000–3000 kg	650 kg	2% or 1 no. per sample	4500 kg	3% or 1 no. per sample
15–100 kg	7.50 kg	2%	150 kg	3%



Fig. 3: Tetrapod being demoulded

4.3 Testing of Rock Materials

The frequency of testing adopted for the rock materials is given in Table-4.

With the above measures it was ensured that only the rock materials which satisfy the requirements were used in the works.

4.4 Casting of Tetrapods

As a large quantity of tetrapods (28,360 nos) were required for the work, the casting of the tetrapods was taken up well in advance to meet the construction schedule. A suitable casting yard was selected near to the shore. Three gantry cranes of 25 tonnes – 2 nos. and 30 tonnes – 1 no. were erected in the casting yard. Number of steel moulds were decided based on the time cycle calculated for each tetrapod. The moulds were made in

Table-4: Testing Frequency of Rock Materials

Rock Material	Frequency of Testing
Core Stone	Initially 1 sample for every 5,000 metric tonnes of rock material placed till 50,000 metric tonnes is completed. Later, 1 sample for every 50,000 metric tonnes of material placed
Armour Units	Initially 1 sample for every 10,000 metric tonnes of rock material placed till 40,000 metric tonnes is completed. Later, 1 sample for every 20,000 metric tonnes of material placed

pieces assembled at site by bolting. Holes were provided for air venting. Vibration was done using needle vibrators as well as by ramming

with wooden hammers from outside. Mockups were conducted for improvement of the moulds, concreting methodology and to decide on its de-moulding and handling period. The moulds were removed generally after 24 hours and handled using the gantry crane in about 72 hours after achieving the required strength for handling. A photograph shows the de-moulding operation in Fig. 3. Water based membrane curing compound is applied on the surface after de-moulding for better curing purpose due to its shape. A photograph shows the view of the tetrapod yard in Fig. 4.

5.0 Construction Methodology

Considering the depths, short lengths of individual arms and the sea conditions, “end-on dumping” method was adopted for the



Fig. 4: Tetrapod casting yard

breakwater construction. The entire break water was constructed in following two distinct phases.

1. End-on dumping of core, Profiling, Armour placement, Sheet piling and Tetrapod placing upto working level of +2.0 m elevation as per drawings (including 0.5 m settlement allowance): The work started from the temporary dyke intersection point (north) and proceeded towards seawater intake pipe (0 UPA) ie south side.
2. Once the breakwater was completed up to +2.0 m elevation up to seawater intake pipe (leaving about 200 m), the following works were carried out from the seawater intake pipe side towards coast.
 - i. Placement and profiling of armour from the operating level to +4.0 m elevation.
 - ii. Placement of filter layer over the armour layer for the required thickness and width as per drawing.
 - iii. Placement of 30-tonne blocks/ 16-tonne blocks (in four corner curves) over the filter layer as per drawing.
 - iv. Placement of RCC pavement concrete of 1 m thickness above the 30-tonne blocks in lengths of 10 m.
 - v. Placement of 5/13/20-tonne tetrapods on the seaward side.
 - vi. Placement of balance quantity of armour beyond tetrapods up to the edge of the concrete blocks in the seaward side.
 - vii. The leeward side of the bund was maintained at the operating level ie, the armour layer is not filled on the leeward side to provide access to the break water dyke construction till the southernmost end.
 - viii. Balance length of break water dyke of about 200 m in both arms was completed in the similar sequence after placement of caisson structures, concrete ballasting and its stabilisation. The area on the lee side which was left for the access road was taken up at the last and filled with armour stones and profiled to the required slope.

5.1 Placement of Materials

5.1.1 Core

The core consisting of 5-1000 kg stones was placed by end-on dumping method using dump trucks from the leading end of the break water. When placed the core takes the natural slope of 1:1.25. Using cranes with grabs and back-hoe excavators, the core materials was placed to achieve the design slope of 1:2.

5.1.2 Armour

Rock armours of 1000-3000 kg were placed by crane fitted with 'grab' individually in the deeper reaches and by excavator in the nearer reaches.

5.1.3 Tetrapod

Tetrapods were placed at pre-designated coordinates by crane positioning system (ASCOREL MC-320) fitted to the cranes. The tetrapods were placed in 2 layers, ensuring that they were properly interlocked with each other to get the required packing density.

5.2 Protection of Placed Materials

Each placed layer was protected by the subsequent layer as soon as possible after placement, leaving a maximum length of each material of 50 m, in order to minimise damage due to waves in the event of storms during the construction period.

5.3 Survey of Profile

After the profiling of rock materials

was completed, a probe with a spherical end of diameter $0.5D_{n50}$ was used along with the crane to take the levels on (sloped) profile surface.

The measurements were carried out at the following intervals across the profile:

- i. Fine and light grading (core)
- 1 m
- ii. Heavy grading (Armour)
- $0.75 \times D_{n50}$

The survey was carried out at every 10 m along the alignment.

To start the survey, a benchmark level was transferred to the nearest point of work. Longitudinal survey points at every 10 m chainage were marked on the working level (+2.0 m) for the positioning of the crane. Spherical probe hung by the crane and controlled by a rope, was positioned at required interval along the slope of break water dyke.

The position of spherical probe on profiled surface was noted using a survey chain tied to the probe in the horizontal plane along the cross section. The individual survey profiles were plotted and superimposed on the theoretical profile to check whether the actual profile is within the tolerances. Once the actual profile fell within the tolerance limits (Table-5), the same was accepted. If the profile did not fall within the tolerance limit then once again the profiling had to be done to satisfy the requirement.

Where D_n is the nominal stone diameter which was calculated as the cube root of the volume of the stone. The volume was calculated by dividing the mass of the stone by the saturated dry density. The subscript 50 refers to the percentage by weight of the stones in the grading having a smaller nominal stone diameter.

Table-5: Vertical Placing Tolerances of Rock Materials

Depth of placing below low water	Bulk-placed core rock of grading effective mean weight. W_{em}		Armour (all armour layers and individually placed rock with grading) effective mean weight. W_{em}	
	Less than 300 kg	More than 300 kg	On individual measurement	Design profile to actual mean profile
Dry above low water	± 0.20 m	+ 0.4 m to - 0.2 m	$\pm 0.3 D_{n50}$	+0.35 D_{n50} - 0.25 D_{n50}
Less than 5 m	+ 0.5 m - 0.3 m	+ 0.8 m to -0.3 m	$\pm 0.5 D_{n50}$	+ 0.6 D_{n50} - 0.4 D_{n50}
5-15 m		+ 1.20 m to -0.4 m		
Greater than 15 m		+ 1.50 m to -0.5 m		

Typical values for the core material (5-1000 kg) are given in Table-6:

$$D_n = \sqrt[3]{\frac{W_{em}}{\rho \times g}}$$

Density of stone: = 2600 kg/m³

$$D_n = \sqrt[3]{\frac{320 \text{ kg}}{2600 \times 9.51}}$$

= 0.232 m Say, 0.23 m

Notwithstanding the tolerance in the above table, the following requirements were also applied to armour layers:

- i. The tolerances of two consecutive mean actual profiles shall be not negative.
- ii. Notwithstanding any accumulation of positive tolerances on underlying layers, the thickness of the layer shall not be less than 80% of the nominal thickness, when calculated using actual profile.

5.4 Provision of Steel Sheet Piles

Sheet piles were provided in the northern portion of the breakwater dyke cross section to prevent the inter-mixing of warm water let out from the discharge channel at shore line and the cold water drawn at the mouth of the breakwater dyke through seawater intake pipes (caissons).

As per drawings, the sheet piles were required to be driven in the cross section of the breakwater dyke till chainage 800 S up to refusal in the rock bed and projecting up to +1.5 m elevation on the top. As per the section details the sheet

Table-6: Values for the Core Material (5-1000 kg)

Gradation	Average Weight	% of weight of the stones	W _{em} (kg)
0-5 kg	2.5 kg	10%	320
5-100 kg	52.5 kg	20%	
100-400 kg	250 kg	40%	
400-800 kg	600 kg	20%	
800-1000 kg	900 kg	10%	

pile was enclosed by 40-120 mm aggregates which was protected by core (5-1000 kg) stones from both ends, having separation layer of 15-100 kg stones.

The following were the characteristics of sheet piles used at KKNPP breakwater dyke, which meet the requirement of drawings:

Manufacturer: CORUS (UK) – Mark - LX 32d

Sectional area: 161 cm²

Yield point: 355 N/mm²

Min.Thickness: 23 mm

Unit wt: 121.60 kg/m

5.4.1 Procedure of Driving

The work of driving of sheet pile involved the following:

- i. Survey for fixing the alignment of sheet pile between the inner and outer bund.
- ii. Positioning of the sheet pile in the guide.
- iii. Driving of sheet pile.
- iv. Cutting the projected length of the sheet pile above el. +1.5 m.
- v. Backfilling with crushed aggregate of size 40-120 mm.

The support beams (4 nos.) at a spacing of 12 m were placed at +1.00 MSL perpendicular to the alignment of sheet pile. Guide beams made of 2 nos. of ISMCs stiffened with 12-mm plate were placed over the support beams along the alignment of sheet pile. The gap between the guide beams was 460 mm. The guide beams were tack welded to the support beams to arrest any movement.

The first sheet pile was positioned accurately, driven by vibro-hammer held with the help of a crane, and tack welded to the guide. Vibro hammer is a generator of unidirectional vibrations consisting of rotating eccentricities producing a centrifugal force with a vertical resultant. The eccentricities are driven by one (or more) hydraulic motor(s) powered by a power pack supplied with the vibro-hammer. Further sheet piles were interlocked with the first pile inside the guide. After the completion of sheet pile driving in one assembly, the tack weld between the sheet pile and guide was cut and the first supporting girder was removed. The guides were shifted to the next location and the driving procedure was repeated.

After the completion of sheet pile driving, filter material of 15–100 kg was filled, profile was checked and then 40-120 mm aggregate was filled. The verticality of the sheet piles was also maintained during the filling process. A photograph shows the sheet piles being driven in position in Fig. 5. About 1,500 metric tonnes of sheet piles were used.

5.5 Placement of Tetrapods

The placing of tetrapods was done in different stages using 150-tonne and 75-tonne crawler cranes. The placing density was kept between 95% and 105% of the theoretical value of the units to be placed as determined from the positioning drawings prepared for the purpose. These drawings also indicated the center of gravity of the units in rectangular or polar coordinates with respect to a fixed crane position.

The tetrapods were placed on sloped approved profile of the armour stones. The tetrapods were lifted using 2 slings tied around and connected to a lifting hook with locking / releasing arrangement, which in turn was connected to the crane hook. The length of the sling used was sufficient, so that the depth of placement of the units could be varied as much as possible. The sling release hook was kept off centre with respect to the centre line of the unit for convenience of release.

To place the tetrapods, the crane was equipped with an electronic



Fig. 5: Sheet piles driven in position

positioning system called “ASCOREL”. Two parameters of positioning viz. crane radius and slew angle of crane were referred to for correct placement of each tetrapods.

The placing density for various tetrapods and total nos. required as per drawings are given in the Table-7:

Experienced divers were engaged to ensure correct orientation and

interlocking of tetrapods below water level. Personal protection gears like mask, diving suit, lifeline anchorage etc were used for the safety of the divers. The exact co-ordinates were identified by plotting individual Tetrapod location on the slopes of the break water dyke. The position of the crane was to be defined in advance and each day’s work planned within the reach of the crane. Once the crane position was fixed in relation to the crane centre,

Table-7: Details of Tetrapods

Tetrapod		No. of Tetrapods Placed			Placing Density (Nos. per 100 m ² area)
Type (Metric tonnes)	Volume m ³	Below MSL	Above MSL	Total	
5	2.085	10,224	6,623	16,847	56
13	5.256	4,906	2,507	7,413	31
20	8.33	2,421	1,679	4,100	24
Grand Total		17,551	10,809	28,360	-



Fig. 6: Tetrapods being placed using a crane

the location of each Tetrapod was found and two values were noted i.e., crane radius and Crane slew angle. Each Tetrapod with relation to the crane had a unique value of crane radius and slew angle. These were tabulated and kept in the crane cabin as reference for placement of units. There were two probes, viz., an inclinometer attached to the crane boom and a slew angle probe attached to the slew gear of the crane which were constantly measuring and sending the respective values to the CPU/display placed in front of the crane operator. With predetermined plotted values of the Tetrapod, the crane operator could place the Tetrapod in the predetermined location. A photograph shows the tetrapod being placed by crane in Fig. 6. A plan and elevation showing the typical dimensions of a 5-tonne tetrapod is given in Fig. 7, while a photograph shows a view of the placed tetrapods in Fig. 8.

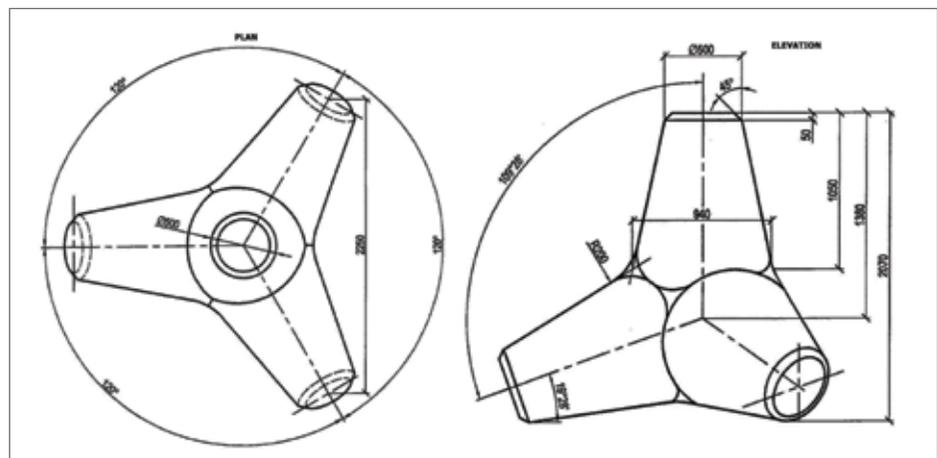


Fig. 7: Tetrapod – 5 T (Plan & Elevation)



Fig. 8: A view of placed tetrapods

6.0 Shore Protection Bund

The design of hydro-technical structures at KKNPP provides for stabilization of the shore line and for prevention of the erosion by construction of shore protection bund structure. This structure is provided all along the shore line of the main plant area at 63.50 S extending to a length of 1.5 km from (-)465.00 E to 1018.50 E and turning towards North till the top meets 8 m contour. The top elevation of the shore protection bund is at +8.00 m MSL.

The cross section of the shore protection bund is made up of rock materials i.e., Core (5-1000 kg) and armour on the sea side with the rock materials of 1000 to 3000 kg weight. On the land side (lee side), filter materials of 40-120 mm are provided for smooth drainage of water of territory.

The plan layout of the shore protection bund is given in Fig.13



Fig. 12: A typical view of the breakwater dyke during construction

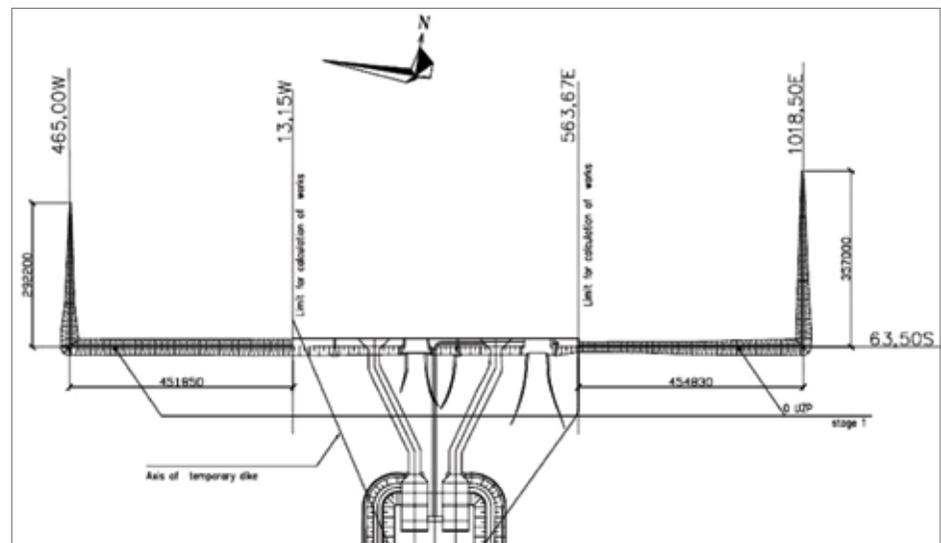


Fig. 13: Plan of Shore Protection Bund

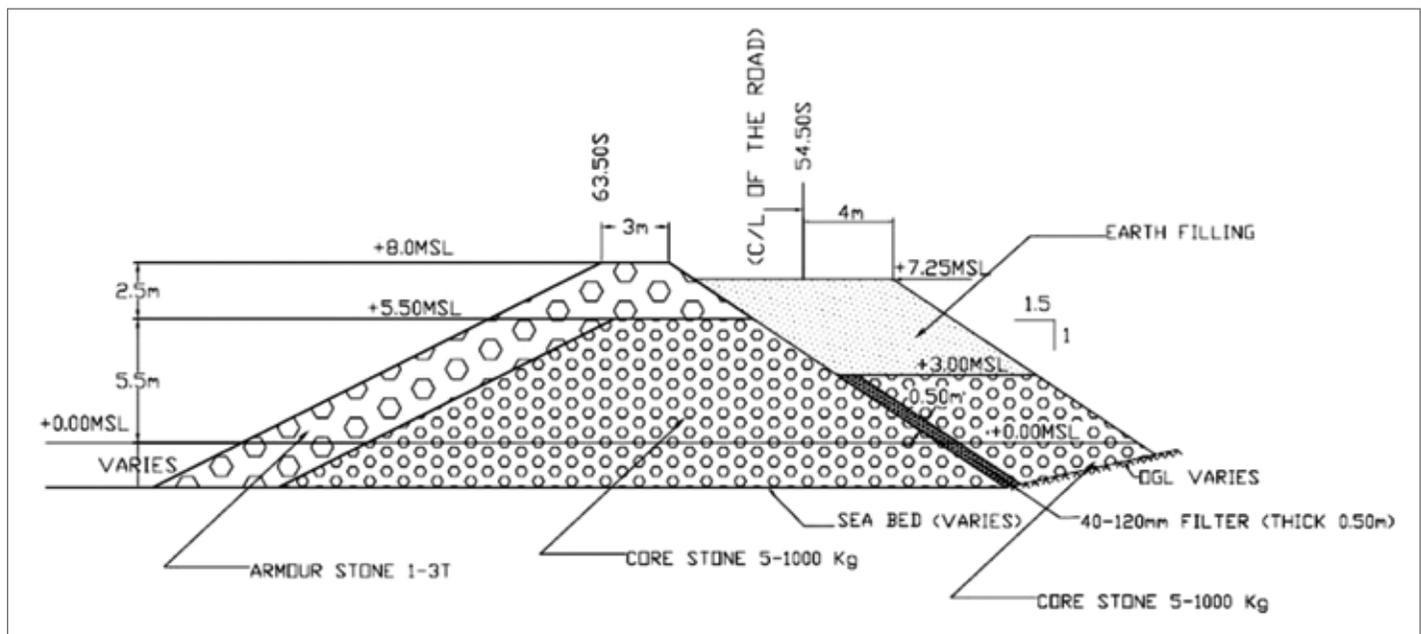


Fig. 14: Cross section of Shore Protection Bund

and the cross section is given in Fig.14. A photograph shows a view of the constructed part of the shore

protection bund in Fig.15. It is worthwhile to mention here that +8.0 m elevation shore protection

bund was able to resist the tsunami wave attack successfully in December 2004.

Table-8: Quantity of Rock Materials Used in the Construction of Breakwater Dyke and shore protection bund

Rock Material Type		Quantity in lakh cu.m		
		Below MSL	Above MSL	Total
Core	5-1000 kg	5.70	2.17	7.87
Armour	1000-3000 kg	1.45	2.90	4.35
Filter	15-100 kg	0.23	0.20	0.43
	40-120 mm	0.64	0.67	1.31
Total		8.02	5.94	13.96



Fig.-15: A view of the shore protection bund

In the construction of breakwater dyke and shore protection bund at KKNPP, the quantities of rock materials used is given in Table-8:

7.0 Conclusion

The massive work of construction of breakwater dyke and shore protection bund at KKNPP-1&2 has been carried out with proper implementation of engineering inputs, advance planning, quality control at each stage of construction and close monitoring. The work has been carried out successfully as per the requirement of the Working Documentation of Russian Federation as well as taking into account unfavourable sea conditions at Kudankulam site.



R.R. Kamath, Additional Chief Engineer (Projects-LWR), completed his B.E (Civil) from Mangalore University in 1987 and M.Tech (Hydraulics) from Mysore University in 1989. At KKNPP 1&2, he was the Engineer-in-Charge of Package C-VI (Construction of Hydro-technical Structures). He has a total experience of more than 28 years in NPCIL in the varied fields of design, coordination, quality assurance, civil construction and contract management.



tête-à-tête

with

Fred Dermarkar

President, CANDU Owners Group (COG)

Mr. Fred Dermarkar, President & CEO, COG delivering a lecture on 'Long-term Plans for CANDU Operational Safety' at the WANO conference

Mr. Fred Dermarkar, President & CEO, CANDU Owners Group was here in India to attend the WANO-Tokyo Center PHWR Operational Performance Improvement Seminar in May 2017. On the sidelines of the event, Mr. Amritesh Srivastava, Editor, Nu-Power grabbed an opportunity to interact with him. Presented here are excerpts of the interview.

For our readers, could you describe the role of COG?

The CANDU Owners Group (COG) is a private, not-for-profit corporation funded voluntarily by CANDU/PHWR operating utilities worldwide, Canadian Nuclear Laboratories (CNL) and supplier participants.

COG's vision is CANDU/PHWR excellence through collaboration. To achieve its vision, COG and its

members work together with suppliers and other stakeholders to solve the industry's most challenging technical problems, share operating experience (OPEX) and work toward regulatory acceptance through collaboration to enhance safety and reliability, strengthen human performance as well as environmental and financial performance.

Each year, COG invests about C\$65 million in research, development and joint projects to further innovation in

"COGonline.org, the COG member website includes a searchable database of more than 40,000 listings of operating experience and other documents and publications that can serve as valuable resources to members."

the performance of CANDU stations worldwide. It also provides multiple forums and channels for sharing of OPEX and for other forms of collaborative information exchange.

COG has been fulfilling this role for more than three decades. It is a trusted nuclear industry leader comprised of highly-skilled employees with extensive experience in many facets of CANDU/PHWR nuclear technology.

How is the process of information exchange related to operating experience actually implemented at COG?

There are several facets to COG's Information Exchange programme:

- COG hosts dozens of workshops annually, including several that are part of COG Collaboration Week,

a week-long event that provides international and Canadian COG members an opportunity for cross-functional dialogue in many areas of nuclear operations, maintenance, engineering and management. The week also provides participants opportunities to learn more about the programmes COG offers and to better understand the research and development activities COG undertakes in six programme areas;

- In addition to the forums, workshops and technical committees, COG provides a point of entry into many other programmes through its partner organisations including the International Atomic Energy Agency (IAEA), the Electric Power Research Institute (EPRI) and the World Association of Nuclear Operators (WANO), to name just a few.
- As well, COGonline.org – the COG member website – includes a searchable database of more than 40,000 listings of operating experience and other documents and publications that can serve as valuable resources to members;
- COG has developed a robust Supplier Participant programme that serves as a collaboration interface between suppliers and utilities to facilitate improved knowledge and understanding and to improve the security and safety of the global supply chain. There are now 18 members in the programme, including the first

international member, KEPCO E&C; and

- COG has developed multiple forums for timely information exchange between utilities that allow for a free flow of questions and answers as well as shared OPEX and even assistance in real time when a member is trying to solve a problem in their plant that may already have been encountered elsewhere.

These are the opportunities at a high level but I encourage participants from all our member organisations to set up meetings with their COG relationship manager to help them develop a plan to find the COG tools that will provide them the most value.

Share with us some success stories catalysed by COG.

Recently, I received a letter from the Director of the WANO Tokyo Centre thanking COG for our efforts in supporting the PHWR Operational Performance Improvement Seminar in Mumbai in early June. This seminar was illustrative of the value members receive from being part of a network of nuclear stations with common designs and shared goals. It also reflects the strength of our diversity and the insights and experiences that can be

“Each year, COG invests about C\$65 million in research, development and joint projects to further innovation in the performance of CANDU stations worldwide.”

collected and shared for continuous improvement by all. The seminar included almost 30 presentations by some of the world’s leading PHWR experts as well as formal information sessions that were well attended with active participation from across the COG membership.

In any given week or month, we have members who are solving challenges by talking with counterparts across the COG network. Through COG’s inter-station assistance programme, COG and its members have helped some of our members avoid or shorten outage durations by providing spare parts that would have taken far longer to procure without the COG programme, especially in light of supply chain issues related to aging. We have a robust obsolescence management programme that has helped our members address obsolescence-issues and in some cases, find better part solutions through re-engineering efforts. Fueling machine valve research completed in the past year is an excellent example where a re-engineering project improved cost and efficiency over the existing options. In the same vein, a COG initiative has developed improved methods for steam generator cleaning that could help improve the performance and life expectancy of steam generators.

COG’s fuel channel life management programme

The COG fuel channel life management (FCLM) programme is an example of a programme

that has allowed some CANDU plants to continue operations well beyond the anticipated end of life date. This research has achieved results by validating and managing margins in fuel channels, resulting in billions of dollars of added revenue through continued operation. It has also meant far greater operational flexibility during mid-life refurbishment, which has ensured continued supply of electricity in Ontario as it undergoes multiple unit refurbishments.

COG leader forums and working level peer groups have also made significant inroads in improved safety and reliability through shared best practices and coordinated initiatives in many areas of operation and maintenance leading to improved performance outcomes.

“For governments that want to mitigate climate change while providing people a safe, reliable, clean and affordable electricity source abundant enough on which to build an economy; nuclear can certainly be that option.”

As well, research and joint projects conducted by COG and its members have assisted in developing the proof points to validate industry positions resulting in more positive regulatory outcomes and in improved training. Post Fukushima, COG-facilitated efforts helped the industry respond effectively to ensure we are well-prepared in the highly-unlikely event of another

such unexpected scenario at a nuclear plant. In addition to the important emergency preparedness and technical outcomes, this helped to restore public confidence in the wake of the Fukushima events.

Tell us about the CANTEACH project.

CANTEACH is a knowledge repository that provides high quality technical documentation relating to the CANDU nuclear energy system. This information is public and is intended for use in various aspects of education, training, design and operation.

The CANTEACH Project aims to provide an information exchange network for people interested in the CANDU energy system. Contributors are industry experts who hold valuable knowledge and experience in diverse aspects of CANDU technology and its applications, and unique expertise in the areas of science and technology, nuclear power design and construction, project management and development of engineering tools.

Contributors include people working in organisations that produce electrical power utilising nuclear energy, CANDU power plant vendors, educational institutions, regulatory agencies and other CANDU-related organisations interested in freely exchanging educational and training material.

COG provides administrative and web support to CANTEACH. The website is canteach.candu.org.

What have been the lessons learned post-Fukushima and how have these been implemented in CANDU reactors in Canada and elsewhere?

Immediately after the event, each of the CANDU/PHWR utilities, working together as the COG CANDU Industry Integration Team (CIIT), responded swiftly by developing action plans for robust methods for responding to severe external events. This response included research, analysis and development and execution of an implementation plan. Through the initial work, we gained valuable insight into the behaviour and mitigation for beyond design basis accidents, including severe accidents. Through implementation of preparation and training programmes at CANDU/PHWR stations, we have prepared for them.

Lessons learned included:

- Station design must consider external hazards with consequential failures;
- Impacts should be characterised by beyond design basis events (BDBE);
- Hydrogen mitigation;
- Irradiated fuel bay cooling and/or inventory maintenance;
- Emergency water and power systems adequacy;
- Severe accident management measures for BDBEs;
- Emergency planning and response adequacy; and

- Unique challenges posed by multi-unit stations under common mode events.

The COG-led CIIT provided a forum where these differences could be shared and helped align solutions across the global CANDU/PHWR community.

CANDU reactors have come a long way. What have been the recent developments?

CANDU/PHWR reactors have come a long way in large part because of the commitment of the utilities to continuously improve both the way they operate and maintain the plants. Innovations in these areas have meant significant improvements in forced loss rates and the overall plant condition. As well, our members, through COG, have invested in research that allows us to understand the reactors full potential and to harness their capabilities for better performance.

An excellent example of this is the continued operation of the fuel channels beyond the nominal life of 210,000 effective full power hours (EFPH). COG, on behalf of some of its members, has been able to validate safety margins in aging fuel channels that allow for continued operation beyond original assumptions. And, as we continued our research, we have been able to manage and validate for longer periods still. This research and development is continuing.

This has meant billions of dollars in additional revenue for these stations. It also gives jurisdictions the ability

to defer expensive greenfield development or avoids the need for carbon-emitting alternatives. And, it has provided flexibility to manage refurbishment activities in multi-unit stations. Ultimately, it means longer life for the units pre- and post-refurbishment. This makes the business case for CANDU/PHWR that much more attractive.

Any recent developments in waste utilisation and disposal in the context of CANDU?

Waste and disposal are areas of significant interest for the industry, especially as the nuclear plants age and with major project work like the refurbishments at several CANDU plants. COG has recently started a Radioactive Waste Leadership Forum intended to develop a comprehensive and sustainable strategy for dealing with radioactive wastes and their impacts. Specifically, it will seek to develop a coordinated and integrated strategy for long-term management of all radioactive waste materials. Currently, this is a forum for Canadian radioactive waste owners to discuss common issues and build alignment on strategic long-term solutions for management, storage

COG has recently developed a small and medium reactor (SMR) forum to provide our members an opportunity to establish technical positions and requirements to support the development of a common policy and vision for these new technologies.

and disposal of waste. Having said that, the lessons coming out of the forum and subsequent work should certainly be transferable to other CANDU and PHWR utilities.

Is there any move by Canadian nuclear power industry to diversify beyond CANDU type, say, Fast Breeders?

We know there are many types of reactors being developed beyond the traditional CANDU design. This is an exciting time for the industry because people are envisioning new nuclear technology options to meet different sets of needs than the original design. The traditional CANDU plant serves a large baseload, grid design very well. And, now, potentially there are opportunities to fill many other types of needs using nuclear as well such as small grid or off-grid applications for remote communities. This is innovative and it is exciting because it has the power to positively change people's lives.

COG has recently developed a small and medium reactor (SMR) forum to provide our members an opportunity to establish technical positions and requirements to support the development of a common policy and vision for these new technologies. There will be many considerations as our members determine the feasibility and the best path forward. The actual technology is just one consideration. It needs to be put into the context of many other siting and operating questions. Fortunately, over the past half a century, we have gained

significant experience and insight into managing everything else that comes with nuclear generation.

How is plant life extension of CANDU reactors managed globally?

A: Continued operation of the nuclear stations really depends on our ability to manage our own performance and our capacity to innovate how we manage the plants. On behalf of its members, COG currently invests about \$65 million each year in R&D and joint projects. Much of that effort is focused on this question. And we have had some real success. Certainly, the fuel channel life management programme is a big part of this effort. As well, we have many other research projects geared to validating and improving safety, which helps us to achieve the necessary regulatory approvals for continued operation. As well, our efforts to achieve excellence in project management in refurbishment and major component replacement projects through training, management of the supply chain and other areas has made a significant impact on creating a viable business case for continued operation. We have also seen good management of older plants. In some cases, CANDU stations are achieving their best performance in the later years of operation because of the improvements in management and maintenance as well as plant changes arising from research. For example, through R&D we now have a better understanding of aging and have developed inspection and repair methods to mitigate

aging. We are sharing operating experience in a way that allows us to learn from others rather than having to experience events first hand. We are also sharing and learning from best practices through collaboration such as COG's Asset Management Peer Group.

How is the nuclear power industry bracing up to face cheap natural gas?

A: Every jurisdiction is going to consider the mix of generations most effective and efficient based on availability, cost, how it meets their environmental goals and public support, to name a few of the big factors. The best thing we can do as operators, regardless of competitive generation forms, is to continuously improve our performance in all aspects. The goal for nuclear is to be the safest, most reliable and affordable option with desirable environmental performance. There will be price fluctuation and other factors in the market. Some of those will be out of our control. But we can control a lot of things, namely around our performance.

For governments that want to mitigate climate change while providing people a safe, reliable,

“India has been developing its indigenous programme for more than 40 years and operates the largest fleet of PHWR reactors outside Canada, thereby bringing a diversity of perspectives to a common technology.”

clean and affordable electricity source abundant enough on which to build an economy; nuclear can certainly be that option.

Your long-term view of the Canadian nuclear power industry.

I feel very positive on this.

The Canadian nuclear power industry is currently seeing a resurgence in activity with the refurbishment project at Ontario Power Generation's Darlington site, the major component replacement programme at Bruce Power (also in Ontario) and the completion and continued operation of the New Brunswick Power, Point Lepreau station. In Canada, nuclear contributes \$6-billion annually to Canada's economy and employs (directly and indirectly) 60,000 people. The refurbishment projects mean another 30 years or more operation for those units.

As well, there is substantial interest in the potential for new technologies including exploration of small and medium reactors (SMRs).

As a country, Canada has embraced its climate change commitments and nuclear power is a powerful tool in meeting those commitments. The federal government has also indicated a strong interest in leveraging nuclear as a tool for “fostering innovation and energy security.”

As an industry, it will be up to us to continue to perform both in our operations and our projects, in a manner that earns the confidence of

Canadians to allow us to fulfill this mandate. COG's programmes, from research to information exchange are enablers of continuous performance improvement with this goal in mind.

Performance is dependent on the utilities and the supplier community working effectively together, which is why COG and its members have invested in the Supplier Participant programme and formed partnerships with organisations like the Organisation of Canadian Nuclear Industries (OCNI), which represents Canadian nuclear suppliers.

What prospects do you see in respect of further cooperation between Canada and India?

The relationship between the nuclear industry in Canada and India can be rich and highly symbiotic. Both have much to gain from the other.

As the origin of the technology development and the pioneer of CANDU/PHWR operation, Canada has a significant history and body of operating experience and knowledge. This can provide India incredible insights for safe and reliable operation today and in the future.

At the same time, India is a country that brings its own culture, learnings and approaches. Canada can also learn much from India as it continues to develop its nuclear programme. India has been developing its indigenous programme for more than 40 years and operates the

largest fleet of PHWR reactors outside Canada, thereby bringing a diversity of perspectives to a common technology.

The most valuable thing we can do as two countries is to work together, alongside the entire CANDU operator and supply communities. Together, we can share best practices, lessons learned, and invest together in common goals. By ensuring safety and high performance globally, we can protect and build upon the strong reputation CANDU/PHWR has earned.

What do you see as the major challenges for the nuclear power industry in the coming years and CANDU in particular?

Our greatest challenges are also our greatest opportunities. We have talked about a lot of these already:

“Nuclear is a large, baseload power generation solution with almost no greenhouse gas emissions. Of all the electricity generation options, it is the one that currently can have the largest single, positive effect of any generation form in mitigating the impacts of climate change.”

- Enhancing cost performance;
- Asset management as plants age;
- Effective refurbishment;
- Continued public support through strong performance;
- Best practice security and emergency preparedness; and

- Effective transition into a digital world.

All of these are issues we need to continue to work on.

And perhaps most importantly: We need to work together. An issue impacting one plant will impact all plants around the world, particularly those plants that share a common technology. The world today is small and the ripples are big. We must lift each other up.

At the recently held COP22, there was an all-round enthusiasm for accelerated mitigation of climate change. Your comments.

Nuclear is a large, baseload power generation solution with almost no greenhouse gas emissions. Of all the electricity generation options, it is the one that currently can have the largest single, positive effect of any generation form in mitigating the impacts of climate change.

At the same time, because it is a large, baseload generation that can be highly reliable and affordable, it can create quality of life and can power an economy.

By harnessing nuclear power safely and effectively, we can provide a vital service and an incredible tool to the world in enriching people's lives, while also helping protect the globe from the devastating impacts of climate change. We are fortunate to work in an industry where we can have such a significant and positive effect on people's lives. It is worth the effort.



WANO-TC Seminar on PHWR Operational Performance Improvement at Mumbai

An international conference on PHWR Operational Performance Improvement was organised by World Association of Nuclear Operators-Tokyo Center (WANO-TC) at Mumbai on May 30-31, 2017.

A galaxy of experts in PHWR technology participated in the event. The high-profile event saw a host of technical presentations on this vital topic.

With 18 Pressurised Heavy Water

Reactors (PHWRs) in operation in the country, PHWRs are the workhorse of India's nuclear power programme.

The Plenary Session began with Welcome Address delivered by Mr. D. Gawande, Director (Operations), Nuclear Power Corporation of India Limited (NPCIL) and Opening Remarks presented by Dr. Naoki Chigusa, Director General, WANO-TC. The keynote Address was presented by Mr. G. Nageswara

Rao, Former Director (Operations), NPCIL.

The plenary session concluded with a presentation on Long-term Plans for CANDU Operational Safety by Mr. Fred Dermarkar, President & CEO, CANDU Owners Group (COG).

This was followed by presentations on themes, including Recent PHWR Operation Experiences; PHWR Pressure-tube Refurbishment; The PHWR Design, Engineering and Operation Issues; Recent



Experience with Primary Equipment; and Post-Fukushima Countermeasures in PHWRs.

Also, there were three specific topic proceedings, viz., Fueling and Fuel Handling Experiences; Annulus Gas Experiences; and Chemistry and Tritium Management.

The Closing Session consisted of a panel discussion on takeaways from the seminar, followed by concluding remarks.



Amur Falcon – pictured in Karnataka around Kaiga Generating Station

Amur Falcon

Scientific Name: *Falco amurensis*

Where to spot in our Courtyard:
Kaiga Generating Station (KGS)

Status as per IUCN Red List:
Least Concerned

Kaiga Generating Station – A nature’s paradise

The Kaiga Generating Station at Kaiga in the Uttar Kanada District of Karnatak state is home to a cluster of four nuclear power plants, each of 220 MW capacity. Proposal for establishment of another two units of 700 MW at Kaiga has been approved by the Government of India recently. Kaiga site is surrounded by the mountains of Western Ghats, which makes this place unique in terms of biodiversity.

Physical Characteristics

Amur Falcon (*Falco amurensis*) belongs to the Falconidae family of birds. It is a small raptor which is found in large flocks in North East Asia, Siberia and China. During breeding season, it migrates to Southern Africa through North East India and a few patches of Western India.

The male Amur Falcon measures around 25 to 30 cm in length and weighs around 100 to 155 grams, whereas females are slightly larger and weigh around 110 to 190 grams. With the dark sooty grey back, the males are distinguished from the females. The thighs, vent and the under tail coverts of the males are reddish brown in color. The cheeks and throat are plain white in color and the face bears a dark eye patch and moustache in case of males. The females are

pale with dark scaly markings on white underparts. Orange eye ring, a red cere and reddish orange feet differentiate the females from the males. The wings are long in both and measure around 63 to 71 cm. The juveniles resemble the females with slightly pale and reddish brown feathers. The Amur Falcon is one of the few birds of prey having white claws.

Presence

Amur Falcon is distributed across Asia, Siberia, Mongolia, North Korea and China. This bird is a visitor to India during breeding seasons. During winter, it migrates to Africa through India and Arabian Peninsula. Apart from Africa, it also breeds in North East India. Amur Falcon is spotted around Kaiga Generating Station at Uttar Kanada district of Karnataka.



Conservation and education for protecting the environment is necessary. This is witnessed in the case of Amur falcon in Nagaland and Manipur in India.

Habitat

Amur Falcon inhabits in open woodland, marshy woodland, river side woodland and in some cases in wooded steppe. During winter, it can be spotted in savanna, grassland, trees and sometime in roosts in towns.

Food

Amur Falcon largely feeds on insects. Sometimes it feeds on small birds and amphibians. During early morning or late evening, it feeds the most. It captures most of the prey in flight and sometimes by hovering from the ground. The migration of Amur Falcon coincides with the migration of Dragon flies, which is thought to provide food during the migration route of Amur Falcon. The Amur falcon has one of the longest migration routes.

Breeding

The breeding season is between May and June and several pairs may nest close together in wooded country or marshes. The abandoned nest of other species of birds and even tree hollows are used for nesting by this species. The female lays around three to four eggs and both the parents take turns to incubate the eggs. The eggs hatch in a month's time; chicks are cared by both the parents. The young ones leave the nest in about a month.

Threats

Every year in winter season, Nagaland's Doyang Reservoir

welcomes a large number of Amur Falcons. In fact, it is believed to be the single largest congregation of Amur Falcons anywhere in the world. Mass slaughterer of Amur falcons is done in Nagaland and Manipur mainly for meat and sale. The fisherman's drape the trees along the reservoir with fishnets to capture the birds. Large-scale conservation and education programme by the environmental conservation agencies, of government and private, throughout Nagaland and Manipur have resulted in protection of this visiting bird in India. The hunters have now become the protectors.

S.K. Jena

Manager (Corporate Communication),
NPCIL Headquarters.

He is also an amateur bird watcher.

Photographs: G. Mohandas, Sr. PS, SD's Office,
Kaiga Generating Station



A Titan of Indian Science



DR. HOMI J. BHABHA

(1909 – 1966)

His lofty dream ensured a coveted place for India in an elite club of nations with nuclear technology. His foresight will continue to serve India not for decades but centuries. The path he set us on has spawned many spin-off technologies that are contributing to various aspects of our daily life tangibly as well as intangibly.

Yes, he is known as the 'Father of Indian nuclear power programme'.

Here we fondly remember him on his 108th birth anniversary - 30th of October.

Dr. Homi Jehangir Bhabha was an accomplished nuclear scientist and physicist. In 1927, a young Bhabha, then just 18, went to England to study engineering at Cambridge, but soon realised that his true love was science – especially nuclear physics.

In 1935, he received a Ph.D in Physics from Cambridge University. At Cambridge, Bhabha interacted with eminent physicists like Niels Bohr, Paul Dirac and Enrico Fermi.

Bhabha returned to India in 1939 and worked under Nobel laureate Sir C.V. Raman at Indian Institute of Science in Bangalore (now Bangaluru).

He recognised the importance of nuclear technology for India very early. Way back in 1944, even before India's independence, Dr. Bhabha envisioned a



Bhabha with Albert Einstein, Hideki Yukawa and John Wheeler at Princeton



Dr. Homi Bhabha with Niels Bohr during International Colloquium on Function Theory at TIFR, 1960



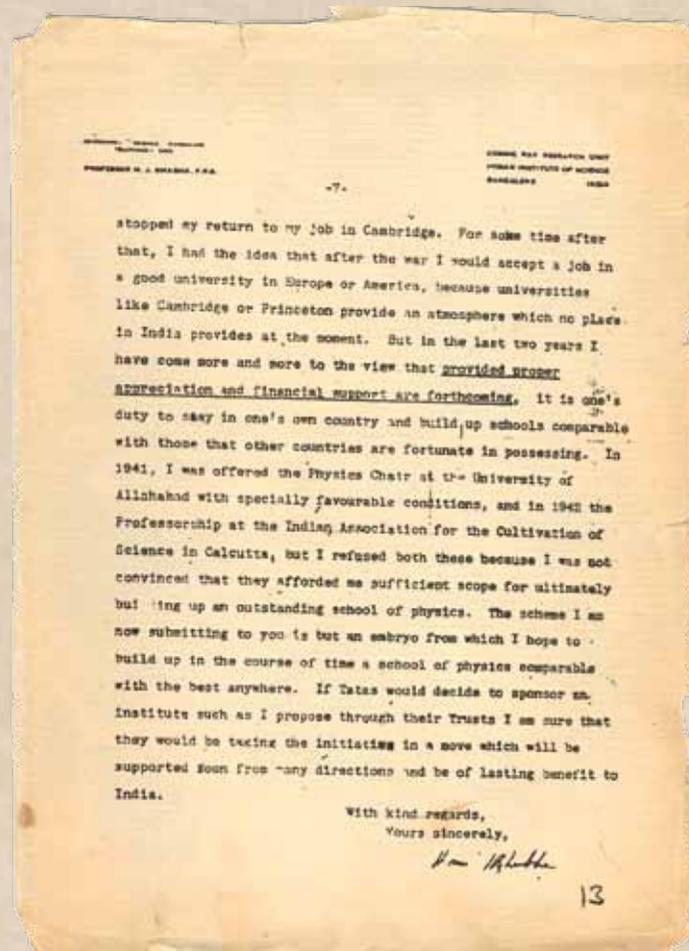
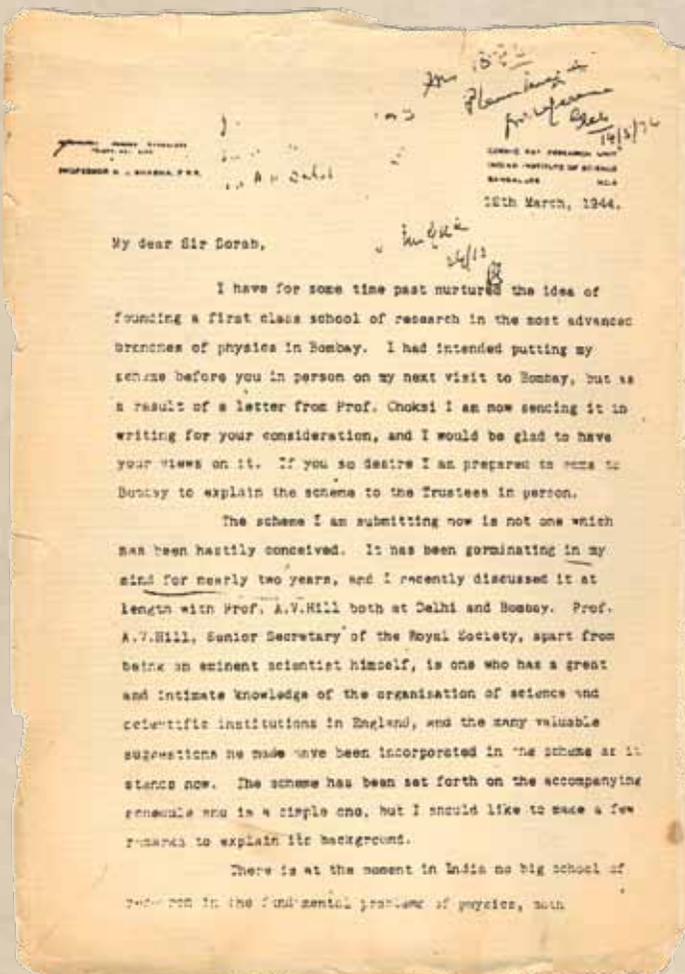
Pandit Nehru, Lal Bahadur Shastri and Dr. Homi Bhabha

prosperous and dynamic India based on energy self-sufficiency.

With a clear vision and a sense of purpose, Dr. Bhabha ushered India in the 'Nuclear Age'. Dr. Bhabha, an institution builder, played a vital role in establishing the Tata Institute of Fundamental Research (TIFR) in 1945, the Atomic Energy Commission (AEC) in 1948, and the Atomic Energy Establishment, Trombay (AEET) in 1954, which was later renamed as Bhabha Atomic Research Centre (BARC), as well as the Department of Atomic Energy (DAE) in the same year.

Realising the tremendous potential of thorium as a nuclear fuel, he conceptualised and laid the foundation of India's three-stage nuclear power programme, based on the use of natural uranium initially and with the aim to eventually utilise the vast reserves of thorium available in India for the long-term energy security for the nation.

“THE FATHER OF INDIAN NUCLEAR POWER PROGRAMME”



Bhabha's historic letter of 1944 that led to the foundation of Tata Institute of Fundamental Research in 1945, which in turn acted as a stepping stone for India's initiation into atomic energy.

My dear Sir Sorab,

I have for some time past nurtured the idea of founding a first class school of research in the most advanced branches of physics in Bombay. I had intended putting my scheme before you in person on my next visit to Bombay, but as a result of a letter from Prof. Choksi I am now sending it in writing for your consideration, and I would be glad to have yours views on it.

– The opening paragraph of Dr. Bhabha's historic letter of 1944 to Sir Dorabji Tata Trust.



Bhabha – The Connoisseur

Not many people know that Dr. Bhabha was an ardent lover of fine arts. He also sketched and painted with the flair of an accomplished artist.

Early in his youth, Bhabha was influenced by an environment that adored art – Western music, paintings, literature. The young Bhabha took lessons in drawing and painting. His romance with art continued to grow during his years at London and Oxford.

Later, he put together a fabulous art collection at the Tata Institute of Fundamental Research (TIFR) at Mumbai, making it unique among scientific institutions.



Bhabha painted this self-portrait at the age of 17



One of his works depicting an opera performance



A sketch of C.V. Raman by Bhabha

His Prophetic Words

Nuclear power will play a greater role in India's electricity portfolio in the medium and long term due to its undeniable merits and the inadequate availability of other energy resources.

It is absolutely in the interest of India to have a vigorous school of research in fundamental physics, for such a school forms the spearhead of research not only in less advanced branches of physics but also in problems of immediate practical application in industry.

When nuclear energy has been successfully applied for power production in say a couple of decades from now, India will not have to look abroad for its experts but will find them ready at hand.



‘Atom on Wheels’

Touring the Hinterland, Sculpting Bonds of Trust

Engaging people for sharing with them facts on nuclear power and radiation is a vital component of NPCIL’s public awareness programme. Among a bouquet of initiatives, a mobile exhibition ‘Atom on Wheels’ is a high-impact innovation that provides close interaction with people at the grassroots. The effectiveness of this initiative comes from an amazingly simple concept of a traveling bus equipped with educational paraphernalia covering villages and towns that are in the vicinity of an upcoming or proposed site of a nuclear power plants. This

“walking right up to their doorstep” approach allows direct engagement with the local populace. This novel information-exchange initiative cuts through the tangle of myths and misconceptions about nuclear power and radiation, replacing anxiety and confusion with clarity and trust.

Travelling Bus: Sharing information innovatively

To fulfill this need to disseminate reliable information on nuclear energy and radiation among the target audience, Nuclear Power Corporation of India Limited

(NPCIL) organised a grassroots initiative to promote the usefulness of nuclear power for the country, its practicality and safety, in the form of an educational rural integration programme that was implemented in Rajasthan, Madhya Pradesh, Maharashtra, Gujarat, Haryana and Andhra Pradesh. The mobile exhibition was launched as part of this initiative.

The main objective of this innovative travelling exhibition was to invite rural folk from different backgrounds to understand the actual nature of nuclear energy and



its benefits along with the scientific facts on radiation and safety-related aspects of nuclear power. Fulfilling this mandate, 'Atom on Wheels' – in its conceptualisation as well as execution – has emerged as an innovatively different approach to address myths and apprehensions related to nuclear power.

The travelling bus was designed from the outset to interact with people in a very attractive and lively manner. The bus travelling in these aforementioned states visited almost all the villages and towns in the vicinity of an upcoming or proposed site of a nuclear power plant, covering schools, community centers, medical centers, local

village administrations and municipalities as well as other important locations, to engage students, women, workers, youth, voluntary organisations, members of the local village administration etc., for them to have a unique experience of viewing this traveling exhibition.

This specially designed bus hosted informative posters, panels, banners, miniature models and audio-video information related to nuclear power and facts on radiation. This exhibition, with all its colourful images and messages, shared information in a simple and lucid way. Also presented along with this was the history of

Indian nuclear power programme. The exhibition emphasised topics such as comparison of traditional energy resources, the urgent need for expanding nuclear power in the country, as well as safety, cost-effectiveness and supply reliability of nuclear power.

Information galore

The air-conditioned bus carried about 15 to 20 information panels depicted on its both sides. An LCD television and a projector system were also available in this bus, the purpose of which was to show to the visitors short animated films such as 'Ek Tha Budhiya', 'Budhiya ki Sair', 'Badal Gaya Budhiya' as well as other cartoon animations covering various topics related to nuclear power. Through these films the visitors could expand their understanding of nuclear power. The exhibition material, including information panels, pamphlets, booklets, etc., prepared in regional languages, were distributed among people to make it simple for them to assimilate the shared information easily. Wherever the bus travelled, comic books based on the cartoon character 'Budhiya' were also distributed among the people.

This novel activity was organised every four months at about 240 to 250 villages in the target regions in each states. During a span of two years, more than 1500 villages and around 6 lakhs people in the target areas were covered by this massive campaign.

Into the hinterland

On September 23, 2015, this nationwide campaign was launched



Glimpses of the journey of Atom on Wheels

in the Mahi Banswara district of Rajasthan, where the District Collector flagged off the 'Atom on Wheels' exhibition bus on a public awareness tour to the nearby villages falling within a perimeter of 100-150 km from the proposed nuclear power plant as the epicenter. In Rajasthan, the campaign was implemented in four phases. Later, the exhibition bus toured the state of Haryana, covering regions in the vicinity of the upcoming Gorakhpur Haryana Anu Vidyut Pariyojana (GHAVP), followed by Madhya Pradesh (Chutka); Gujarat (Mithi Virdi); Maharashtra (Jaitapur) and Andhra Pradesh (Kovvada).

This novel attempt to address the common apprehensions about nuclear power has connected the target audience to the realities of mainstream development. The information provided in this mobile exhibition dispelled the generally prevalent myths and misconceptions about nuclear power and radiation by presenting true facts. The exhibition depicted India's main energy sources of electricity generation, such as coal, hydro, solar, wind and biomass. However, their availability is currently limited vis-à-vis the growing demand. Therefore, we must tap other options for power generation, among which is nuclear power, a proven option that is safe, pollution-free and economical.

To address misconceptions about radiation, the exhibition depicted the fact that all of us are surrounded by natural background radiation at all places and all the time. Radiation is present in the air we breathe, the food we eat and in



Glimpse of Flag off ceremony held at Kovvada in presence of officials of Srikakulam district.

the homes in which we live. We get higher radiation doses during air travel, from eating bananas, sun's rays, and even from granite used in kitchen platforms, etc., to name a few. In contrast to this, the radiation from a nuclear power plant is so low that it is negligible compared to the natural background radiation and also well below the permissible regulatory limits, and there is no likelihood of occurrence of cancer due to the operation of a nuclear power plant.

Based on various images and scientific information, the exhibition also showcased the fact that the use of nuclear power mitigates global warming to a significant extent and also helps in preserving the environment and its green cover. The people were also informed about the fact that the water released from a nuclear power plant is allowed to cool to well below the permissible limits before releasing it into water bodies, so that there is no detrimental effect on the aquatic and marine life. Sharing of such information is helping people

perceive nuclear power from a perspective of facts instead of hearsay.

The success of 'Atom on Wheels' is based on the key advantages offered by this approach, namely, instant accessibility, deeper reach and direct interaction. Based on the enthusiastic response it received from wherever it travelled, this innovative mobile exhibition has been a remarkable success. While this current campaign has concluded with thumping success, this concept will continue to serve its function effectively in future campaigns as well, enabling sharing of vital facts on nuclear power with the people at the grassroots level, so that they can reap greater benefits of enhanced economic growth and also contribute more to the upward march of the nation.

Amritesh Srivastava
Senior Manager
(Media and Corporate Communications),
NPCIL, Mumbai
He is also Editor of Nu-Power.

Nagpur Science Centre's Expo 2017

To create awareness about nuclear power and to dispel myths and misconceptions about nuclear energy, Nuclear Power Corporation of India Limited (NPCIL) undertakes various public outreach activities round the year as a part of its Public Awareness Programme for different strata of the society. Here are the glimpses of some of the exhibitions in which NPCIL participated recently.

Science Centres spread across the country have been instrumental in creating affinity for scientific attitude, seeking truth through application of science. NPCIL has benefitted immensely through its association with these science centres, which provide a platform to disseminate scientific messages and facts to common people.

To make best use of the opportunity, NPCIL participated in the Science Expo-2017 organised by Raman Science Centre, Nagpur from January 18-22, 2017. NPCIL put up a stall at the Expo, which attracted



Students at the NPCIL Stall

over 60,000 visitors, who were amply briefed about various facets of nuclear power by the NPCIL's

public awareness team.

[NPCIL HQ News Desk]

SHODH 2017

NPCIL's Jaitapur Nuclear Power Project (JNPP) participated in the engineering

college event called Engineering College Technical Extravaganza SHODH 2017 from April 1-2, 2017

at Gharda Institute of Technology, Lothe, Dist. Ratnagiri. NPCIL put up an exhibition stall displaying a simplified miniature interactive PHWR model, stand-in panels and public awareness literature. The event was witnessed by engineering and science college students from the Konkan region. Around 2000 students and teachers from the schools as well as engineering and polytechnic colleges visited the NPCIL stall and discussed about the working of a nuclear power plant, its safety features and environmental aspects.



Students taking keen interest in the brief given by NPCIL resource person

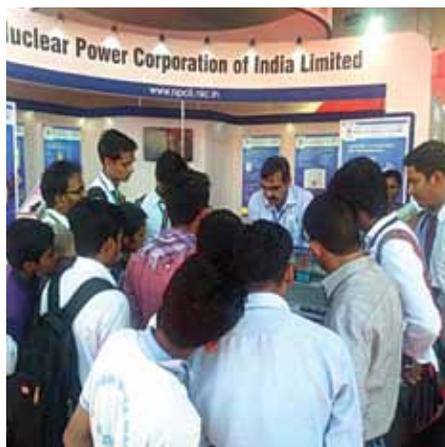
[NPCIL HQ News Desk]

Bhopal Vigyan Mela – 2017

Bhopal Vigyan Mela is a Science and Technology Expo organised by the Government of Madhya Pradesh annually in collaboration with scientific societies like Vigyan Bharti with an aim to create awareness among the people about science and technology developments.

NPCIL participated in the Bhopal Vigyan Mela - 2017 held at Bhopal during March 3-6, 2017. NPCIL set up an interactive gallery with informative exhibits, a simplified miniature interactive PHWR model, and publications. The stall showcased Indian nuclear power programme, safety aspects, benefits of nuclear energy among other information on the subject. About 1.5 lakh people, including students, teachers as well as general public visited the NPCIL pavilion.

[NPCIL HQ News Desk]



Glimpses of Bhopal Vigyan Mela – 2017

Workshop for Journalists at TMS



Journalists attending the workshop

As part of the public awareness programme, a workshop for journalists was organised by Tarapur Maharashtra Site (TMS) on June 8, 2017 at WANO Hall, TAPS-1&2 Colony. A total of 20 journalists participated in the workshop. Mr. Hemant Kumar, Site Director, TMS inaugurated the programme.

The journalists were briefed about nuclear energy, operation of a nuclear power plant, radiation protection and safety, emergency drills carried out at the site, including offsite emergency, and various CSR activities undertaken by the site for inclusive development of the surrounding villages.

[NPCIL HQ News Desk]

Scientific Meets for Medicos

Sharing of scientific facts on nuclear power and related aspects with the public has been at the core of the public awareness activities of Nuclear Power Corporation of India Limited (NPCIL). Among the various initiatives conceived and implemented by NPCIL is a series of scientific meets-cum-workshops for doctors, medical personnel and students studying medicine. Scientific facts on nuclear energy were shared with the participants, who were also explained that there is no linkage between the operation of a nuclear power plant and cancer. Also, emphasised was the fact that radiation is present everywhere in nature and that the radiation from the operation of a nuclear power plant is negligible and that the natural background radiation surround us at all the times.

K.J. Somaiya Medical College, Mumbai

A workshop for doctors of Somaiya Medical College, Mumbai was conducted on January 25, 2017 at the college campus under the Doctors' Meet programme. This programme aimed to create awareness about radiation and its effects as well as to dispel misconceptions about cancer.

Indian Medical Association (IMA), Vashi chapter

About 100 practicing General Practitioners (GPs) of Navi



K.J. Somaiya Medical College, Mumbai



Indian Medical Association (IMA), Vashi chapter

Mumbai were sensitized by NPCIL resource-persons to various facets of radiation during an extended seminar organised by the Indian Medical Association (IMA), Vashi chapter on February 12, 2017.

Maharaja Agrasen Medical College, Haryana

Another scientific meet on 'Radiation and Cancer' was conducted in the college auditorium of Maharaja Agrasen Medical College, Haryana, on March 25, 2017. About 250 doctors, students



Maharaja Agrasen Medical College, Haryana

and paramedical staff participated in the meet. Dr. Naveen Mummudi from the Tata Memorial Centre (TMC) presented a slew of data and statistics indicating that prevalence of cancer in areas around nuclear power plants is either equal to or even less than the national average. He also threw light on several important facts about radiation, types of radiation, the ALARA (as low as reasonably achievable) principle, including such facts that there is radiation even in food items of daily consumption such as milk and fruit.

MGM Medical College, Kalamboli

Two awareness sessions on 'Effects of Radiation' for a batch of PG doctors and faculty members of MGM Medical College, Kalamboli, were organised on July 11, 2017. Scientific facts on concepts of radiation, safe dose levels and



MGM Medical College, Kalamboli

epidemiological studies indicating no excess incidence of cancer around nuclear installations were shared with the participants. The interesting history of the discovery of radiation and the evolution of its measurement units were also discussed.

[NPCIL HQ News Desk]

Exhibition on ‘Achievements of Ministries of Science & Technology and Earth Sciences’



Glimpses of the exhibition

Recently, NPCIL participated under the Department of Atomic Energy (DAE) pavilion in the exhibition organised at the Parliament Complex, on ‘Achievements of Ministries of

Science & Technology and Earth Sciences’ during July 28 to August 11, 2017. The exhibition was inaugurated by the then Vice President of India Shri Mohammad Hamid Ansari. The objective of

the exhibition was to focus on products and spin-off technologies developed and highlight the interventions made by various Ministries that will have an impact on the society.

Shri Ansari along with Smt. Sumitra Mahajan, Speaker, Lok Sabha; Dr. Harsh Vardhan, Minister at Ministry of Science & Technology, Ministry of Environment, Forest and Climate Change and Ministry of Earth Sciences; Dr. Jitendra Singh, Minister of State (Independent Charge) for the Ministry of Development of North Eastern Region, Prime Minister Office, Personnel, Public Grievances and Pensions, Department of Atomic Energy and Department of Space; Smt. Renuka Chowdhury, Chairperson of the Department related Parliamentary Standing Committee on Science and Technology, Environment & Forests and other dignitaries visited the DAE pavilion. The fortnight-long exhibition was also visited by a large number of Members of Parliament, senior officials and Parliamentary staff.



Shri M.H. Ansari, the then Vice President of India, along with other dignitaries being briefed on the workings of a 700-MW nuclear power plant through a semi-dynamic miniature model of the plant

At the exhibition stall, a semi-dynamic miniature model of nuclear power plant was displayed along with banners, posters and other public awareness publications by NPCIL. Visitors were briefed on the implementation of India's three-stage nuclear power programme,

various beneficial aspects of nuclear energy and the latest developments. Films on safety, clean and green aspects of nuclear power, NPCIL's voluntary Environment Stewardship Programme and the corporation's achievements were also screened.

[NPCIL HQ News Desk]

Public Awareness Seminars at Nagpur



Seminar participants at Rajiv Gandhi College of Engineering and Research

Nuclear energy awareness seminars of half-day duration each were conducted at the following three prominent engineering colleges of Nagpur during August 5-7, 2017.

1. Rajiv Gandhi College of Engineering and Research (RGCER)
2. Dr. Babasaheb Ambedkar College of Engineering and Research (DBACER)
3. Yeshwantrao Chavan College of Engineering (YCCE)

In addition to imparting awareness on safety of nuclear power and



Seminar participants at Rajiv Gandhi College of Engineering and Research

radiation, topics pertaining to electrical safety systems were also discussed. The focus of the programme was on sharing facts on the safety of nuclear power and its affordability with the participants, which included college faculty members as well as hundreds of students.

The faculty members also participated in deliberations and open-house discussions.

[NPCIL HQ News Desk]

Public Awareness Programmes for School Children

School, Sanodar village and Sahjanand Vidhyalaya, Bapada village. Sanodar village and Bapada village is situated at an aerial distance of about 13 km and 15 km, respectively, from the Mithivirdi plant location.

Boys' Primary School, Sanodar Village

About 230 students from Class 5 to 8 attended the programme. Banners mounted on standees were exhibited at the school. Information on nuclear power was provided describing need for enhanced electricity generation, various sources of energy, depleting natural resources, increasing pollution, global warming and its consequences, nuclear fuel, chain reactions, nuclear power generation process, natural and manmade radiation, AERB dose limits, various uses of radiation in daily life, safety features of nuclear power plants, etc. Students' queries related to radiation and safety features were also addressed.



Information about India's 3-stage nuclear power programme being shared with teachers

As part of the ongoing nationwide public awareness programme of NPCIL to bring enhanced awareness to the masses about nuclear energy, safety of nuclear power and radiation, public

awareness events were organised recently at two schools near the proposed nuclear power plant at Mithivirdi in Gujarat.

The programmes were conducted on June 16, 2017 at Boys' Primary



Benefits of nuclear power being explained to the students

Sahjanand Vidhyalaya, Bapada Village

About 300 students from class 9 to 12 attended the programme. Banners mounted on standees were exhibited at the school. A documentary movie ‘NPCIL Song’,

‘HRS’ and a short movie in Gujarati ‘India Needs Nuclear Power’ were shown to the students. Vital facts on nuclear energy and radiation were shared with them. A short movie in Hindi on Tarapur Atomic Power Station, telecast by National

Geographic channel, was also shown to the students.

An informative book in Gujarati ‘Anu Urja - Saral Samaj’ was distributed among the students.

[NPCIL HQ News Desk]

Vocational Trainee Students Visit NAPS

A site visit of Narora Atomic Power Station (NAPS) was organised for 110 vocational trainees in the month of July 2017.

During the visit, students were taken to Energy Information Centre and were briefed on the need for nuclear power based on its clean and green attributes, workings and operation of nuclear power plants, safety and security features, environment safety and various myths related to radiation through display boards, steam generator model, plant schematic model, 3D model of reactor and turbine building, coolant and calendria tube model, fuel bundle replicas, etc.



Young trainees being briefed on various operations of nuclear power plant

The students also visited turbine building, control room and Environment Survey Laboratory

during the field visit.

[NPCIL HQ News Desk]

Social Welfare Activities by TMS

Tarapur Maharashtra Site (TMS) undertakes various welfare activities continually for the development of the neighbouring communities as a part of corporate social responsibility. Some of the welfare activities undertaken recently were:

Inauguration of Primary Health Centre

A Primary Health Centre at Popharan village was inaugurated by Mr. Hemant Kumar, Site Director, TMS on January 21, 2017. The function was presided over by Dr. Ajay Sankhe, Founder Member, Bhaktivedanta Hospital and Research. The inauguration ceremony was attended by State officials and senior officials of TMS. The centre will provide free health services to neighbouring villages.



Facilities provided by Primary Health Centre at Popharan village



Groundbreaking Ceremony of Internal Roads

Groundbreaking ceremony of internal roads at Kurgaon village was performed on March 16, 2017 in the presence of Gram Panchayat officials, members, villagers and senior officers of TMS. Mr. Hemant Kumar, Site Director, TMS, was the chief guest for the ceremony.

[NPCIL HQ News Desk]



Mr. Hemant Kumar, Site Director, TMS during ground breaking ceremony

NPCIL Participates in CSR Fair-2017

NPCIL participated in the “Corporate Social Responsibility (CSR) Fair-2017”, during May 4-6, 2017 at Pragati Maidan, New Delhi. The fair was inaugurated by Chief Guest Mr. Anant Geete, Minister for Heavy Industries and Public Sector Enterprises.

The event was organised by the Department of Public Enterprises,



A view of CSR Fair - 2017 held at New Delhi.



Ministry of Heavy Industries & Public Enterprises and PHD Chamber in collaboration with Oil and Natural Gas Corporation. It provided a platform to all stakeholders, including Central Ministries / Departments, CPSEs / State Public Sector Undertakings, for showcasing their CSR activities and sharing their best practices. It also provided an opportunity to connect with non-governmental organisations working in different fields covered under CSR.

NPCIL put a stall at the fair to showcase NPCIL's contribution and achievements in the activities of CSR around its nuclear power plant sites. The NPCIL stall was visited by a large number of people during the programme. The visitors were highlighted about NPCIL's CSR policy, various activities carried out



Visitors at the NPCIL stall

in the areas of education, healthcare, infrastructure development, skill development and sustainable

development at different locations of power plant sites.

[NPCIL HQ News Desk]

Free Eye Camp by Kakrapar Gujarat Site

A three-day eye camp was organised by Kakrapar Atomic Power Station (KAPS) Hospital in association with Tejas Eye Hospital, Mandvi, for the benefits of nearby villages during February 26-28, 2017.

A total of 526 patients were examined by ophthalmologists, out of which 100 patients were screened for cataract surgery with implantation of intraocular lens. 330 patients underwent refraction for correction and were given refraction spectacles. Patients were also given free medicines upon discharge.

[NPCIL HQ News Desk]



Pre-operative screening and evaluation of patients at KAPS Hospital

Upgradation and Installation of Hairpin Heat Exchangers at MAPS

G. Ashok • Bhupal Sharma • G. Harikrishnan • J. C. Tripathi • A. K. Rastogi

The steam generating equipment in MAPS-1&2 are ‘hairpin’ type and comprise of eight boiler assemblies arranged in two banks of four boilers each. One boiler assembly consists of eleven ‘inverted-U’ type heat exchangers, (called hairpin heat exchangers, or hairpin HXs for short) mounted in parallel on inlet and outlet heavy water manifolds and connected to the steam drum through individual short risers. These HXs (Figure-1) are identical to RAPS heat exchangers and contain 195 Monel-400 tubes of 12.7 mm outside diameter x 1.24 mm thickness. Heavy water (D₂O) flows through these tubes whereas

feed water enters the shell at the bottom of one leg called preheat leg.

Eighty-eight Monel inverted U-tube hairpin type primary heat exchangers cater to the steam requirement of Unit-2 of Madras Atomic Power Station (MAPS-2), a 220 MWe PHWR-type nuclear power plant (NPP).

With primary fluid in the tube side and feed water for steam generation in the shell side these 88 HXs are arranged in 8 boilers (4 in each side) in a series parallel arrangement with 8 PCPs, 24 parallel slide gate isolating valves (two for each boilers and one PCP discharge valve). Each

hairpin HX consists of 195 Monel (SB193) U-tubes 12.5 mm OD and 1.25 mm wall thickness.

Each heat exchanger has a heat transfer surface area of 39.1 m². The tube-to-tube sheet is a welded joint and further expanded to avoid crevice corrosion along the tube sheet thickness. Hairpin HX shell side design pressure is 49.92 kg/cm² and design temperature is 263.9 °C. Tube side design pressure is 94.92 kg/cm² and design temperature is 298.9 °C.

History

MAPS-1 was commissioned in the year 1983 followed by MAPS-2

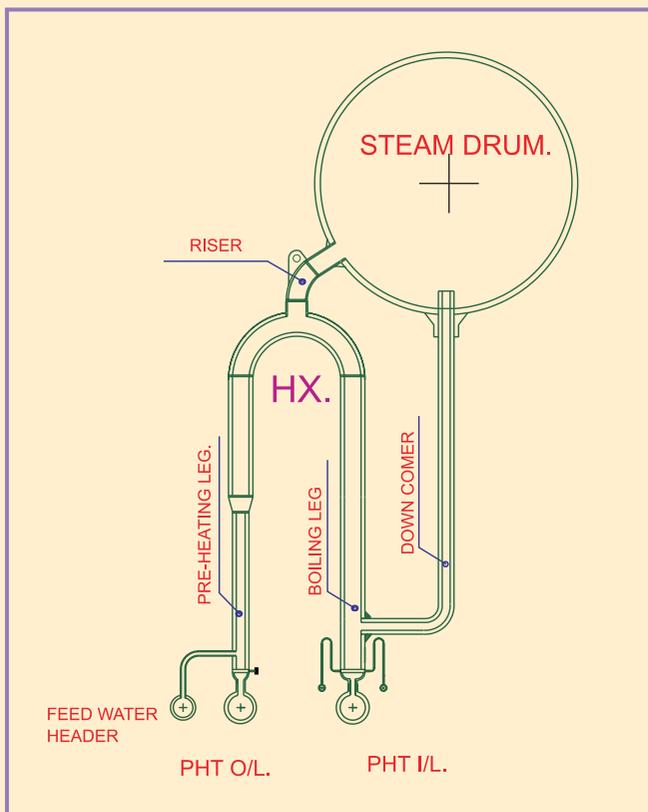


Fig.1: Boiler HX

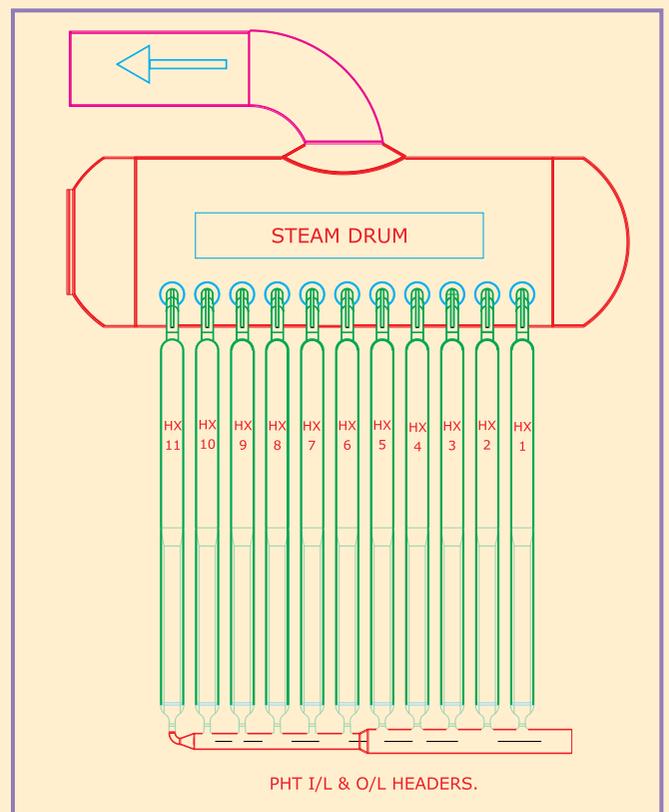


Fig.2: Monel-400 Tubes

in the year 1985. Two hairpin HXs in MAPS-1 and 5 hairpin HXs in MAPS-2 developed leaks during the course of unit operation. The absence of physical and remote access for health assessment of steam generator tubes and lack of provisions to remove the deposits on the feed waterside above boiling leg tube sheet resulted in under-deposit corrosion and the consequent tube failures.

MAPS-2 was taken off the grid for a planned campaign to replace the Zircalloy-2 pressure tube with zirconium niobium (2.5% w/w) pressure tubes. Being the ideal time for the steam generator replacement, it was decided to procure 88 hairpin HXs and the contract was awarded to three

different firms in order to meet the tight supply schedule.

Removal And Replacement Of Heat Exchangers

The heat exchangers, 11 in a row for a boiler, are spaced at a distance of 18” from the centerline of the first HX leg to the centerline of the adjacent HX leg, giving hardly a gap of two inches between the two adjacent boiling legs. Each heat exchanger is of 7-meter height and weighs approximately 3 tonnes. Each hairpin HX has 11 pipe connection of assorted sizes like 1/2”, 2 1/2” 5” and 8”. The location is congested, ruling out the use of automated tool, tackles and automatic welding machines and making the whole job a manpowerintensive skill-oriented work.

The background dose rate was ranging from 100-200 mR/hr inside the north and south boiler cabinet initially and progressively decreased with old heat exchangers getting replaced with new ones during the course of the work.

The operating data of RAPS-1&2 and MAPS-1&2 show that while RAPS-1&2 units were operating trouble-free, the MAPS units experienced tube leak problems since January 1995 onwards.

Till June 2000 there had been 7 failures – 2 in MAPS-1 and 5 in MAPS-2.

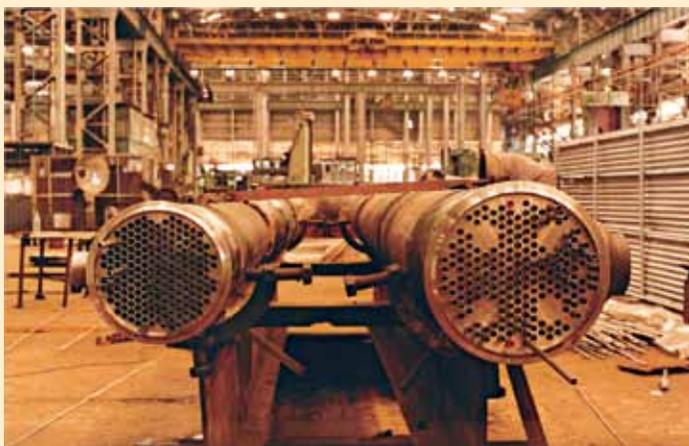
This hairpin design was adopted in 1960s, and Monel-400 was considered excellent tube material



A close-up of removed boiler tubes near tube sheet



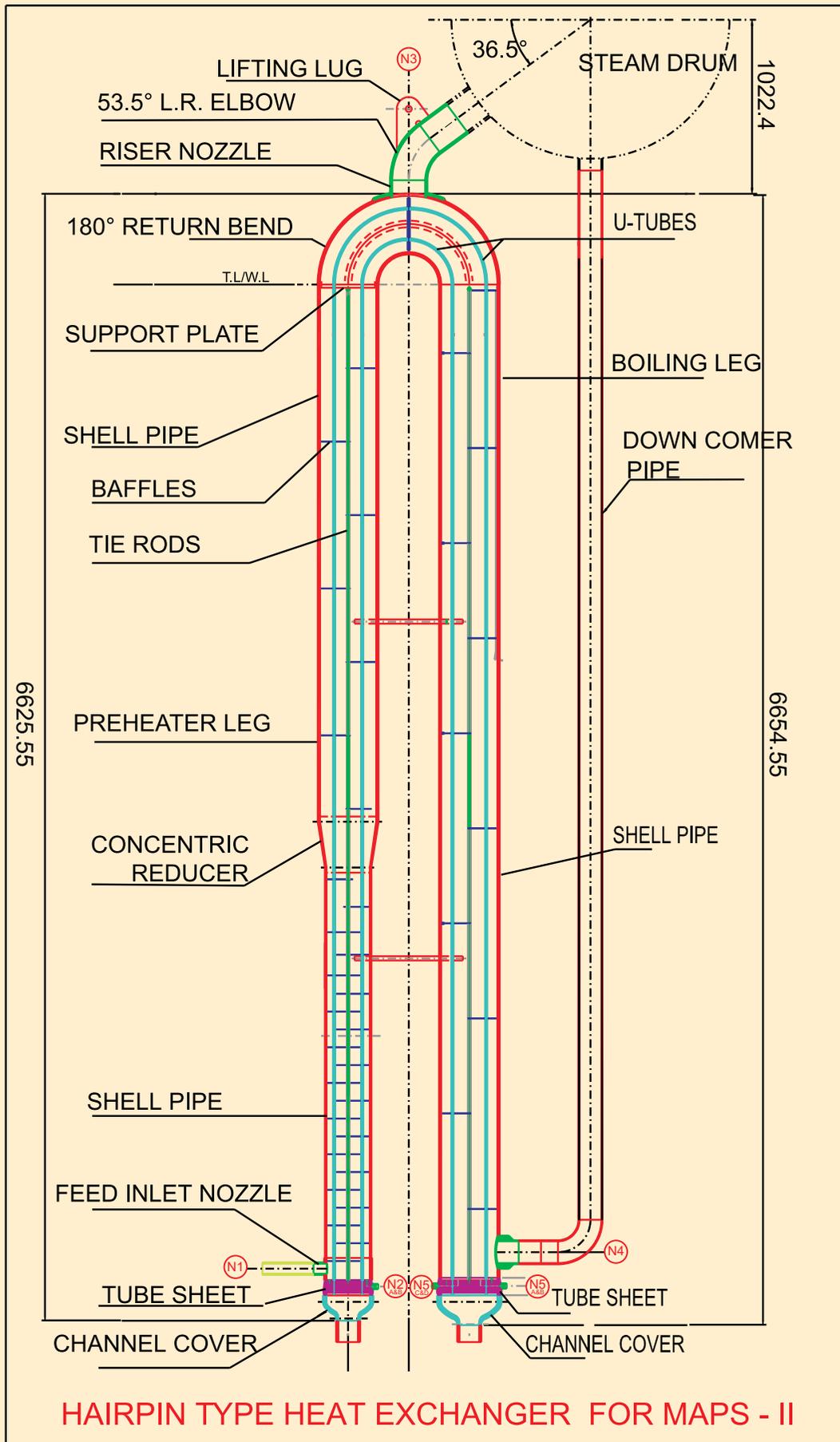
One of the removed HXs at MAPS-2 showing degraded tubes



A close-up of a hairpin HX from tube sheet side at the shop floor of Messrs BHPV, Vizag



A close-up of Monel-400 tube-bundle from the return band side of a hairpin HX manufactured at the shop of Messrs BHPV, Vizag



**Table-1: Leak Incidents in Hairpin Type Steam Generator
(As on January 1, 2001)**

Incident	Date	Unit No.	Boiler No.	HX No.	Leak Rate kg/hour
1	February 1995	MAPS-2	BO-5	HX-10	2.6
2	September 1996	MAPS-2	BO-5	HX-2,5	9.2
3	February 1999	MAPS-2	BO-7	HX-8	2
4	March 1997	MAPS-1	BO-2	HX-2	10
5	June 2000	MAPS-1	BO-1	HX-10	10

for steam generator tubes at that time. The design though did not incorporate any features for inservice inspection (ISI) of tube bundles and for plugging of the degraded tubes. At that time ISI of the tubes was not mandatory.

Leak Incidents In MAPS-1&2 Hairpins

There have been 5 leak incidents in total at MAPS-1&2 units involving 7 hairpins. These incidents are given in Table-1.

Degradation mechanism for Monel tubes

The failures at MAPS were due to a corrosion attack on the outside of tube wall in the sludge pile zone close to the tube sheet. In the initial days at MAPS (before the induction of polishing plant in the condenser circuit), several instances of seawater ingress into the secondary side on account of condenser leaks were reported. At each occasion chloride ion concentration would go up in the boiler water requiring addition of sodium phosphate to neutralise it. The deposition of phosphates on the tube sheet was responsible for the formation of hard, sticky sludge leading to the degradation of MAPS steam generator tubes. Ionic copper leaches out of Monel in oxidising atmosphere (i.e. pH value < 5 and oxygen level < 20 ppb).

No damage was observed on the tube sheet material and the tubes beyond the sludge accumulation zone.

Corrective Measures

Means to mitigate the problem were worked out on the following lines:

1. Change the blow-down facility from intermittent to 1/2% continuous. The adequacy of the blow-down line size in creating enough turbulence necessary for removing the sludge and the effectiveness of the continuous blow-down in controlling the sludge accumulation was also checked.

2. Continuous chemical addition for better chemistry control of the boiler water.
3. Development of secondary side chemical cleaning process.
4. Replacement of the hairpins by new HXs with or without design modifications / refurbishment of the old HXs. Provision of ISI was also considered but dropped later due to the complex nature of the tooling.
5. Modification in design for visual inspection and removal of sludge from secondary side. This provision was incorporated in two sample hairpins on each bank only.

The Need For En-Masse Replacement Of Hairpin HXs

Based on the investigations of these failures and the assessment of the health of the boiler tubes (See Table-2), it was considered essential to replace all the hairpin HXs in both the units of MAPS. This activity for MAPS Unit-2 was



Dr. V. K. Chaturvedi (the then CMD, NPCIL) with the engineers of NPCIL and BHEL inspects one of the HXs

Table-2: Summary of the Probability Analysis for Life Assessment of MAPS Boilers

	Estimation based on	
	Op. Period	EFPYS
MTTF	7.875 years	3.3 years
Life Expectancy i.e. probability of survival of any tube		
After one year	88.07%	74.08%
After two year	77.57%	54.88%
After three year	68.31%	40.65%
After four year	60.17%	30.12%
After five year	53%	22.13%

planned along with EMCCR and other upgradation works.

The analysis was carried out both on the basis of no. of operating years and EFPYs.

The en-masse replacement of boiler hairpins in MAPS units was considered on the following grounds:

- The rate of failure of the hairpins was expected to increase with the passage of time. The life expectancy of MAPS boilers has been evaluated utilising the existing operational data at MAPS site. The results had indicated that there was a substantial fall in the life expectancy of MAPS boilers (Table-2).
- Corrective measures recently undertaken e.g. continuous blow down, secondary side chemical cleaning etc. may reduce the rate of degradation but would not be successful in arresting the tube degradation totally.
- En-masse replacement would be cost effective since unscheduled plant shutdowns on account of tube leaks could be avoided.
- Adequate ISI provisions to assess tube health/degradation were not available in the existing design. Since the present day

operating procedures in nuclear power stations specify ISI as a mandatory requirement, modified design of hairpins to include suitable provisions for ISI was considered. Accordingly, detailed discussions with reputed robotics suppliers for the design, manufacture and supply of ISI tooling were held. It became apparent that the development of suitable ISI tooling for the existing hairpin design was very complex. It was then concluded that some design modifications were essential in the construction of the hairpin to facilitate ISI. Accordingly, tool accessibility for the inspection of the shellside

tube bundle was provided. These design modifications were found feasible.

Schedule of en-masse hairpin replacement

Schedule of en-masse hairpin replacement work for MAPS-2 was made to suit the coolant channel replacement works so that full advantage of the planned shutdown could be taken.

A detailed schedule, based on the experience gained during the isolation and removal of two hairpins at MAPS earlier and also time required for the procurement of new hairpins, was worked out.

Strategy And Action Plan

Procurement Strategy

Since all 88 hairpins were to be procured in a short time, various alternatives were considered. Finally, the following procurement strategy was adopted:

- The tender was floated on a 'limited tender basis'.
- The critical material was procured separately.



One of the HXs ready for dispatch at the shop floor of BHPV

- Total quantity of hairpins to be manufactured was distributed among three vendors.
- Carbon steel and some other materials were procured by the individual manufacturers.

Manufacturing Strategy

- Identify competent vendors
- Create healthy competition among all the vendors
- Critically examine the

manufacturing schedules, resequence the activities with more parallel paths, identify and cutting down the idle time

- Ensure timely input of all data and resolving the issues related to design, QA and manufacturing beforehand
- Plan the job dynamically and follow up the jobs on continuous basis at all the three shops simultaneously

- Air freight some key items to meet the schedules
- Increase work centers in-house, while off-loading machining / fabrication of sub-assembly to outside sub-vendors
- Involve the top management to impress upon the priority

Action Plan

A tentative schedule for MAPS-2 hairpin replacement was worked out. It was prepared considering annual shut down of 18 months. However, the shut down time was reduced, which resulted in a severe time constraint on the delivery schedule.

With this procurement strategy some time was saved in placement of the purchase orders. The job was also split among three vendors and tighter targets were set in the purchase order itself.

As there was a minor delay in receiving some vital imported items due to reasons beyond control, vendors had revised the delivery schedule. The vendors had proposed 22 weeks for manufacturing of 5 hairpins only and required 42 weeks for completing another 22. As one of the vendors was to manufacture 44 hairpins, the time required was still longer.

The manufacturing of the hairpins at all the three vendors shop was taken up as per the manufacturing strategy as given in the earlier section. The work was completed well in time with the 88th hairpin manufactured on April 27, 2003. Some important dates are given in Table-3.



Experimental setup for chemical cleansing of boiler tubes near tube sheet

Table-3: Some important dates of hairpin HX replacement of MAPS-2

1.	Sanction of board for replacement of MAPS-2 hairpin	February 7, 2001
2.	Placement of Purchase Order	September 18, 2001
3.	Supply of first lot of Free Issue Material	May 21, 2002
4.	Supply of first hairpin HX	December 5, 2002
5.	Supply of 93 th hairpin HX	April 24, 2003
6.	Erection of first hairpin HX	December 15, 2002
7.	Erection of 88 th hairpin HX	May 6, 2003

Table-4: Best times achieved during the fabrication of hairpin-type HXs for MAPS-2

Sr. No.	Description	Time in days
A.	Tube Sheet Overlay Cladding	2
1.	10" Tube Sheet drilling	1.5
2.	14" Tube Sheet drilling	1.5
3.	Down Commer Pipe + 90 Bend Welding + NDT	1
4.	Return bend + 8" pipe + 53 Bend Welding NDT	1
B.	Pre-heat Leg Assembly (10")	
5.	Pre heat leg (10") + Reducer Welding + NDT (Parallel)	2
6.	10" Tube shell + Monel Shell Welding + Nozzle (Parallel)	2
7.	Pre heat leg monel shell + Sr. No. 6	2
8.	Pre heat leg skeleton (seal ring, tie rod)	1
9.	Pre heat leg reducer + 14" pipe fit up and welding	1
C.	Boiling Leg Assembly	
10.	14" pipe + Nozzle Welding (Parallel)	1
11.	Boiling Heat Leg Skeleton	1
12.	14" Tube Sheet + Pipe Welding	1
D.	Full Assembly	
13.	Pre heat leg + Boiling Leg + return bend inner half fit up	1
14.	Tube Loading	1
15.	180 return bend inner half fit up welding	1
16.	Tube Trimming	1
17.	TTP Welding	1
18.	TTP NDT	1
19.	180 Outer Half Welding (Parallel)	1
E.	Assembly Testing	
20.	Shell Side Helium Test	1
21.	Tube Expansion	1
22.	Ball Test	0.5
23.	Shell Side Hyd. Test	1
24.	Channel Cover Welding + NDT	1
25.	5" Pipe + Channel cover welding 0.5	0.5
26.	Tube Side Helium Test	1
27.	Tube Side Hyd. Test	1
28.	Sand Blasting	1
29.	Painting	1
30.	Despatch	1

Table-4 lists best times achieved for some of the activities during manufacturing of the hairpins. The time taken for almost all activities was compressed by a factor of 4 or 5 from the original estimates.



G. Ashok, SME (Mechanical Maintenance unit) is a Mechanical Engineering graduate from Madurai Kamaraj University, 1988 joined NPCIL through the 32nd batch of BARC Training School. He joined MAPS in the year 1989 and was associated with various maintenance jobs of Feed Water system, Moderator System, DGs and Turbine Generators. He has formulated a good deal of maintenance procedures and has evolved a well organised 'Good practices for mechanical maintenance'. He took over as SME (mechanical) in February 2002. He has to his credit the successful completion of MAPS-2 upgradation jobs in mechanical maintenance section like Steam generator heat exchanger replacement of thermal shield fans with axial flow fans, modification of hopkinson valves gland with new live loading arrangement, modification of turbine rotor, introduction of thrust bearing for moderator pumps etc.



G. Harikrishnan, SO/F MMU.A, is a graduate in Mechanical Engineering from Delhi College of Engineering 1986-joined NPCIL in 1989. He had a 2½ years experience with a paper manufacturing company prior to joining NPCIL. He joined Mechanical Maintenance in the year 1991 and was associated with PHT and moderator system maintenance activities. He was the overall coordinator for the enmasse boiler heat exchangers replacement in MAPS-2. He was involved in the PCP seal modification and retrofitting of hydrodynamic seal in place of the original hydrostatic mechanical seals, modification of hopkinson valves gland with new live loading arrangement etc.



A. K. Rastogi, Mr. A.K. Rastogi joined the 14th batch of training school of Bhabha Atomic Research Centre (BARC) (1970-71) after graduating for his BE (Hons.) in Mechanical Engineering from Birla Institute of Technology (BITS), Pilani. He was posted at RAPP-1&2 site to look after the site related design issues. He also completed his master's degree (M. Tech) in Thermal Engineering from IIT Delhi in 1975. He moved to NAPP site in 1980 where he was in-charge of quality assurance of all piping jobs. In 1990 he came to Mumbai to join the RAPP 5 to 8 group and worked for planning and procurement of reactor components. After working briefly in reactor services group where he was responsible for development of plans, procedures and procurement of SG service/ inspection equipment he joined the procurement directorate. Presently he is working in this directorate as Associate Director (SG & HTE) responsible for manufacturing the steam generators and heat exchangers for various projects. He is also responsible for procurement of boilers for MAPS-2 and MAPS-1 and development of SG inspection tooling/ service equipment.



Bhupal Sharma, a postgraduate in Chemical Engineering is presently working as a n Additional Chief Engineer (HTE). After completing his M.E. from Indian Institute of Technology (IIT), Roorkee in 1974 he worked as Shift Engineering in a chemicals and fertilisers company for one year. He joined erstwhile PPE in 1975. He was responsible for planning and procurement of distillation columns, electrolytic cells, heat exchangers and other pressure vessels for heavy water upgrading plants at RAPS, MAPS and NAPS. From 1985 onwards he has been looking after the procurement of all heavy water heat exchangers for KAPP-1&2, KAIGA-1&2 and 3&4, RAPP-3&4 and 5&6 and TAPP-3&4. He was also responsible for the procurement of boilers for MAPS-2 and MAPS-1. He is a Life Member of National Institute of Heat & Mass Transfer, Indian Institute of Chemical Engineers and Indian Nuclear Society.



J. C. Tripathi, a Mechanical Engineer from the 28th batch of BARC Training School is working as Deputy Chief Engineer in HTE Group of Procurement Directorate. He has a diploma in management from Kota Open University. He was associated with reactor erection at NAPP construction site. Presently he is involved in the development of SG inspection tooling and fabrication of MAPS boilers.

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State of the Climate in 2016

Executive Summary

Takeaway Points

J. Blunden and D. S. Arndt

State of the Climate is an international, peer-reviewed publication released each summer. It is the authoritative annual summary of the global climate published as a supplement to the Bulletin of the American Meteorological Society.

The report, compiled by National Oceanic and Atmospheric Administration's (NOAA) Center for Weather and Climate at the National Centers for Environmental Information is based on contributions from scientists from around the world. It provides a detailed update on global climate indicators, notable weather events, and other data collected by environmental monitoring stations and instruments located on land, water, ice, and in space.

The following salient events and trends are reported in greater depth in the State of the Climate in 2016, the supplement to the Bulletin of the American Meteorological Society Vol. 98, No. 8, August 2017. Figures shown here are drawn from the supplement and are not cited in the text below.

GLOBAL CLIMATE. The dominant greenhouse gases released into Earth's atmosphere—carbon dioxide, methane, and nitrous oxide—all continued to increase and reach new record high abundances. Increases in the global annual mean atmospheric concentrations of methane and nitrogen dioxide from 2015 to 2016 were generally consistent with decadal trends, but the 3.5 ± 0.1 ppm rise in global annual mean carbon dioxide from 2015 to 2016 was the largest annual increase ever observed in the 58-year measurement record.

The global average carbon dioxide concentration at Earth's surface for 2016 was 402.9 ± 0.1 ppm, surpassing 400 ppm for the first time in the modern atmospheric measurement record and in ice core records dating back as far as 800,000 years.

Owing to the combination of strong El Niño conditions early in the year and a long-term upward trend, Earth's surface observed record warmth for a third consecutive year, with the 2016 annual global surface temperature surpassing the previous record of 2015, albeit by a much slimmer margin than that by which the 2015 record was set. Above Earth's surface, the globally averaged lower troposphere temperature was also record high according to all datasets analyzed, while the lower stratospheric temperature was record low according to most of the *in situ* and satellite datasets.

The global warmth was associated with extensive drought, surpassing most years in the post-1950 record

and strongly influenced by the El Niño. For any given month during 2016, 12% or more of global land was experiencing at least severe drought conditions, the longest such stretch in the record.

GLOBAL OCEANS. The globally averaged annual sea surface temperature (SST) for 2016 was record high, just surpassing the previous record of 2015 by about 0.01°C . The global SST trend for the twenty-first century to date (2000–16) of $+1.62^\circ\text{C century}^{-1}$ is much higher than the longer-term (1950–2016) warming trend of $+1.00^\circ\text{C century}^{-1}$.

Global mean sea level also reached a new record high in 2016, marking the sixth consecutive year, and in 21 out of the last 23 years, it has increased compared to the previous year. The new high reflects the ongoing multidecadal trend during the satellite altimetry era, $3.4 (\pm 0.4)$ mm yr^{-1} , as well as the continuation of El Niño into spring 2016.

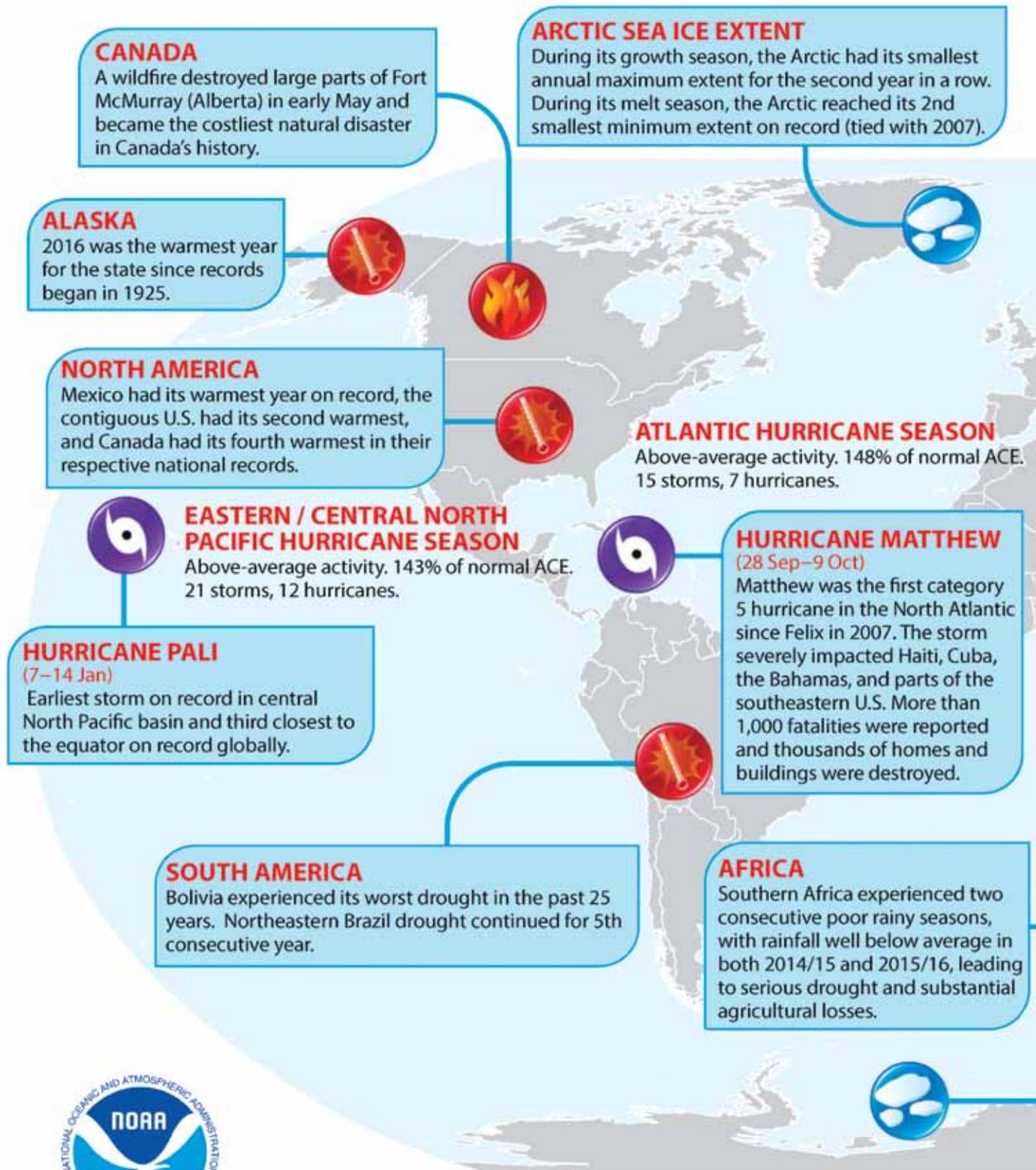
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In final form: 11 July 2017

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Please Note: Material provided in this map was compiled from NOAA's NCEI State of the Climate and authorship for this report. For more information please visit: <https://www.ncdc.noaa.gov/so>

Geographical distribution of selected notable climate anomalies and events in 2016.

EUROPE

Europe experienced its 3rd warmest year, behind only 2014 (record warm) and 2015 (2nd warmest), making the past three years the three warmest in the 107-year continental record. The average winter (Dec 2015–Feb 2016) temperature was record high.

ASIA

Asia observed its 3rd warmest year on record, behind 2015 (record warmest) and 2007 (2nd warmest). Apr, Aug, and Sep were each record warm, while Oct and Nov were both cooler than their long-term averages.

TYPHOON LIONROCK

(16–31 Aug)

Lionrock impacted northeastern areas of the Democratic People's Republic of Korea (DPRK), where rainfall of up to 320 mm in four days led to catastrophic flooding and 133 fatalities.

CHINA

China observed its wettest year since national records began in 1951.

INDIA

India reported its warmest year since records began in 1901. Eight of its warmest 10 years have occurred since 2000.

WESTERN PACIFIC OCEAN TYPHOON SEASON

Average activity.
30 storms, 13 typhoons.

NORTH INDIAN OCEAN CYCLONE SEASON

Near-average activity.
5 storms, 1 cyclone.

SOUTH PACIFIC OCEAN CYCLONE SEASON

Average activity.
8 cyclones.

SOUTH INDIAN OCEAN CYCLONE SEASON

Near-average activity.
8 storms, 5 cyclones.

AUSTRALIAN CYCLONE SEASON

Below-average activity. Lowest number of named storms since reliable records began in 1970.
7 storms, 3 cyclones.

AUSTRALIA

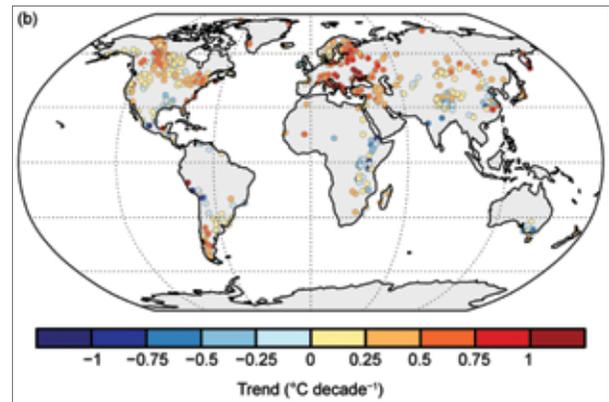
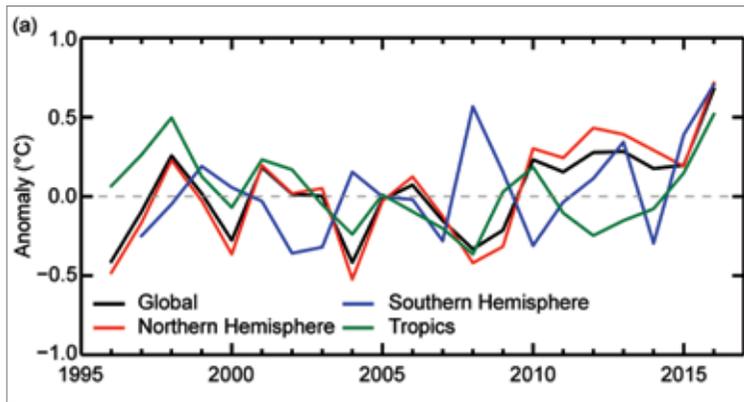
Australia observed its 4th warmest year in its 107-year national record. Tasmania was record warm. Nine of the past 10 years (excepting 2010) have been warmer than average and 7 of the 10 warmest years have occurred since 2005.

ANTARCTIC SEA ICE EXTENT

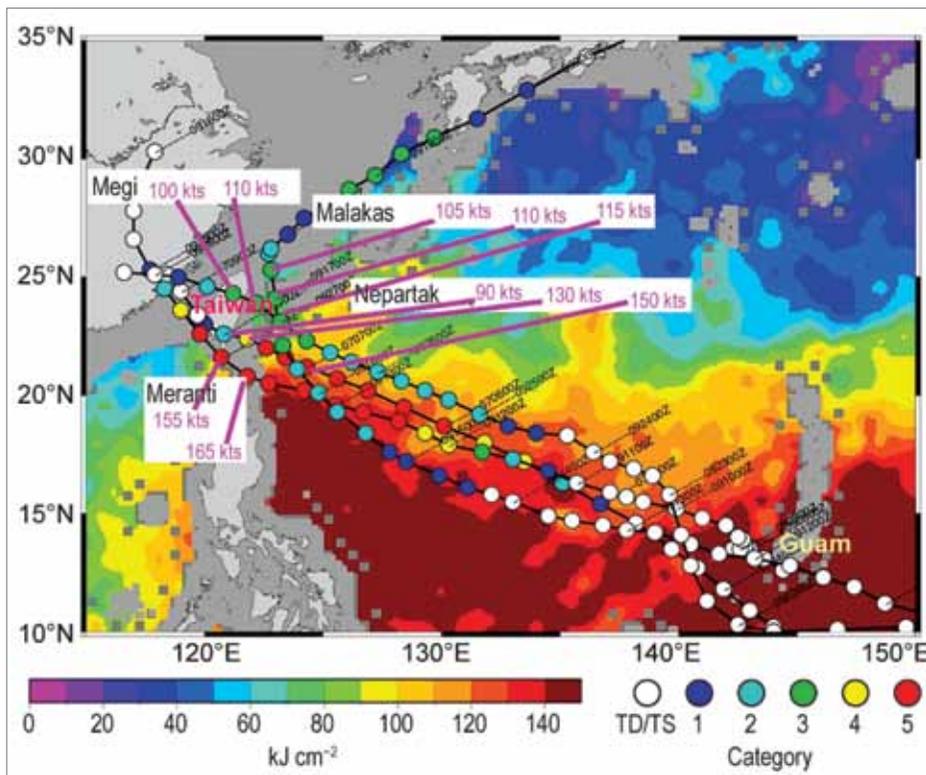
Record low values in austral spring contrast with record high values during 2012–14.

Reports, the WMO Statement on the Status of the Global Climate in 2016 (WMO-No. 1189),

tc



Warming Lakes: Warmth can encourage bacterial blooms and lower water quality. In 2016, lakes overall were the warmest they've been in the 21-year record. The global and equally weighted lake surface water temperature (LSWT) anomaly was +0.65°C, with warm conditions noted in both the Northern (NH) and Southern Hemispheres (SH). LSWT from 681 lakes show (a) global and regional annual average anomalies (°C), and (b) 1996–2016 LSWT trend (°C decade⁻¹). Annual LSWTs are calculated for the warm season (Jul–Sep in NH; Jan–Mar in SH), and LSWT trends are calculated on these anomalies. (Fig. 2.3 in *State of the Climate in 2016*; see discussion there in section 2b2.)



Typhoons for Taiwan: Even with a late start and a lull in August, few regions have ever recorded a more severe tropical season than Taiwan did in 2016. Four typhoons (Supertyphoons Nepartak and Meranti, category 4 Typhoon Malakas, and category 3 Typhoon Megi) approached Taiwan. Their peak intensity and intensity closest to Taiwan are depicted over a background based on daily composite of the four pre-typhoon tropical cyclone heat potential (i.e., integrated heat content from SST down to the 26°C isotherm depth) maps from 3 July, and 9, 12, and 22 September. (Fig. SB4.3 of the *State of the Climate in 2016*; see discussion there in sidebar 4.2.)

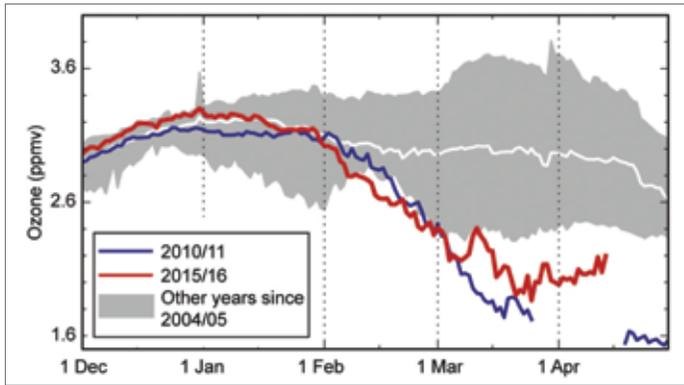
Global annual ocean heat content (OHC) saw a slight drop compared to the record high of 2015. Over the period 1993–2016, there are statistically significant warming

trends of OHC in the Southern Hemisphere, mostly north of the Antarctic Circumpolar Current, where much of Pacific Ocean carbon sequestration is observed.

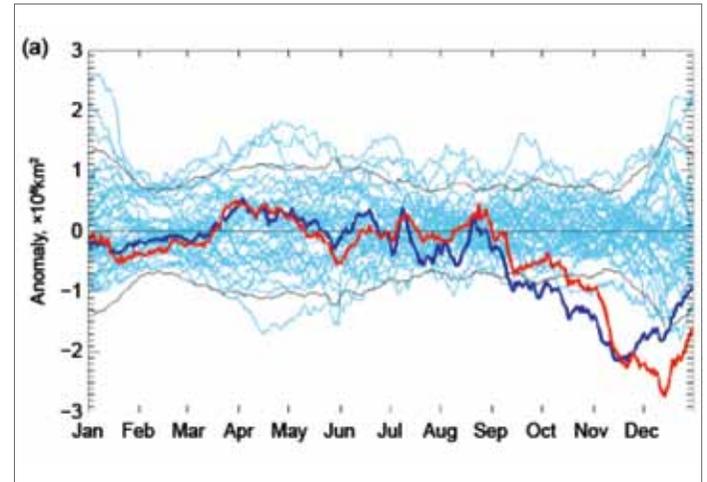
The overall ocean rate of uptake of carbon from the atmosphere has generally risen along with atmospheric carbon dioxide concentrations.

THE TROPICS. Globally, 93 named tropical storms were observed during 2016, above the 1981–2010 average of 82, but fewer than the 101 storms recorded in 2015. Three basins—the North Atlantic and the eastern and western North Pacific—experienced above-normal activity in 2016. The Australian basin recorded its least active season since the beginning of the satellite era in 1970.

Overall, four tropical cyclones reached Saffir–Simpson category 5 intensity—one each in the North Atlantic, South Indian, western North Pacific, and southwest Pacific basins. This is half the number of category 5 storms recorded in 2015. In terms of accumulated cyclone energy (ACE), the North Atlantic basin recorded its first above-normal season since 2012, with more than 2.5 times the average ACE of the previous three seasons. Category 5 Hurricane Matthew alone produced 35% of



Arctic Ozone Loss: Winter destruction of Arctic stratospheric ozone in 2015/16 initially proceeded faster than the recordsetting loss of 2010/11. The ultimate decline was not a record, but exceeded nearly all years since 2004. The period of activated chlorine destroying ozone halted early due to March warmth. The averaged ozone mixing ratios (ppmv) plotted above are for the area bounded by the polar vortex at approximately 18 km altitude, measured by the Aura Microwave Limb Sounder. The solid white line is the average for 2004/05 to 2014/15 (minimum/maximum range in gray) with 2010/11 and 2015/16 excluded. Gaps in the blue line for 2010/11 are missing data. The 2015/16 record (red line) ends early because the vortex was not defined after mid-April. (Fig. 5.26 in *State of the Climate of 2016*; see discussion there in section 5j.)



Late-Season Southern Sea Ice Melt: Sea ice extent was close to the means around Antarctic in winter, but on 31 August reached its peak—a record early date (according to the satellite data). From then on SH ice extent (red line) and area (blue line) daily anomalies departed dramatically from the 1981–2010 mean. Thin blue lines represent the historical daily values of extent for 1979–2015, while the thin black lines represent ± 2 std. dev. of extent. As recently as 2012–14 daily sea ice extent/area set record highs in the region. (Fig. 6.8a in *the State of the Climate in 2016*; see discussion there in section 6f.)

the season's ACE. The western North Pacific's activity was similarly dominated by two typhoons (Lionrock and Meranti) accounting for about 25% of the total seasonal ACE.

THE ARCTIC. The 2016 average temperature of land surfaces north of 60°N was 2.0°C above the 1981–2010 average, breaking the previous record of 2007, 2011, and 2015 by 0.8°C and representing a 3.5°C increase since the record began in 1900. This region is warming at more than twice the rate of lower latitudes.

On 24 March, the sea ice extent at the end of the growth season saw its lowest maximum in the 37-year satellite record, tying with 2015 at 7.2% below the 1981–2010 average. The September 2016 Arctic sea ice minimum extent tied with 2007 for the second-lowest value on record, 33% smaller than the 1981–2010 average. Arctic sea

ice cover remains relatively young and thin, making it vulnerable to continued extensive melt.

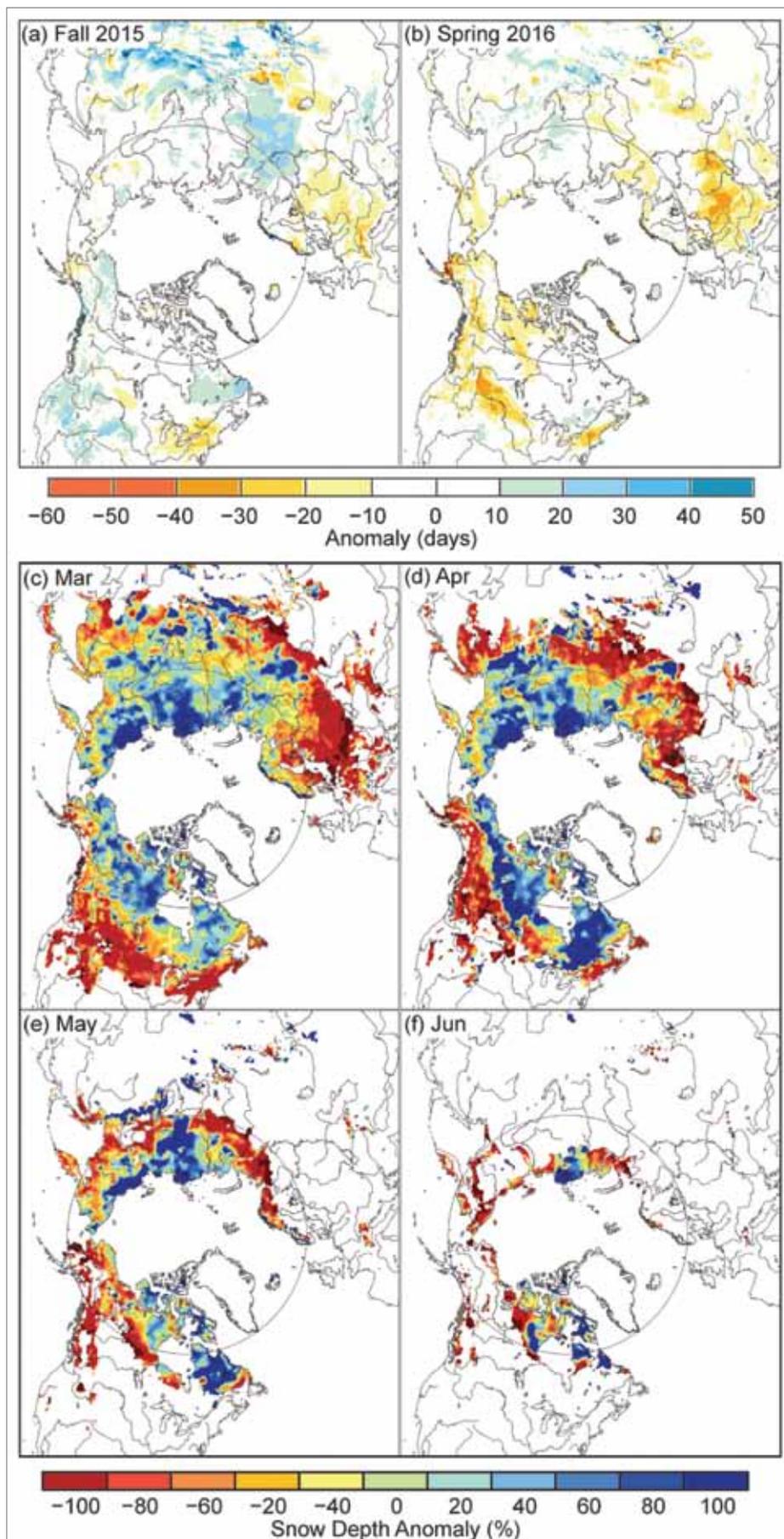
The mass of the Greenland ice sheet, which has the capacity to contribute ~7 m to sea level rise, reached a record low value, with enhanced melting occurring in the southwest and northeast regions. The onset of the surface melt was the second earliest (after 2012) in the 37-year satellite record.

The spring snow cover extent (SCE) has also undergone significant reductions, particularly since 2005. In 2016, new record low April and May SCEs were reached for the North American Arctic. In addition to warming air temperatures, there is also evidence of decreasing pre-melt snow mass (an indication of shallower snow), which may further precondition the snowpack for earlier and more rapid springtime melt.

Continuing a pattern below the surface, record high temperatures at 20-m depth were measured at all permafrost observatories on the North Slope of Alaska and at the Canadian observatory on northernmost Ellesmere Island. Thawing permafrost has the potential to release significant amounts of greenhouse gases.

ANTARCTICA. Monthly low surface pressure records for March, June, and September were broken at many stations. New monthly high values (since 1957) of the southern annular mode index, a measure of the zonal mean pressure difference between 40° and 65°S, were set in March and June, +4.36 and +3.66, respectively.

Monthly high surface pressure records for August and November were set at several stations. During this period, record low daily and monthly sea ice extents were observed, with the November



mean sea ice extent more than 5 standard deviations below the 1981–2010 average. These record low sea ice values in austral spring 2016 contrast sharply with the record high values observed during 2012–14.

With cool surface temperatures prevailing during the 2015/16 melt season, most of the continent and ice shelves showed negative melt duration anomalies (compared to 1981–2010). However, the Ross Ice Shelf showed an unusual and widespread positive melt season relative to the 1981–2010 mean. Although the Antarctic Peninsula typically experiences the longest melt seasons relative to the rest of the continent, the Peninsula melt duration anomalies in 2015/16 were mostly negative.

Over the region, springtime Antarctic stratospheric ozone depletion was less severe compared to the 1991–2006 average (a period of peak chlorine and bromine over Antarctica), but ozone levels were still low compared to pre-1990 levels.

REGIONAL CLIMATES. North America. Mexico was record warm for 2016 (since 1971), while

Diminished Arctic Snow Pack: A shallow snowpack combined with spring warmth led to diminished snow cover extent (SCE) in the Arctic. Below-normal SCE anomalies (relative to 1981–2010) set records in March and April 2016 in the North American Arctic; spring SCE anomalies were also negative in Eurasia. Snow cover duration departures (days; with respect to 1998–2010) from the NOAA Interactive Multisensor Snow and Ice Mapping System (IMS) data record for the (a) 2015 fall season and (b) 2016 spring season. Snow depth anomaly (% of 1999–2010 average) from the Canadian Meteorological Centre (CMC) snow depth analysis for (c) March, (d) April, (e) May, and (f) June 2016. (Fig. 5.18 in *State of the Climate 2016*; see discussion there in section 5g.)

the United States observed its second warmest year on record (since 1895), behind 2012. After being plagued by heat and drought

for several years, California had its first wetter-than-average year since 2012. To the north in western Canada, with abnormally warm and

dry conditions prevailing for about a year, the Fort McMurray wildfire burned nearly 590,000 hectares and became the costliest disaster

About The Report

This is the twenty-seventh annual State of the Climate report. The series originated as an annual Climate Assessment published by NOAA's Climate Analysis Center (CAC), now the Climate Prediction Center. The first to be published in BAMS was the Climate Assessment for 1995. Editorial leadership transitioned to NOAA's National Climatic Data Center, now the National Centers for Environmental Information, with Climate Assessment for 2000. State of the Climate in 2002 was the first of the series with its current name.

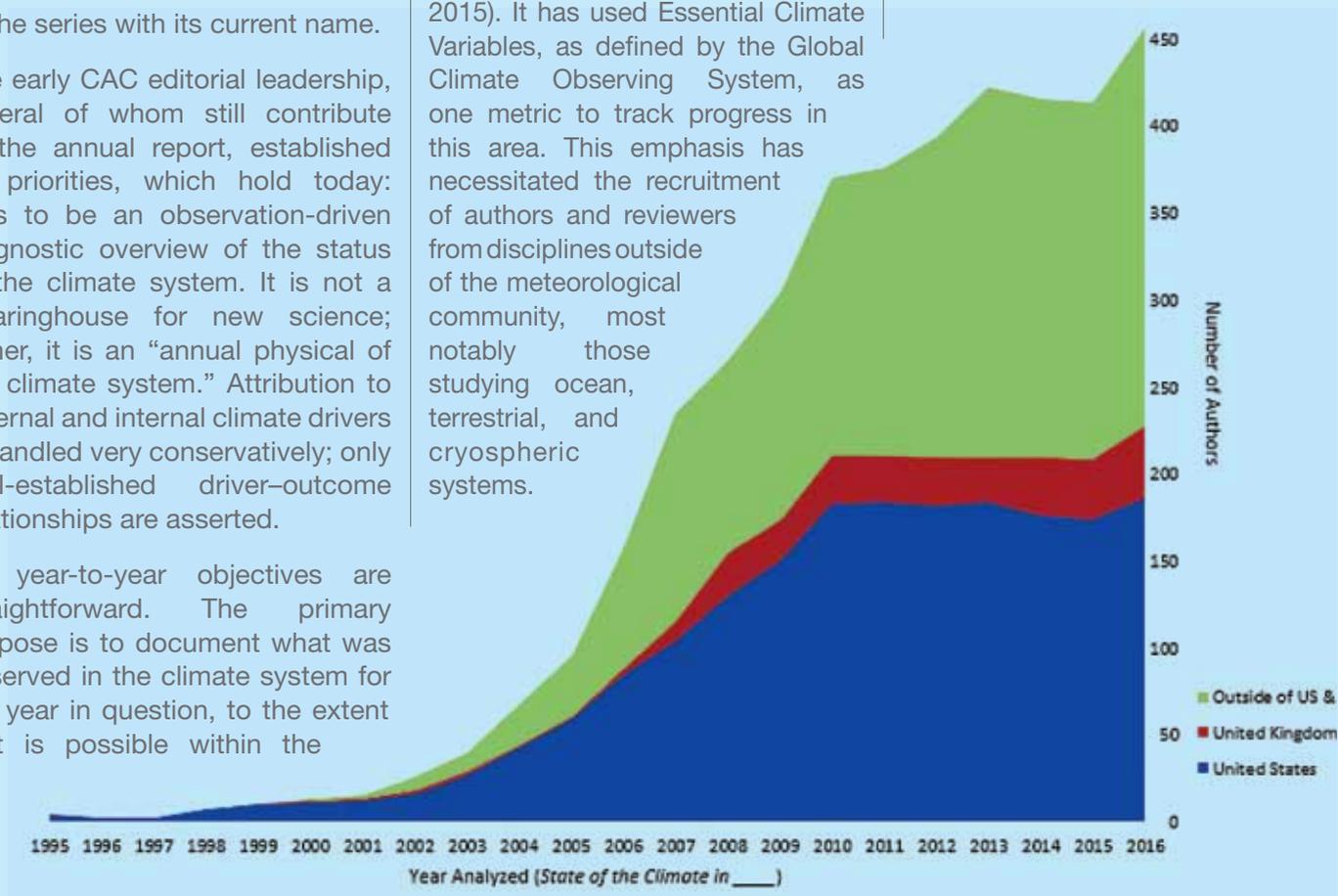
The early CAC editorial leadership, several of whom still contribute to the annual report, established its priorities, which hold today: it is to be an observation-driven diagnostic overview of the status of the climate system. It is not a clearinghouse for new science; rather, it is an "annual physical of the climate system." Attribution to external and internal climate drivers is handled very conservatively; only well-established driver-outcome relationships are asserted.

Its year-to-year objectives are straightforward. The primary purpose is to document what was observed in the climate system for the year in question, to the extent that is possible within the

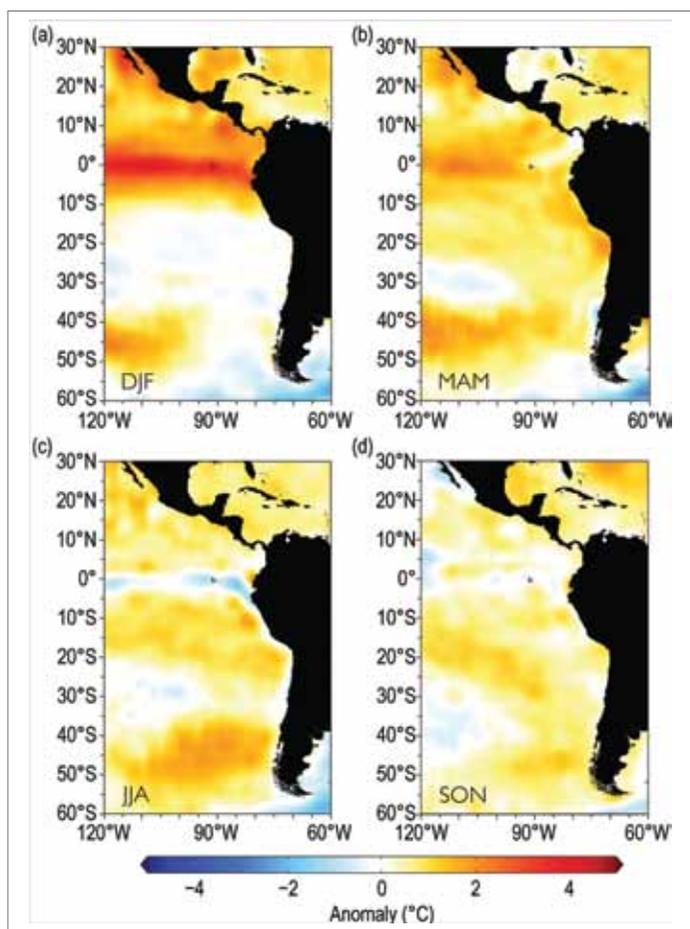
publishing window. Authors are encouraged, if possible, to place those observations in historical perspective, using standard climate monitoring tools such as anomalies, departures from a baseline, or measures of unusualness. To the extent that data allow it, assessments of longer-term trends are of value.

In the last decade, the State of the Climate has pursued a strategy of a more comprehensive assessment of the climate system (Rosenfeld 2015). It has used Essential Climate Variables, as defined by the Global Climate Observing System, as one metric to track progress in this area. This emphasis has necessitated the recruitment of authors and reviewers from disciplines outside of the meteorological community, most notably those studying ocean, terrestrial, and cryospheric systems.

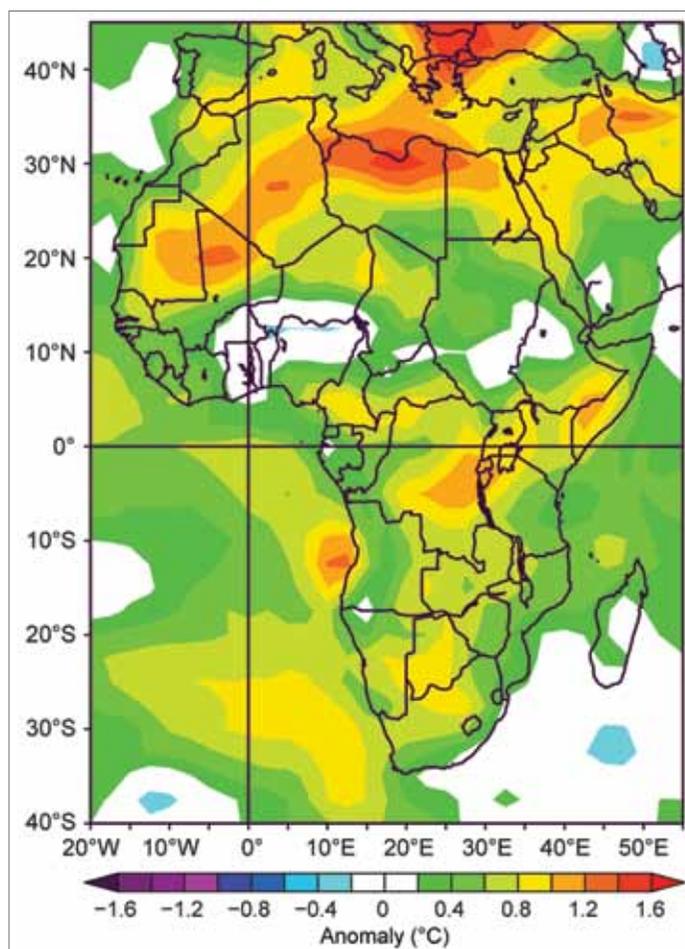
Viewing the State of the Climate as a series, in its entirety, provides insights from something of a history-of-science perspective. As the document has grown, its authorship and leadership—not just its scope—have become more diverse. State of the Climate is now much more international, with authors from more than 60 countries this year. And, as a set, it tracks our capacity for, our commitment to, and our collaboration in observing the climate system.



The number of authors, by national affiliation, for each edition of State of the Climate published by BAMS, from Climate Assessment for 1995 through State of the Climate in 2016. Because a small number of authors in any given edition may be affiliated with institutions in multiple nations, this is not an exact author count.



Influential El Niño: Higher-than-normal Pacific equatorial SSTs contributed to Amazonian drought and wildfires, but also to record-setting rains in April in Argentina and Uruguay. El Niño eventually gave way to cooler or near-neutral equatorial conditions, but waters generally remained warm along the South American coast. SST anomalies here were calculated with 1971–2000 base period. (Fig. 7.12 in *State of the Climate in 2016*; see discussion there in section 7d.)



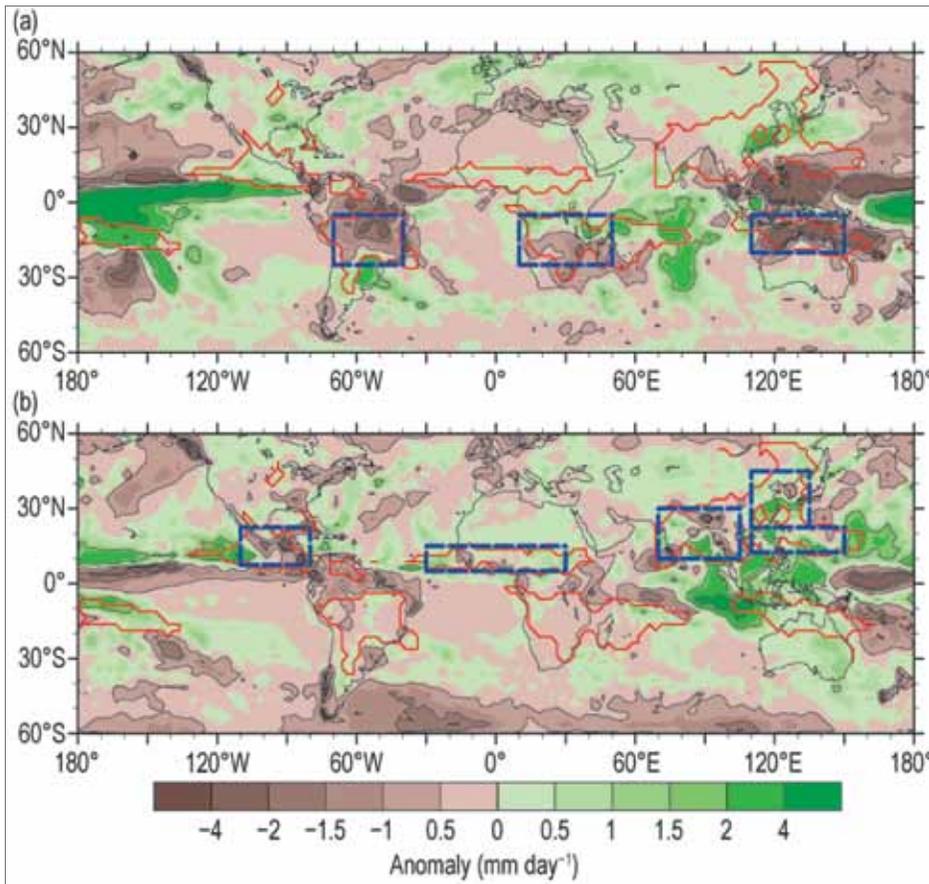
African Temperatures: The above-average surface air temperature anomalies for 2016 in Africa included the second-highest annual mean (of a 66-year record) in South Africa and persistent summer heat waves in the north. Meanwhile, December brought an unusually severe cold snap to Ethiopia and Sudan. (Fig. 7.16 in the *State of the Climate in 2016*; see discussion there in section 7e.)

in Canadian history, with \$3 billion (U.S. dollars) in insured losses.

Central America and the Caribbean. Most reporting stations in Central America had higher-than-average temperatures in 2016, primarily due to more frequent warmer-than-average days as opposed to extreme temperatures. In the Caribbean, Cuba reported its fourth-highest annual temperature in the 66-year national record. Several tropical cyclones impacted the region. Notably, Hurricane Matthew affected Cuba, Barbados, St. Lucia, the Dominican Republic, and Haiti.

The storm caused Haiti’s largest humanitarian emergency since the 2010 earthquake, with two million people affected and more than 540 fatalities reported for the country. In eastern Cuba approximately \$2.5 billion U.S. dollars in damages were incurred. In late November Hurricane Otto—the strongest North Atlantic hurricane so late in the season and the latest on record in the Caribbean Sea—severely impacted Panama, Costa Rica, and Nicaragua, with 18 fatalities and more than 2,400 damaged or destroyed homes.

South America. The 2016 annual temperature was above normal across much of South America, including 2°–3°C above average in most of central South America, but cooler-than-average conditions were observed across southeastern Bolivia, Paraguay, southeastern Brazil, Uruguay, and central and northern Argentina. During 27–30 April, most of Paraguay was affected by its most intense cold wave in 57 years. It was dry in several areas. In northeastern Brazil, strong anomalous negative soil moisture and drought conditions were observed for the



A Tale of Two Monsoon Seasons: Global land monsoon precipitation is strongly influenced by ENSO, which evolved from the peak of a strong El Niño at the start of the SH monsoon season to a weak La Niña by the end of the following NH monsoon season. The SH precipitation anomalies averaged for (a) November 2015–April 2016 were notably negative in many regions. In (b) May–October 2016 the anomalies were reversed in the NH monsoon season. The red lines outline the global monsoon precipitation domain that is defined by 1) the annual range (local summer minus winter) precipitation exceeding 300 mm and 2) the summer mean precipitation exceeding 55% of the total annual precipitation amount. Here the local summer denotes May–September for the NH and November–March for the SH. The precipitation indices for each regional monsoon are defined by the areal mean precipitation in the corresponding rectangular regions (dashed blue). (Fig. 4.18 in *State of the Climate in 2016*; see discussion there in section 4e.)

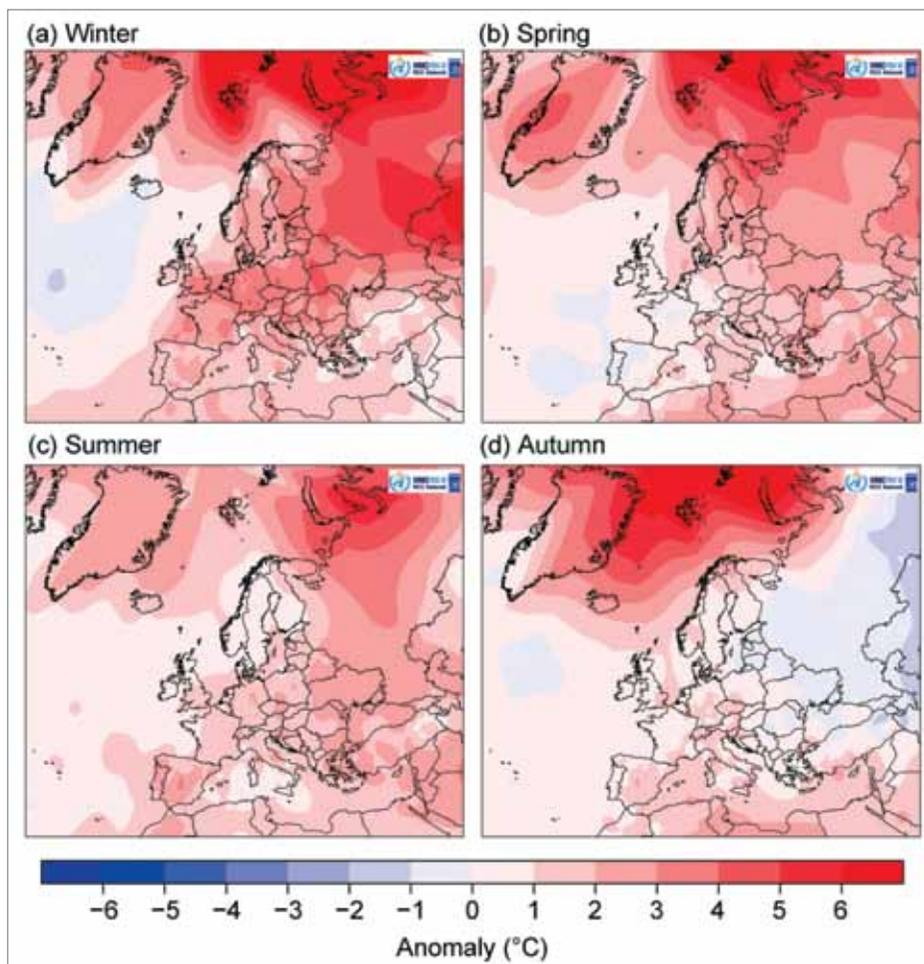
fifth consecutive year, making this the longest drought on record in this region. Dry conditions were also observed in western Bolivia and Peru, causing severe wildfires and water supply shortages. It was Bolivia's worst drought in the past 25 years. Wet conditions were observed throughout the year across southern South America, causing repeated heavy flooding in Argentina, Paraguay, and Uruguay. Africa. In 2016, most of Africa

experienced above-average temperatures. Several stations in Morocco reported temperatures among their highest since the start of their records in 1960. In Egypt, maximum temperatures reached 48°C on 27 and 28 May at Luxor. Record high temperatures were observed over Guinea, southern Mali, and Sierra Leone in August. South Africa reported the second-warmest year in its 66-year record. In the western Indian Ocean, Mauritius was record warm for

2016, while Mayotte and Comoros Islands each reported their second-warmest year. Generally, rainfall over the region covering 7.5°–15°N was above average, whereas it was below average over most of equatorial Africa and south of the equator. The strong El Niño at the beginning of 2016 contributed to drought in the first months of the year in southern Africa.

Europe and the Middle East. The annual land surface temperature for Europe was the third highest in the record dating to 1851, with a +1.41°C departure from the 1961–90 average. A long list of record temperatures in 2016 in European Russia, including its warmest winter [December–February (DJF) 2015/16] since national records began in 1891; seasonal departures ranged up to +6°C. In June, daily maximum temperature records were set in Israel, surpassing 44°C, more than +1°C higher than any previous record in the 67-year history. In early autumn Switzerland had its warmest September in its 153-year record, Germany reported 95 sites with new monthly records, and France observed temperatures up to 7°C above average. Several strong storms were reported across the continent. Norway was hit by several storms in January alone, and a new record wind speed of 48.9 m s⁻¹ was measured on 29 January at Krakenes, north of Bergen. On 23 June, the Netherlands reported hailstones up to 10 cm in its province of Brabant, causing approximately \$530 million U.S. dollars in damages.

Asia. Annual mean surface temperatures were above normal



Warmth in Europe: Europe and the Middle East were largely warmer than normal in 2016, as seen in near-surface air temperature anomalies ($^{\circ}\text{C}$) for Europe and the Middle East using interpolated CLIMAT data from the German Weather Service (Deutscher Wetterdienst; 1961–90 base period) for (a) DJF (winter), (b) March–May (MAM; spring), (c) June–August (JJA; summer), and (d) September–November (SON; autumn). (Fig. 7.37 in *State of the Climate in 2016*; see discussion there in section 7f.)

across most of Asia and Siberia in 2016, especially north of 60°N . India, South Korea, and Singapore each observed their warmest year on record, as did eastern Japan. China reported its third-warmest year since national records began in 1951. However, there was anomalous cold over parts of the continent: in January, -55.0°C was observed at Otgon station in western Mongolia, the second-lowest absolute minimum temperature for the country since records began in 1961. Wetter-than-usual conditions in central

Asia alleviated the 2014/15 drought in southern Russia. The summer monsoon (June–September) typically contributes about 75% of South Asia’s annual precipitation. The monsoon set in over Kerala, in southwestern India, on 8 June, seven days later than average; it covered the entire country by 13 July, two days earlier than normal. Monsoon seasonal rainfall over India was 97% of its 1951–2000 average. Hong Kong observed its wettest autumn on record.

Oceania. New Zealand observed its warmest year since its national

records began in 1909, while Australia reported its fourth-warmest in its 107-year record. In February, Severe Tropical Cyclone Winston (category 5) became one of the strongest tropical cyclones to make landfall in the southwest Pacific in recorded history. Winston killed 44 people and damaged or destroyed about 40,000 homes in Fiji on 20 February, with about 40% of the nation’s population significantly impacted by the storm. Damage in Fiji alone was estimated to be \$1.4 billion U.S. dollars. Across Micronesia, annual rainfall totals were mostly below average, setting some new all-time dry records, particularly in October 2015–March 2016. In the southwest Pacific the El Niño likely had its greatest impact in Vanuatu, where annual rainfall was the lowest on record at Lamap (1,197 mm) and Port Vila (956 mm), since 1961 and 1953, respectively, and was in the lowest 10% of observations at the other five observation stations on the island. From May through the end of the year, a strong negative Indian Ocean dipole event developed, contributing to Australia’s wettest May–October in the 117-year record.

REFERENCES

- Rosenfeld, J., 2015
The state of the horizon 2015. Bull. Amer. Meteor. Soc., 96, 1056–1058.

Source: State of the Climate in 2016 Special Supplement to the Bulletin of the American Meteorological Society
Vol. 98, No. 8, August 2017

Portion reproduced:
Executive Summary
(<http://www.ametsoc.net/sotc2016/ExecSummary.pdf>)

2016 Shatters Record for Alaska's Warmest Year

In 2016, Alaska experienced widespread warmth, shattering average temperature records that in some cases have been kept for more than a century. Many communities around the state recorded their highest average temperatures ever. That includes Alaska's largest city, Anchorage, where the average temperature was 4.5 degrees Fahrenheit above normal. Some places not only broke previous records, but exceeded them by huge margins (see map below). Another first: 2016 was the first time Nome's annual average temperature was above freezing. At 32.5 degrees F, it broke the previous (2014) record of 31.6 degrees F.

An outstanding feature of the 2016 climate was the remarkable persistence of the mild (for Alaska) weather. In a more typical year,

we'd expect there to be warmer than average days and weeks and periods of colder than average temperatures that roughly balance over the course of the year. This was most definitely not the case in 2016 though, when warmer-than-average days outnumbered cooler-than-normal days by an amazing 9 to 1 ratio. Nearly all of the cooler than normal days were squeezed in near the end of the year, from mid-November to mid-December (see graph below).

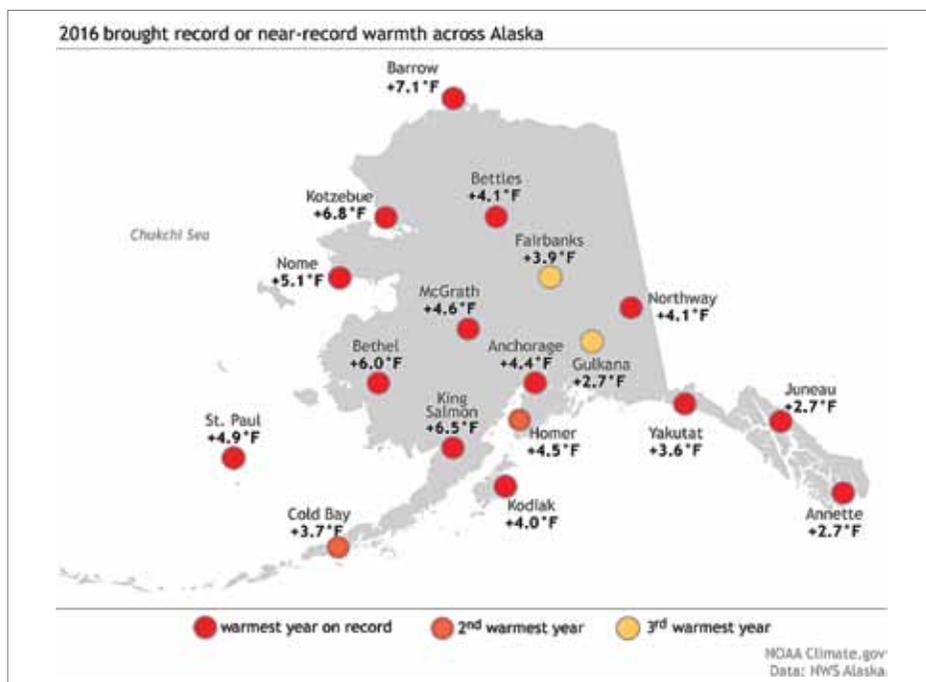
Superimposed on the long-term warming trend, the 3 to 7 degree temperature anomaly for most of the state in 2016 had a cascading effect on things like infrastructure, the Arctic ice pack, permafrost, tree lines on the mountains, and the subsistence way of life of many of the region's native peoples.

Snow melted much earlier than normal. On the big rivers of Alaska, many places saw record or near record early break-up of ice in the spring, and freeze-up on rivers in the autumn was delayed as well. Autumn sea ice extent was exceptionally low, with minimums near Alaska not reached until Oct 11, about two weeks later than the recent average. Most unusually, open water persisted in the central Chukchi Sea into December.

Despite the record warmth, the state's 2016 wildfire season was kept in check by the exceptionally wet conditions over parts of the state's interior. A total of over 500,000 acres burned in 2016, a number slightly above the longer term median. In contrast, 6.2 million acres burned during Alaska's record fire season in 2004. The state's second worst fire season occurred during Alaska's fourth warmest year, 2015, when 5.1 million acres were scorched.

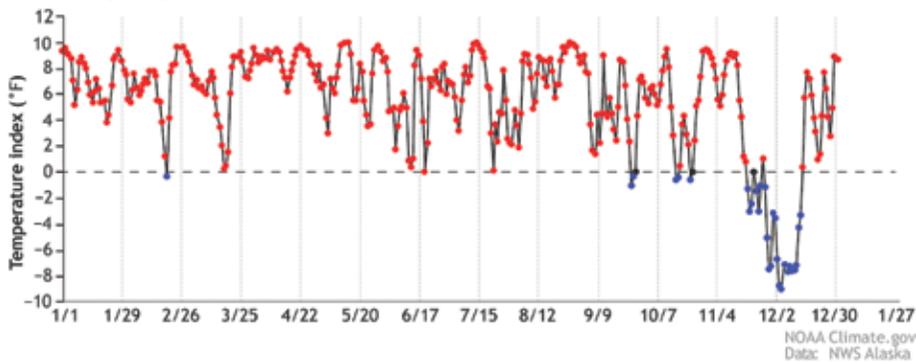
The widespread warmth in 2016 was the result of multiple factors: a strong El Niño last winter, persistently warm ocean surface temperatures near Alaska, and the long-term temperature increase due to human-produced greenhouse gases.

El Niño winters often feature persistent patterns, and early 2016 featured persistent low pressure in and near the Aleutians. When that happens, the low draws mild, southerly air over much of the state. Ocean temperatures near Alaska have been persistently above normal since 2013, in part because



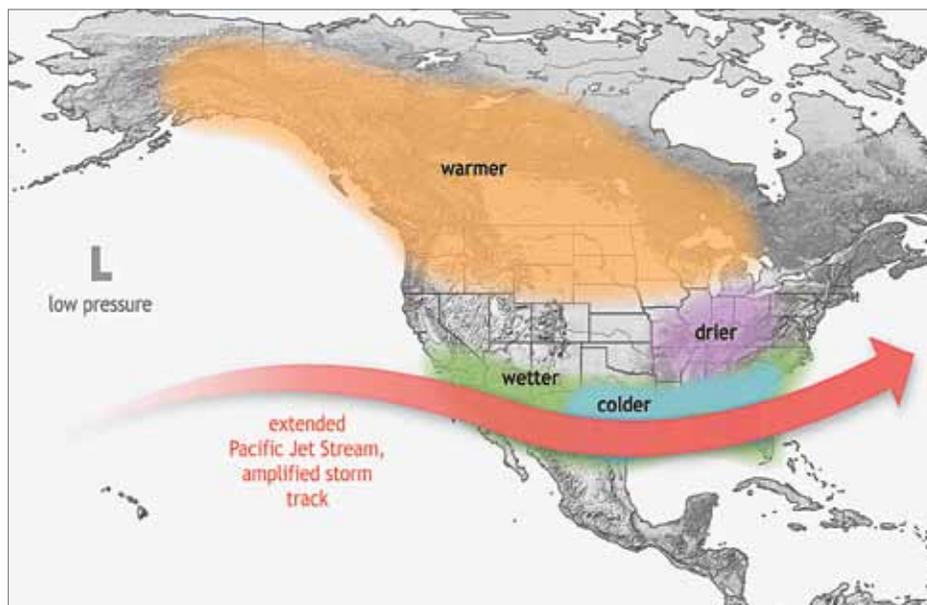
Sites of record and near-record warmth in Alaska in 2016. NOAA Climate.gov map adapted from original by Rick Thoman, NWS Alaska Region headquarters.

Alaska daily temperatures 2016



Difference from average daily temperature index based on 25 stations chosen to represent the diverse geography of Alaska. Alaska experienced only 30 below normal temperature days in 2016. NOAA Climate.gov graph adapted from original provided by Rick Thoman, NWS Alaska Region headquarters.

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Typical impacts of El Niño on the jet stream and winter climate across the United States. NOAA Climate.gov map by Fiona Martin.

of the prevailing weather patterns and in part due to larger scale ocean circulations. In fact, parts of the Eastern Bering Sea and North Pacific Ocean saw the warmest ocean surface temperatures of record during the 2016 spring and summer.

The persistent southerly flow during the winter left much of low-elevation mainland Alaska with significantly below average snowpack at the end of winter. In most areas, the snow also melted out early, enhancing the

spring warmth. 2016's warmth is also part of the long-term trend of rising Northern Hemisphere temperatures since the early twentieth century.

The northern part of the state was off to warm start in 2017. A series of storms forcing warm air north of the Bering Strait meant every community on Alaska's usually-frigid North Slope was above freezing on New Year's Day. Barrow reached 36 degrees F, tying an all-time January record.

Still, it is unlikely Alaska will set

a new warm temperature record in 2017. However, sea ice extent around Alaska and over most of the Arctic remains very low and what ice is out there is, for the most part, much thinner than in years past, a potentially significant factor for the upcoming summer. Ocean surface temperatures near Alaska are still warmer than normal, especially in the Bering Sea.

For the January through March late winter season, NOAA's Climate Prediction Center is forecasting only modest shifts away from the "baseline" odds (equal chances for above, near, or below average temperature or precipitation) for parts of the state, in part because of competing influences. The ongoing, but weakening, La Niña tilts the odds to the cold side, while low sea ice and warmer than average sea surface temperatures favor warmer than average temperatures. There are equal chances for above or below or near normal precipitation except in west and northwest Alaska, where low sea ice extent slightly favors significantly above precipitation.

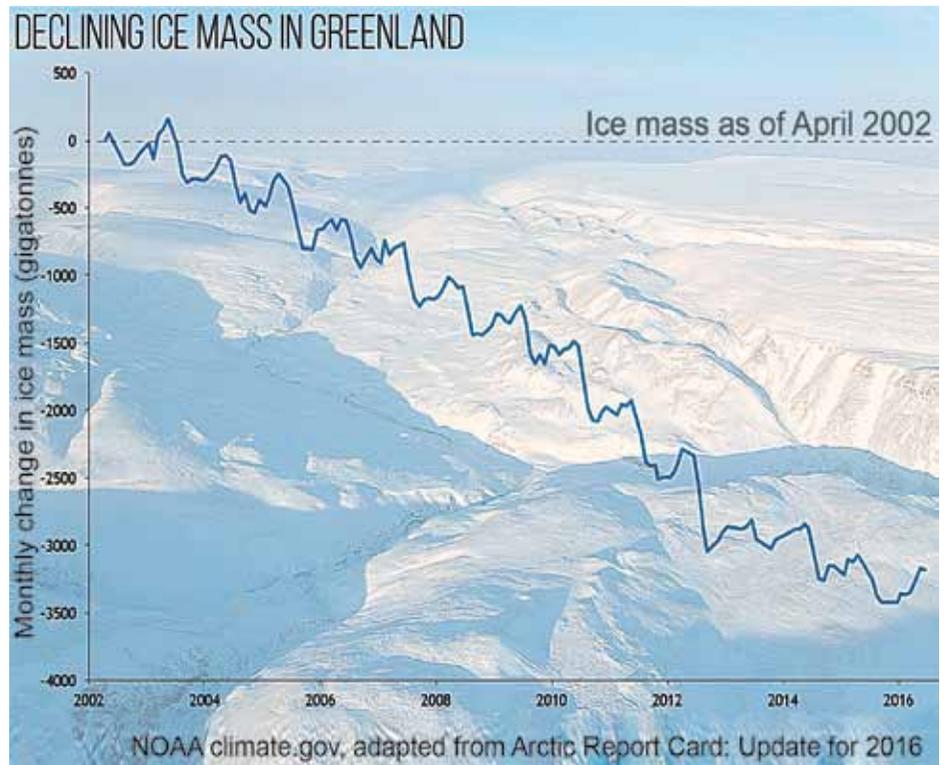
Source: <https://www.climate.gov/news-features/features/2016-shatters-record-alaskas-warmest-year>

Greenland Ice Mass Loss Continued in 2016

Although surface melt on the Greenland Ice Sheet did not set a new record in 2016, the long-term trend of decreasing mass continued, according to the latest Arctic Report Card from NOAA and its partners. Multiple factors likely contributed to ice loss in 2016: early melt-season onset, low reflectiveness (“albedo” to climate experts), and unusually high air temperatures and prolonged melt in some regions.

Adapted from the 2016 Arctic Report Card, this graph shows monthly changes in Greenland's total ice mass between April 2002 and April 2016. The ice mass amounts measured (vertical axis) are relative to the ice mass as of April 2002 (horizontal line set to 0). Report card authors estimated the changes based on measurements by NASA's Gravity Recovery and Climate Experiment (GRACE). The background photo is from Operation Ice Bridge.

The ups and downs in the graph track the accumulation of snow in the cold season and the melting of the ice sheet in the warm season. *The Arctic Report Card: Update for 2016* reported that between April 2015 and April 2016, Greenland lost approximately 191 gigatonnes of ice, roughly the same amount that was lost between April 2014 and April 2015. Though the April 2015–



Declining Ice Mass:
Monthly changes in Greenland's total ice mass between April 2002 and April 2016

April 2016 mass loss was lower than the average April-to-April decline over the entire observation period, it continued the long-term melt trend: approximately 269 gigatonnes per year from 2002 to 2016.

Over the course of the 2016 warm season, melting was especially pronounced in Greenland's southwest and northeast. Melt season lasted about 30 to 40 days longer than usual in the northeast, and about 15 to 20 days longer along the west coast. Albedo (the proportion of incoming solar radiation reflected back into space) was the fifth lowest since the year

2000. Albedo was particularly low in the southwest, and near normal only in the northwest.

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Reference

M. Tedesco et al. (2016). Greenland Ice Sheet. In Richter-Menge, J., Overland, J.E., Mathis, J. (2016) Arctic Report Card: Update for 2016.

Source: <https://www.climate.gov/news-features/featured-images/greenland-ice-mass-loss-continued-2016>



आप सभी को हार्दिक अभिवादन!

एनपीसीआईएल अपनी सफलता की यात्रा को निरंतर आगे बढ़ाते हुए उन्नति के एक नये शिखर की ओर अग्रसर हो रहा है। इस सफलता को जारी रखते हुए एनपीसीआईएल ने 31 मार्च, 2017 को 1000 मेगावाट की क्षमता वाली कुडनकुलम परमाणु ऊर्जा संयंत्र इकाई-2 (केकेएनपीपी-2) का वाणिज्यिक प्रचालन प्रारम्भ करके, देश की न्यूक्लियर विद्युत उत्पादन क्षमता को बढ़ाकर 6780 मेगावाट कर दिया है, जिससे प्रचालन के अन्तर्गत आने वाले रिएक्टरों की कुल संख्या 22 हो गई है।

विगत 3 वर्षों में एनपीसीआईएल ने केकेएनपीपी-1 एवं 2 वीवीईआर रिएक्टरों का प्रचालन आरम्भ करके न्यूक्लियर विद्युत उत्पादन की कुल क्षमता में लगभग 40% की बढ़ोत्तरी की है। इस महत्वपूर्ण प्रयास की वजह से देश के दक्षिणी क्षेत्र में बिजली की उपलब्धता में काफी सुधार हुआ है और तमिलनाडु, कर्नाटक, केरल एवं पुडुचेरी के लाखों घर रौशन हुए हैं। साथ ही वित्तीय वर्ष 2016-2017 के दौरान एनपीसीआईएल ने कुल 40,001 मिलियन यूनिट बिजली का रिकार्ड उत्पादन किया है। इसके अलावा

कुडनकुलम कार्यस्थल पर दो और रिएक्टरों का निर्माण कार्य भी फर्स्ट पोर ऑफ कॉन्क्रीट के साथ शुरू हो चुका है। इनमें से प्रत्येक की क्षमता 1000 मेगावाट की होगी।

इसके साथ ही मुझे आप सबको ये बताते हुये अत्यंत हर्ष का अनुभव हो रहा है कि केंद्र सरकार द्वारा भारतीय परमाणु ऊर्जा कार्यक्रम को और भी अधिक गति प्रदान करने के उद्देश्य से फ्लीट मोड में 10 नयी स्वदेशी 700 मेगावाट (पीएचडब्ल्यूआर) परमाणु ईकाइयाँ और 1000 मेगावाट (वीवीईआर) प्रत्येक की क्षमता वाले कुडनकुलम 5-6 इकाई लगाने के लिए प्रशासनिक एवं वित्तीय मंजूरी प्राप्त हुई है। साथ ही साथ हाल ही

एनपीसीआईएल अपनी सफलता की यात्रा को निरंतर आगे बढ़ाते हुए उन्नति के एक नये शिखर पर अग्रसर हो रहा है। इस सफलता को जारी रखते हुए एनपीसीआईएल ने 31 मार्च, 2017 को 1000-मेगावाट कुडनकुलम परमाणु ऊर्जा संयंत्र इकाई-2 (केकेएनपीपी-2) का वाणिज्यिक संचालन प्रारम्भ किया

में भारत और रशिया के बीच कुडनकुलम परमाणु विद्युत संयंत्र 5 एवं 6 के लिये तीन अनुबंधों पर भी हस्ताक्षर हो गये हैं।

इन रिएक्टरों का निर्माण एनपीसीआईएल द्वारा चरण बद्ध तरीके से किया जायेगा। वर्तमान में निर्माणाधीन रिएक्टरों के पूर्ण होने पर निकट भविष्य में देश में स्थापित परमाणु ऊर्जा की क्षमता लगभग 13,000 मेगावाट हो जायेगी। केंद्र सरकार द्वारा अनुमोदित 10 नये स्वदेशी 700 मेगावाट के रिएक्टरों की स्थापना से अगले कुछ वर्षों में भारतीय उद्योग जगत के विकास और रोजगार के नये अवसर भी सुनिश्चित होंगे, जिससे स्वच्छ तरीके से बिजली बनाने के प्रयासों को बल मिलेगा। इन परमाणु विद्युत संयंत्रों में भी संरक्षा प्रणालियाँ आधुनिकतम एवं अंतर्राष्ट्रीय मानकों के अनुरूप होंगी। भारत सरकार द्वारा इन नये पीएचडब्ल्यूआर की यह स्वीकृति भारतीय वैज्ञानिकों और अभियंताओं की व्यापक क्षमताओं को उजागर करती है।

स्वदेशी पीएचडब्ल्यूआर रिएक्टरों के साथ साथ एलडब्ल्यूआर रिएक्टरों की स्थापना की योजना का कार्यान्वयन भी शीघ्रता से

इन रिएक्टरों का निर्माण एनपीसीआईएल द्वारा चरणबद्ध तरीके से किया जायेगा। वर्तमान में स्थापित निर्माणाधीन रिएक्टरों के पूर्ण होने पर निकट भविष्य में देश में स्थापित परमाणु ऊर्जा की क्षमता लगभग 13,000 मेगावाट हो जायेगी। केंद्र सरकार द्वारा अनुमोदित 10 नये स्वदेशी 700 मेगावाट के रिएक्टरों की स्थापना से अगले कुछ वर्षों में भारतीय उद्योग जगत के विकास और रोजगार के नये अवसर भी सुनिश्चित होंगे, जिससे स्वच्छ तरीके से बिजली बनाने के प्रयासों को बल मिलेगा

चल रहा है। साथ ही आपको यह बताते हुए भी खुशी हो रही है कि आंध्र प्रदेश के श्रीकाकुलम में आने वाले कोवाडा परियोजना के लिए प्रथम फेज में लगभग 484 एकड़ की भूमि राज्य सरकार द्वारा एनपीसीआईएल को आवंटित की गयी है। यहाँ पर 6 (6 X 1208 मेगावाट) विद्युत संयंत्र प्रस्तावित हैं।

आज की तारीख में दुनिया के लिए यह महत्वपूर्ण है कि अपने वातावरण को किसी भी प्रकार की हानि पहुँचाये बिना बिजली की वैश्विक माँग को किस तरीके से पूरा किया जाए। आगे आने वाले समय में परमाणु ऊर्जा की हिस्सेदारी और भी अधिक बढ़ेगी, क्योंकि यह पर्यावरण के अनुकूल, सुरक्षित, स्वच्छ एवं हरित तरीके से बिजली उत्पादन में पूरी तरह से सक्षम है। ग्रीनहाउस गैस उत्सर्जन को रोकने एवं बढ़ते ग्लोबल वार्मिंग पर अंकुश लगाने के लिए किये जा रहे वैश्विक प्रयासों के अनुसार एनपीसीआईएल भी पूर्ण रूप से स्वच्छ ऊर्जा उत्पादन के लिए प्रयासरत है। साथ ही पर्यावरण संरक्षण के लिए भी एनपीसीआईएल पूर्णतया प्रतिबद्ध है। इस अत्यंत महत्वपूर्ण मुद्दे के प्रति हमारी प्रतिबद्धता एनपीसीआईएल के 'पर्यावरण पर्यवेक्षक कार्यक्रम' (ईएसपी) के अन्तर्गत तैयार किए

गये कई कार्यक्रमों से प्रतिबिंबित होती है। यह कार्यक्रम पर्यावरण संरक्षण और पुनरोद्धार के लिए एनपीसीआईएल की एक स्वैच्छिक पहल है। एनपीसीआईएल अपने इस प्रयास को पूर्ण निष्ठा के साथ निभा रहा है। इस अद्वितीय कार्यक्रम के माध्यम से वनस्पतियों और जीवों के संरक्षण के लिए कई विशिष्ट कार्यों को किया जाता है।

सुरक्षित एवं पर्यावरण के अनुकूल, स्वच्छ, हरित और किफायती विद्युत उत्पादन करने के साथ ही हम अपनी नीतियों एवं कार्यों के माध्यम से सामाजिक समावेशन के मार्ग पर निरंतर आगे बढ़ रहे हैं। यही कारण है कि हम निगमित सामाजिक दायित्व के तहत अपने विद्युत संयंत्रों के आसपास के क्षेत्रों में शिक्षा, स्वास्थ्य, बुनियादी ढांचे के विकास एवं सामुदायिक कल्याण के कार्यों में सहभागिता कर क्षेत्र के समग्र विकास में अपना विनम्र योगदान कर रहे हैं।

इसके साथ ही, लोगों को परमाणु ऊर्जा के लाभों से अवगत कराने के लिए एनपीसीआईएल द्वारा बहुआयामी और व्यापक राष्ट्रव्यापी जन-जागरूकता कार्यक्रम का निरंतर आयोजन किया जा रहा है। जिसमें व्याख्यान, संगोष्ठी, कार्यशालाएँ, प्रदर्शनियाँ, चलित प्रदर्शनी (एटम ऑन व्हील्स) आदि शामिल हैं। सिर्फ इतना ही नहीं, लोगों को परमाणु ऊर्जा संयंत्र को करीब से जानने के लिए वहाँ का भ्रमण भी कराया जाता है। एनपीसीआईएल देश-भर में स्थित विज्ञान केन्द्रों में सिलसिलेवार तरीके से परमाणु ऊर्जा विषय पर स्थायी दीर्घाओं

सुरक्षित एवं पर्यावरण के अनुकूल, स्वच्छ, हरित और किफायती विद्युत उत्पादन करने के साथ ही हम अपनी नीतियों एवं कार्यों के माध्यम से सामाजिक समावेशन के मार्ग पर निरंतर आगे बढ़ रहे हैं।

का निर्माण कर रहा है, जिससे हर वर्ष लाखों आगंतुकों को परमाणु ऊर्जा से जुड़े विभिन्न आयामों को जानने एवं समझने का मौका मिलता है।

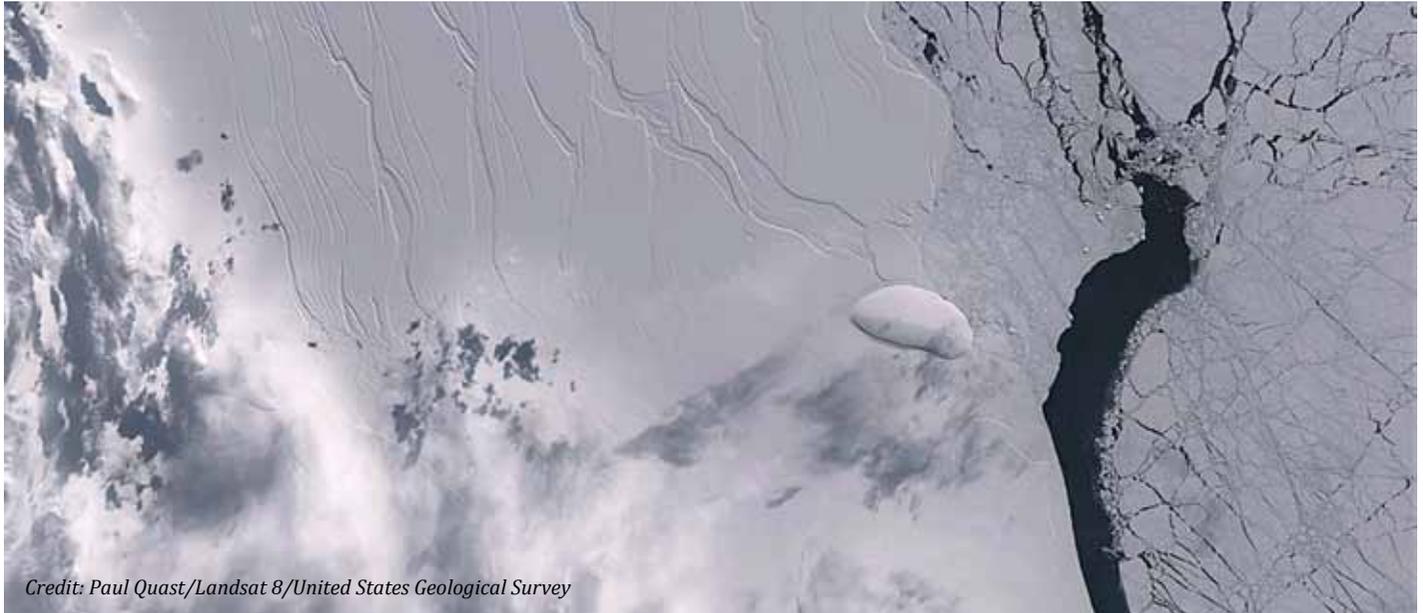
संरक्षा हमारी सर्वोपरि प्राथमिकता है, जो हमारे कार्यों में सतत रूप से परिलक्षित होती रही है। अपने इन अथक प्रयासों के लिए एनपीसीआईएल को हाल ही में नेशनल सेफ्टी काउंसिल ऑफ इंडिया (एनएससीआई) द्वारा संरक्षा पुरस्कार, इंस्टीट्यूट ऑफ पब्लिक एंटरप्राइज (आईपीई) द्वारा सतर्कता उत्कृष्टता पुरस्कार और परमाणु ऊर्जा विभाग द्वारा आयोजित संरक्षा एवं व्यावसायिक स्वास्थ्य पेशेवर सम्मेलन में सम्मानित किया गया है।

आज हमारा देश, स्वच्छ ऊर्जा के विकल्प की ओर सुनिश्चित रूप से आगे बढ़ रहा है। देश में सुरक्षित और किफायती परमाणु ऊर्जा उत्पादन के लगभग पाँच दशकों के अनुभव के साथ, परमाणु ऊर्जा से विद्युत उत्पादन को एक उत्कृष्ट एवं बेहतरीन स्रोत के रूप में पहचाना गया है, जो आज की तारीख में बहुत अधिक महत्वपूर्ण है। साथ ही, आज ग्लोबल वार्मिंग से निपटने और आर्थिक प्रगति को बढ़ावा देने के संदर्भ में परमाणु ऊर्जा का अपना अलग मुकाम है। और इस प्रकार एनपीसीआईएल में हम पूर्ण उत्साह के साथ भविष्य में भी कार्बन उत्सर्जन रहित तकनीक के द्वारा विद्युत उत्पादन को आगे बढ़ाते हुए देश की प्रगति के मार्ग को प्रशस्त करने में अपनी महत्वपूर्ण भूमिका निभाते रहेंगे। इसी आशा एवं विश्वास के साथ नव नर्ष की बहुत बहुत शुभकामनायें...

आपका
(एस. के. शर्मा)

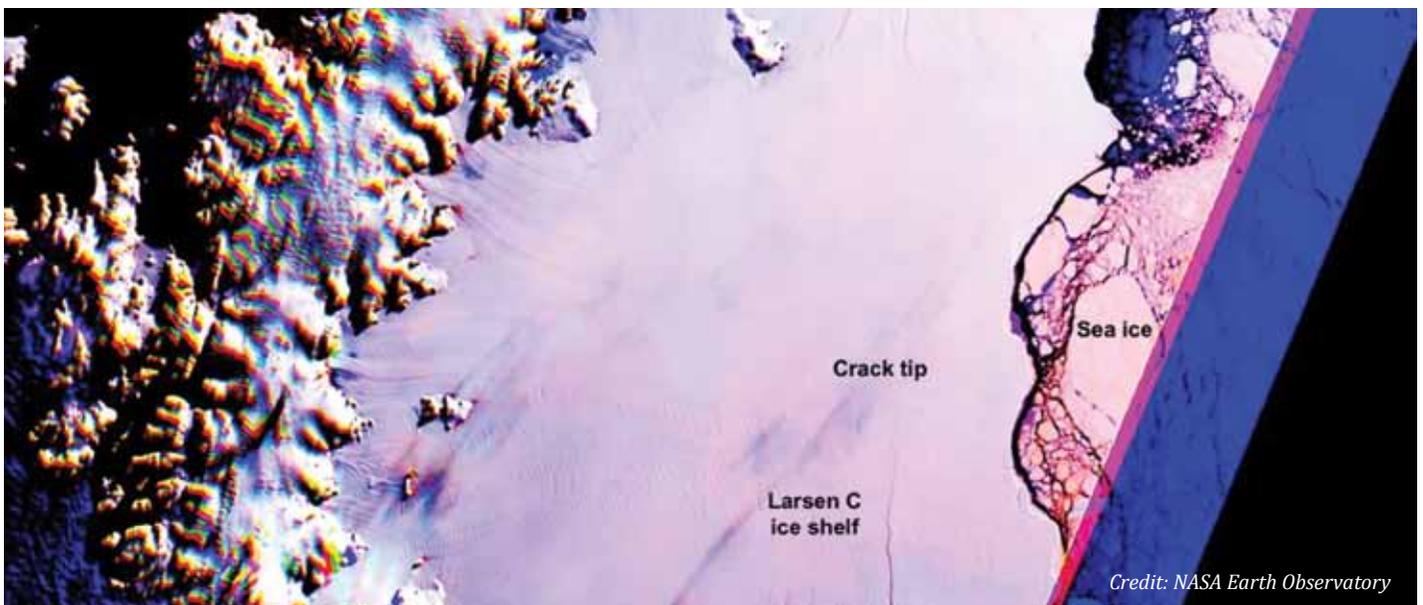
How An Iceberg Four Times the Size of Delhi Broke Away from Antarctica

Antarctica's Larsen C ice shelf — Antarctica's fourth largest — began developing a crack in 2010. By November 2016, the crack had grown into a rift that was 70 miles (113 km) long and 300 feet (91 m) wide. The rift continued to grow for the next several months, reaching a size of about 109 miles (175 km) in length and 1,500 feet (460 m) in width by January 2017 and later to about 124 miles (200 km) in length on July 6, 2017.



Credit: Paul Quast/Landsat 8/United States Geological Survey

The massive crack in Antarctica's Larsen C ice shelf as photographed on March 8, 2017



Credit: NASA Earth Observatory

The massive crack in Antarctica's Larsen C ice shelf as photographed on March 8, 2017

Eventually, a gigantic mass of ice — measuring approximately 2,240 square miles (5,800 square kilometers) in size and weighing about one trillion tons — broke away from the parent Larsen C ice shelf between July 10 and July 12 and landed up floating in the sea.

Plants Under Operation

Unit - Location	Reactor Type	Present Capacity (MW)	Date of Commencing Commercial Operation
TAPS-1, Tarapur, Maharashtra	BWR	160	October 28, 1969
TAPS-2, Tarapur, Maharashtra	BWR	160	October 28, 1969
TAPS-3, Tarapur, Maharashtra	PHWR	540	August 18, 2006
TAPS-4, Tarapur, Maharashtra	PHWR	540	September 12, 2005
RAPS-1*, Rawatbhata, Rajasthan	PHWR	100	December 16, 1973
RAPS-2, Rawatbhata, Rajasthan	PHWR	200	April 1, 1981
RAPS-3, Rawatbhata, Rajasthan	PHWR	220	June 1, 2000
RAPS-4, Rawatbhata, Rajasthan	PHWR	220	December 23, 2000
RAPS-5, Rawatbhata, Rajasthan	PHWR	220	February 1, 2010
RAPS-6, Rawatbhata, Rajasthan	PHWR	220	March 31, 2010
MAPS-1, Kalpakkam, Tamil Nadu	PHWR	220	January 27, 1984
MAPS-2, Kalpakkam, Tamil Nadu	PHWR	220	March 21, 1986
NAPS-1, Narora, Uttar Pradesh	PHWR	220	January 1, 1991
NAPS-2, Narora, Uttar Pradesh	PHWR	220	July 1, 1992
KAPS-1, Kakrapar, Gujarat	PHWR	220	May 6, 1993
KAPS-2, Kakrapar, Gujarat	PHWR	220	September 1, 1995
Kaiga-1, Kaiga, Karnataka	PHWR	220	November 16, 2000
Kaiga-2, Kaiga, Karnataka	PHWR	220	March 16, 2000
Kaiga-3, Kaiga, Karnataka	PHWR	220	May 06, 2007
Kaiga-4, Kaiga, Karnataka	PHWR	220	January 20, 2011
KKNPP-1, Kudankulam, Tamil Nadu	VVER	1000	December 31, 2014
KKNPP-2, Kudankulam, Tamil Nadu	VVER	1000	March 31, 2017
Total		6780	

*Owned by DAE

Projects Under Construction

Project	Capacity (Mw)
KAPP-3&4, Kakrapar, Gujarat	2 X 700 PHWRs
RAPP-7&8, Rawatbhata, Rajasthan	2 X 700 PHWRs
KKNPP-3&4	2 X 1000 PHWRs
GHAVP-1&2	2 X 700 PHWRs
Total	6200
PFBR**, Kalpakkam	1 X 500 FBR

**Being implemented by BHAVINI

ASIA

RISING ON WORLD NUCLEAR POWER MAP...



While Asia constitutes more than one-third in terms of numbers of operating nuclear power plants today, the picture will be distinctively different in future. Asian region is poised to become a world leader in nuclear power development. Of the 57 units currently under construction in the world, two-thirds (39 units) are in Asia. Similarly, of the 162 units planned world over, 97 will be set up in Asia.