ISSN 0971-9911
LC No.:99936677

Nu-Power

Vol. 27 (3-4), 2016 - Published in 2017

An International Journal of Nuclear Power

COP21/22

1.5C is better than 2C

It's high time we put brakes on global warming before it is too late

KKNPP-1:
Dedication to Indo-Russian Friendship & Cooperation

Kudankulam Nuclear Power Plant unit-1 (KKNPP-1), the 21st nuclear power reactor in India, was dedicated to Indo-Russian friendship and cooperation on August 10, 2016. The unit was jointly dedicated by Hon'ble Prime Minister of India Shri Narendra Modi and His Excellency Mr. Vladimir Putin, President of the Russian Federation. The event was organised via a video conference.

The unit is already in service, having started commercial operation on December 31, 2014.

KKNPP-2:
Dedication to Indo-Russian Partnership

On October 15, 2016, the second 1000-MW reactor Unit-2 at Kudankulam Nuclear Power Project, KKNPP-2, was dedicated to the Indo-Russian Partnership, during the BRICS Summit, by the Hon'ble Prime Minister of India Shri Narendra Modi and His Excellency Mr. Vladimir Putin, President of the Russian Federation. The VVER-type nuclear power reactor is an identical twin of KKNPP Unit-1.

KKNPP-2:
First Criticality to Full -Power Operation

The second unit of Kudankulam Nuclear Power Project (KKNPP-2) was synchronised to the southern grid on August 29, 2016 at 1117 hours, following which it began generating 245 MW initially. The Unit had attained first criticality (controlled self-sustaining nuclear fission chain reaction in the reactor for the first time) on July 10, 2016.

First Criticality

Synchronisation to Grid

Full-Power Operation

KKNPP-2 attained its full-power capacity of 1000 MW on January 21, 2017.

TO GIVE THEM
A CLEANER TOMORROW
WE NEED
TO GIVE THEM
A CLEANER TODAY

Thinking about their wellness is thinking about India's wellness. At Nuclear Power Corporation of India Limited, we pledge that each one of us will be the force to energise the Swachh Bharat Abhiyan. Because we believe it's our duty to give them back a better tomorrow.

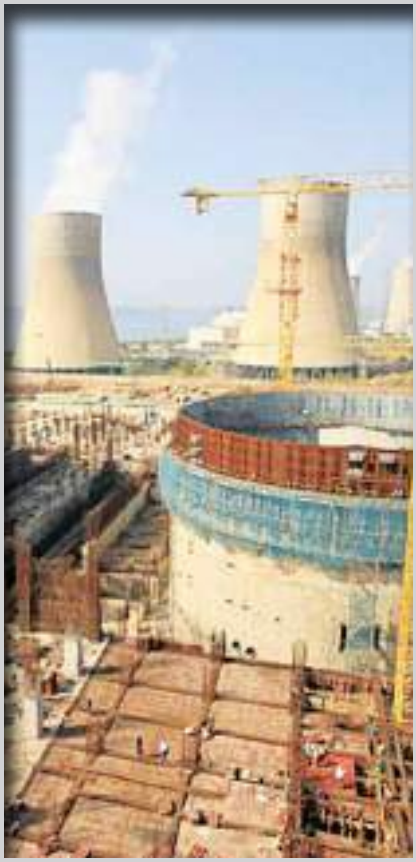
Issued in Public Interest by

एनपीसीआईएल
NPCIL

Nuclear Power Corporation of India Limited
(A Government of India Enterprises)

Nuclear power is safe, pollution-free and combats global warming

Contents



Nu-Power - An International Journal of Nuclear Power is published half yearly by Nuclear Power Corporation of India Limited

All correspondence should be addressed to

The Editor,
Nu-Power - An International Journal of Nuclear Power
9N17, Vikram Sarabhai Bhavan, Anushakti Nagar, Mumbai - 400 094, INDIA
Fax: 91-22-25991926 | E-mail: amritesh@npcil.co.in | Website: www.npcil.nic.in

Nu-Power is available free of charge to a limited number of readers. Requests for copies should be made to the Editor.

Environment on Top Post-COP22

Amritesh Srivastava
Editor

Actions envisaged in the UN's historic Paris Climate Change Agreement received enormous boost at the COP22 agreement arrived at in Marrakech by 200 countries in November 2016. Slated for achievement of targets by the end of 2018, the strategies articulated by nations bring good tidings in an otherwise bleak scenario of a planet under constant threat from environmental impairment.

Potentially irreversible changes on the planet have already begun to take place.

We are being pummelled by a monster of our own making and have wondered many a time whether all is lost. The World Health Organization says more than nine out of 10 people worldwide live in areas with excessive air pollution; over 3 million die annually of strokes, heart disease and lung cancer. Can we ever bring back the environmental tidiness of the good old days of the pre-Industrial era? The background score from Paris Marrakech sounds redeeming because we might soon turn the tide over. In this issue **we wish to set your sights on the COP21/22 meets** in Paris and Marrakech, the epoch-making moment of a record number of 171 nations signing an international agreement on a single day and the fast-tracking of action-plans by representatives of countries. Modern civilization has come to us at a price we cannot afford any more. The unforeseen consequences of global warming in 2016 made the world sweat with dread. **Hence the lead story relating to COP21/22,** and the cheer these summits bring.

Consider the facts:

- 2015 surpassed 2014 as the warmest year since the mid 19th century
- Carbon dioxide concentration hit a new high
- Number of extremely hot days during the year became abnormally high
- Ice-loss from glaciers crossed all thresholds of the past 36 years

This issue **carries substantiation of these shockers** by credible bodies like NASA and the American Meteorological Society in the hope that the information will catalyze actions for controlling the root cause of this malaise- GHG emission- by those with the power to manifest such actions.

171 countries converged in Paris and as the UN Secretary General, Ban ki-Moon, summed it up: "signed a new covenant with the future." India was quick to announce its plans to quadruple the country's renewable power capacity to 175 gigawatts by 2022. Since renewable alone cannot meet the country's future demands of power, our planners have included nuclear as a viable supplement in their covenant with the future, with several nuclear reactors on the anvil. Atomic power holds the potential to arrest global warming. The dedication of Unit-1 of Kudankulam Nuclear Power Project (KKNP) to Indo-Russian cooperation jointly by the Hon'ble P.M of India and H.E President of Russian Federation in the presence of Hon'ble C.M of Tamil Nadu, and the synchronization of KKNPP Unit-2 to the southern grid, are celebratory milestones in the journey of India's nuclear power. **Read the report in this issue.**

Having reached the stage of maturity, India's nuclear power programme continues to evolve with incremental and breakthrough improvements undertaken continually in our plants. Read about these innovations in the pages that follow. Plus the usual assortment of news, events and regular features is there too.

And do write back to the Editorial Board in case you have comments or suggestions. A reader-centric journal matters to us as much as it does to you. Help us renew Nu-Power each time we present it to you.

HAPPY READING!

(Amritesh Srivastava)

COP21/22

Special

COP21: Historic Paris Agreement on Climate Change

195 Nations Set Path to Keep Temperature Rise Well Below 2 Degrees Celsius

An historic agreement to combat climate change and unleash actions and investment towards a low carbon, resilient and sustainable future was agreed by 195 nations in Paris on December 12, 2015.

The Paris Agreement for the first time brings all nations into a common cause based on their historic, current and future responsibilities.

The universal agreement's main aim is to keep a global temperature rise this century well below 2 degrees Celsius and to drive efforts to limit the temperature increase even further to 1.5 degrees Celsius above pre-industrial levels.

The 1.5 degree Celsius limit is a significantly safer defense line against the worst impacts of a changing climate.

Additionally, the agreement aims to strengthen the ability to deal with the impacts of climate change.

To reach these ambitious and important goals, appropriate financial flows will be put in place, thus making stronger action by developing countries and the most vulnerable possible, in line with their own national objectives.

"The Paris Agreement allows each delegation and group of countries to go back home with their heads held high. Our collective effort is worth more than the sum of our individual effort. Our responsibility to history is immense" said Laurent Fabius, President of the COP21 UN Climate change conference and French Foreign Minister.

The minister, his emotion showing as delegates started to rise to their feet, brought the final gavel down on the agreement to open and sustained acclamation across the plenary hall.

French President Francois Hollande told the assembled delegates: "You've done it, reached an ambitious agreement, a binding agreement, a universal agreement. Never will I be able to express more gratitude to a conference. You can be proud to stand before your children and grandchildren."

UN Secretary General Ban Ki-moon said: "We have entered a new era of global cooperation on one of the most complex issues ever to confront humanity. For the first time, every country in the world has pledged to curb emissions, strengthen resilience and join in common cause to take common climate action. This is a resounding success for multilateralism."

Christiana Figueres, Executive Secretary of the UN Framework Convention on Climate Change (UNFCCC), said: "One planet, one chance to get it right and we did it in Paris. We have made history together. It is an agreement of conviction. It is an agreement of solidarity with the most vulnerable. It is an agreement of long-term vision, for we have to turn this agreement into an engine of safe growth."

"Successive generations will, I am sure, mark the 12 December 2015 as a date when cooperation, vision, responsibility, a shared humanity and a care for our world took centre stage," she said.

Agreement Captures Essential Elements to Drive Action Forward

The Paris Agreement and the outcomes of the UN climate conference (COP21) cover all the crucial areas identified as essential for a landmark conclusion:

- Mitigation – reducing emissions fast enough to achieve the temperature goal

- A transparency system and global stock-take – accounting for climate action
- Adaptation – strengthening ability of countries to deal with climate impacts
- Loss and damage – strengthening ability to recover from climate impacts
- Support – including finance, for nations to build clean, resilient futures

As well as setting a long-term direction, countries will peak their emissions as soon as possible and continue to submit national climate action plans that detail their future objectives to address climate change.

This builds on the momentum of the unprecedented effort which has so far seen 188 countries contribute climate action plans to the new agreement, which will dramatically slow the pace of global greenhouse gas emissions.

The new agreement also establishes the principle that future national plans will be no less ambitious than existing ones, which means these 188 climate action plans provide a firm floor and foundation for higher ambition.

Countries will submit updated climate plans – called nationally determined contributions (NDCs) – every five years, thereby steadily increasing their ambition in the long-term.

Climate action will also be taken forward in the period before 2020. Countries will continue to engage in a process on mitigation opportunities and will put added focus on adaptation opportunities. Additionally, they will work to define a clear roadmap on ratcheting up climate finance to USD 100 billion by 2020.

This is further underlined by the agreement's robust transparency and accounting system, which will provide clarity on countries' implementation efforts, with flexibility for countries' differing capabilities.

"The Paris Agreement also sends a powerful signal to the many thousands of cities, regions, businesses and citizens across the world already committed to climate action that their vision of a low-carbon, resilient future is now the chosen course for humanity this century," said Ms Figueres.

Agreement Strengthens Support to Developing Nations

The Paris Agreement underwrites adequate support to developing nations and establishes a global goal to significantly strengthen adaptation to climate change through support and international cooperation.

The already broad and ambitious efforts of developing countries to build their own clean, climate-resilient futures will be supported by scaled-up finance from developed countries and voluntary contributions from other countries.

Governments decided that they will work to define a clear roadmap on ratcheting up climate finance to USD 100 billion by 2020 while also before 2025 setting a new goal on the provision of finance from the USD 100 billion floor.

Ms. Figueres said. "We have seen unparalleled announcements of financial support for both mitigation and adaptation from a multitude of sources both before and during the COP. Under the Paris Agreement, the provision of finance from multiple sources will clearly be taken to a new level, which is of critical importance to the most vulnerable."

International cooperation on climate-safe technologies and building capacity in the developing world to address climate change are also significantly strengthened under the new agreement.

Source: UNFCC, December 12, 2015 (Abridged)

As per provisions, the Paris Agreement entered into force on November 4, 2016, 30 days after 55 countries, representing 55 percent of global emissions, deposited their instruments of ratification, acceptance or accession. Indeed, the tally on Oct 4, 2016 exceeded both these thresholds, with 73 countries and the European Union, exceeding 55 percent of emissions. As of January 26, 2017, 127 parties have ratified the Agreement and there are 194 Signatories.

COP22

Nations Take Forward Global Climate Action at 2016 UN Climate Conference

Countries accelerated global climate action across a broad range of areas at the 2016 United Nations climate change conference as they fast-tracked the political and practical aims of the historic Paris Climate Change Agreement.

Multi-billion and multi-million dollar packages of support for clean technologies; building capacity to report on climate action plans, and initiatives for boosting water and food security in developing countries were also among the many new announcements and initiatives launched.

Meanwhile governments set a rapid deadline of 2018 to complete the rule book for operationalizing the Paris Agreement to ensure confidence, cooperation and its success over the years and decades to come.

Businesses, investors, cities and local governments also issued new climate change commitments, adding to the thousands announced in the run up to the Paris climate conference last year.

For example, a club of sub-national governments, the Under 2 Coalition, who have committed to reduce their emissions by at least 80 percent by 2050, announced their membership has grown to 165.

- The combined GDP of these 165 members is close to $26 trillion – a third of the global economy – and cover a population of around one billion people living in North America, Europe, Latin America, Africa and Asia.

The Climate Vulnerable Forum a group of more than 40 vulnerable nations, released a declaration that strengthens the call to limit global temperature rise to as close to 1.5 degrees Celsius as possible.

- Their Marrakech Vision commits these countries to various ambitious aims, including achieving 100% renewable energy between 2030 and 2050.

Several countries – Canada, Germany, Mexico and the United States – announced ambitious climate strategies out to 2050, reflecting the long-term goal of the Paris Agreement to achieve climate neutrality and a low-emission world in the second half of the century.

Patricia Espinosa, Executive Secretary of the UN Framework Convention on Climate Change (UNFCCC), said, “The landmark Paris Agreement set the course and the destination for global climate action. Here in Marrakech, governments underlined that this shift is now urgent, irreversible and unstoppable”.

This new era of implementation and action for climate and for sustainable development was captured in the Marrakech Action Proclamation. “I would like to pay tribute to the Government of Morocco and the President of the Conference, Mr. Salaheddine Mezouar, for their remarkable success. COP22 has been what it needed to be, a COP of action that has accelerated progress under the Paris Agreement across finance, new initiatives, ambition and solidarity between nations and across continents,” she said.

Mr. Mezouar, President of the 22nd Conference of the Parties (COP22), said, “The Kingdom of Morocco is fully engaged in the success of this COP and will energetically carry out its role as President. At the outcome of the last fifteen days, our vision has been

consolidated and we are working to make concrete progress and to carry out breakthrough actions from now until the end of 2017".

"It will be necessary to respect the commitment of $100 billion dollars from now until 2020. Faced with the magnitude of what is required for dealing with the impacts of climate change, turning billions into trillions is indispensable. 2017 must be the year of large scale projects, of mobilizing finance, and accessing financial facilities that will be necessary for adaptation," he added.

Ms. Espinosa added, "During COP22, the strength, the support for and the robustness of the Paris Agreement was furthered underlined, with nine more ratifications received at the UN in New York and the promise of many more to come. Nations reaffirmed that the agreement is in their national interests and a key catalyst to a better, more prosperous future for their citizens".

COP22, hosted by Morocco's King Mohammed VI, saw over 50 Presidents, Prime Ministers and Vice Presidents, along with over 110 Ministers and Heads of Delegation. It also witnessed the first meeting of the Paris Agreement's top governing body following early entry into force of the Paris Agreement on 4 November.

At the close Fiji was announced as the incoming President of the 2017 UN climate conference (COP23) which will be hosted by the UNFCCC in Bonn

Key Outcomes and Initiatives

Rule Book

A crucial outcome of the Marrakech climate conference was to move forward on writing the rule book, or operational manual, of the Paris Agreement.

The agreement calls for a significant boost of transparency of action, including for measuring and accounting emissions reductions, the provision of climate finance, and technology development and transfer.

It also includes work to design the adaptation communications, which is the primary vehicle under the Paris Agreement to share individual adaptation efforts and support needs.

Countries pressed forward on this and set a fast track date of 2018 for completion. Countries have already built the foundation for this by peer assessing each other's actions to cut emissions through a transparent process that began in 2014.

Multilateral Assessment

At COP22, seven developing countries presented updates and opened themselves to examination by their peers on how they are moving to a low-carbon economy.

This fits into delivering a system for monitoring, verifying and reporting actions and opens the door to greater ambition under their climate action plans, called Nationally Determined Contributions (NDCs).

Capacity-building Initiative for Transparency

During COP22, the Global Environment Facility (GEF), a multilateral funding arm, announced a Capacity-building Initiative for Transparency backed by 11 developed country donors providing $50 million-worth of funding.

NDC Partnership

Implementation of climate action plans also received a boost from the launch of the NDC Partnership — a coalition of developing and developed countries and international institutions working together to ensure countries receive the technical and financial support they need to speedily meet their climate and sustainable development goals.

Progress by Governments

Governments made progress across key areas of climate action, including climate finance, adaptation, capacity building, technology and gender-responsiveness. This is an overview:

Climate finance

- Countries pledged more than $81 million to the Adaptation Fund, surpassing its target for the year.
- Countries pledged over $23 million to the Climate Technology Centre and Network, which supports developing countries with climate technology development and transfer. As the implementation arm of the Technology Mechanism, the CTCN is a key institution to enable nations realize their commitments under the Paris Agreement.
- The Green Climate Fund (GCF) announced the approval of the first two proposals for the formulation of National Adaptation Plans: Liberia for $2.2 million and Nepal for $2.9 million. Another 20 countries are expected to have their proposals approved soon with up to $3 million each.

- Overall, the GCF is on track to approve $2.5 billion worth of projects.

Adaptation

- The **Adaptation of African Agriculture** initiative, which includes 27 participating countries, showcased how water, soil, climate risk management, funding of small farmers and the Sustainable Development Goals (SDGs) are being addressed with an overall aim of advancing adaptation.

Loss and Damage

- A new five-year framework under the **Warsaw International Mechanism on Loss and** Damage (WIM) will deal with impacts that are not addressed through planned adaptation, including displacement, migration and human mobility and comprehensive risk management.

Capacity Building

- In another show of accelerated climate action, countries operationalized the Paris Agreement's Paris Committee on Capacity Building. It will help build capacity for climate action in developing countries. The members have been elected and the committee will take up its work in May 2017.

Technology

- During COP22, governments learned that in 2016 over 30 projects for cutting emissions with technology transfer objectives were approved by the Global Environment Facility (GEF), with $188.7 million in GEF funding and $5.9 billion in co-financing.

Gender

- Fifteen years after the first decision on women and gender under the UNFCCC at COP7 in Marrakech, governments took another important step towards achieving their goals on gender balance and gender-responsive climate policy by agreeing an extended work programme that includes civil society, businesses and others.

Indigenous Peoples

- COP22 took first steps in making the local communities and indigenous peoples platform operational which was established last year in Paris. This marks a new era of addressing the concerns and needs of indigenous peoples in the climate process. Once operational the platform will allow for an exchange of experiences and sharing of best practices on mitigation and adaptation and ultimately lead to more climate actions.

Others Initiatives Launched

- The UN Environment Programme (UNEP) launched a new global initiative, the **Global Peatlands Initiative,** which aims to reduce global greenhouse gas emissions and save thousands of lives by protecting peatlands, the world's largest terrestrial organic soil carbon stock.

The initiative will mobilize governments, international organizations and academia in a targeted effort to protect peatlands, which contain almost 100 times more carbon than tropical forests.

- The **Solar Impulse Foundation** launched the World Alliance for Clean Technologies as a legacy to the first ever solar flight around the world.

Its goal is to federate the main actors in the field of clean technologies to create synergies, give advice to governments, and promote profitable solutions to the world's most pressing environmental and health challenges.

- The first ever private adaptation and resilience investment vehicle, the **Marrakech Investment Committee for Adaptation Fund** is a $500 million fund launched in partnership with The Lightsmith Group, based in the United States, Bey A Capital, based in Africa, and the Global Environment Facility.

- Over the next four years, the **Middle East and North Africa (MENA) Climate Action Plan** aims to nearly double the portion of World Bank financing dedicated to climate action, taking it to around $1.5 billion per year by 2020.

Global Climate Action

Further impressive announcements were made by cities and sub-national governments to investors and business as part of the Global Climate Action (GCA) spearheaded by Climate Champions Laurence Tubiana and Hakima El Haité.

"Through our mandate as Champions, we have enhanced the participation of non-state actors, encouraging a range of initiatives, both individual and cooperative. The shift to a low-carbon future and a resilient civilization is something that is irreversible," said Climate Champion Laurence Tubiana.

The High-Level Climate Champions launched the **Marrakech Partnership for Global Climate Action** to provide a strong roadmap for how the UNFCCC process will catalyse and support climate action by Parties and non-Party stakeholders in the period 2017 to 2020.

The Champions, along with many countries, states, regions, cities and companies, also launched a new initiative dubbed the "2050 pathways platform" designed to support all those seeking to devise long-term, net zero-greenhouse gas, climate-resilient and sustainable development pathways.

Already, 22 countries have started or are about to start the process of preparing a 2050 pathway and 15 cities, 17 states and regions and 196 businesses have joined the platform.

Announcements linked to GCA events at COP22 include:

- 19 African Capital Markets Authorities and Exchanges, accounting for 26 African countries, have signed and endorsed the **Marrakech Pledge for Fostering Green Capital Markets in Africa.**
- The European Union Commission launched the **European Fund for Sustainable Development** to encourage investment in Africa and the EU Neighbourhood countries, strengthen partnerships, and achieve the Sustainable Development Goals. The plan involves:
    - Value of up to EUR4. 1 billion, triggering regional public and private investment of up to EUR44 billion to 2020.
    - Technical assistance to help local authorities and companies to develop bankable projects and to improve regulatory environments in partner countries.
    - Improvement of the general business environment by supporting reforms in economic governance.

Corporate Climate Action

- The number of companies making climate commitments through the **We Mean Business** coalition has more than doubled since COP21.
    - **We Mean Business** announced that in total, 471 companies with over $8 trillion in market capitalization have undertaken well over a thousand ambitious commitments to climate action.
    - These companies represent every sector and geography globally.
- The **Science Based Targets** initiative continues to see tremendous momentum since Paris. To date, almost 200 companies have joined the initiative, and in the past year, growth has been at a rate of more than two new companies per week.

Energy

- At COP22, the Indian company Dalmia Cement and Helvetia insurance group committed to use 100% renewable power across their operations and join RE100; the global, collaborative initiative with more than 80 of the world's most influential companies.
- Swiss Re committed to double its energy productivity and join **EP100**, a global campaign that works with companies to maximize the economic benefits of every unit of energy it consumes.
- A new private sector-led initiative, the **Renewable Energy Buyers Alliance** (REBA), was announced. REBA builds connections between corporate electricity demand and renewable energy supply.

Cities

- Cities, towns and regions are making big impacts in implementing their climate commitments by acting locally and partnering globally.
- A new assessment tool presented during the Resilience Showcase will allow standardized qualitative reporting of adaptation commitments to the Global Covenant of the Global Covenant of Mayors.
- The Energy Efficiency in Buildings Programme was launched, designed to unlock funds for the improvement of energy efficiency through better coordination, offering technical assistance and financing transformational projects.

Forests

- The Government of Indonesia announced it is implementing a moratorium on clearing super high-carbon, intact peatland. The action builds on Indonesian President Joko Widodo's announcement at last year's Forest Action Day in Paris, to

end new and review existing peat concessions.

- Colombia has announced plans to close the forest frontier as a key component of a post-conflict future. Efforts include focusing development on non-forest lands, implementing strong tenure reform, and placing very large areas of forest under indigenous peoples' control.
- A new partnership between FAO and Google has created **Collect Earth,** an open-source tool that provides access to large collections of free, high-resolution satellite imagery and cloud computing.

Water

- The **Water for Africa** initiative, established by the Kingdom of Morocco and supported by the African Development Bank was launched at COP22, aiming to render justice to Africa through the adoption of a specific action plan that will mobilize different international political, financial and institutional partners.
- The three alliances for basins, megacities and businesses, created at COP21, which today represent more than 450 organizations worldwide, signed a common commitment to mobilize jointly their partners, identify and disseminate good practices and support the development of new projects.

Transport

- The **Global Fuel Economy Initiative** (GFEI) is supporting an additional 40 countries to realize the financial benefits and CO_2 benefits of improved vehicle fuel economy.
- **Airport Carbon Accreditation** scheme now has 173 certified airports worldwide, including 26 carbon-neutral airports – 36% of air passengers now travel through an Airport Carbon Accredited airport.
- The **Mobilise Your City** initiative secured EUR35 million in funding over the last 12 months and launched development of Sustainable Urban Mobility plans in Morocco and Cameroon.

Oceans

- The Kingdom of Morocco has announced its **Blue Belt Initiative** aimed at building the resilience of coastal communities and promoting sustainable fisheries and aquaculture in keeping with SDG14 expectations.
- FAO, World Bank and the **African Development Bank announced the African Package for Climate-Resilient Ocean Economies,** an ambitious package of technical and financial assistance to support ocean economies in Africa and build greater resilience to climate change in coastal areas.
- COP22 Ocean Action partners released the **Strategic Action Roadmap on Oceans and Climate: 2016 to 2021,** which provides a vision for action on oceans and climate in the next five years, addressing six oceans.

Agriculture

- Launch of the **Adaptation for African Agriculture** initiative aims to build the resilience of farmers in Africa by promoting sustainable soil management, better water management and risk management linked with tailored capacity development, policies and funding mechanisms.
- Launch of the **Global Framework on Water Scarcity** supports countries to integrate climate change and sustainable water use into agricultural sectors policies and cross-sectoral dialogue.
- 130 mayors from cities across the world signed the **Milan Urban Food Policy Pact** (MUFPP), which calls for sustainable food systems that foster the accessibility of healthy food for urban citizens, biodiversity protection and food waste reduction.

Momentum for Change at COP22

The UNFCCC secretariat's **Momentum for Change** initiative hosted a series of special events at COP22 from 12 to 17 November. These events celebrated the 2016 Momentum for Change Lighthouse Activities with inspiring videos, photography, roundtable discussions, an exhibition space and an evening award ceremony.

The Momentum for Change Lighthouse Activities are some of the most innovative, scalable and replicable examples of what people are doing to address climate change – these events celebrated these solutions.

Source: UNFCCC (November 18, 2016)

India's Permanent Representative to the United Nations, Syed Akbarudding Ali, hands over the Instrument of Ratification. Photo: Twitter/@MEAIndia

India Ratifies Historic Paris Climate Deal at U.N.

India ratified the Paris Agreement on Climate Change by depositing the instrument of ratification with the United Nations on Sunday, the 147th birth anniversary of Mahatma Gandhi. A special event was organised to mark the occasion, also observed as the International Day of Nonviolence, at the UN headquarters.

India became the 62nd country to ratify the agreement. The agreement will enter into force one month after 55 countries that account for 55 percent of global emissions ratify the agreement. "With today's action by India, which accounts for 4.1 per cent of the emissions, the Agreement only needs slightly more than 3 percentage points to reach the 55 per cent threshold," a UN statement said. At least 14 other countries, representing at least 12 per cent of global emissions, have committed to ratifying the pact before the end of the year.

Living through an age of triumphant industrial capitalism, Gandhi had warned of the dangers posed by the unbridled exploitation of natural resources. Speakers at the event recalled Gandhi's vision that foresaw the pivotal role environment would occupy in development debates decades later.

"Looking back, many now regard him as an avid and early environmentalist. Encapsulating the whole idea of sustainable development more than seven decades ago he had said, "The earth, the air, the land and the water are not an inheritance from our fore fathers but on loan from our children. So we have to handover to them at least as it was handed over to us," said Mr. Syed Akbaruddin, Permanent Representative of India to the UN, after handing over the instrument. President of General Assembly Peter Thomson said Gandhiji would have applauded the UN efforts to make development sustainable and equitable. Deputy Secretary General Mr. Jan Eliasson said the message of nonviolence is as relevant today as it was during Gandhi's lifetime and lauded Hon'ble Prime Minister Shri Narendra Modi for his commitment to environment.

Source: The Hindu (October 2, 2016)

In this news story, the figures reflect the ratification status as on October 2, 2016 — the day on which India ratified the Paris Agreement.

'Father of Climate Change' James Hansen Urges Support for Nuclear Energy at COP21 Climate Talks

Former NASA scientist and the 'Father of Climate Change' Dr. James Hansen, at the COP21 talks in Paris (Image: Thom Mitchell, New Matilda)

A panel of eminent scientists – including James Hansen, the former head of NASA's Goddard Institute for Space Studies and a man dubbed 'the Father of Climate Change' – has called on governments and environmentalists to accept nuclear energy as part of the solution to the climate crisis, at a side event to global negotiations that got underway in Paris.

The renowned climate scientist told that future generations are "screwed" if we continue to emit carbon dioxide, at COP21 event where some of the world's top climate scientists endorse nuclear as a key part of the solution.

A panel of eminent scientists – including James Hansen, the former head of NASA's Goddard Institute for Space Studies and a man dubbed 'the Father of Climate Change' – has called on governments and environmentalists to accept nuclear energy as part of the solution to the climate crisis, at a side event to global negotiations that got underway in Paris.

They told media the two degree target that negotiators involved in the United Nations talks are aiming for is based on politics, not science, and the world needs to use every means available to curb emissions.

Renewable energy like wind and solar, they said, would not be enough alone.

"I think all of us here [on the panel] feel that carbon dioxide emissions are dangerous and that there's no emissions which are acceptable, and we need to

Dr. Ken Caldeira of the Carnegie Institution For Science, at the COP21 talks in Paris (Image: Thom Mitchell, New Matilda)

be stopping all carbon dioxide emissions," said Dr. Ken Caldeira of the Carnegie Institution for Science.

> *They told media the two degree target that negotiators involved in the United Nations talks are aiming for is based on politics, not science, and the world needs to use every means available to curb emissions.*

"Every carbon dioxide emission is a bad thing, and the target is zero," Dr. Caldeira said.

A decorated Australian climate scientist with the University of Adelaide, Dr. Tom Wigley stressed the scientists were "not promoting nuclear energy" but rather "a level playing field".

"We're asking everybody to make sure that because this is such a demanding, challenging problem, we can't close the door to any type of technology," he said.

We have to give a fair and balanced assessment, eschewing ideology and preconceptions to decide on what the energy strategy should be.

Hansen relayed an anecdote to highlight what he sees as the blinkered thinking around the "tremendous intergenerational injustice" of climate change and how it's been exacerbated by blinkered thinking on nuclear energy.

He says 'we should be scared of climate change', Hansen said. "We know that using fossil fuels is not safe, it is very dangerous, and we have to face the fact that this danger of fossil fuels is staring us in the face.

"It's absolutely one hundred per cent certain that we've got a very dangerous situation. And for us to say 'Oh we're not going to use all the tools that we have to try to

> Renewable energy like wind and solar, they said, would not be enough alone.

solve it' is crazy," Hansen said. "We have to use all of the things that we have at our disposal and clearly nuclear power, next generation nuclear power especially, has tremendous potential to be a big part of the solution."

Professor Kerry Emanuel – probably the panelist most skeptical of what's usually called renewable energy, wind and solar – said that using those technologies "we can get to 30 per cent, and then you hit a brick wall".

> *I think all of us here [on the panel] feel that carbon dioxide emissions are dangerous and that there's no emissions which are acceptable, and we need to be stopping all carbon dioxide emissions," said Dr. Ken Caldeira of the Carnegie Institution for Science.*

Hansen argued that concerns over the capability of renewables to act as a full substitute for fossil fuels were common to "by far the majority of scientists" he'd

Dr. Tom Wigley, renowned Australian climate scientist, at the COP21 talks in Paris (Image: Thom Mitchell, New Matilda)

spoken to, and that most "agree that nuclear needs to be part of the solution".

Hansen said that new generations of nuclear technology, which burn around 99 per cent of radioactive fuel, and

Professor Kerry Emanuel – probably the panelist most skeptical of what's usually called renewable energy, wind and solar – said that using those technologies "we can get to 30 per cent, and then you hit a brick wall".

Professor Kerry Emanuel, at the COP21 talks in Paris (Image: Thom Mitchell, New Matilda)

therefore produce almost no waste, are "within 5 or 10 year [away] if we give it priority," but that nuclear power already has a proven track record.

"If you look at France, for example, it has most of its electricity from nuclear power and if you compare the electricity price in France and Germany, it's about half in France what it is in Germany," he said.

"If we have carbon-free electricity in all countries, we've solved the problem, because we can make liquid fuels for transportation from energy if you have abundant carbon-free electricity," Hansen said.

The celebrated climate scientist, famous for sounding the alarm and bringing the issue to public attention through evidence he presented to the United States Congress in the late 1980s, said the crucial next step which should receive far more funding is to "come up with designs that can be built rapidly, and that's what's going to happen in China".

"My hope, to be very frank, is the fact that Chinese leaders are technically trained and they're rational and

Dr. James Hansen, at the COP21 talks in Paris (Image: Thom Mitchell, New Matilda)

they have very strong motives for wanting to move to clean energy," he said.

"Their air pollution is so bad that the public is on the verge of uprising, so they have a very strong reason for wanting to move to clean energies and they're doing as much as they can with solar, with wind, and with nuclear.

"I think that what we're going to see is that they will develop nuclear that they can build rapidly and we, the West, should be working with them to make sure it's as safe as possible.

Hansen argued that concerns over the capability of renewables to act as a full substitute for fossil fuels were common to "by far the majority of scientists" he'd spoken to, and that most "agree that nuclear needs to be part of the solution".

"That's our responsibility because we burned their fair share of the global carbon budget: We've now basically used up the amount of the carbon budget that we can afford to put in the atmosphere, so now we've got to find clean energies."

(Courtesy: newmatilda.com)

The leading Australian website brings renowned researchers, international figures, industry professionals as well as reputed authors on a single global platform, providing in-depth analysis of vital issues affecting humanity, including energy and environment.

The State of the Climate report series is the authoritative annual summary of the global climate. Published in the Bulletin of the American Meteorological Society (BAMS), the report is edited by scientists at NOAA's National Centers for Environmental Information. The 2015 report is based on contributions from more than 450 scientists from 62 countries, drawing on tens of thousands of measurements of Earth's climate.

The report confirmed that 2015 surpassed 2014 as the warmest year since at least the mid-to-late 19th century. The record heat resulted from the combined influence of long-term global warming and one of the strongest El Niño events the globe has experienced since at least 1950. Most indicators of climate change continued to reflect trends consistent with a warming planet. Several markers, such as land and ocean temperatures, sea levels, and greenhouse gases, broke records set just one year prior.

These highlights present a glimpse of our changing planet.

2015 *State of the Climate: Highlights*

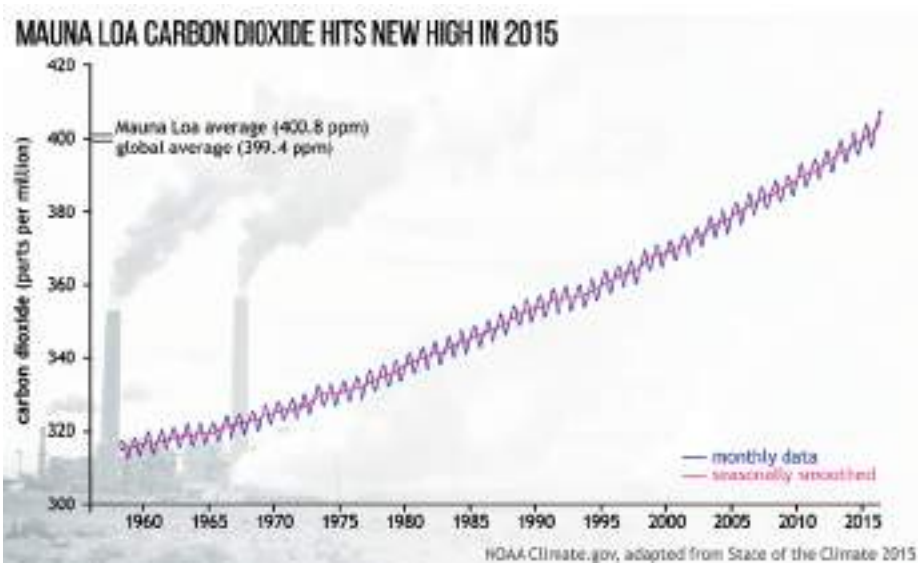
- Carbon Dioxide
- Global Temperature
- Extremely Warm Days
- Ocean Heat Storage
- Mountain Glaciers
- Drought
- Sea Level
- El Niño

Carbon Dioxide

Roberto Molar-Candanosa

Using measurements taken worldwide, scientists estimated that 2015's global average carbon dioxide concentration was 399.4 parts per million (ppm), a new record high. At Mauna Loa Observatory in Hawai'i, where atmospheric carbon dioxide has been recorded longer than anywhere else in the world, the annual average carbon dioxide concentration was 400.8—also a new record, and a new milestone.

The graph to the right shows



monthly average carbon dioxide concentrations recorded at Mauna Loa since 1958. The small-scale ups and downs on the dark blue line show the influence of Northern Hemisphere vegetation on carbon dioxide: higher in winter, when vegetation is dormant, and lower in summer, when plant growth removes carbon dioxide from the air.

The bright pink line shows carbon dioxide concentrations with the seasonal cycle smoothed out, revealing the long-term rise more clearly. The rate of increase has not been steady over time: the line has gotten steeper. That's because the annual growth rate of atmospheric carbon dioxide has roughly tripled, from 0.6 ppm per year in the early 1960s to an average 2.1 ppm during the past 10 years.

At Mauna Loa, carbon dioxide concentrations in 2015 jumped by 3.05 ppm—the largest annual increase in the observatory's record. The previous largest annual jump in carbon dioxide that scientists observed at Mauna Loa (2.93 ppm) was in 1998 during another strong El Niño. El Niño often leads to an expansion of global drought area, an increase in tropical forest fires, and other landscape changes that boost atmospheric carbon dioxide levels.

By burning fossil fuels for energy, human activities have increased the concentration of carbon dioxide in the atmosphere by more than 40% since the Industrial Revolution, causing global warming and making the ocean more acidic.

According to the State of the Climate 2015 report, carbon dioxide was responsible for forcing an energy imbalance in Earth's climate of 1.94 watts of energy per square meter in 2015. In other words, carbon dioxide caused the planet to absorb nearly 2 watts of energy more per square meter than it radiated out to space. Increases in atmospheric carbon dioxide since 1958 are largely due to a fourfold increase in human emissions from fossil fuel combustion and cement production. Back when scientists at Mauna Loa Observatory began to systematically monitor and analyze carbon dioxide levels in the atmosphere, the annual carbon dioxide concentration was about 315 ppm.

The photo in the background of the graph is of Arizona's coal-fired, Cholla power plant. The visible plumes from the smokestacks at coal-fired power plants generally include steam along with carbon dioxide and other gases.

References

E. J. Dlugokencky, B. D. Hall, M. J. Crotwell, S. A. Montzka, G. Dutton, J. Mühle, and J. W. Elkins, 2016: [Atmospheric composition] Long-lived greenhouse gases [in "State of the Climate in 2015"]. Bulletin of the American Meteorological Society (BAMS), 97 (8), S44-S46.

Kaiser, J.W., g.r. Van Der Werf, and A. Heil. (2016) [Biomass burning]

Global Temperature

Emily Greenhalgh

It was another record-breaking year for global temperatures, with warmer-than-average conditions across most of the Earth's surface. According to the State of the Climate in 2015 report, long-term warming and a strong El Niño contributed to the highest annual combined temperature for ocean and land since reliable records began in the mid-to-late 1800s.

The map to the right shows the average temperature departures for 2015 compared to the 1981-2010 averages. Russia and western North America were especially warm. On land, only a few areas, notably Greenland and northeastern Canada, were cooler than average. A strong El Niño resulted in high sea surface temperatures across much of the tropical Pacific, however, areas in parts of the North Atlantic, southern Pacific, and the waters of southern South America were below average.

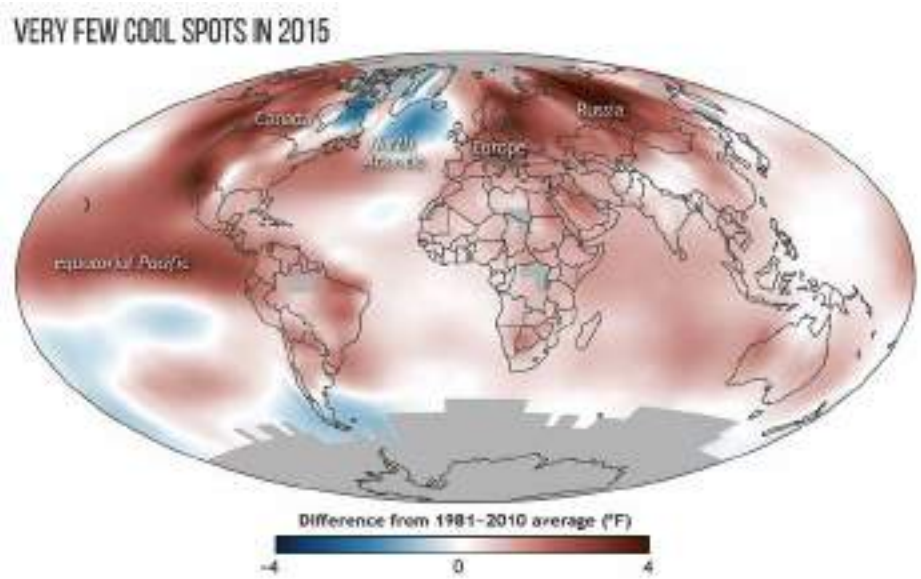
The graph beneath the map shows Earth's temperature history from 1880 to 2015 compared to the 1981-2010 average (dashed line at zero). Surface temperature is dark red; lower troposphere temperature is light red. (The troposphere is the lowest 10 kilometers [6.2 miles] of the atmosphere.)

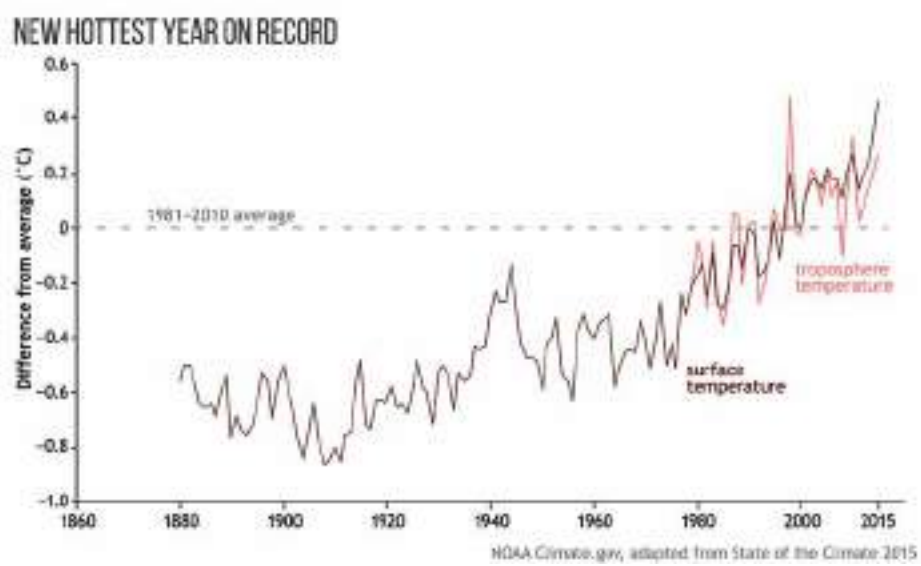
The 2015 global surface temperature was 0.42°C-0.46°C (0.76°–0.83°F) above the 1980-2010 average, depending on the dataset. For the troposphere, 2015 ranked between first and fourth warmest of the past 58 years, again, depending on the dataset.

The 2015 surface temperature broke the previous record set in 2014 by a margin of 0.13°–0.18°C, one of the two largest margins by which one record-warm year has beaten another. Only 1998—also an El Niño year—matched it, when it beat out 1997 by a margin of 0.12°C-0.16°C.

Natural climate variability causes surface temperature to rise and fall from year to year and even decade to decade. However, this short-term variability is increasingly overwhelmed by what is happening over longer timescales: over the span of many decades to a century both the surface and troposphere have warmed. More significantly, 14 of the 15 warmest years on record have occurred since the year 2000.

The time series graph has been simplified from the original State of the Climate figure, which includes several observational time series.





The exact rate of warming estimated from each data set varies somewhat, but they all show a similar trend. We selected NOAA's in situ land and ocean temperature record for the surface temperature history, and the satellite data from Remote Sensing Systems (RSSv3.3) for the troposphere.

Reference

Christy, J.R., 2016: Lower and Mid Tropospheric Temperature [in "State of the Climate in 2015"]. Bulletin of the American Meteorological Society, 97 (8), S13-S15.

Sánchez-Lugo, A., P. Berrisford and C. Morice, 2016: Surface Temperature [in "State of the Climate in 2015"]. Bulletin of the American Meteorological Society, 97 (8), S12-S13.

Extremely Warm Days

Emily Greenhalgh

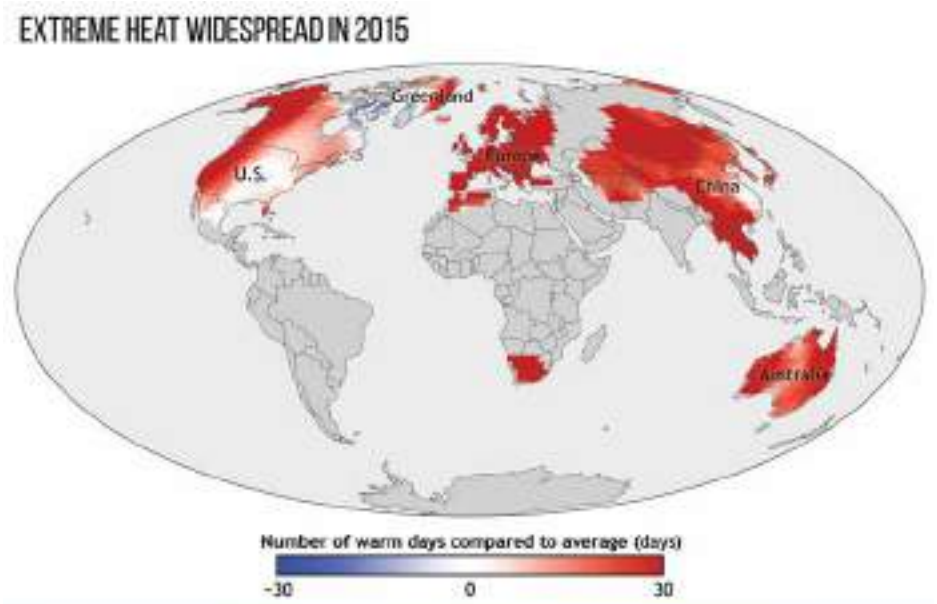
People, plants, and animals don't 'experience' the global average temperature, which we hear so much about in relation to global warming. We experience temperatures locally, through daily temperature extremes. So the number of extremely warm days in a year can be a more meaningful indicator for how people, agriculture, and natural ecosystems feel the effects of climate change. In 2015, the frequencies of extremely warm days and nights were the highest ever recorded in western North America, parts of central Europe, and central Asia.

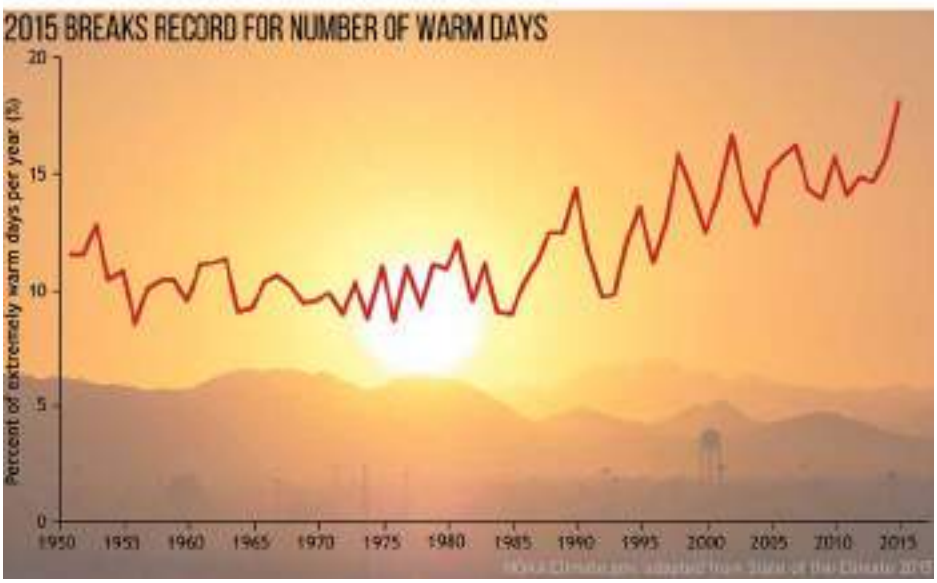
Adapted from the BAMS State of the Climate in 2015 report, the map to the right shows the frequency of warm days in 2015 compared to the long-term (1961-1990) average. For this analysis, days with temperatures warmer than 90 percent of the 1961-1990 seasonal record are considered "extremely warm days." The areas shaded red had a higher-than-average number of extremely warm days in 2015.

The few areas shaded blue—southern Greenland and the eastern United States—had fewer extremely warm days than average. In the eastern United States, this might have been due to the lingering influence of the cold 2014/15 winter.

Below the map, the graph shows the percent of days each year—from 1950 to 2015—that were extremely warm. Although the percent of hot days rises and falls from year to year due to natural variability, the overall global trend is clear: the number of hot days has increased. The year 2015 broke the record for the highest number of extremely warm days in the 66-year record (1.8 times more than the average number according to one dataset).

In 2015, several regions, including western North America, Europe, and large parts of Asia and Australia experienced strong warm anomalies throughout much of the year. There were a number of notable extreme temperature events, including the European summer heat waves, a number of Asian heatwaves (in India, Pakistan, and Indonesia), and a warm spring and fall in Australia, Alaska, and western Russia.





Extremely warm days can pose human health risks, especially in places that lack air conditioning; can stunt crops or interrupt key growth stages; and can stress livestock and other animals, including commercially and recreationally valuable fish in rivers and streams. The National Integrated Heat Health Information System names extreme heat events as one of the leading weather-related causes of death in the United States. According to the National Climate Assessment, from 1999 through 2009, extreme heat exposure caused more than 7,800 deaths.

Reference

M. G. Donat, R. J. H. Dunn, and S. E. Perkins-Kirkpatrick, 2016: Land Surface Temperature Extremes [in "State of the Climate in 2015"]. Bulletin of the American Meteorological Society, 97 (8), S19-S20.

Luber, G. et al, 2014: Ch. 9: Human Health. Climate Change Impacts in the United States: The Third National Climate Assessment, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 220–256. doi:10.7930/J0PN93H5.

Ocean Heat Storage

Roberto Molar-Candanosa

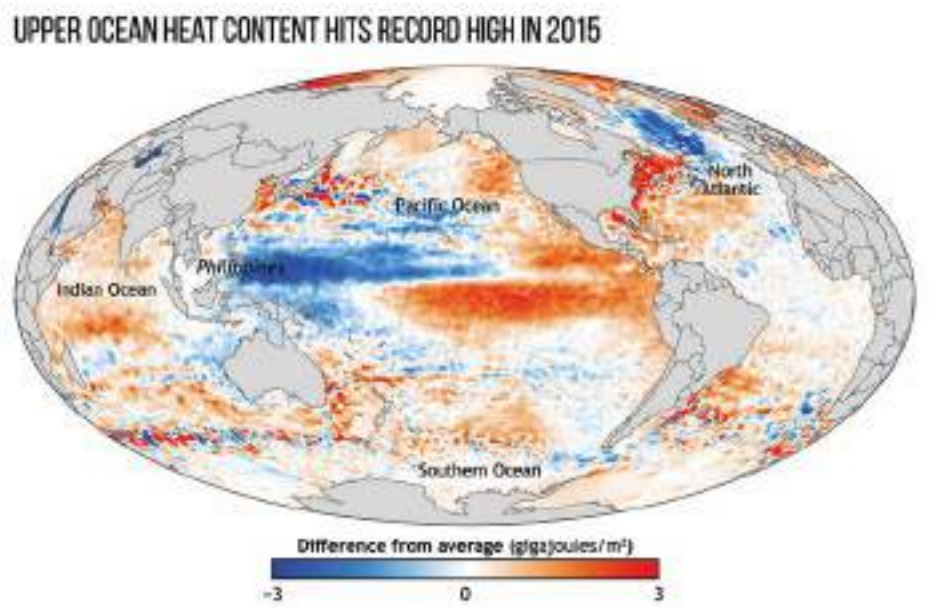
Ocean heat storage has increased substantially since 1993, hitting a record high in 2015, according to the State of the Climate in 2015 report. Ocean warming accounts for over 90% of the warming in Earth's climate system.

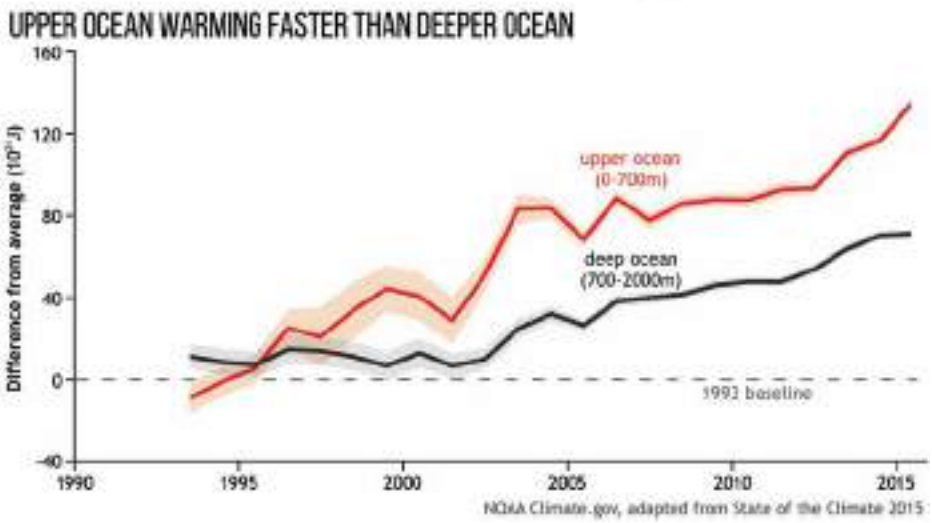
The map to the right, created from in situ ocean temperature and sea level data from satellites, shows heat energy in the top 2,300 feet (700 meters, or slightly less than half a mile) of the ocean in 2015 relative to a 1993-2015 average. Areas in blue show ocean where stored heat was below average, while areas in orange and red show where ocean heat content was above average.

According to the report, upper ocean heat shifted from the western equatorial Pacific toward the central Pacific in 2015, leaving a large pool of water near the Philippines with much-lower-than-average heat content. Meanwhile, heat energy was above average across the rest of the equatorial oceans. These shifts are consistent with the warm phase of a natural climate pattern in the tropical Pacific Ocean and atmosphere known as El Niño.

A similar contrast shows up in the North Pacific: warm off the west coast of North America but cooler to the west. These contrasting temperatures reflect a transitioning Pacific decadal oscillation. The map also shows a large cool patch in the North Atlantic, which might be linked to a weakened Atlantic meridional overturning circulation.

The graph beneath the map shows heat content in the upper 2,300 feet (700 meters) of the ocean (orange) and the deeper ocean (2,300–6,500





feet, gray) relative to a 1993 baseline. Heat energy rises and falls every few years in response to natural patterns like El Niño and La Niña, but those ups and downs are superimposed on a long-term increase.

The orange line is steeper than the gray line, which means heat energy is building up faster in the upper ocean than in the deeper ocean. That pattern is what you'd expect to see as a result of atmospheric heating from greenhouse gases. This graph is simplified from the original State of the Climate report graphic, which included multiple analyses for each ocean layer. All analyses show large increases in ocean heat energy since 1993.

Reference

Johnson G.C., J. M. Lyman, T. Boyer, C. M. Domingues, M. Ishii, R. Killick, D. Monselesan, and S. E. Wijffels, 2016: [Global Oceans] Ocean Heat Content [in "State of the Climate in 2015"]. Bulletin of the American Meteorological Society (BAMS), 97 (8), S66-S70.

Mountain Glaciers

Emily Greenhalgh

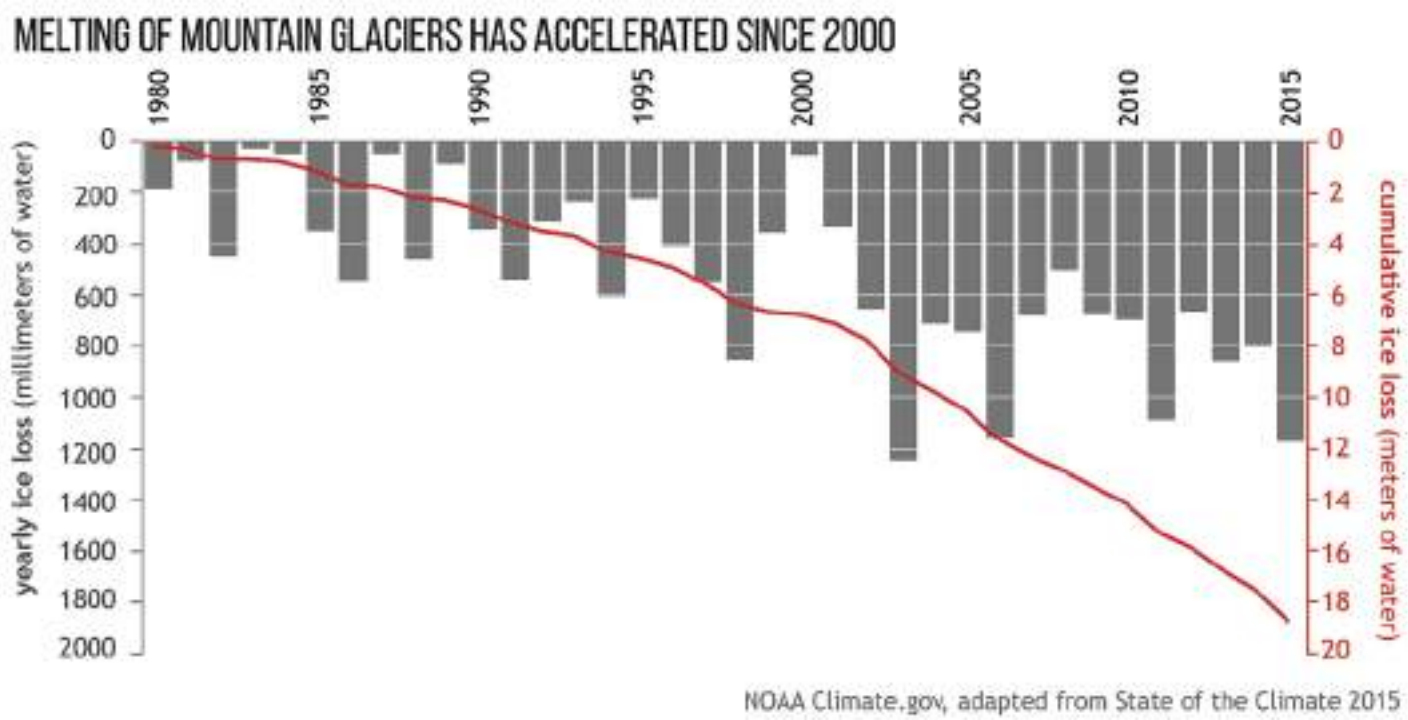
Glaciers grow by accumulating more snow in the winter than they lose through melt and evaporation in the summer. When snowfall and melt perfectly offset each other, glacier mass is in balance. When melt and evaporation outpace snow accumulation, the glacier loses mass. In 2015, glaciers across the globe, on average, continued to shrink for the 36th consecutive year.

The graph at right shows annual gain or loss in mass for 41 reference glaciers (gray bars) from 1980 to 2015 and the long-term accumulated loss (red line). There are more than a hundred glaciers in the World Glacier Monitoring Service's network. "Reference glaciers" are those that have been monitored for 30 years or more.

At the time of this year's State of the Climate publication, only 27 of the 41 reference glaciers had reported data, but the preliminary numbers indicate that the 2015 loss will join 2003 as one of the two highest losses in the 36-year record. In 2015, reference glaciers lost an amount of ice equivalent to a depth of 1,162 millimeters of water (3.8 feet) spread out across the surface of the glaciers. In 2003, reference glaciers lost an average of 1,268 millimeters of water (just over 4 feet), the greatest loss in a single year.

The 2015 State of the Climate report called the ongoing retreat "without precedent on a global scale," for the observed period. Cumulative mass loss since 1980 is 18.8 meters, "the equivalent of cutting a 20.5 meter [67-foot] thick slice off the top of the average glacier."

Around the world, hundreds of millions of people rely on glacier melt for their drinking water and for crop irrigation. In some areas,



glacial meltwater that keeps streams running is the only thing that keeps plants and animals hydrated during hot, dry seasons. In other parts of the world, dams on glacier-fed rivers are key sources of hydroelectric power. Meltwater from glaciers also contributes to sea level rise. The retreat and disappearance of mountain glaciers worldwide is one of the clearest signs we have that the global climate is warming over the long term.

References

Pelto, M.S., 2016: Alpine Glaciers and Ice Sheets [in "State of the Climate in 2015"]. Bulletin of the American Meteorological Society, 97 (8), S23-S24.

Drought

Emily Greenhalgh

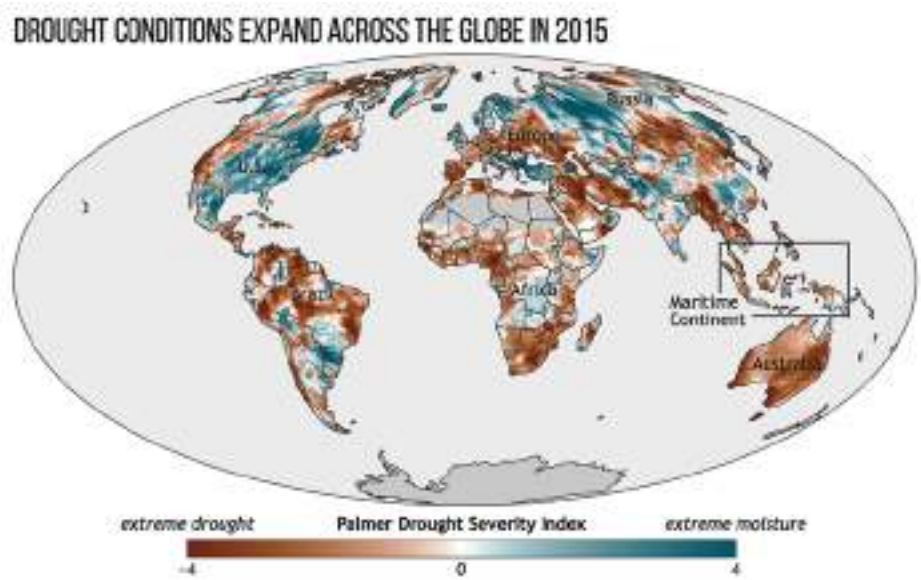
2015 was a tough year for vegetation, both natural and agricultural, with a near-record area of global land surfaces in some state of drought. The area in severe drought increased from 8% at the end of 2014 to 14% by the end of 2015.

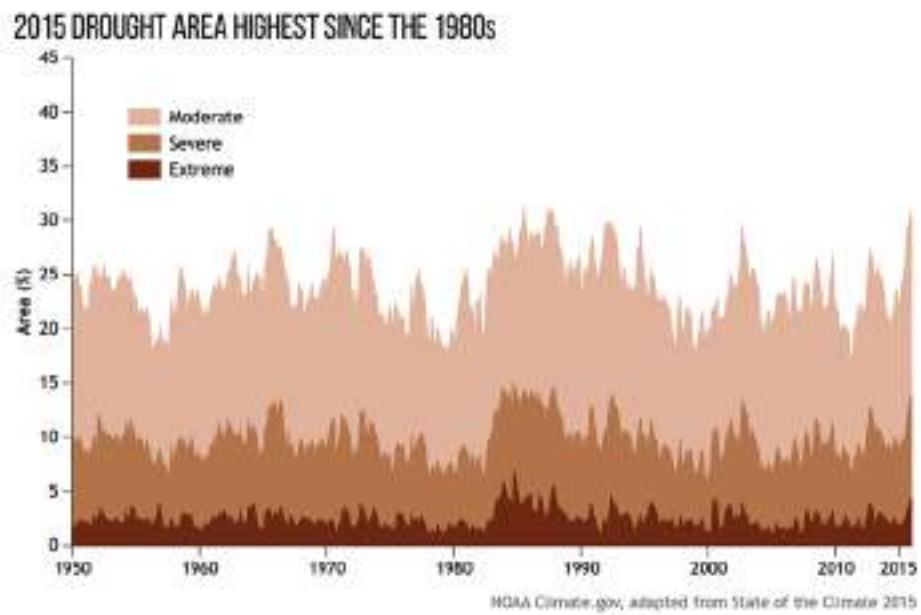
Adapted from the BAMS State of the Climate 2015, the map to the right shows the areas that experienced drought conditions in 2015. The darker the brown, the more extreme the drought. Patterns on the map partially reflect the impact of El Niño: the Caribbean, the Amazon region of South America, southern Africa, and the Maritime Continent (Southeast Asia) all tend to experience dry conditions during El Niño.

The graph shows the percentage of global land area (excluding ice sheets and deserts) in a moderate, severe, or extreme drought. By the end of 2015*, 30% of the global land was in drought, with 14% in a severe or extreme drought, the two most dire categories. This is among the highest since modern record keeping began in the 1950s. The area in drought conditions in 2015 was exceeded only by some years in the mid-1980s.

The regional patterns of drought in 2015 are partly associated with the strong El Niño event that developed in Northern Hemisphere spring. The large expansion of drought-affected area was similar to an expansion that took place in 1982, also a strong El Niño year, and the climate experts writing in the State of the Climate 2015 report warn that the full impact of El Niño on global drought conditions might not be apparent until 2016.

In the U.S., California continued to experience severe or extreme drought conditions. Drought conditions in some Central American and Caribbean nations contributed to food insecurity in the region. Extensive severe or extreme drought affected many countries in southern Africa, intensifying as El Niño progressed. Many areas of South America either continued earlier drought conditions, or were hit with new droughts in 2015. Despite wetter El Niño conditions, for example, parts of Chile remained in a severe 6-year drought.





Dry conditions were widespread across Australia, specifically along the west coast, the southeast, and parts of Queensland, continuing from 2014. Farther north, dry conditions were established in many parts of the Maritime Continent, other parts of Southeast Asia, China and Mongolia.

In Europe, there was a strong contrast between the wet conditions of the southeast and Turkey and the severe drought in Eastern Europe and western Russia, which affected important crop production there.

Note about the graph: More observations for the final months of 2015 are yet to become available.

References

Osborn, T.J., J. Barichivich, I. Harris, G. van der Schrier, and P. D. Jones, 2016: Monitoring global drought using the self-calibrating Palmer Drought Severity Index [in "State of the Climate in 2015"]. Bulletin of the American Meteorological Society, 97 (8), S32-S36

Rodell, M., D.P. Chambers, and J.S. Famiglietti, 2016: Groundwater and terrestrial water storage [in "State of the Climate in 2015"]. Bulletin of the American Meteorological Society, 97 (8), S30-S32

Sea Level

Roberto Molar-Candanosa

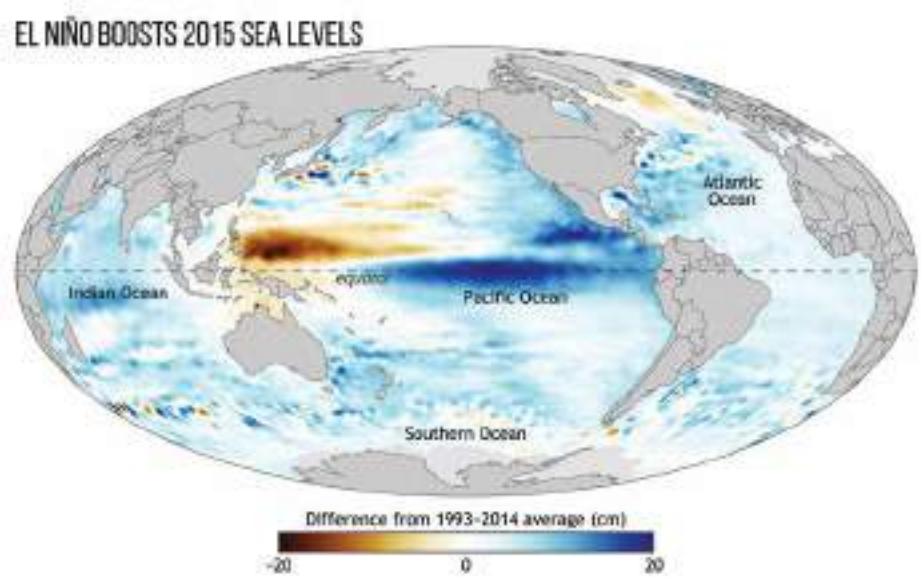
Background photo of Satellite Beach, Florida by Roberto Mangual

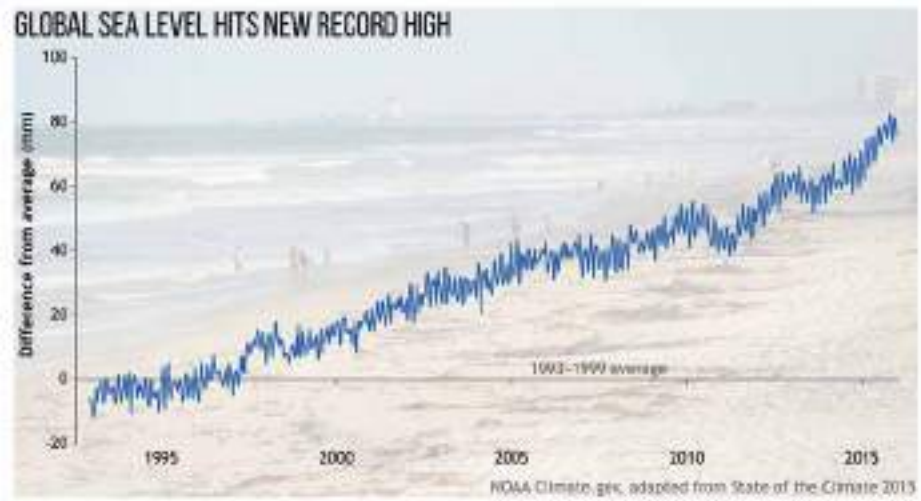
The global mean sea level in 2015 was approximately 7 centimeters (2.7 inches) above the 1993 average, making it the highest observed since the satellite altimeter record began in 1993, according to the State of the Climate in 2015 report. Regional variations highlighted the short-term influence of climate phenomena like the Pacific Decadal Oscillation and the largest El Niño event since 1997/98.

The map to the right shows sea level in 2015 compared to the 1993-2014 average based on satellite altimeter data. Places where sea level was up to 20 centimeters (7.8 inches) higher than average are dark blue, and places where sea level was up to 20 centimeters (7.8 inches) below average are brown.

A wide swath of blue across the central tropical Pacific shows the influence of 2015's strong El Niño, which pushed sea level an estimated 10 millimeters (0.4 inches) above the long-term trend. Meanwhile, sea levels in the western equatorial Pacific were far below average, a sign of El Niño's weakened trade winds that pushed surface water east out of the region.

The graph beneath the map shows yearly global sea level since 1993 compared to the 1993-1999 average line (gray line at zero). Sea level has





risen at an average rate of 0.33 centimeters (0.1 inches) per year since the satellite altimeter record began in 1993, which is faster than the rate of rise in the early part of the twentieth century.

Some ocean regions are rising faster than others. Regions with high rates of sea level rise in recent years include the western Pacific and Indian Oceans, while some areas of the eastern Pacific, Southern, and North Atlantic Oceans have experienced no change or falling sea level. These variations are not long-term and are largely related to wind patterns over the past 20 years associated with climate patterns like the Pacific Decadal Oscillation.

Background photo of Satellite Beach, Florida, by Roberto Mangual.

Reference

M. A. Merrifield, E. Leuliette, P. Thompson, D. Chambers, B. D. Hamlington, S. Jevrejeva, J. J. Marra, M. Menéndez, G. T. Mitchum, R. S. Nerem, and W. Sweet, 2016. [Global Ocean] Sea level variability and change [in "State of the Climate in 2015"], Bulletin of the American Meteorological Society (BAMS), 97 (8), S80-S82.

El Niño came, saw, and conquered

Rebecca Lindsey

A record-smashing hurricane season in the central North Pacific. Water rationing in Puerto Rico. The biggest one-year jump in atmospheric carbon dioxide concentrations on record. Severe drought in Ethiopia. The hottest global surface temperature—by one of the largest margins—on record.

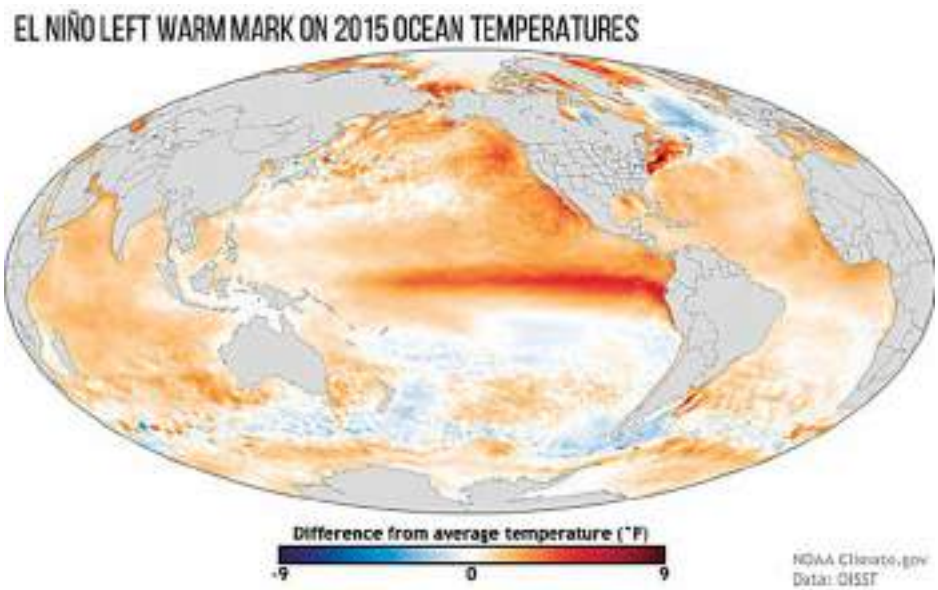
Those are just a few of 2015's major climate happenings documented in the recently released State of the Climate 2015 report from NOAA and the American Meteorological Society. While the events were scattered across the globe, they all had one thing in common: they were all connected to one of the three strongest El Ninõs in the historical record.

Worldwide sea surface temperatures in 2015 compared to the 1981-2010 average. A dark orange swath through the tropical Pacific Ocean in image center shows the year-long influence of El Niño. Map by NOAA Climate.gov, based on OISST data from NCEI.

A Pacific pattern with a global echo

El Niño is the warm phase of a natural climate pattern called "ENSO," which is short for El Niño-Southern Oscillation. During El Niño, the prevailing winds near the equator in the Pacific relax. Surface waters in the central and eastern Pacific warm up. A major hotspot of tropical rainfall and convection (rising air) develops over the warm waters.

The warm up for the 2015 El Niño event actually began in 2014. Monthly sea surface temperatures in a key ENSO-monitoring region hit the El Niño threshold—0.5°C above



average—in October 2014 and remained elevated through winter. But the atmosphere didn't fully start cooperating until March 2015, when NOAA forecasters declared El Niño officially underway.

By December 2015*, however, disruptions in temperature, rainfall, and surface air pressure across the tropical Pacific were on par with two of the strongest El Niños in the historical record: 1982 and 1997.

The build up of ocean and atmosphere disruptions in the months leading up to the peaks of the three strongest El Niños in the historical record 1982-82 [sic] (purple), 1997-98 (charcoal), and 2015-16 (pink). NOAA Climate.gov graph, adapted from Figure 4.1 in State of the Climate in 2015.

Because of the Pacific Ocean's tremendous size, disturbances there can lead to climate disturbances around the globe. To the rest of the global atmosphere, the arrival of El Niño in the Pacific is like a giant ringing a bell so loudly that it knocks the dishes off the shelves in a house down the street. The atmosphere hears the echoes from El Niño from thousands of miles away.

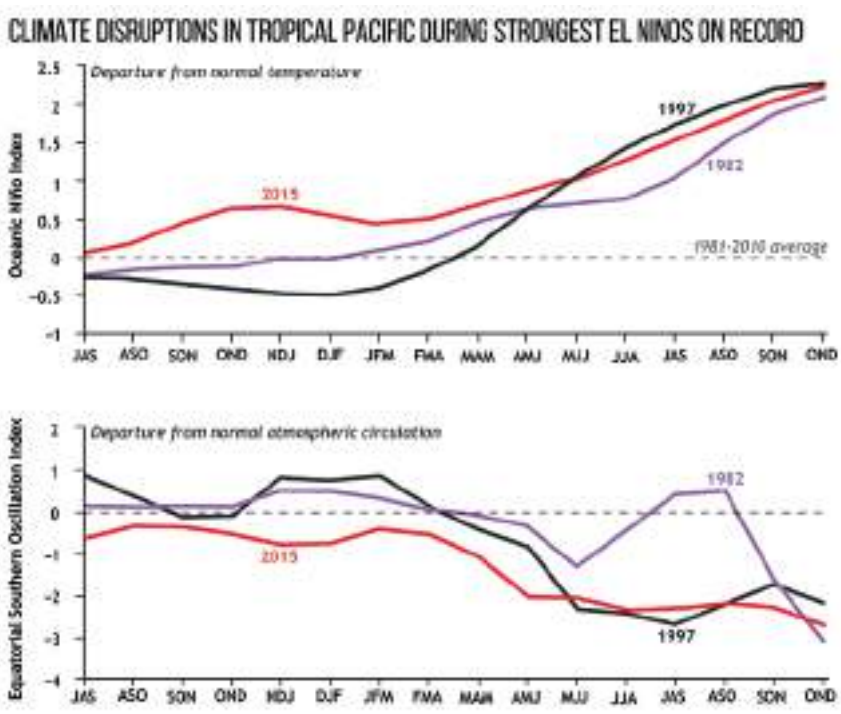
Typical impacts of El Niño on Northern Hemisphere winter (top) and summer (bottom) climate patterns. Maps by NOAA Climate.gov, adapted from originals by the Climate Prediction Center.

Some of the 2015 El Niño's loudest "echoes"

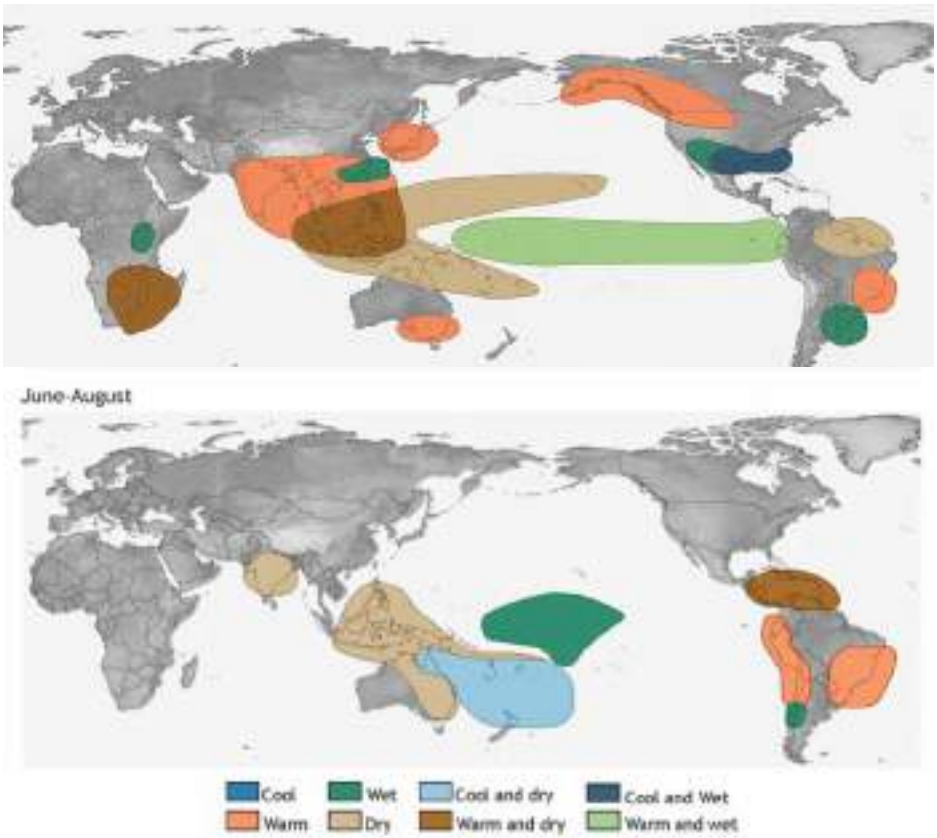
Every El Niño is somewhat different, even strong ones. Still, many regions experienced climate extremes and anomalies in 2015 that are typical of El Niño years. Pulled from the State of the Climate report, here are some of the loudest echoes of the 2015 El Niño.

Record-smashing hurricane season in the central North Pacific

Sixteen tropical cyclones formed in or passed through the unusually warm central Pacific hurricane basin in 2015. That's more than 3 times the 1981-2010 average of 4.7 cyclones per season, and 4 more than the previous record of 12, set in 1992 (also an El Niño year). In late August, the basin sustained three Category 4 hurricanes at the same time, which was a first, not just for the central Pacific basin, but for any basin during the modern record.



The build up of ocean and atmosphere disruptions in the months leading up to the peaks of the three strongest El Niños in the historical record 1982-82 [sic] (purple), 1997-98 (charcoal), and 2015-16 (pink). NOAA Climate.gov graph, adapted from Figure 4.1 in State of the Climate in 2015.



Typical impacts of El Niño on Northern Hemisphere winter (top) and summer (bottom) climate patterns. Maps by NOAA Climate.gov, adapted from originals by the Climate Prediction Center.

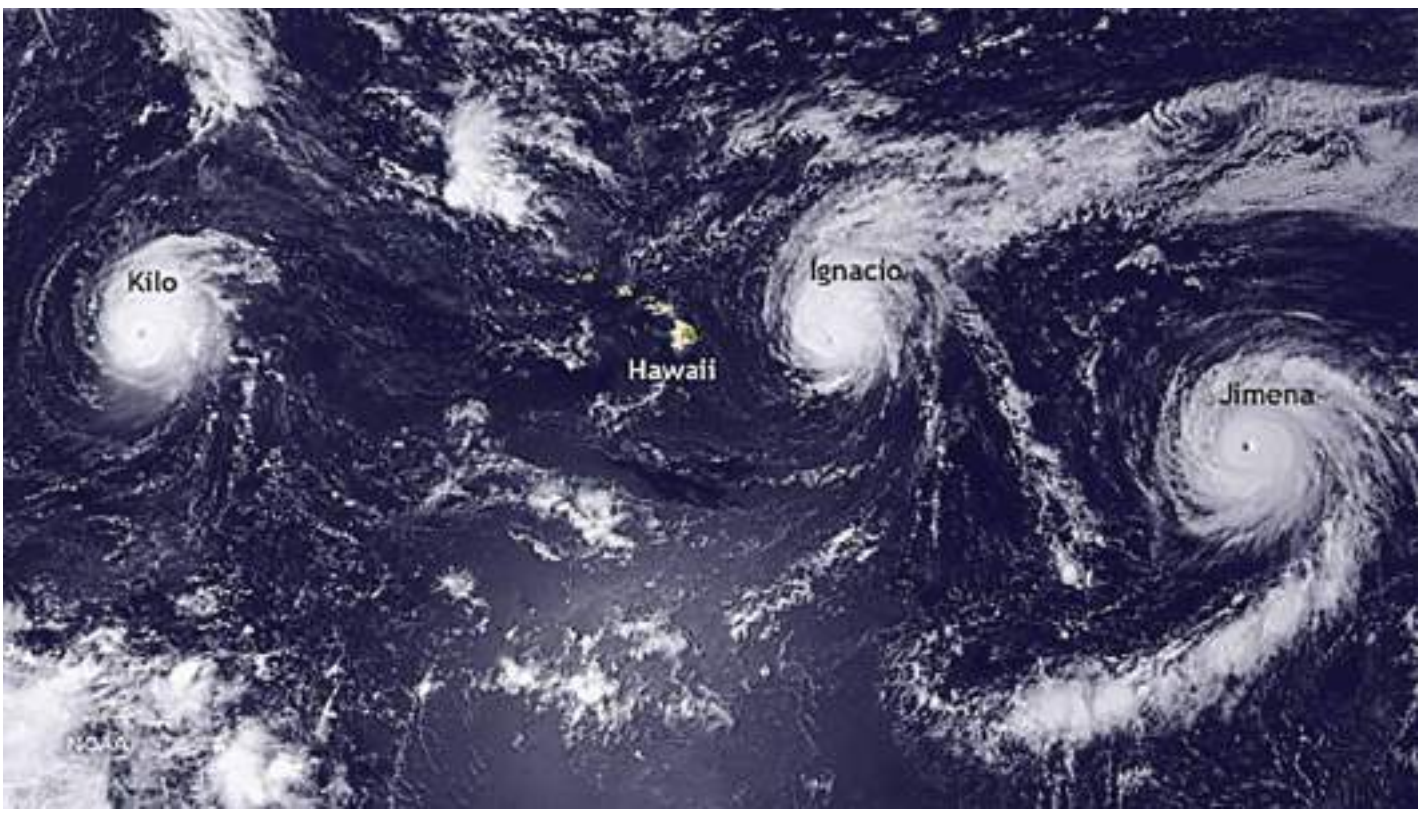
Once-in-500-year drought in the Caribbean

Temperatures were high and rainfall was low across the entire Caribbean in 2015. Ten island nations experienced severe drought. Emergency water rationing occurred in St. Lucia and in San Juan, the capital of Puerto Rico.

In Antigua, the 1-billion-gallon reservoir behind the Potworks Dam went dry. Sixty-five percent of the island's farmers went out of business. Rainfall deficits were the largest on record dating back to 1928. The return period for rainfall so low is estimated to be 1 in 500 years.

New global temperature record

The global average surface temperature in 2015 came in first in the race for warmest year on record, beating out the previous record—set in 2014—by 0.13°-0.18°C, depending on the dataset. This



Satellite image of record-breaking trio of Pacific hurricanes, Kilo, Ignacio, and Jimena on August 31, 2015. NOAA GOES West image from NOAA EVL

wasn't just a new record for warmth, it was also the largest margin by which one year has beaten another since 1998 (which was also an El Niño year!).

Biggest one-year jump in atmospheric carbon dioxide levels at Mauna Loa

The global average carbon dioxide concentration at Mauna Loa Observatory made the biggest 1-year jump of the modern record: 3.1 parts per million. The previous largest annual jump in carbon dioxide that scientists observed at Mauna Loa (2.93 ppm) was in 1998 during another strong El Niño.

El Niño often leads to an expansion of global drought area (less plant growth and carbon dioxide uptake), an increase in tropical forest fires (release of stored carbon from wood and leaves), and other landscape changes that boost atmospheric carbon dioxide levels. Among the major contributors in 2015 were rampant forest fires in Indonesia.

The overactive fire season was attributed to El Niño-linked drought, which made degraded forests surrounding agricultural lands very flammable. When seasonal agricultural burning got underway, the fires spread into surrounding forests, causing an environmental and public health emergency.

Drought in Ethiopia

Few places have as long and devastating a history with drought and famine as Ethiopia, and El Niño tends to raise the likelihood for failed rainy seasons and drought. In 2015, northern, central, and southeastern Ethiopian highlands received 50%–90% of their normal rainfall. In the northeastern highlands, it was as little as 30%. More than 8 million people required food aid as a result of lost crops.

A pall of brownish-gray smoke obscured the island of Borneo in this satellite image from October 19, 2015. Locations where the satellite detected active fire are outlined in red. Image from NASA Earth Observatory.

*This article is based on analysis and details of E Niño published in the 2015 State of the Climate report, which covers climate during the calendar year. The 2015 El Niño continued through winter and spring of 2016. More information about the event in 2016 is available in ENSO blog.

References

Benedetti, A., F. Di Giuseppe, J. Flemming, A. Inness, M. Parrington, S. Rémy, and J. R. Ziemke. (2015) Atmospheric composition changes due to the extreme 2015 Indonesian fire season triggered by El Niño. Sidebar 2.2. [State of the Climate 2015, Chapter 2 (Global climates). K. M. Willett, D. F. Hurst, R. J. H. Dunn, and A. H. Dolman.]

Bell, G. D., M. Halpert, and M. l'Heureux. (2015) ENSO and the Tropical Pacific. In State of the Climate 2015, Chapter 4: The Tropics. H. J. Diamond and C.J. Schreck, Eds.

Mekonnen, A., J.A. Renwick, and A. Sanchez-Lugo, Eds. Chapter 7: Regional Climates. In State of the Climate 2015, Blunden, J., and D.Arndt, Eds.

Source: *National Oceanic and Atmospheric Administration (NOAA)*

Web Link: *https://www.climate.gov/news-features/features/2015-state-climate-highlights*

2016 Climate Trends Continue to Break Records: NASA

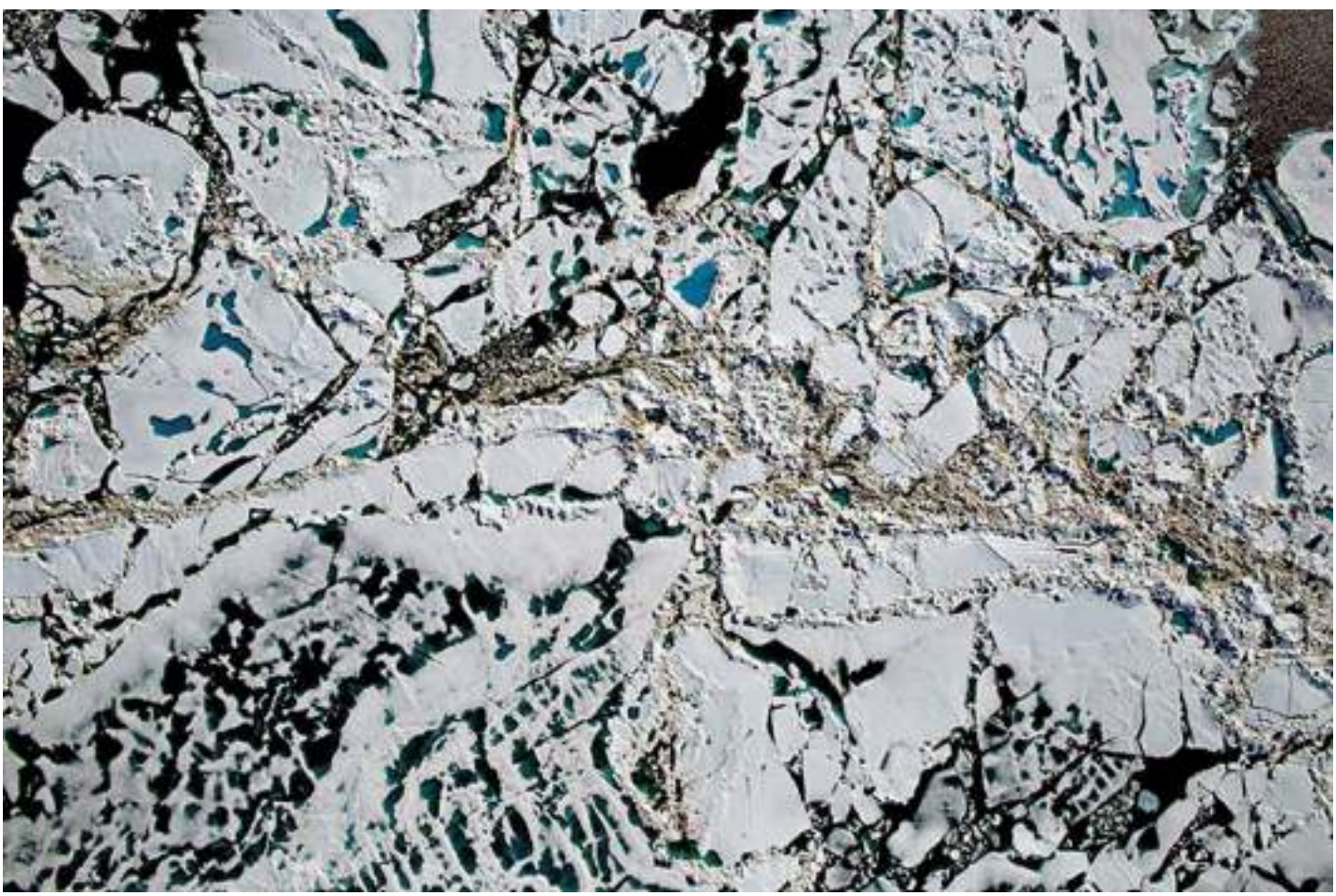
Two key climate change indicators — global surface temperatures and Arctic sea ice extent — have broken numerous records through the first half of 2016, according to NASA analyses of ground-based observations and satellite data.

Each of the first six months of 2016 set a record as the warmest respective month globally in the modern temperature record, which dates to 1880, according to scientists at NASA's Goddard Institute for Space Studies (GISS) in New York. The six-month period from January to June was also the planet's warmest half-year on record, with an average temperature 1.3 degrees Celsius (2.4 degrees Fahrenheit) warmer than the late nineteenth century.

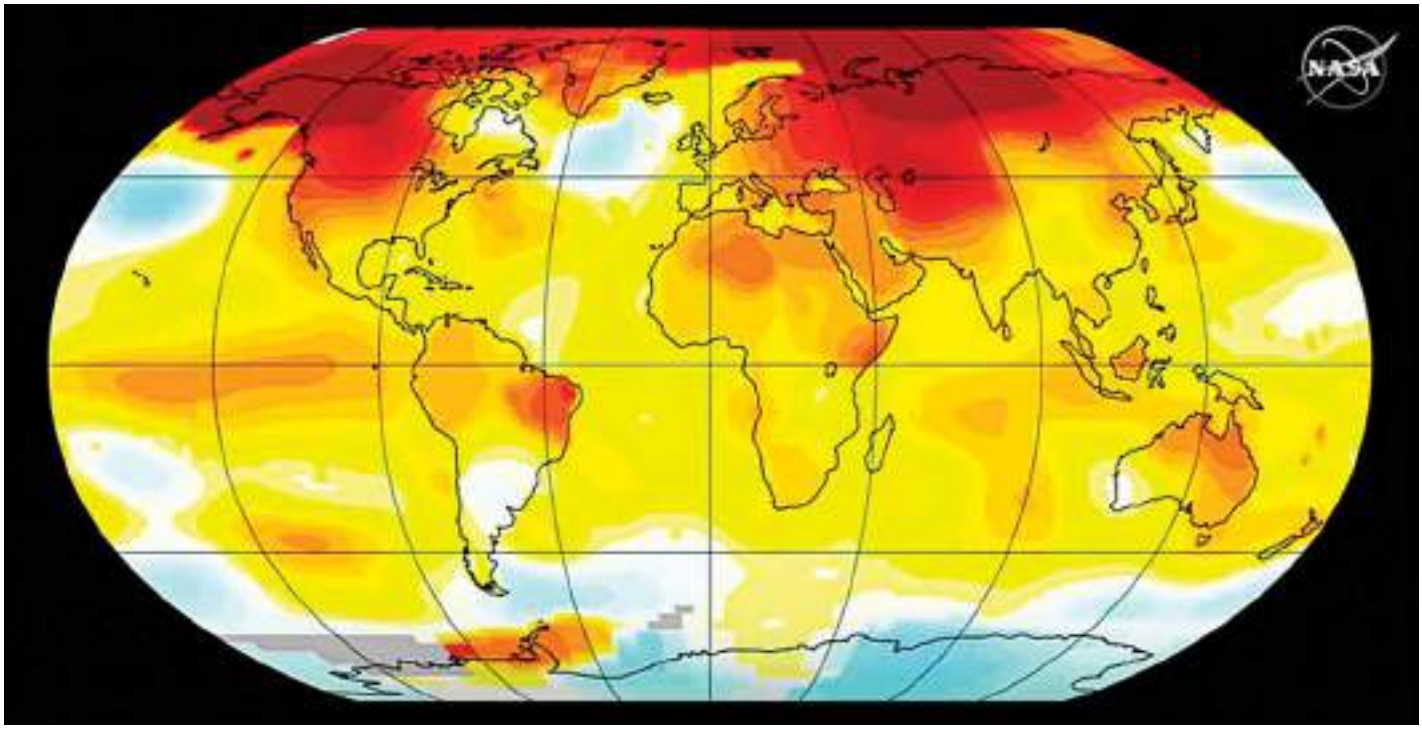
Five of the first six months of 2016 also set records for the smallest respective monthly Arctic sea ice extent since consistent satellite records began in 1979, according to analyses developed by scientists at NASA's Goddard Space Flight Center, in Greenbelt, Maryland. The one exception, March, recorded the second smallest extent for that month.

While these two key climate indicators have broken records in 2016, NASA scientists said it is more significant that global temperature and Arctic sea ice are continuing their decades-long trends of change. Both trends are ultimately driven by rising concentrations of heat-trapping carbon dioxide and other greenhouse gases in the atmosphere.

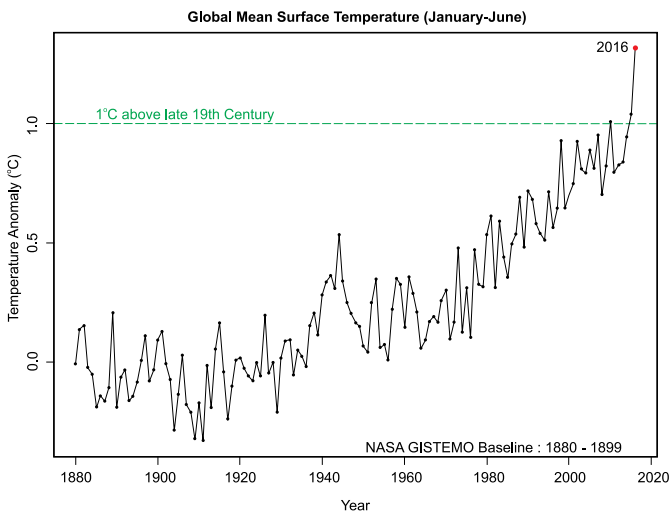
The extent of Arctic sea ice at the peak of the summer melt season now typically covers 40 percent less area than it did in the late 1970s and early 1980s. Arctic sea ice extent in September, the seasonal low point in the annual cycle, has been declining at a rate of 13.4 percent per decade.



Each of the first six months of 2016 set a record as the warmest respective month globally in the modern temperature record, which dates to 1880. Meanwhile, five of the first six months set records for the smallest monthly Arctic sea ice extent since consistent satellite records began in 1979.



Chunks of sea ice, melt ponds and open water are all seen in this image captured at an altitude of 1,500 feet by the NASA's Digital Mapping System instrument during an Operation IceBridge flight over the Chukchi Sea on Saturday, July 16, 2016. Credit: NASA/Goddard/Operation IceBridge.



The first six months of 2016 were the warmest six-month period in NASA's modern temperature record, which dates to 1880. Credit: NASA/Goddard Institute for Space Studies.

"While the El Niño event in the tropical Pacific this winter gave a boost to global temperatures from October onwards, it is the underlying trend which is producing these record numbers," GISS Director Gavin Schmidt said.

Previous El Niño events have driven temperatures to what were then record levels, such as in 1998. But in 2016, even as the effects of the recent El Niño taper off, global temperatures have risen well beyond those of 18 years ago because of the overall warming that has taken place in that time.

The global trend in rising temperatures is outpaced by the regional warming in the Arctic, said Walt Meier, a sea ice scientist at NASA Goddard.

"It has been a record year so far for global temperatures, but the record high temperatures in the Arctic over the past six months have been even more extreme," Meier said. "This warmth as well as unusual weather patterns have led to the record low sea ice extents so far this year."

Source: http://climate.nasa.gov/news/2465/2016-climate-trends-continue-to-break-records/

(Published: July 19, 2016)

The goal is to limit global warming to less than 2C compared to pre-industrial times, or even better, to 1.5C, if possible.

KKNPP Unit-2 Attains Full Power Operation

The second unit of Kudankulam Nuclear Power Project, KKNPP-2, attained its full-power capacity of 1000 MW on January 21, 2017.

The 100% unit reactor power was attained by raising power output in stages to generate full power of electricity as per laid down procedures and in line with stage-wise regulatory clearances accorded by the Atomic Energy Regulatory Board (AERB).

Upon achieving commercial operation, KKNPP-2 will add 1000 MW of electricity to the southern grid and raise the contribution of nuclear power in the country from the current installed capacity of 5780 MW to 6780 MW.

KKNPP-2 is the 22nd nuclear power reactor in the country and India's second Pressurised Water Reactor belonging to Light Water Reactor category. With this, now the KKNPP site holds the distinction of having two largest power reactors in the country.

The state-of-the-art VVER reactors of KKNPP incorporate enhanced safety features that ensure the highest level of safety, in line with the current international standards and incorporate a combination of active safety systems as well as passive safety systems like Passive Heat Removal System, Hydrogen Recombiners, Core Catcher, Hydro Accumulators and Quick Boron Injection System. This combination of multi-layered safety features ensures safety of the plant, public and environment.

Synchronisation to the grid

Earlier, KKNPP-2 was synchronised to the southern grid on August 29, 2016 at 1117 hours and began generating 245 MW. The Unit had attained its first criticality (controlled self-sustaining nuclear fission chain reaction in the reactor for the first time) on July 10, 2016. The reactor power was then increased in stages to generate full power of 1000 MW electricity.

[NPCIL HQ News Desk]

Foundation for KKNPP-3&4 Laid

Hon'ble Prime Minister of India Shri Narendra Modi and His Excellency Mr. Vladimir Putin, President of the Russian Federation, laid the foundation of KKNPP Units-3&4 on October 15, 2016 through video-conferencing from the BRICS summit in Goa.

Mr. S.K. Sharma, Chairman and Managing Director of Nuclear Power Corporation of India Limited (NPCIL) and Mr. Valery Limarenko, President of Atomstroyexport, jointly laid the foundation concrete for Units-3&4 at the Kudankulam power plant site.

Mr. R Banerjee, Project Director, NPCIL; Mr. N. Nagaich, HR Director, NPCIL; Mr. R. S. Sundar, the then Site Director, KKNPP; Mr. PA Pillai, Project Director, KKNPP-3&4 and senior officials of the Atomstoryexport were present on the occasion.

[NPCIL HQ News Desk]

A glimpse of the dedication event of KKNPP-1 via video conference

Dedication of KKNPP Units-1&2

The 1000 MW, KKNPP Unit-1 (KKNPP-1) was dedicated to **Indo-Russian Friendship and Cooperation** on August 10, 2016. The reactor was jointly dedicated by Hon'ble Prime Minister of India Shri Narendra Modi and His Excellency Mr. Vladimir Putin, President of the Russian Federation via video conference.

The unit is remarkably India's largest single power generation unit. Set up at Kudankulam in Tamil Nadu in technical cooperation with the Russian Federation, it is a shining example of Indo-Russian friendship and cooperation. The state-of-the-art Light Water Reactor of VVER type is the harbinger of a new phase of international cooperation for nuclear power generation in the country, bringing 'additionality' to the Indian nuclear power programme for stepping up nuclear power generation in the country.

The unit is already in service, having started commercial operation on December 31, 2014. With KKNPP-1 the installed capacity of nuclear power generation in the country stands at 5780 MW. Electricity from KKNPP-1 is fed to the southern grid.

Tweets from the Hon'ble Prime Minister of India

> Kudankulam 1 is an important addition to India's continuing efforts to scale up production of clean energy.

> We salute the dedication & hard work of team Russia & congratulate them for result of their labour.

> Have always deeply valued our friendship with Russia; it is fitting that we jointly dedicate Kudankulam Nuclear Power Plant Unit 1.

The Hon'ble Prime Minister of India said…

"In dedicating Kudankulum 1, we mark another historic step in India-Russia relations. Its successful completion is not just another fine example of the strength of our special and privileged strategic partnership; it is also a celebration of our abiding friendship. And, it is only a start of our collaboration in this field."

"Today's event is also a joyful occasion for the team of Indian and Russian engineers, scientists and technicians. We salute their dedication and hard work and congratulate them for the fruits of their labour."

Dedication of KKNPP-2

On October 15, 2016, the second 1000-MW reactor Unit-2 at Kudankulam Nuclear Power Project, KKNPP-2, was dedicated to the **Indo-Russian Partnership**, during the BRICS Summit, by the Hon'ble Prime Minister of India Shri Narendra Modi and His Excellency Mr. Vladimir Putin, President of the Russian Federation. The VVER-type nuclear power reactor is an identical twin of KKNPP Unit-1.

[NPCIL HQ News Desk]

Dr. Sekhar Basu, Chairman AEC & Secretary DAE (right) greeting Mr. S.K. Sharma, CMD, NPCIL (left) upon taking over charge from Mr. K.C. Purohit, former CMD, NPCIL (centre)

Mr. S.K. Sharma Takes Over as CMD, NPCIL

Mr. Satish Kumar Sharma took over as the Chairman & Managing Director of Nuclear Power Corporation of India Limited (NPCIL) in a ceremony held on May 31, 2016 at NPCIL HQ, Mumbai. The occasion was graced by Dr. Sekhar Basu, Chairman, Atomic Energy Commission (AEC) & Secretary, Department of Atomic Energy (DAE); Mr. K.C. Purohit, former CMD, NPCIL; Directors, senior officers and the employees of NPCIL.

On taking over the charge of CMD, NPCIL, in his address to NPCIL parivar members, Mr. Sharma expressed that safety in all aspects of nuclear power plants in India would continue to be his highest priority. He also sought cooperation of one and all of the NPCIL's Parivar in effectively meeting the challenges in implementing the Indian nuclear power programme safely and reliably. He expressed confidence that NPCIL members will continue to participate with zeal and commitment, as always, in taking the organisation to newer heights in the coming years.

Mr. Sharma, a Distinguished Scientist of *Department of Atomic Energy*, completed his BE (Electronics) degree from the Maulana Azad National Institute of Technology (MANIT), Bhopal in 1980 and graduated with distinction from the 24th batch of BARC Training School in 1981. He started his career at Rajasthan Atomic Power Station-1&2, a harbinger of Indian PHWR technology, where he contributed immensely in different functional areas.

Subsequently, Mr. Sharma has held several key positions in Indian nuclear power stations, including that of Site Director at Rawatbhata Rajasthan Site, before assuming the position of Director (Operations) in the year 2015.

With his rich and diverse experience, he has contributed immensely towards the improvement of overall performance of NPCIL. He has also worked in a key position for improving the safety and reliability of nuclear power stations across the world in association with an international team of nuclear experts in WANO-TC (World Association of Nuclear Operators – Tokyo Centre). This varied experience has exposed him to various reactor technologies and to assimilate new ideas as well as new approaches.

[NPCIL HQ News Desk]

Generator Rotor insertion in Stator

Generator Rotor Insertion in Stator Core at KAPP-3

The first 700-MW generator rotor of 13.135-metre length and 1.216-m diameter Type-THDF 115/67 hydrogen-cooled, apparent power – 842.9 MVA, active power – 716.5 MW, 2 pole, 3000 rpm, 21 kV voltage and weighing 75.8 MT was successfully inserted into the stator core on January 9, 2017 in Turbine Building of Kakrapar Atomic Power Project unit-3 (KAPP-3).

Earlier, pre-erection activities, viz., cleaning of stator and rotor, checking of special tools, lifting and handling devices were completed and skid shoes assembled with rotor. Sliding pedestals and skid plates were inserted inside the stator to receive the rotor. IR and PI value of stator were taken in advance and brought to acceptable limit. The bottom end shields of both sides were placed in position. All the stator internals parts were checked from FME point of view by a task force committee and clearance given for rotor insertion. Detailed handling and erection process was carried out jointly by site execution team of NPCIL and M/s Bharat Heavy Electricals Limited and thus the milestone activity of Generator Rotor insertion in stator core was successfully completed at KAPP-3.

[NPCIL HQ News Desk]

KAPP-3&4: Approaching Completion of Major Works

The construction activities at Kakrapar Atomic Power Project-3&4 (KAPP-3&4), India's first indigenously designed Nuclear Power Reactor of 700 MW series, are presently in full swing, with the commissioning of Electrical and Common Services systems. Many equipment and components are being progressively delivered and erected. As on January-end 2017, the overall physical progress of KAPP-3 is about 85% and that of KAPP-4 is about 70%.

In Unit-3, test-charge of Start-Up Transformer (SUT) was completed in the month of September 2015. Subsequently, pre-commissioning of further electrical systems such as CI-IV, CI-III & CI-II switchgears/Motor Control Centres (MCCs) along with associated transformers have been independently completed. Now, Auxiliary Power System with SUT is being planned for energising on permanent basis from the Main Control Room. Various Common Service systems, viz., Fire Water System, Chilled Water System and Service Water System equipment erection and associated piping works have been completed and are ready for system commissioning. Also about 75% of Circuit Hydro Test in Common Services Piping System has been completed. Critical path activity of Feeder

A panoramic view of KAPP-3&4

erection job shall commence in the month of March 2017. The preceding job of feeder erection, i.e., header boiler piping is in progress and scheduled to be completed by mid-March 2017. All main plant civil construction works have been completed, except Inner Containment (IC) and Outer Containment (OC) dome concreting. Finishing works of all major buildings are also nearing completion. IC dome structure has been lifted as a single unit of 365 MT to the Reactor Building (RB) Ring Beam, which is a major milestone of the project and also a first-of-a-kind activity in Indian nuclear history. Fabrication of all three Turbine Condensers is completed up to neck level. Subsequently, condenser tubing work was commenced and Condenser-B tube insertion job was completed. Generator rotor was successfully inserted in Generator Stator on January 9, 2017 in Unit-3. The HP and LP turbine erection works is progressing well.

In Unit-4, Reactor Building internal structures, including SG vaults, Inner Containment Wall and Ring Beam construction, have been completed. Also, fabrication of IC dome structure works has been completed. Erection of all eight Reactor Headers has been completed in FM Vault. Major equipment such as Pressuriser, ECCS Accumulator and PDHRS tank erection is in progress. Coolant Channel End-fitting pre-assembly has been completed. Preparation for Calandria Tube rolling in FM Vault is in progress. Calandria Tube trimming has been completed.

[NPCIL HQ News Desk]

A view of RAPP-7 Reactor Building

RAPP-7&8: Construction and Erection at Full Pace

The construction of Rajasthan Atomic Power Project units-7&8 (RAPP-7&8) is in progress. Civil works are in progress on many fronts. Various equipment/components are being progressively delivered and erected at site. The overall physical progress of RAPP-7 is about 70% and that of RAPP-8 is about 57% as on January-end 2017.

In Unit-7, the major milestone of installation of Calandria Tubes has been completed during the year and the installation of Coolant Tubes is in progress. In Reactor Building-7 (RB-7), erection of liner panels of Ring Beam, which is a part of Inner Containment dome, is completed and preparation for concreting work is in progress. Construction of one of the Steam Generator Vaults is completed and that of the other vault is in progress. In Reactor Auxiliary Building-7 (RAB-7), concreting of Main Air Lock Slab, EL 100-m slab is completed and work on EL 105-m slab is in progress.

In Unit-8, End-shields and Calandria have been lowered and aligned in Calandria Vault and welding is nearing completion. In RB-8, work on 6th tier of Inner Containment wall is in progress and concreting of EL 109-m slab is completed.

In Control Building (CB), casting of EL 111-m slab of Unit-7 side has been completed and work for EL 116-m slab is in progress. On the Unit-8 side, the work for EL 106-m part slab is completed.

Construction has reached up to 118 m in Turbine Building-7, EL 126-m slab in Electrical Building and EL 105-m slab in Pipe & Cable Bridge.

In Turbine Building-8, Concreting of EL 104-m part slab is completed and reinforcement work for Turbo-Generator (TG) Deck is in progress. Casting of EL 122-m part slab of Electrical Building, EL 111-m slab of Pipe & Cable Bridge as well as SUT and Generator Transformer (GT) foundations has been completed. Construction of miscellaneous foundations and fire walls is in progress.

Construction of Safety-related Pump House, Safety-related Electrical House, Fire Water Pump House and Chlorination Plant is in progress. Civil construction of Plant Water Pump House and DM Water Plant is nearing completion.

Construction of four Natural Draught Cooling Towers (NDCT) and four Induced Draught Cooling Towers (IDCT) is in progress.

Till date, more than 5.38 lakh cu.m of concreting has been done at site.

Erection of Piping for Nuclear and Common Services systems and equipment like PHT shutdown pumps, ECCS accumulators, LZC system equipment, etc. in RB-7, RAB-7 and CB is in progress. Hydro-testing of Condenser Cooling Water (CCW) inlet and outlet lines of Unit-7 has been completed. Laying of balance CCW pipes for unit-7 is in progress. Erection of electrical cable trays and equipment like panels, switchgears, etc. in Control Building, RAB-7 and TBEB-7&8 is in progress.

Erection of 2 DG sets and related piping work in SAB-7B has been completed.

400-kV Switchyard, Sujalpur-I and Sujalpur-II lines, along with Line Reactors have been charged and synchronised.

[NPCIL HQ News Desk]

RAPP-7&8 400-kV Switchyard Charged

The 400-kV switchyard of RAPP-7&8

It was a momentous occasion for Rajasthan Atomic Power Project-7&8 (RAPP-7&8) at 1815 hrs. on July 29, 2016 when 400-kV switchyard of RAPP-7&8 was successfully charged after its interconnection with the existing 400-kV switchyard of Rajasthan Atomic Power Station-5&6 (RAPS-5&6).

The erection and commissioning activity of 400-kV switchyard was completed under close coordination by the Electrical, Civil and O&M groups of the project. It was highly challenging task, as it is an extension of existing 400-kV switchyard of RAPS-5&6, which is an operating station. Construction and erection work involved activities like excavation using rock blasting without causing any damage to the charged switchyard. This challenge was met with very precise planning, control and coordination.

The switchyard is now connected to the national grid and ready to evacuate 1400 MW from RAPP-7&8.

[NPCIL HQ News Desk]

Outer face of calandria showing one of the End-Shields with the installed calandria tubes

Calandria Tube Installation at RAPP-7 Completed

At 2154 hrs. on July 27, 2016, a major construction milestone was reached at RAPP-7 when installation of 392 calandria tubes was completed successfully. It was a proud moment for the dedicated project team as the job was completed in a short period of 39 working days with untiring effort and efficient planning.

Calandria tubes are a key component of Pressurised Heavy Water Reactor and its installation includes high-precision rolling of the tubes at both ends with the tube sheet of End-Shields. The activity involved meeting stringent quality requirements during all its phases such as trimming to size, cleaning, tube-insertion and rolling under clean room conditions. Multi-level quality checks were carried out, including helium leak-testing to the requirement as specified.

[NPCIL HQ News Desk]

Coolant Channel Installation at KAPP-3

Outer face of calandria showing one of the End-Shields with the installed coolant tubes

In 700-MW Indian PHWR, there are 392 Coolant Channels. The Coolant Channel installation activity consists of pre-assembly of End-Fittings (shrink-fitting) of CS Ring, Liner Tube rolling, and Split Sleeve installation with Journal Ring and Retainer rings), Coolant Tube trimming to the required dimension, Shrink-fitting and rolling of one end of the Pressure Tube (PT) with End-Fitting (EF) outside RB, Installation of the one end rolled EF-PT assembly from south side, shrink-fitting and rolling of second end of PTs with EFs from north side, bellow-lip welding, air-hold test of individual coolant channel assembly and installation of positioning assembly.

Coolant Channel installation is a critical activity of reactor core, with very stringent requirements. To fulfill and achieve the intended installation requirements and stipulations of AERB, procedures were prepared and reviewed by all the concerned agencies at the Kakrapar Atomic Power Plant units-3 (KAPP-3) site as well as at HQ. To ensure the effective implementation of procedures, hold point, checklist, route card etc., a three-stage inspection check of every activity was implemented and each activity immediately documented after its completion. The coolant channel installation of KAPP-3 has been completed in all respects on June 4, 2016.

[NPCIL HQ News Desk]

Inauguration of Construction Power Supply at GHAVP

Mr. Preman Dinaraj, the then Director (Finance), NPCIL, inaugurated 11-kV construction power supply at Gorakhpur Haryana Anu Vidyut Pariyojana (GHAVP) on July 30, 2016. The line was charged by Dakshin Haryana Bijli Vitran Nigam (DHBVN) state officials, who were also present along with GHAVP officials on this occasion.

The then Director (Finance) also inaugurated the milestone for GHAVP Township and addressed GHAVP employees.

[NPCIL HQ News Desk]

Mr. Preman Dinaraj, the then Director (Finance), inaugurating the construction power supply by unveiling the plaque.

Successful Development and Implementation of in situ Machining around End-Shields Cooling Pipelines at KAPP-3

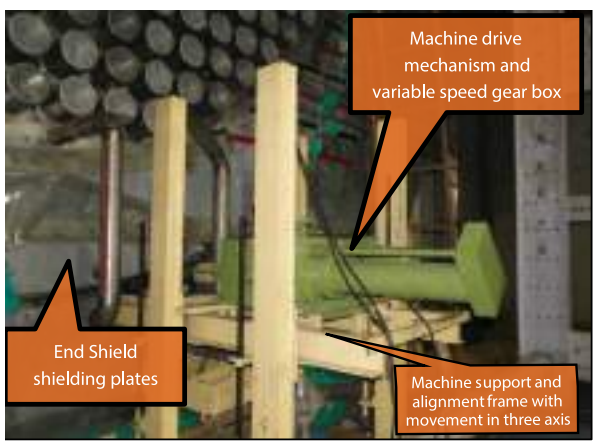
At Kakrapar Atomic Power Plant units-3 (KAPP-3), the End-Shield cooling outline pipes, coming out of each End-Shield, touched Annular Shielding plates and 10-mm-thick SS ring on End-Shields at local points. Later on, during design analysis carried out by HQ Design group, it was observed that a gap of a minimum of 3 mm is necessarily required all around the End-Shield cooling outlet pipes to allow thermal expansion. Since shielding plates and End-Shield cooling outlet pipe header were already installed during this period, it was a big challenge to create a gap around all outlet pipes of End-Shields. After reviewing the situation at the site, a task was assigned to KAPP-3&4 site and site Reactor Engineering group to develop an *in situ* machine for creating a gap all around the cooling outlet pipes by cutting shielding plates to a depth of 200 mm, without damaging the pipes and End-Shield.

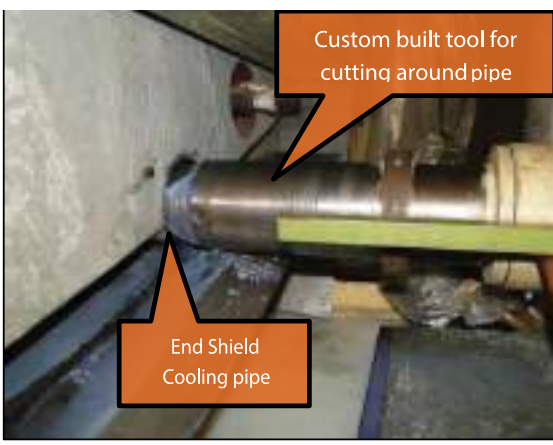
Tool and Machine Development

To create uniform gap all around the pipe the process of machining was chosen, as it was a dimensionally controlled process. Further the concept of specialised hollow cylindrical cutting tool with cutting edges was developed in consultation with various tool manufactures.

To drive the tool and align the tool axis, separate drive and supporting movable structure were designed to take all loads in the limited space available at site. Since the cooling pipelines of End-Shields were also to be protected during machining, a concept of fixed SS sleeve was introduced to guide the tool over the cooling outlet pipes without damaging it.

During the manufacturing of tool and machine, mockups were made to simulate cutting on actual size of pipe with site constraints. Once the tool and machine were developed with suggested changes by vendor, the machining trials were conducted on mockups. During machining on mockups, the machining parameters were fine-tuned to avoid any deviations during machining on actual job at site.





Machining on job at site

After successful completion of in situ machining on mockups and qualification of machine operator, complete machine was again assembled in Fuelling Machine vaults of KAPP-3. The tool axis of machine was aligned with the use of movable machine frame, in line with individual axis of each cooling outlet pipe. To protect the cooling pipe surface, an SS sleeve was tight-fitted over each pipe during cutting and further to guide the cutting tool during operation. For each cooling pipe location, the machine was adjusted to meet the pipe elevation and its axis alignment requirements.

The machine was shifted in Fuelling Machine vaults and the *in situ* cutting around all ten cooling outlet pipes of both End-Shields (five pipes on each End-Shield) was successfully completed. Inspection for achieved gap after machining and visual was done by NPCIL QA group and all the pipe locations met the requirements without any deviation.

[NPCIL HQ News Desk]

Awards Galore for NPCIL at NSCI Safety Awards

National Safety Council of India (NSCI) is a national-level apex body in India, set up by the Ministry of Labour, Government of India with the goal of creating and strengthening Safety, Health and Environment (SHE) culture in workplace and integrating the same with work culture. On April 6, 2016, national-level NSCI Safety Awards-2015 for organisations in manufacturing, construction and Micro, Small & Medium Enterprises (MSME) sectors were presented by Mr. Bandaru Dattatreya, Minister of State (Independent Charge), Labour & Employment, Govt. of India, at a function organised at Vigyan Bhawan, New Delhi. Here are glimpses of awards received by NPCIL plant sites.

'Sarva Shreshtha Suraksha Puraskar' to RAPS-3&4

Mr. D.D. Jain, Technical Services Superintendent, RAPS-3&4, receiving the award from Mr. Bandaru Dattatreya, Minister of State (Independent Charge), Labour & Employment, Govt. of India

'Shreshtha Suraksha Puraskar' to KAPP-3&4

Mr. Lokesh Kumar, the then Project Director, KAPP-3&4 (left), receiving the award from Mr. Bandaru Dattatreya, Minister of State (Independent Charge), Labour & Employment, Govt. of India

Maharashtra Safety Award for TAPS-3&4

Mr. R.M. Godbole, CS, TAPS-3&4, receiving the award from Mr. Arvind Doshi, Chairman, NSC-MC

TAPS-3&4 received the Maharashtra Safety Award from National Safety Council - Maharashtra Chapter (NSC-MC) for achieving Lowest Average Accident Frequency Rate for Year-2014 and Longest Accident-Free Period for Year-2014. The award was received by Mr. R.M. Godbole, CS, TAPS-3&4 on September 19, 2015 from Mr. Arvind Doshi, Chairman, NSC-MC.

'Suraksha Puraskar' to RAPP-7&8

Mr. Vivek Jain, Chief Project Engineer and Mr. J.R. Khatsuriya, Head (Industrial Safety & Fire), RAPP-7&8, receiving the award from Mr. Bandaru Dattatreya, Minister of State (Independent Charge), Labour & Employment, Govt. of India

National Safety Award for TAPS-3&4

Mr. Hemant Kumar, the then Station Director, TAPS-3&4 (right), receiving the award from from Mr. Bandaru Dattatreya, Minister of State (Independent Charge), Labour & Employment, Govt. of India

Tarapur Atomic Power Station-3&4 (TAPS-3&4) has won the prestigious 'National Safety Award' by Directorate General Factory Advice Service & Labour Institutes (DGFASLI), Ministry of Labour & Employment, Govt. of India for the performance year 2013. The award was received by Mr. Hemant Kumar, the then Station Director, TAPS-3&4 on September 17, 2015.

[NPCIL HQ News Desk]

NPCIL Bags 'Corporate Vigilance Excellence Award'

Mr. S.K. Acharya, CMD, Neyveli Lignite Corporation Limited (2nd from right), presenting the award to Mr. Prateek Goswami, CVO, NPCIL and Mr. V.K. Gupta, GM (Vigilance)

The Institute of Public Enterprise (IPE), Hyderabad was established in 1964 for the study of issues and policies relating to public enterprises (PEs). The IPE has instituted a Corporate Vigilance Excellence Award from 2013-14. The award is given for the best practices adopted by public enterprises for vigilance function. Nuclear Power Corporation of India Limited (NPCIL) also participated and was declared winner in the category 'Power Sector Enterprises' for the year 2015-16.

Mr. Prateek Goswami, Chief Vigilance Officer (CVO), NPCIL, along with Mr. V.K. Gupta, GM (Vigilance); Mr. N.S. Kamath, Vigilance Officer, Kaiga Generating Station and Ms. D.J. Pereira, Manager (Human Resources-DC) received the award on behalf of NPCIL on February 18, 2016 at the 7th Conclave of Vigilance Officers organised by IPE. The award was presented by the Chief Guest of the function Mr. S.K. Acharya, Chairman and Managing Director, Neyveli Lignite Corporation Limited.

[NPCIL HQ News Desk]

5th Annual Greentech CSR Award for MAPS

NPCIL's Madras Atomic Power Station (MAPS) has bagged the prestigious '5th Annual Greentech CSR Award 2015' in the Gold category for its community-based ice plant project under its CSR initiatives. The award was received by Mr. K. Narasimha Reddy, ACE (Engineering Directorate), NPCIL office, Hyderabad on behalf of Station Director on November 28, 2015 at the 16th Annual Greentech Environment and CSR Conference 2015 at Hyderabad.

Mr. K. Narasimha Raddy, ACE (Engineering Directorate), NPCIL, Hyderabad (left) receiving the award from Mr. Kamaleshwar Sharan, President, Greentech Foundation (centre) and Mr. S.K. Acharya, CMD, Neyveli Lignite Corporation Limited (right)

MAPS undertakes many welfare measures for the development of the neighbouring communities. As part of the above initiative, an ice plant of 7.5-tonne capacity was constructed by MAPS in association with Plant (an NGO in Chennai) in the fishing village of Kokilamedu in Kancheepuram District of Tamil Nadu, adjacent to the plant site, to increase the commercial value of the marine species for sustainable livelihood of fishermen folk. The ice plant was dedicated to fishermen community by Mr. R. Banerjee, Director (Projects), NPCIL, Mumbai.

[NPCIL HQ News Desk]

AERB Awards for Kakrapar Gujarat Site

Fire Safety Award for KAPS-1&2

Mr. D.A. Chavda, Head (IS&F), KAPS-1&2 (left) and Mr. L.K. Jain, the then Site Director, Kakrapar Gujarat Site (right) receiving the award from Mr. S.A. Bhardwaj, Chairman, AERB (centre)

Kakrapar Atomic Power Station Unit-1&2 (KAPS-1&2) received Atomic Energy Regulatory Board (AERB) Fire Safety Award for the year 2015 in Category-I for its outstanding performance in Fire Safety. Mr. L.K. Jain, the then Site Director, Kakrapar Gujarat Site and Mr. D.A. Chavda, Head (Industrial Safety & Fire), KAPS-1&2 received the award from Mr. S.A. Bhardwaj, Chairman, AERB during 33rd DAE Safety & Occupational Health Professionals Meet held at Institute for Plasma Research (IPR), Gandhinagar, Gujarat on November 23, 2016.

Environment Protection Award for KAPP-3&4

(From left to right) Mr. L.K. Jain, the then Site Director, KAPS; Mr. Lokesh Kumar, the then Project Director, KAPP-3&4 and Mr. Ajay Naranje, Head (IS&F) KAPP-3&4 receiving the award from Mr. S.A. Bhardwaj Chairman, AERB

Kakrapar Atomic Power Project Unit-3&4 (KAPP-3&4) received AERB Environment Protection Award for the year 2015. Mr. L.K. Jain, the then Site Director; Mr. Lokesh Kumar, the then Project Director, KAPP-3&4 and Mr. Ajay Naranje, Head (IS&F), KAPP-3&4 received the award from Mr. SA Bhardwaj, Chairman, AERB during 33rd DAE Safety & Occupational Health Professionals Meet held at Institute for Plasma Research (IPR), Gandhinagar, Gujarat on November 23, 2016.

[NPCIL HQ News Desk]

NPCIL Conferred PRSI National Awards

PRSI National Awards-2016

Nuclear Power Corporation of India Ltd. (NPCIL) won 38th Public Relations Society of India (PRSI) National Awards 2016 for "Halls of Nuclear Power" and "Connecting Lives – Nationwide Media Facilitation and Public Awareness programme" in the categories of Best Public Awareness Programme and Best Communication Campaign (External Public), respectively, during 38th All India Public Relations Conference held at Kolkata.

Award for Best Communication Campaign

Award for Best Public Awareness Programme

Mr. Amritesh Srivastava, Senior Manager (Media & Corporate Communications), NPCIL (left), receiving the award from Dr. Chandan Mitra, Member of Parliament, Rajya Sabha and Editor & Managing Director, The Pioneer (2nd from right) and Dr. Ajit Pathak, National President, PRSI (1st from right)

On behalf of NPCIL, the awards were received by Mr. Amritesh Srivastava, Senior Manager, Media & Corporate Communications, NPCIL.

[NPCIL HQ News Desk]

Hon'ble Prime Minister of India Shri Narendra Modi and His Excellency Mr. Barack Obama President of the United State of America at the White House (Image: Indian Prime Minister's Office)

US-India Deal Helps Pave Way for New Nuclear in India

Westinghouse can start building six AP1000s in India following an agreement signed on June 7, 2016 during talks at the White House between Hon'ble Prime Minister of India Shri Narendra Modi and His Excellency Mr. Barack Obama President of the US. It is the first such opportunity for a US company since the countries signed a civil nuclear deal in 2008.

According to a joint statement by the two leaders, Nuclear Power Corporation of India and Westinghouse Electric can now begin engineering and site-design work for the reactors. The final contract is to be completed in June 2017.

"Culminating a decade of partnership on civil nuclear issues, the leaders welcomed the start of preparatory work on-site in India for six AP 1000 reactors to be built by Westinghouse and noted the intention of India and the US Export-Import Bank to work together toward a competitive financing package for the project," the statement said.

Once completed, the project would be among the largest of its kind, it said, "fulfilling the promise of the US-India civil nuclear agreement and demonstrating a shared commitment to meet India's growing energy needs while reducing reliance on fossil fuels."

The US-India Contact Group has worked to address the issues presented by a 2010 Indian law on nuclear liability through India's ratification of the Convention on Supplementary Compensation for Nuclear Damage, the statement noted.

The USA and India "share common climate and clean energy interests and are close partners in the fight against climate change", it continued. "Leadership from both countries helped galvanize global action to combat climate change and culminated in the historic Paris Agreement reached last December," it added.

The USA "reaffirms its commitment" to join this agreement as soon as possible this year, it said, and India "similarly has begun its processes to work toward this shared objective".

Mr. Obama welcomed India's application to join the Nuclear Suppliers Group (NSG), and re-affirmed that India is "ready for membership", according to the joint statement. It added that the USA has called on NSG Participating Governments to support India's application when it comes up at the NSG Plenary later in June 2016.

Source: WNN
(Published: June 8, 2016)

The integrated head package is placed upon the reactor vessel of Haiyang-1 (Image: SNPTC)

First Two AP1000s Move Closer to Commissioning

The integrated head package has been installed on top of the AP1000 reactor pressure vessel of unit-1 of the Haiyang nuclear power plant in China's Shandong province. Meanwhile, hydraulic testing has been completed of the primary circuit of Sanmen-1, expected to be the first Westing house AP1000 to begin operating.

The integrated head package combines several separate components in one assembly and aims to allow the rapid removal of the reactor vessel head during a refueling outage. It includes a lifting rig, seismic restraints for control rod drive mechanisms, support for reactor head vent piping, power cables, cables and a conduit for in-core instrumentation, cable supports and the cooling shroud assembly. Mounted directly on the reactor vessel head, the system helps to minimise the time, manpower and radiation exposure associated with head removal and replacement during refueling.

Sanmen-1 hydraulic tests

SNPTC announced that hydraulic testing had been completed of the three-loop primary circuit of the Sanmen-1 AP1000.

The tests involved filling the reactor's primary circuit with water, which is circulated by the reactor coolant pumps to verify that the welds, joints, pipes and components of the reactor coolant system and associated high-pressure systems meet regulatory standards. The pressure within the circuit was raised to a maximum of 21.6 MPa, while the water in the circuit was heated to 60°C.

Sanmen-1 will now undergo a series of three thermals tests before being loaded with fuel and started up later this year.

The 215-tonne integrated head package for Haiyang-1 was installed on the reactor vessel on May 25, 2016, plant constructor State Nuclear Power Technology Corporation (SNPTC) announced.

In September 2007, Westinghouse and its partners the Shaw Group received authorisation to construct four AP1000 units in China: two at Sanmen in Zhejiang province and two more at Haiyang in Shandong province.

Sanmen unit-1 is expected to be the first AP1000 to begin operating, in September, while Haiyang-1 is expected to start up by the end of the year. Containment tests have already been successfully conducted at both units. All four Chinese AP1000s are scheduled to be in operation by the end of 2017.

Four AP1000 reactors are being built in the USA – two each at Vogtle and Summer – while three AP1000s are also proposed for the Moorside site in the UK.

Source: WNN
(Published: May 26, 2016)

Watts Bar-2 Connected to Grid, Generates Electricity for First Time

The Tennessee Valley Authority's (TVA's) Watts Bar-2 nuclear unit near Knoxville in Tennessee, USA, has generated electricity onto its power grid for the first time after it was connected to the grid, TVA said.

Watts Bar-2 reached first criticality on May 23, 2016. TVA said reactor operators have begun an initial test run of generation equipment. The team is using this run to collect data to be sure generating equipment is prepared for continuous full-power operation later this summer.

The next step is full-plant testing of systems and controls at increasing reactor power levels up to 100 percent power. TVA said these tests will be repeated multiple times to ensure the plant operates safely as designed. Watts Bar-2 is a 1,165-MW Westinghouse pressurised water reactor.

Once in commercial operation, it will be the first US reactor to start generating power since 1996, when Watts Bar-1 was commissioned.

Source: NucNet
(Published: June 7, 2016)

Reactor Operator Bill Hahn syncronises Watts Bar-2 to the TVA power grid on June 3, 2016

"Nuclear power will help provide the electricity that our growing economy needs without increasing emissions. This is truly an environmentally responsible source of energy."

– Michael Burgess
Member of the United States House of Representatives

EIA Sees Strong Growth in Nuclear Generation to 2040

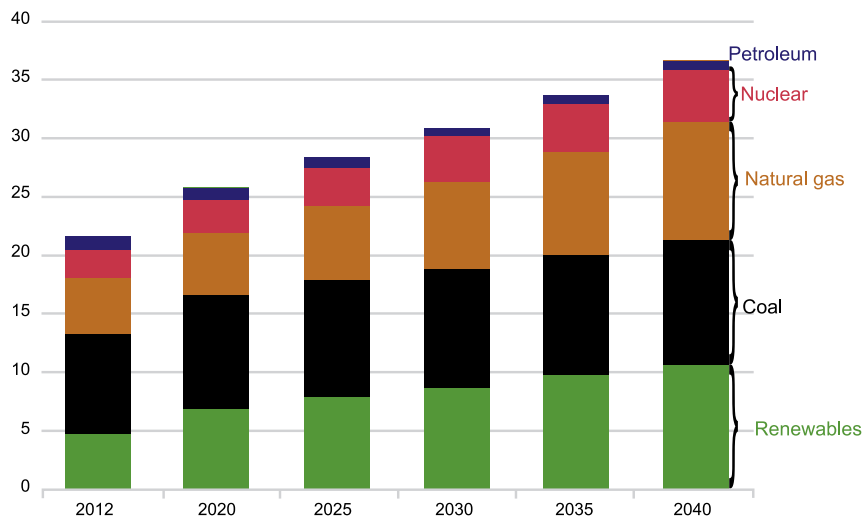
Global nuclear electricity generation is expected to almost double by 2040, according to the latest projection by the US Department of Energy's Energy Information Administration (EIA). Most of this growth will be in the developing world, it said.

Releasing the latest edition of its International Energy Outlook on May 11, 2016, the EIA said total world energy consumption will increase by almost 50%, from 549 quadrillion British thermal units in 2012 to 815 quadrillion Btu in 2040. This growth will be driven by industrialisation in non-OECD countries, especially in Asia, the EIA said.

"Developing Asia accounts for more than half of the projected increase in global energy use through 2040," said EIA administrator Adam Sieminski. "This increase will have a profound effect on the development of world energy markets." By 2040, almost two-thirds of the world's primary energy will be consumed in the non-OECD economies, according to the EIA.

Although consumption of non-fossil fuels is expected to grow faster than consumption of fossil fuels, fossil fuels will still account for 78% of primary energy in use in 2040. Coal will be the world's slowest growing energy source, rising by 0.6% annually from 153 quadrillion Btu in 2012 to 180 quadrillion Btu in 2040. China, the USA and India will remain the top three coal-consuming countries, together accounting for more than 70% of world coal use. Natural gas consumption will grow 1.9% annually over the same period.

According to the EIA, global electricity generation will increase by 69% between 2012 and 2040, from 21.6 trillion kWh in 2012 to 25.8 trillion kWh in 2020 and 36.5 trillion kWh in 2040.



World net electricity generation by energy source, 2012-2040, in trillion kWh (Image: EIA)

While renewable energy sources are projected to be the world's fastest growing energy source for electricity production between 2012 and 2040, growing an average 2.9% annually, nuclear energy will be the third fastest growing after natural gas. Global nuclear generating capacity is expected to see 2.3% annual growth between 2012 and 2040, from 2.3 trillion kilowatt-hours (kWh) to 4.5 trillion kWh. Its share of total primary energy over this period will increase from 4% to 6%.

"Concerns about energy security and greenhouse gas emissions support the development of new nuclear generating capacity," the EIA said. China alone, which plans to add 139 GW of nuclear capacity by 2040, accounting for 61% of world nuclear capacity growth.

Among OECD countries, only South Korea has a "sizeable increase" in nuclear generating capacity (15 GW), the EIA notes. However, reactor shutdowns in Canada and Europe, together with reduced capacity in Japan, will see an overall drop of 6 GW in nuclear capacity in OECD nations by 2040.

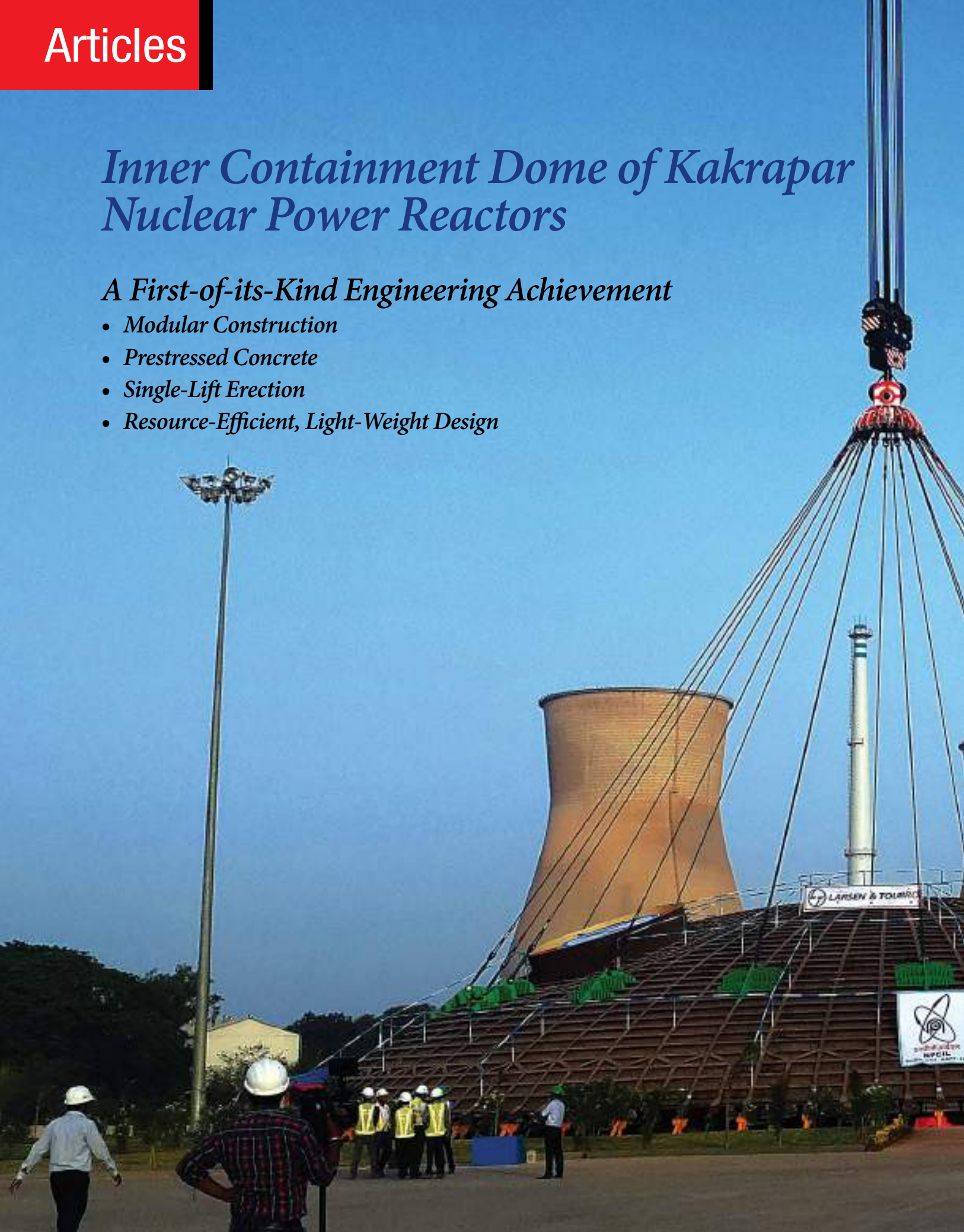
Despite the move towards lower-carbon energy sources, energy-related CO_2 emissions are projected to increase from 32 billion tonnes in 2012 to 36 billion tonnes in 2020 and then to 43 billion tonnes in 2040, a 34% increase from 2012 to 2040. "Much of the growth in emissions is attributed to developing non-OECD nations, many of which continue to rely heavily on fossil fuels to meet the fast-paced growth of energy demand," the EIA said.

Source: WNN
(Published: May 12, 2016)

Inner Containment Dome of Kakrapar Nuclear Power Reactors

A First-of-its-Kind Engineering Achievement

- *Modular Construction*
- *Prestressed Concrete*
- *Single-Lift Erection*
- *Resource-Efficient, Light-Weight Design*



Conceptualisation, Design and Engineering of Inner Containment Dome Liner of 700-MW PHWRs at Kakrapar

Dr. Rajiv Ranjan, SO/G; Sujita Jha, SO/C; Abhishek Tripathi, SO/D; Madhumangal Das, SO/E; Indrajit Ray, SO/H; G. Prabhakar, SO/H; Raghupati Roy, SO/H+; Arvind Shrivastava, SO/H+, NPCIL, HQ

1. Introduction

The 700-MW Pressurised Heavy Water Reactor (PHWR) is first-of-its-kind in the Indian PHWR programme and has evolved after forty years of design, construction, commissioning and operating experiences. As a part of major improvements in the design of Inner Containment (IC) structure with respect to earlier 220-MW and 540-MW nuclear power plants, 6-mm-thick metallic liner has been introduced on the inner surfaces along with use of 500-MT-capacity prestressing cables. The IC structure is of prestressed concrete, consisting of an 850-mm-thick cylindrical wall, capped with an 850-mm-thick segmental dome. Ring beam is provided between the segmental dome and cylindrical IC wall to form a smooth transition between the two segments that serves the structural role in resisting forces due to geometrical discontinuity and functional role of housing prestressing anchorages.

The liner is a non-structural member provided as an additional leak-tight barrier that will reduce any radioactive release through the containment in case of design basis accidents and design extension conditions as well as improve the leak tightness during normal operating condition. This will provide improved decontamination of the IC structure in an event of design basis events inside the containment. However, the metallic liner and its anchorage system are designed as a structural member during concreting. There it will be used as a self-supporting formwork on the inner face of the containment structure during concreting.

The final configuration of the IC ring beam and dome liner-backing member system, including the sizes of various pours and its sequence and the Steam Generator (SG) Trestle and its configuration, have been evolved based on various trials of the stage-wise sequential analyses simulating the exact boundary conditions after each pour of concrete. Analysis of the system and design of the same as per ASME Section III Division 2[1] is based on scheme, wherein the locked-in-responses in the liner-backing member system due to previously concreted pours are carried forward and added to the response analysis of further pours. This way, IC dome liner system has been engineered to be self-supporting during construction of IC dome and also to be lifted as a single unit of 355 MT with the help of heavy-duty crawler crane LR 11350. State-of-art modularisation technique for the erection and installation of the entire dome liner has been implemented.

This is a first-of-its-kind attempt in the world as the 8-m-high and 46-m-diameter double curvature segmental spherical dome, with two large openings (of 6-m diameter) for SG replacement was a challenge to be lifted as a single unit. This thin-shelled segmental structure is unique due to its combined membrane and flexure behaviour due to geometrical discontinuity posed by these two large SG openings. Once installed, this has not only eliminated the requirements of the IC dome shuttering assembly conventionally used for dome construction, but also led to a saving of good amount of structural steel and construction time. Installation of IC dome liner system opens two parallel work fronts, wherein the construction of IC dome is decoupled with erection of various system and piping inside reactor building. This parallelisation of work will lead to significant saving in construction time and optimum use of site infrastructure. Fabrication of the IC dome liner system panels at workshop and assembly of the same on ground lead to better quality control.

This article brings out the salient features adopted during the conceptualisation, design and detailed engineering of the IC dome liner as a self-supporting formwork during construction stage and engineering it to be lifted as a single unit.

2. Conceptualisation

IC domes have been conventionally constructed for the earlier 220-MW and 500-MW PHWRs, using nearly 500 MT of structural steel dome-supporting arrangement. The earlier construction of dome required supporting system with a

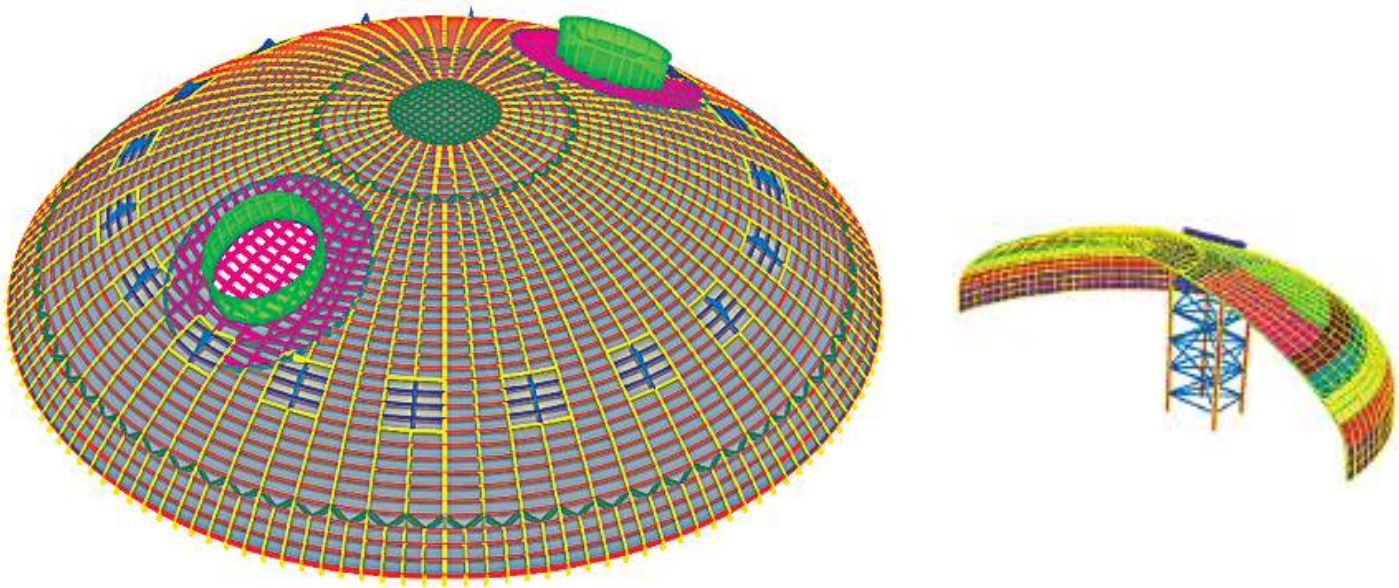


Figure 1: General arrangement of backing members on the IC dome

Part sectional view

central compression ring and heavy trusses for single use. As per the initial design, the IC dome liner was to be fabricated and lifted in three concentric rings and subsequently concreted with supports from the dome supporting arrangement. The idea of departing from the conventional form of constructing IC dome and instead designing it as a self-supporting formwork by strengthening the anchorage seemed too challenging. This would not only eliminate the requirement of 500 MT of dome supporting structural steel but would also bring in the advantages of modularisation of such large and massive component in terms of time, economy, optimisation and quality. With the availability of large capacity heavy duty LR11350 crawler crane, the idea gained momentum and this led to detailed engineering of the IC dome liner system to be designed as a self-supporting formwork and to be lifted as a single unit.

3. IC dome liner-anchorage description

The integral liner is 6-mm-thick low-alloy carbon steel plate and used as a shuttering during stage wise concreting of the IC dome. The liners of the IC dome has been cold rolled to the desired curvature and stiffened by a grid work of structural backing members. The structural backing member system is a continuous meridional-circumferential grid work of rolled structural steel of ISHB150-3, welded to the liner plates are spaced at an angle of 10˚, 5˚ and 2.5°. Wherever, there is a change in the angle, bracings have been used. All circumferential members (ISHB 150-3) are spaced at a curved distance of 600 mm centre-to-centre and are placed between two consecutive meridional members. The meridional and circumferential members are stitch-welded to the 6 mm thick liner.

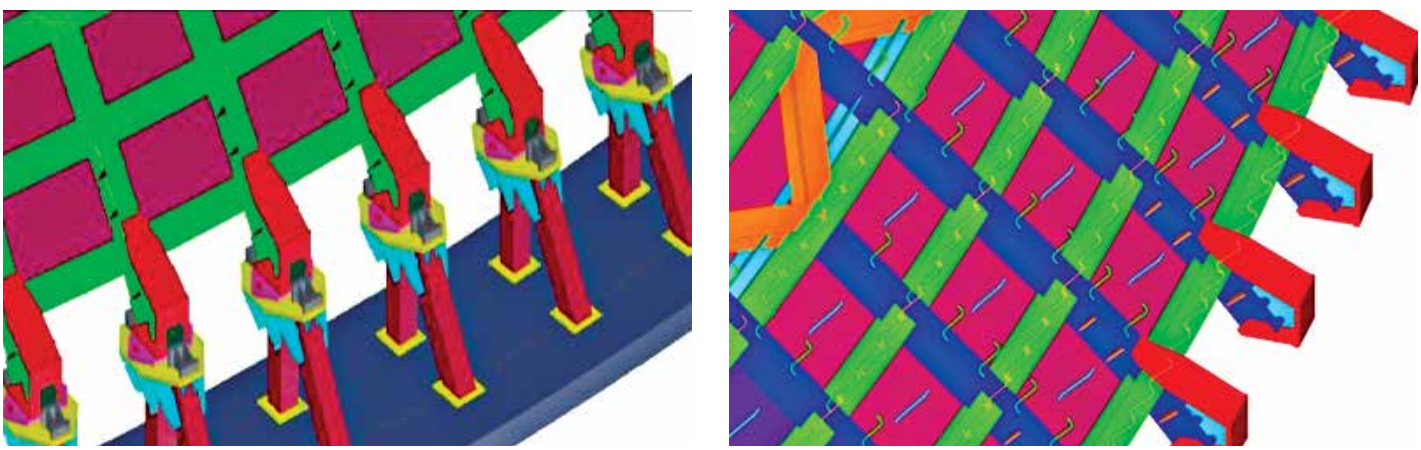


Figure 2: Seating arrangement in the assembly area and isometric view of dome part of seating arrangement

The IC dome liner is supported around the SG opening area from the SG enclosure wall (North and South) at EL132000 using SG Trestle supports. The SG Trestle is trapezoidal in geometry with the four columns braced vertically and horizontally along diagonal for additional torsional stiffness. The SG Trestle has been engineered such that the four Steam Generators can be placed either before (as in case of KAPP-3) or after construction of the dome. The arrangement of IC dome liner along with the SG Trestle is shown in Fig. 1.

The entire dome liner backing member system along with the liner plate has been fabricated in 53 panels. SG cylindrical EPs are fabricated separately and assembled with dome liner at assembly area. Detailed fabrication drawings for each of these panels have been made using professional 3D software.

Seating arrangement

A seating arrangement has been provided at 144 locations on the meridional ISHB150-3 members that are located on ring beam. The seating arrangement of the IC dome liner in the assembly area and the isometric view of dome part of seating arrangement of IC dome liner are shown in Fig. 2. The seating arrangement in the assembly area is a replica of the seating arrangement provided on the concreted ring beam to simulate the actual installation process.

Table 1: Summary of weight of components for crane capacity assessment

Structural components for crane capacity assessment	Weight (MTon)
6-mm liner plate	86.88
ISHB (150-3) and other backing members	176.51
40-mm-thick lifting plate	3.1
Built-up section around lifting location	15.67
Containment Spray System (CSS) plus access platform/ladder	18.0
SG opening cylindrical EP	12.30
Miscellaneous (EP, EP strengthening arrangements, weld metal, cleat plates)	13.22
Total	**326**
Total with mill tolerance @ 2.5%	**334**
Weight of slings and crane hook connector including mill tolerance	21.5
Total load handled by crane (approx.)	**355 T**

Handling arrangement as a single unit

A number of options were planned and scrutinised to lift the IC dome liner as a single unit. The criteria for selection of the handling arrangement were chosen based on stresses in the backing members at and near the lifting locations and the deformation behaviour of the IC dome liner. The option implemented at site consists of lifting it using 18 numbers of 54 mm diameter HYFLEX steel crane cables. The material of the crane cable has tensile strength of 1960 MPa with a minimum breaking load of 207 MT. The angle of inclination of the crane cable with the horizontal is 55°. The loading plane has been made co-incident with the plane of centre of gravity of the IC dome liner. Crane

Figure 3: Schematic and FE model developed for analysing handling stress for IC dome liner and actual liftting of IC dome liner

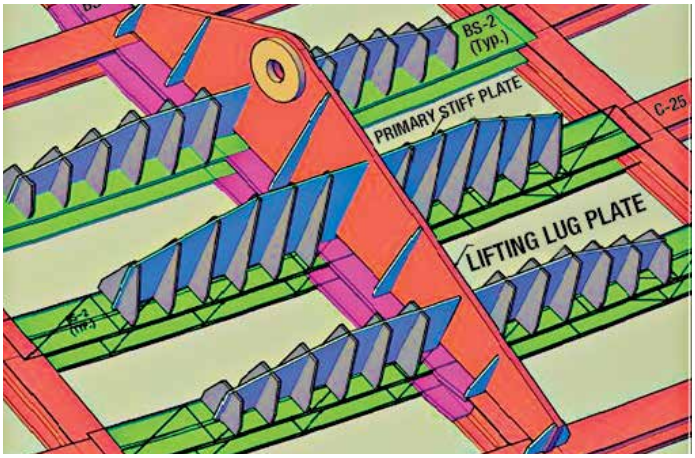


Figure 4: Strengthening arrangement near lifting locations

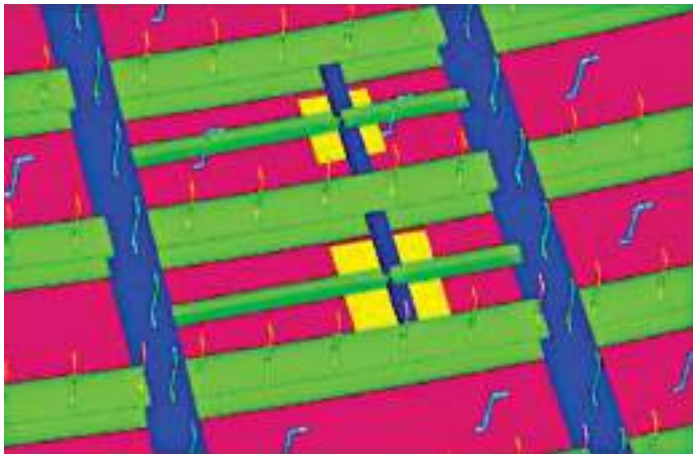


Figure 5: Strengthening arrangement at EP locations

capacity assessment of heavy duty LR 11350 crane, which is having a maximum capacity of 1350 MT at 12 m radius, has been performed to arrive at the safe working load of the crane at 44 m radius and works out to be 373 MT. The summary of the weights of each of the component used for crane capacity assessment is given in Table-1. The maximum permissible wind speed during operation of crane, as per the crane load manual is, 9 m/sec. The FE model developed to analyse the IC dome liner and the actual lifting of the same is shown in Fig. 3.

Strengthening arrangement around lifting and Embedded Parts locations

At locations where the crane cable is connected to the IC dome liner-backing member system, local strengthening has been provided at the lifting locations and the same has been shown in Fig. 4. The strengthening arrangement has been modelled for stress analysis during the process of lifting and installation but has not been considered for stress analysis of the IC dome liner-backing member system during the process of construction.

The IC dome liner has been lifted along with the Containment Spray System (CSS), its inspection platform and the Hydrogen and Steam Condensation Monitoring System (HSCMS). The Embedded Parts (EPs) provided for CSS and HSCMS systems are strengthened such that the self-weight of the systems, during lifting, are transferred to the neighbouring backing members and not to the liner plate. The details of the EP strengthening arrangement are shown in Fig. 5. The EPs have been so located that they do not cut any of the dome liner backing member system.

Crane hook connector

A crane hook connector has been provided that connect all the 18 crane cables to the crane hook. The cables are connected to the crane hook connector using bow-and-shackle arrangement. The crane hook connector has been designed for the worst case of snapping of one crane cable. The view of the crane hook connector is shown in Fig. 6.

Material

6-mm-thick low carbon steel liner plate conforming to IS 2062 E250 (Fe 410 W) Quality C and the backing members conforming to IS 2062 E250 (Fe 410 W) Quality A have been provided. The material for the dome concrete is M45,

TABLE 2. Allowable Stresses and Strains as per ASME Section III Division 2

Category	Stress-Strain Allowable (1), (2)		Remarks
	Membrane	Combined Membrane and Bending	Note: (1) Types of strains limited by this table are strains induced by other than construction related liner deformation. (2) Strain in in./in. or mm/mm. f_{py} = yield strength of steel=250 MPa, ϵ_{st}, ϵ_{sc}= tensile and compressive strain, $f_{st}=f_{sc}$= tensile and compressive stress
Construction	$f_{st}=f_{sc}=2/3\ f_{py}$	$f_{st}=f_{sc}=2/3\ f_{py}$	
Service	$\epsilon_{st} = \epsilon_{sc} = 0.002$	$\epsilon_{st} = \epsilon_{sc} = 0.004$	
Factored	$\epsilon_{sc} = 0.005$	$\epsilon_{sc} = 0.014$	
	$\epsilon_{st} = 0.003$	$\epsilon_{st} = 0.010$	

Figure 6: Crane hook connector

having a characteristic strength of 45 MPa. In the sequential, stage wise analysis of the IC dome, four different properties of the same concrete has been assumed based on the age of the pour, viz., 7 days, 14 days, 21 days and 28 days, to simulate the strength gain of already poured concrete. The development of modulus of elasticity and strength of concrete have been verified with respect to actual values obtained from concrete laboratory for the grade of concrete used in the actual construction of the IC structure.

The time variation of the modulus of elasticity of normal weight concrete is calculated as per ACI 349-85:

$$E_c = 4734\sqrt{f'_{cj}}\ (\text{MPa})$$

The variation of the compressive strength of concrete has been assumed as per the French code BAEL as:

$$f'_{cj} = \frac{j}{4.76 + 0.83\,j} f'_{c,28}$$

Where, E_c = modulus of elasticity of concrete, f_cj^' = compressive strength at j^{th} day, and f_(c,28)^'= 28-day compressive strength.

Allowable stresses and strains

The IC dome liner has been designed as per provisions of ASME, Section III, Division 2. The allowable stresses in liner for construction load combinations and allowable strains for service and factored load combinations are limited to that given in Table CC-3720-1 of the code, which are reproduced in Table-2.

Stress-based allowables have been specified, as the liner behaves as a structural material during construction phase, whereas strain-based allowables are specified under service and factored load combination. Strain based allowable are used under service and factored load combination as the liner is designed as a non-structural member and allowed to deform beyond its elastic limit, leading to absorption of strain energy. However, the limits are specified so that the liner does not tear apart leading to functional failure.

4. Analysis and design methodology for handling stage

Analysis and design of the IC dome liner has been carried out during the process of lifting and installation at the specified location on ring beam. The IC dome liner has been analysed for dead load, which includes self-weight of the single unit system, weight of lugs and anchors, SG opening cylindrical EP, 40-mm-thick lifting plate, CSS, HSCMS and wind load during lifting process. Subsequently, design of the IC dome liner has been carried out. The IC dome liner is subjected to wind load during the process of lifting and as per the recommendation of the crane manual for its safe operation, maximum wind speed considered is 9 m/s.

To envelop all possible scenarios during the process of lifting and installation of IC dome liner-backing member system, following cases considering snapping and misfit of crane cables have been analysed:

- Case-1: No snapping of crane cable and all cables are equally stressed
- Case-2: No snapping of crane cable but cables are unequally stressed due to misfit of length
- Case-3: Snapping of one out of 18 crane cables @ SG opening area along N-S axis
- Case-4: Snapping of one out of 18 crane cables in IC dome general area near E-W axis
- Case-5: Snapping of one out of 18 crane cables near SG opening area

Proper arrangement, in the form of turnbuckle installed at each crane cable, is made to ensure that each crane cable is stressed as per the design requirement. However, under

an event of any misfit in the length of the cable, the load transfer in all the 18 cables will not comply with the design requirement. To account for any such misfit, parametric analysis has been carried out by varying the diameters of all crane cables randomly such that load-carrying capacity of crane cable varies from 79% to 121%, keeping the mean value as 100%. This analysis has been covered under Case-2 mentioned above. The deformed shape of the IC dome liner for Case-2 and Case-5 are shown in Fig. 7 and Fig. 8, respectively. Load carried by each of the 18 crane cables has been measured through load cells installed for each of the crane cable. Load cell measurements have been used to adjust the stresses in the cable by use of turnbuckle such that the stresses are as per the design requirements.

The analysis of IC dome liner during lifting and installation has been carried out using 3D FE models developed in FE software SAP2000. The global displacements and forces/moments in the liner plate and its backing members are extracted from the FE analyses for all the five cases mentioned above and are post-processed to evaluate the stress level in liner-backing member system. Based on the analysis results, following are the general observations:

- Stresses are higher near lifting point and gradually reduce with distance away from it.
- All circumferential and meridional members above lifting plane are in compression.
- All circumferential members below the lifting plane are in compression and meridional members are in tension except few circumferential rings around loading plane.

The maximum tension in the crane cable is 24.2 MT for Case-1 and 37.4 MT for snapping Case-5, and is much less than the breaking load of 207 MT. During installation, the dome liner will swing as a rigid body, due to the absence of any lateral restraint and under such condition the maximum tension in the cable has been evaluated and is found to be less than the minimum breaking load of the crane cable. The entire single unit of IC dome liner has also been checked for resonance effect due to wind-induced vibration and it is ensured that the structural frequency under lifted condition is far away from the frequency of the fluctuating component of the measured wind speed.

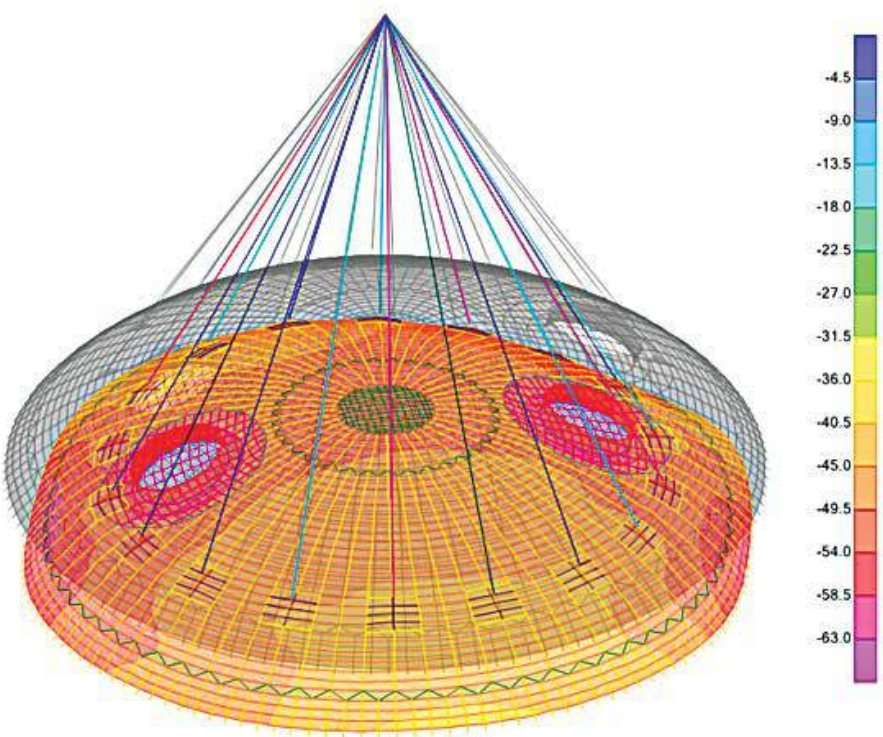


Figure 7: Deformed shape of IC dome liner for Case-2 (Scale factor for deformation 1:100)

The design requirement is found to have been met at all locations, under both normal condition (without any crane cable snapping) as well as during postulated snapping of one crane cable (either near SG opening area or general area of the IC dome or in general area near SG opening). The case of unequal stressing of crane cables have also been examined and found to meet design requirements. At locations where the crane cable is connected to the IC dome liner-backing member system, local strengthening has been provided at the lifting locations and the same has been shown in Fig. 4. It is concluded that there is no progressive failure of backing members as well as crane cables even after snapping of one crane cable.

5. Analysis and design methodology after erection phase

The IC dome liner has been designed to be self-supporting and capable of resisting all loads under construction, normal operation and accident conditions. Both the postulated and incidental loads have been considered under construction phase. The IC dome liner is also designed to resist design basis wind load during liner erection and installation as well as temperature effect due to solar radiation once the IC dome liner has been installed at its intended location. The temperature load due to solar

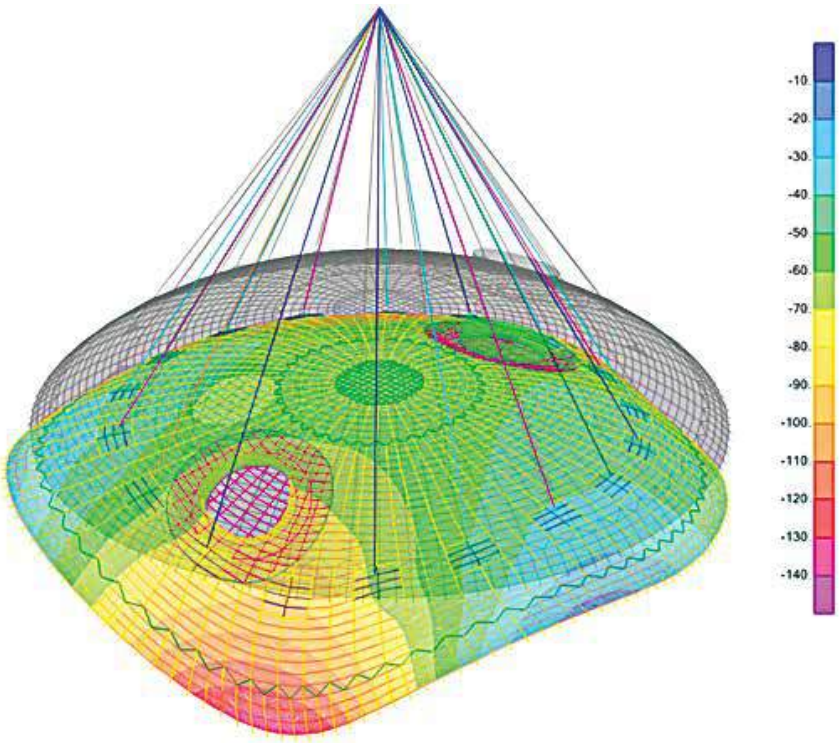


Figure 8: Deformed shape of IC dome liner for Case-5 (Scale factor for deformation 1:100)

radiation has been calculated using the ASHRAE formulations and have been validated using actual temperature measurement using a laser interferometer. The configuration of the liner-backing member system for the dome portion has been based on iterative trial analyses where the following parameters were finalised based on the optimisation study for: pour sequence, arrangement of backing members, support requirements and geometrical properties of meridional and circumferential backing member system.

Loading conditions

Once the entire liner-backing member assembly is installed, the dome will be casted in eight different pours. As per the erection sequence, the entire IC dome liner is erected as a single unit and placed at 144 seating locations provided on the IC ring beam. After alignment and welding with the ring beam bearing plates, the IC dome liner is connected to the SG Trestle at 60 locations (30 each for the North and South side). The IC dome liner assembly will be subjected to the temperature load due to solar radiation and wind loading under both of these boundary conditions as mentioned below. As such, analysis for temperature loading due to solar radiation and wind loading and subsequent design adequacy of IC dome liner has been performed considering both the boundary conditions:

- Condition-I: Dome assembly seated at 144 locations on the ring beam and locked.
- Condition-II: Dome assembly seated and connected at 144 locations on ring beam and 60 locations of SG supporting trestle and locked.

Analyses for temperature load due to solar radiation have been performed considering the following conditions:

- **Case A:** Summer
- **Case B:** Winter

It has been conservatively assumed in the analysis that the entire dome-liner backing member system will be subjected to the same solar radiation at every location, independent of the azimuth of the sun.

Similarly, analyses for wind load have been performed considering the following wind pressures:

- **Case A:** Suction pressure

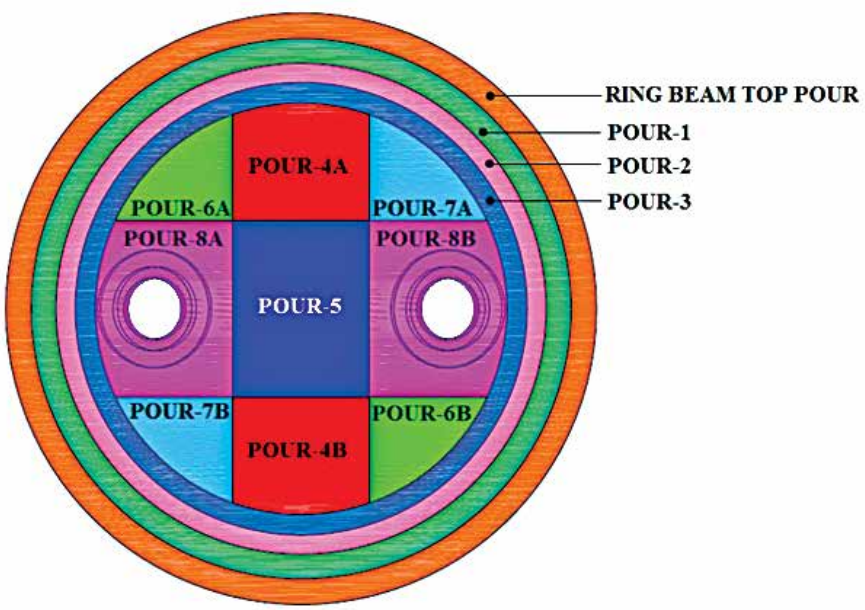


Figure 9: Pour sequence for the IC dome

Figure 10: 3D FE Model for IC post Ring Beam Construction

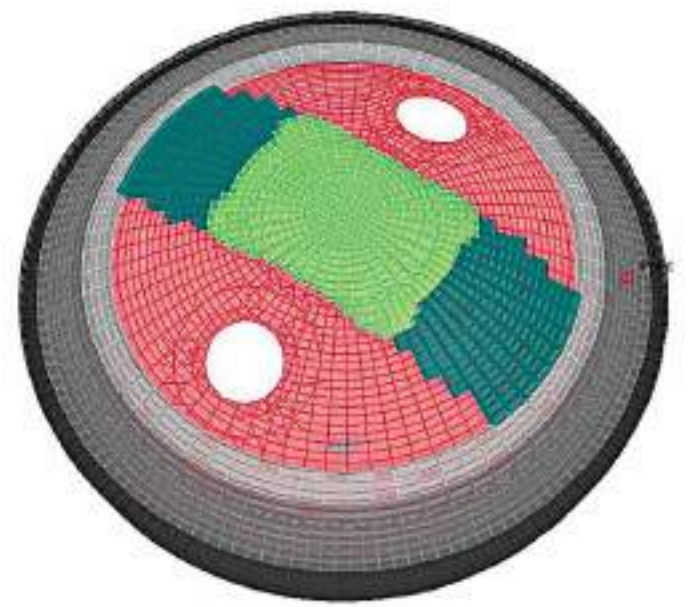


Figure 12: FE Model for Analyzing IC structure during Pour-6 concreting

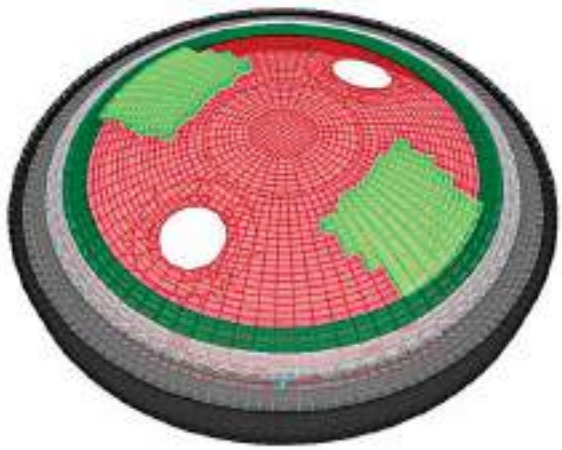


Figure 11: FE Model for Analyzing IC structure during Pour-5 concreting

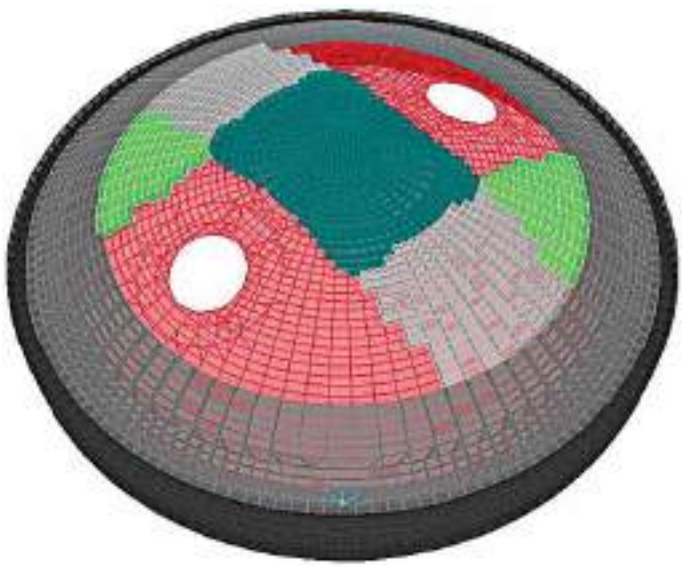


Figure 13: FE Model for Analyzing IC structure during Pour-7 concreting

- **Case B:** Lateral thrust along the horizontal directions

As the IC dome liner is asymmetric, wind load analysis for lateral thrust have been performed for both N-S and E-W wind directions. Once the dome liner has been installed at its seating location and before concreting the first pour of dome, design adequacy of already cast ring beam concrete and IC dome liner have been checked for the following loading conditions:

a) **Shear check of ring beam concrete due to thermal expansion of IC dome liner due to solar radiation:** Once the IC dome liner is installed and locked at its intended location on ring beam and SG Trestle, any thermal expansion or contraction will induce shear on the ring beam concrete due to the lateral thrust.

b) **Shear check of ring beam concrete due to lateral thrust of IC dome liner due to wind loading:** Once the IC dome liner is installed and locked at its intended location on ring beam and SG Trestle, shear will induce at ring beam for both

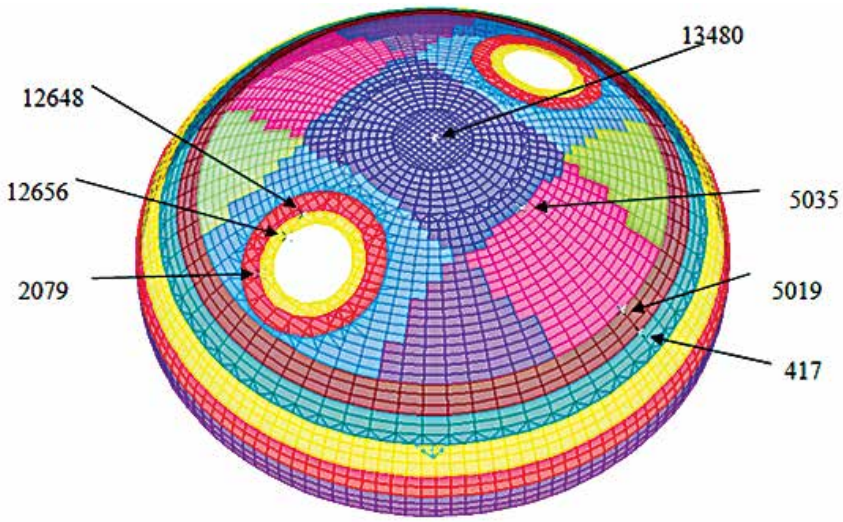


Figure 14: Location of salient nodal points used for displacement monitoring

suction pressure and lateral pressure due to design basis wind loading.

c) **Shear check of ring beam concrete due to concreting of Pour-1 of IC dome:** Design adequacy of the ring beam concrete for shear friction, at construction joint, has been carried out for the maximum thrust induced by dome liner-backing member assembly due to concreting of Pour-1 of IC dome.

d) **Design adequacy check of IC dome liner due to temperature loading on account of solar radiation:** Design adequacy has been checked for thermal loading due to solar radiation. The induced stresses in the IC dome liner, during lifting and subsequent placement on the seating arrangement has been considered as *locked-in response* and is added to the induced response due to temperature load.

e) **Design adequacy check of IC dome liner due to wind loading:** Design adequacy has been checked under wind loading condition. The induced stresses in the IC dome liner, during lifting and subsequent placement on the seating arrangement, have been considered as *locked-in response* and are added to the induced response due to wind loads.

During the process of placement of the seating plate of the IC dome liner on the bearing plate of the ring beam, the frictional resistance between the two seating plates may not allow for elastic rebound of the IC dome liner at these 144 seating locations. The frictional resistance developed, will induce locked-in response in the dome liner system. The same has been evaluated separately and is later added to the induced response of IC dome liner due to temperature and wind loadings.

FE analyses have been performed for all above loading conditions when the IC dome liner is placed on the 144 seating arrangement provided on the ring beam concrete and 60 seating arrangement provided on the SG Trestle. From the results of analyses and design adequacy check, it is concluded that the IC dome liner will perform satisfactorily under the loading conditions considered. The thickness of the liner plate and the ISHB-150-3 section of backing members are adequate to perform its intended function under such loading scenario.

6. Analysis and design methodology during construction phase

Pour Sequence for IC Dome

The pour sequence adopted for the construction of IC dome is shown in Fig. 9. The pour sequence has been finalised after several iterations that have been carried out based on the design checks of different liner-backing member configurations during construction phase.

The entire dome will be constructed in eight pours, with the first three circular pours starting from the ring beam level towards the crown. This

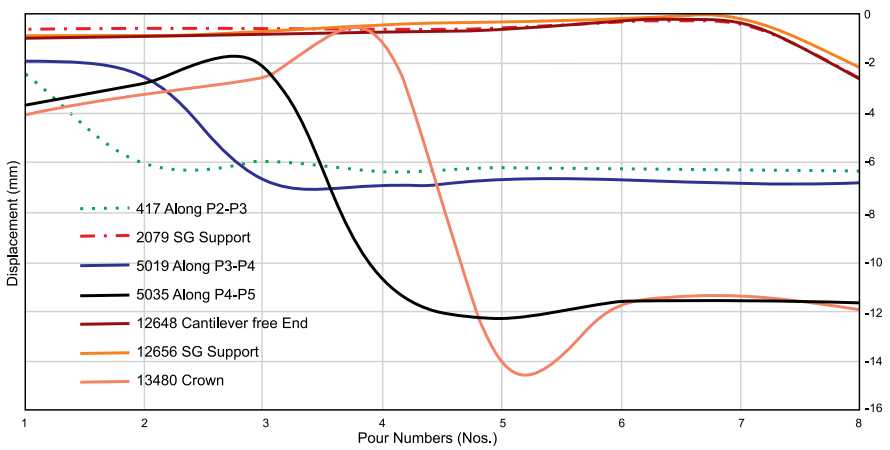


Figure 15: Vertical displacement profile for salient points after concreting of each pour

reduces the span of the dome as concreting progresses. The pour sequence has been designed such that a central arch is formed in the E-W direction, after the fourth and fifth pour is cast, that bears the load of subsequent pours. Pour number 8A and 8B are each of nearly 450 MT and separate support arrangements, in the form of SG Trestles, have been provided to control deflection.

Loads and basis for load combination

The liner-backing member system is designed to resist all applicable loads and their combinations during construction phase, including self-weight, reinforcement, prestressing tendons and sheathing loads, live load, green concrete pressure, incidental and top formwork load. The self-weight includes all structural members of the IC dome liner system, containment spray system (CSS) and its access staircase and maintenance platform, Hydrogen Steam Concentration Monitoring System (HSCMS), along with embedded parts of CSS and HSCMS. As the pour progresses, the concrete that has already been poured will achieve stiffness and strength value depending upon its age. Solid elements, representing the already concreted pour, are used to simulate the effect of the stiffness on the response analysis of the liner-backing member system. These are simulated using eight FE models, each representing the state of ICS after each pour. These solid elements in the FE model are assigned geometric properties as per the dome thickness and material properties as per the age of casting. 7-day gap between each pour has been assumed in the analysis for assigning material properties. The time variations of the modulus of elasticity and compressive strength of concrete are simulated in FE models as brought out above. The total volume of concrete is 2097 cu.m and the total weight considered is nearly 4600 MT.

The basis of load combination for the sequential analyses, corresponding to all the eight FE models, is based on scheme wherein the locked-in responses in the liner-backing member system due to previously cast pours are carried forward and added to the response analysis of the new FE model. For each stage, various loads are classified into those imposing locked-in response and those that will be relieved after the completion of a particular pour. As the dome concreting progresses, locked-in responses from previous pours are carried forward and added to response from the new pour. These locked-in-responses are any response parameter, e.g., the liner stress, frame element forces, displacements, etc.

FE model details and analysis methodology

The IC dome liner has been analysed using a combination of classical method[2] and mathematical approach using FEM. Eight detailed 3-D finite element model has been developed to analyse the exact behaviour when used as a self-supporting formwork during construction stage. The IC cylindrical wall is modeled as shell element, while the ring beam is modeled as solid element. The liner plate has been modeled as shell element. The grid work of backing members are modeled as beam element and the dome concrete is modeled as solid element. The 3-D FE model that serves as the base model for the sequential analysis is shown in Fig. 10. The FE model developed for Pour-5, Pour-6 and Pour-7 is shown in Fig. 11, Fig. 12 and Fig. 13, respectively (only the part above ring beam is shown). Similar models have been developed for other pours, each depicting the physical state of the IC structure after each pour.

In all the FE models, the properties of the dome concrete keep on changing depending upon the duration of casting, which has been assumed as 7 days between each successive pour.

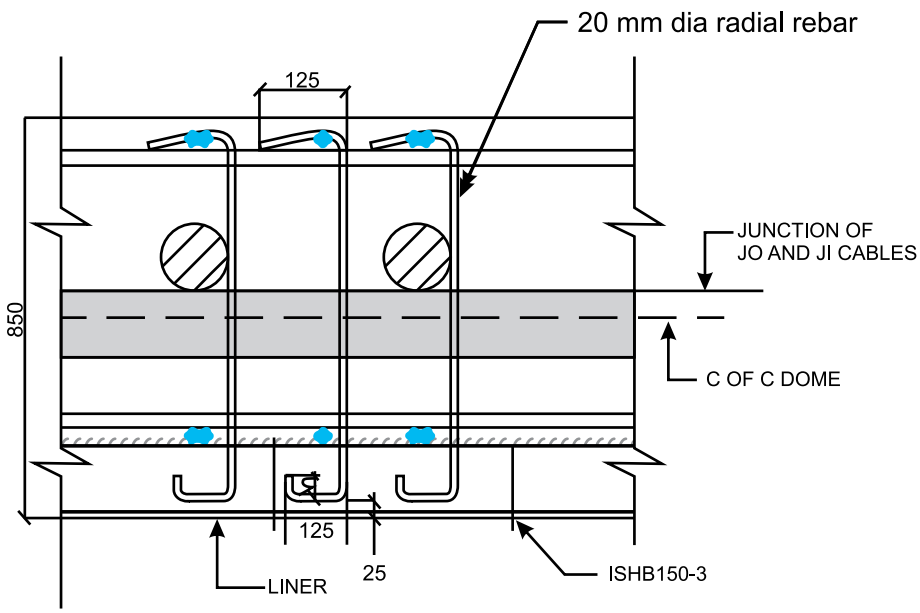


Figure 16: Arrangement of radial reinforcement at a typical liner backing member-concrete interface

The SG opening space has been stiffened using cross members, similar to backing members of IC dome, which will take care of the membrane deformation of the liner-backing member system during concreting of the various pours. In all the multiple models that have been developed for the sequential analysis, the finite elements representing the cylindrical wall, ring beam, dome liner plate and its supporting frameworks have been kept as same. The change is only in the progressive addition of solid elements depending upon the pour sequence and material properties of these elements depending upon the age of casting. The IC is considered fixed at the raft wall junction. The SG opening supporting framework is supported on the SG enclosure wall and is considered fixed at that elevation.

Analysis results and design of liner-backing member system

The stresses in the backing members and displacement are extracted from the sequential analysis for each pour and are post-processed for the final response. For the IC dome, the backing members get embedded in the concrete in a sequential manner depending upon the pour sequence adopted for the dome construction. These backing members are checked for its design adequacy in bending, compression and tension and the allowable values are limited to two-thirds of yield stress as per ASME, Section III, Division 2. The stresses in the liner panels have been limited to two-thirds of the yield stress. The peak vertical displacement is -20.39 mm and occurs at the centre of Pour 4, while concreting Pour 4. The peak N-S direction horizontal displacement is -3.90 mm and the peak E-W direction horizontal displacement is -7.43 mm. A typical profile of the variation of vertical displacement after concreting of each pour of concrete at various salient points (Fig. 14) is shown in Fig. 15.

The stresses due to combined action of biaxial bending and axial forces in the backing members are extracted from each of the analyses and are post-processed for response after each pour. The maximum stresses in the circumferential and meridional members are within two-thirds of the yield stress. The stress in liner has been checked as per classical formulation for a rectangular plate fixed at all ends subjected to normal pressure. The maximum panel size in each of the pour area is computed from the configuration of the backing members. The stress in the liner panels is within the permissible limit of two-thirds yield stress.

Anchor design

Anchors have been provided along the thickness direction of the IC dome that is designed to provide resistance against tearing/fracture at the interface between adjacent concrete pours. The normal pressure on a pour area being concreted will induce a tearing effect at the top flange plate-concrete interface of the already poured concrete. This splitting will induce compression in the bottom part and tension on top part of the IC dome cross-sectional area. The anchors have been designed to resist this splitting. Simplified and conservative assumptions have been made for the anchor design. 20-mm-diameter bars has been provided in the dome as radial reinforcement at spacing of 225 mm c/c in the JO direction and 450 mm c/c in the JI direction of dome cable profile. These radial bars span between top and bottom mat of dome reinforcement. These radial bars have been used as anchors by extending it from the bottom reinforcement mat to the liner plate with a gap of 25 mm from the liner plate. The radial reinforcements acting as anchors are checked for development length in compression below the splitting plane and tension above the splitting plane typical arrangement is shown in Fig. 16.

Analysis for incidental point loads

Analysis has been carried out for an incidental point load of 500 kg applied simultaneously at 3 locations on the IC dome. The deformation and stresses in the backing members are very small around the area of load application and hence are not combined with other loads for the sequential analysis.

Stresses in the solid elements

Concrete tensile stress has been evaluated at every stage of loading. Concrete has been modelled using eight-noded solid elements with incompatible bending mode formulation that are able to capture the bending behaviour even with single solid element across the thickness of the IC dome[3]. In general, eight-noded solid elements exhibit shear locking due to spurious shear strain and are incapable of capturing the bending behaviour. To capture the bending behaviour even with a single solid element across the thickness, bending modes are added to the element displacement field. These displacement fields are called as incompatible because, at locations other than nodes, they allow overlaps or gaps between adjacent elements. The element formulation has been validated and the maximum tensile stresses in cast concrete for all the groups due to sequential pouring of concrete of IC dome is found to be 1.34 MPa, which is less than the modulus of rupture of concrete.

Design of seating arrangement

A seating arrangement has been provided at 144 locations on the meridional members of the ring beam, where the IC dome liner will be placed. The seating arrangement consists of a 25-mm-thick bearing plate welded to the meridional members and an additional strut has been provided that will be embedded in ring beam concrete. This seating arrangement of the IC dome liner system has been designed such that it is capable of taking the entire load without help from the ring beam liner backing member system. The design of the seating plate has been based on gross conservative estimates of the vertical and lateral thrust of the IC dome liner on the ring beam liner. However, once the ring beam bearing plate and dome seating plate are bolted and welded, the ring beam liner backing member system will also contribute to the load resistance path. The top portion of the ring beam liner-backing member welded to the ring beam bearing plate is separately checked for its capability to bear the entire load of the IC dome liner system without the help from the seating arrangement consisting of the strut assembly. Design adequacy check has also been performed such that any eccentricity in placement of the IC dome liner on the ring beam liner (due to fabrication and erection tolerances) will not induce undue stresses that are more than allowable.

7. Analysis and design methodology for post-construction phase

Analysis and design of IC liner has been carried out for load combinations specified in ASME Section III Division 2, with load factors for all load cases as 1.0. The normal and shear stresses and strains at the inner face of concrete of IC structure are calculated from the stress resultants for each element and for each load combination using Hook's law of linear elastic stress distribution. As liner is integrated with inner face of IC structure, the strains on the liner is same as that of inner face of IC structure at the location where it is connected to concrete through its backing members. Strain compatibility is considered at the connection points between liner and concrete. The strain in the liner plate at the junction of the backing member is worked out by combining the strains obtained from the IC analysis. Additional strains on account of shrinkage and temperature effect are taken into account. The principal strains and maximum shear strain of concrete on inner face of IC structure are calculated and limited as per Table-2. The design of liner is checked for buckling within a panel under all service load combinations. In order to satisfy buckling criteria, a stiffener in the middle of the long span is provided such that the effective span is reduced.

8. Conclusion

The IC dome liner has been designed as a self-supporting formwork during the construction process, capable of resisting all construction and environmental loads and the system has been engineered to be installed as a single unit with the help of heavy-duty crawler crane LR 11350. This first-of-its-kind attempt in the world as the 8-m-high and 46-m-diameter segmental spherical dome with two large openings has been a challenge both in terms of design as well as fabrication and installation. Presence of the two large openings in the IC dome has made the dome liner assembly unique in the world in view of its complicated geometry around these openings. The conceptualisation and the entire engineering of the IC dome liner system, including installation aspects, have been carried out in-house at Nuclear Power Corporation of India Limited (NPCIL).

Successful installation of this IC dome liner assembly at Kakrapar marks a major step towards implementation of state-of-art modularisation technique in nuclear power plant construction, creating history in NPCIL. This has eliminated the requirements of the IC dome shuttering assembly, conventionally used for such dome construction, leading to a saving of large quantity of structural steel, which resulted in savings both terms of economics as well as construction time. With this installation, parallel work fronts are opened up, which will significantly accelerate the construction and erection activities of the project.

Acknowledgement

The authors are grateful to Mr. U.C. Muktibodh, Director (Technical) for his constant support and motivation throughout the process of analysis and design of the IC dome liner meant to be erected as a single unit and its design as a self-supporting formwork.

References

1. ASME Section III Division 2 Code for Concrete Containment Rules for Construction of Nuclear Facility Components, ASME, Three Park Avenue, NY 10016, USA
2. Young C Warren, Roark's Formulas for Stress & Strain, McGraw Hill Book Company
3. SAP Analysis Help manual, Computer and Structures Inc., 1995 University Avenue Berkeley, CA 94704.

Dr. Rajiv Ranjan is a gold medalist in Civil Engineering from Tilkamanjhi Bhagalpur University. He joined NPCIL in 2000 after a one-year orientation course from the 43rd batch BARC training school. He obtained his doctorate degree from IIT Bombay, Mumbai with specialisation in the non-linear analysis of reinforced concrete structures subjected to impact loading. He is involved in analysis and design of safety related nuclear power plant (NPP) structures and various developmental works related to the impact resistance of Outer Containment, impulse resistance of structures, soil-structure interaction analysis, margin assessment of tall building due to beyond design loading, etc.

Sujita Jha graduated in Civil Engineering from MIT, Muzaffarpur in 2010 and obtained her post-graduation degree from IIT Roorkee in 2012. She joined NPCIL in 2013 and was posted in the civil design group at HQ. She is involved in the preparation of detailed structural steel drawings, general arrangement drawings and review of fabrication drawings of IC dome liner-backing member system. She is involved in the analysis and design of Inner Containment ring beam liner and IC dome liner during the process of lifting and during construction.

Abhishek Tripathi is gold medalist in Civil Engineering from MITS, Gwalior. He later completed his M.Tech from IIT Delhi securing first rank with specialisation in Geotechnical and Geo-environment engineering in 2011. He joined NPCIL in 2011 and is from the DGFS'08 batch of BARC training school. He has been involved in the analysis and design, drawings and review of documents pertaining to safety related structures of RAPP-7&8. He was involved in the in-house analysis and design of IC dome liner backing member system and in margin estimation of D2O towers for beyond design basis wind loading.

Madhumangal Das completed his graduation in Civil Engineering from Bengal Engineering College and later completed his post-graduation from IIT Kharagpur, with first rank in Structural Engineering. He joined NPCIL in 2005 from DGFS'03 batch of BARC training school. He has worked in the field of in-house analysis and design of safety-related nuclear power plant structures and has been involved in in-house engineering of activities related to lined inner containment structure, outer containment structure and nuclear building raft of KAPP-3&4 and RAPP-7&8.

Indrajit Ray is from 35th batch of BARC Training School. He completed his graduation from Bengal Engineering College, Shibpur. His area of expertise is in-house engineering of safety-related structures of nuclear power plants with emphasis on containment structure and reactor building, soil-structure interaction analysis, margin assessment of tall structures, ultimate load bearing capacity assessment of containment structures. His responsibilities also encompass obtaining relevant acceptances of design documents from AERB and implementation of design intent at project sites.

Prabhakar Gundlapalli has an M.Tech degree in Nuclear Engineering and Technology in 1990 from IIT Kanpur, and graduation in Civil engineering discipline with first class distinction in 1988 from National Institute of Technology, Jamshedpur. His work domain includes aircraft impact studies, protection of Containment from external missiles, blast and explosion loads, design of prefabricated ring liner and self-supporting dome. He is also member of various committees of AERB (CESC and PDSC) and draft codes of BIS.

Raghupati Roy is from the 33rd Batch of BARC training school. He completed his graduation in Civil Engineering and post-graduation in Structural Engineering from Jadavpur University, Kolkata. His areas of specialisation are in-house engineering of prestressed containment structures of Indian PHWRs including liner, non-linear analysis for evaluation of its ultimate load bearing capacity, seismic analysis and design of NPP structures, push-over analysis and seismic margin assessment etc. He was involved in the development of a compact layout for the 700-MW PHWR and sub-sequent engineering of safety-related structures of 700-MW PHWRs. He is also a member of various committee of AERB (CESC, ACROCSE) and BIS.

Arvind Shrivastava is a Civil Engineering graduate from Jiwaji University, Gwalior. He later obtained his M.Tech degree from IIT Kanpur with specialisation in structural engineering. Presently, he heads the Civil Engineering group at NPCIL HQ and leads the team involved in the analysis and design of NPP structures and obtaining regulatory clearances for all project activities and engineering, including support to operating stations. His areas of interest include seismic analysis, wind analysis, flood analysis, RC and prestress concrete design and aging management & life extension of NPP structures. He is also member of various safety/code committees of AERB and BIS.

Self-Supporting Inner Containment (IC) Dome at KAPP

Fabrication, Assembly, Load Testing and Erection at Unit-3

Lokesh Kumar, the then Project Director; J.S. Virdee, Project Director; M. Kotaiah ACE (Civil); H.N. Ramesha, Project Engineer (Civil); Rajesh Kumar, Technical Officer/E, KAPP-3&4

On June 9, 2016 history was created in Indian nuclear power industry. At unit-3 of Kakrapar Atomic Power Project (KAPP-3), a self-supporting Inner Containment (IC) dome weighing around 355 MT was successfully erected on IC ring beam top at 45-m height from the ground level. This article elaborates the details of its fabrication, transportation, assembly, load testing, mockups, erection, measurement and challenges faced during construction. Another dome is also being constructed for unit-4.

Modular construction is the need of the hour for its many benefits. In line with this, at Nuclear Power Corporation of India Limited (NPCIL), there has been a definitive thrust in this direction. Some of such examples are Preformed Ring Liner (PRL), Erection of Fuelling Machine Vault structural beams as a single unit and self-supporting dome, to name a few. Needless to say, modular construction reduces construction time and allows better control on quality aspects, as a result of which work can be executed in a safer and more efficient manner. The cost of construction can also be reduced substantially by adopting modular construction.

Introduction

A pair of first-of-its-kind 700-MW Indian Pressurised Heavy Water Reactors (PHWRs) are being constructed at KAPP-3&4 in the state of Gujarat in India. These reactors have a number of unique design features, mainly for enhancement of safety and to reduce construction time. The carbon steel liner on Inner Containment (IC) of about 50-meter diameter encasing the Reactor Building is one of them.

The IC dome liner system weighing 355 metric tonnes (MT) was engineered to be lifted as a single unit with the help of a heavy-duty crawler crane of 1350-T capacity. This first-of-its-kind IC dome has a height of 8 m and a diameter of 47.042 m, and is a double-curvature segmental dome with two large openings (6 m in diameter). It was a real challenge to lift this huge structure as a single unit, so a state-of-the-art modular construction methodology was adopted, which is in line with such methodologies adopted at other nuclear power plants around the world.

KAPP-3 IC Dome Details

Diameter	: 47.042 m
Height	: 8 m
Weight	: 355 MT
Welding length	: 5000 m
Openings in dome	: 2 Nos.
Openings diameter	: 6 m
Meridional Members (ISHB 150-3) Length	: 1900 m
Circumferential Members (ISHB 150-3) Length	: 3400 m

As per the original methodology (of taking the supports from floor down below), the total structural steel requirement was calculated to be approximately 680 MT. However, with the revised methodology, the total structural steel requirement was reduced to 540 MT by adopting a modular construction methodology.

Precision workmanship along with micro-level planning made it possible to complete the structural fabrication of this giant dome in four-and-a-half months.

Other than achieving a significant saving in the amount of structural steel, the modular methodology also lead to:

a) Improvement in the performance of the IC dome liner system, as its entire assembly, welding and NDT testing was done at ground level.

b) Ease of erection and alignment on the existing wall/ring beam liner due to the single-unit structure.

c) Release of the elevation (EL) 115.5-m and EL 132-m floors of the Reactor Building to other groups, thereby paving the way

for parallel working by other groups, which shortened the construction schedule.

Before going into the details of the IC dome of KAPP-3&4, some highlights of dome erected at Kudankulam Atomic Power Project (KKNPP) are given below, mainly to visualise the volume of work handled at KAPP-3&4.

The dome at KKNPP

The dome of Kudankulam Nuclear Power Plant (KKNPP) units is hemispherical, with a radius of 22 m. At KKNPP, the dome liner was installed in three parts, the details of which are given below.

	Part 1	Part 2	Part3
Bottom Dia.	44 m	42.5 m	35.2 m
Top Dia.	42.5 m	35.2 m	6 m
Height	5.6 m	7.6 m	8.81 m
Weight	67.5 MT	80 MT	130 MT

The total weight of dome in KKNPP above the springing level (cylindrical portion) was around 277.5 MT for the surface area of 3041 sq.m.

Of the three parts of the dome liner of KKNPP, Part-I was erected 'panel by panel' (15 panels) with the help of a tower crane. Part-II & Part-III of the dome were preassembled at two different areas on ground and erected one after the other.

The dome at KAPP-3&4

IC dome is of segmental geometry, consisting spherical portions of two different radii. The shape of the IC dome liner at KAPP is 'Torospherical'. A ring beam was provided between the segmental dome and cylindrical IC wall to form a smooth transition between the two segments, which served the structural role of resisting lateral thrust and functional role of housing prestressing anchorages of the IC Wall and dome.

IC dome liner diameter is 47.042 m and a vertical height of around 8 m. The full assembly of the dome weighs around 355 MT. The weight also includes weight of Containment Spray System (CSS) pipes, platform, handrails, etc. The weight of Hydrogen Steam Concentration Monitoring System (HSCMS) also adds to the weight.

The bifurcation of weights of various elements of the dome is given below.

Liner	:	87 MT
ISHBs	:	177 MT
Evener Beam (Lifting Beam)	:	12.36 MT
Tools and tackles	:	11.8 MT
CSS	:	11.5 MT
HSCMS	:	0.045 MT

The material used for backing members is (ISHB150-3), conforming to IS 2062 E250 (Fe410 W) Quality A and for 6-mm-thick liner plate conforms to IS 2062 E250 (Fe410W) Quality C.

To maintain torospherical shape of the dome, the meridional members are bent in the flange direction and circumferential member are bent both in flange and web direction.

Mockups

Following mockups were conducted in order to ensure that final product was as per the design intent.

- Bending mockups of ISHBs
- Fit-up mockup near SG opening area
- Mockup of entire system of liner, meridional members, circumferential members etc. near SG area

Fabrication

Fabrication drawings

Based on the detailed structural drawings, fabrication drawings

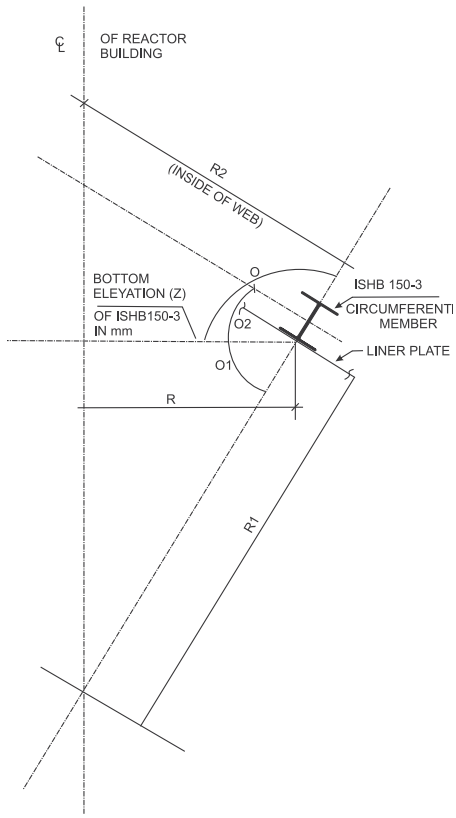


Figure 1: Sketch showing bending of ISHBs (circumferential members) in both the directions

were prepared for ease of execution and also to understand the intricate details of joints configuration. Special 3D software was used to prepare the fabrication drawings. All these drawings were checked thoroughly by execution and design engineers.

Main backing members (ISHBs)

Initially, the backing structures of IC dome liner were engineered as built-up section of a depth of

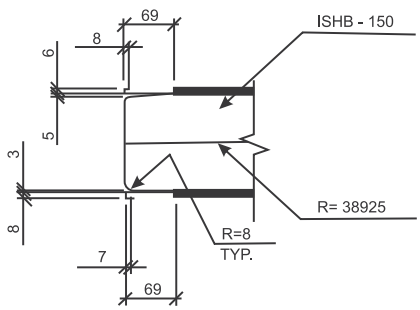


Figure 2: Sketch showing notch cutting of ISHBs

137 mm in order to optimise the design of both metallic liner backing member system and IC dome liner. However, to reduce welding, built-up members were replaced with rolled sections of ISHB 150-3, which substantially reduced construction time, cost and effort.

These ISHBs are seldom used in the general structures. Hence, these are not readily available in the market and were specially ordered.

Bending of ISHBs

After selecting the backing members as rolled sections of ISHB-150-3, one of the major challenges was to perform two-dimensional bending on heavy weight section with strict tolerances. It was felt prudent to perform mockup studies to carry bending for a grid encompassing meridional and circumferential backing members to get the essence of problems that may occur during job execution.

Based on Mockup studies, decision was taken to use hydraulic pressing machine for the bending operation of members. Based on the type of curvature to be attained and position in which it was required to be bent, a variety of dies were used for bending of the members.

All circumferential members were bent both in flanges and web direction to achieve planar radius as resultant after placement of panel with the given angle of tilt. Amongst flanges and web, the flange was bent first and the web was bent later. Every bent portion was checked with the templates for its correctness with respect to the required curvature. Bent flanges were rechecked after web bending.

Meridional members were bent in flanges only with the same radius as required for the geometry in vertical plane.

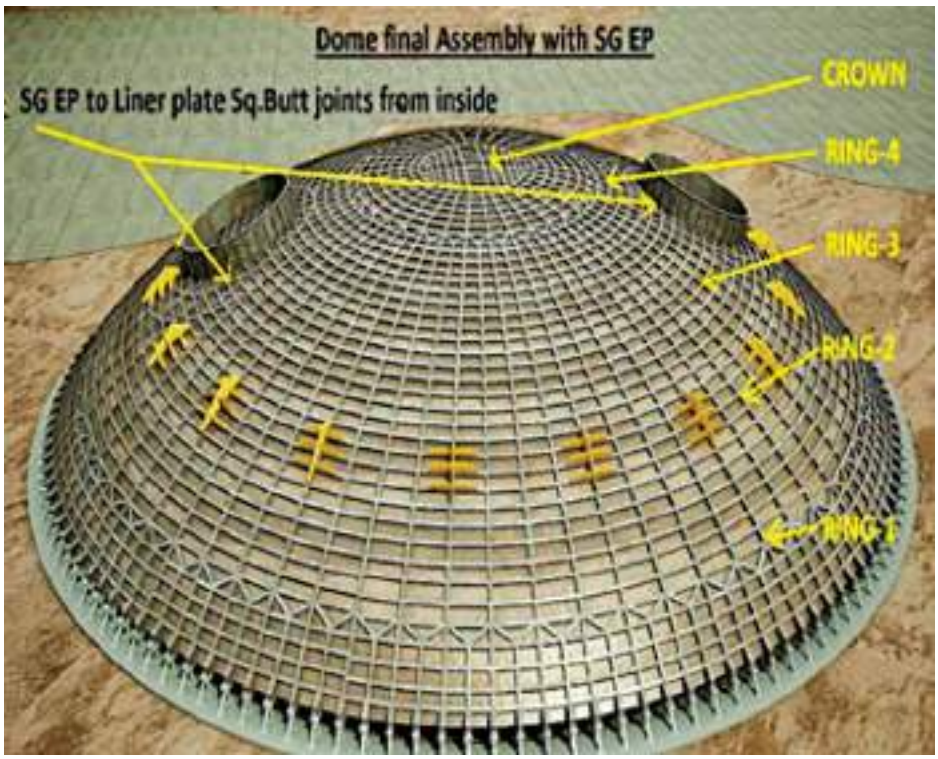


Figure 3: The rings for dome assembly

Bent members were cut to the required length, well ahead of the ends of the members (around 300 mm) in both directions, since it is not possible to bend the ends of the members. They were notch-cut to fix in web of other members, for which close tolerances were maintained so that sound fillet welds of web to web could be achieved. Because of higher flange width and thickness, it was necessary to follow sequential cutting, which took more time (3 times more) and also it was complicated to cut in slope and to maintain different radii at corners.

Jigs

A jig is the replica of the panel. Any uneven warps, out of contour, alterations present in the jig will reproduce in panels. Hence, utmost care was taken to fabricate the jigs, for which profile was crucial.

Based on the difference in sizes and profiles, there were ten different types of panels, which required ten different types of concave and convex jigs (total 20). But, in order to meet construction schedule, a total of 34 jigs were made, including four transportation jigs.

Templates

In order to check the profiles of the jigs, templates were prepared. Each template was prepared and checked on full scale layout. Based on type of curvature (meridional or circumferential), purpose (for execution or inspection), type (male or female), more than 200 templates

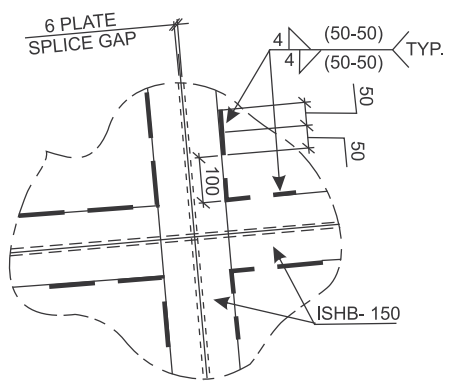


Figure 4: Sketch showing stitch welding of ISHB's with liners

were prepared and used during the fabrication of 53 panels of IC dome liner.

Liner panels

Initially, the entire assemblage was divided into 29 panels. In view of handling constraints (volume-wise) and to limit the distortions during handling, the entire assembly was divided into 53 panels. The details of panels are given as follows.

Tier	No. of Panels
1st Ring	16
2nd Ring	16
3rd Ring	8
4th Ring	8
Crown	1
Combined 3rd & 4th	4
Total	**53**

Fabrication Process

After the fabrication of the jigs, a plate of 6-mm-thick carbon steel cut to the required sizes were trimmed to the required radii at top and bottom and placed on the jig. Plates were so wedged that it takes the required profile of the jig. A 100% contact between plate and jig member was ensured before locking. Bent ISHBs were brought and kept at the designated location on the fitted-up plate and then locked.

ISHBs were welded to 6-mm plate with stitch-welding as per design drawings. Due to the large amount of welding in between the plates and ISHBs, it was a challenge to bring the profile of the panels within stipulated tolerances. So, depending on the spacing of the members, type of joint and position of weld, diverse formations of welding sequences were adopted in order to restrict distortion of the panels within the required tolerances. In order to control distortions, it was decided to perform welding operation only by two welders in order to limit heat input at any given time. Those two welders had to perform simultaneous welding in opposite direction to control welding distortions.

During fabrication, at one end of the panel, a temporary meridional member was placed. This member was removed before the next adjacent panel was placed at dome assembly area. The purpose of providing this temporary member was to retain the profile of the panels during handling, transportation and erection.

Shrinkage allowances were considered during the cutting of the plates during the fabrication stage itself. A 20-mm extra plate was provided on one side and top side of the panels to take care of welding shrinkages.

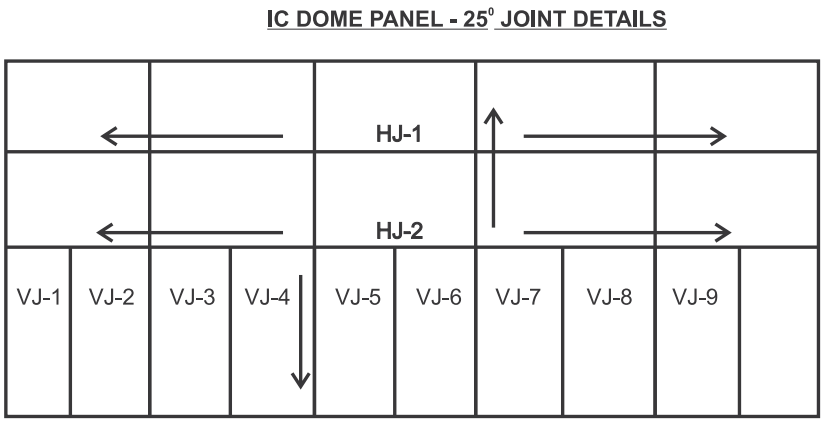


Figure 5: Welding sequence (liner-to-liner welding)

After completion of welding, panels were flipped on to the 'welding jig/ convex jig' with the help of 40-MT mobile crane and hydra. All possible precautionary measures were taken to avoid distortion by making use of evener beam at the lifting end and chain block at another end.

Besides general area panels, there were special panels, which did not have normal curvature. These panels formed the Steam Generator (SG) opening of 6-m diameter. The SG opening area is thickened by 175 mm both at top and bottom over and above dome concrete thickness, and liner panels are fabricated accounting the same. Any opening in the structure whether it is plane or curved attracts more stresses. Hence, the area needed to be strengthened and to achieve this, two rings of ISHBs were placed around SG opening.

Due to change in geometry, there are more intricacies in backing members detailing and joint formation. Due to non-uniform profile of the backing members and high congestion of three different kinds of members (circular rings, meridional and circumferential) and to check feasibility for proper fixing of the members, to check the feasibility of welding at the joints, to check bending to match kinks and curvature and to review concreatability aspects, a mockup was performed for this area.

Based on learnings from the mockup, decisions were taken to simplify the joints configuration by (a) introducing bent plates at junction placing; (b) plates at top flange of ISHB; (c) forming notches at top flange for concretability; (d) new flange plate by cutting existing flanges of rolled section, and (e) where abrupt bends were difficult to perform, by placing new plate in place to the required profile.

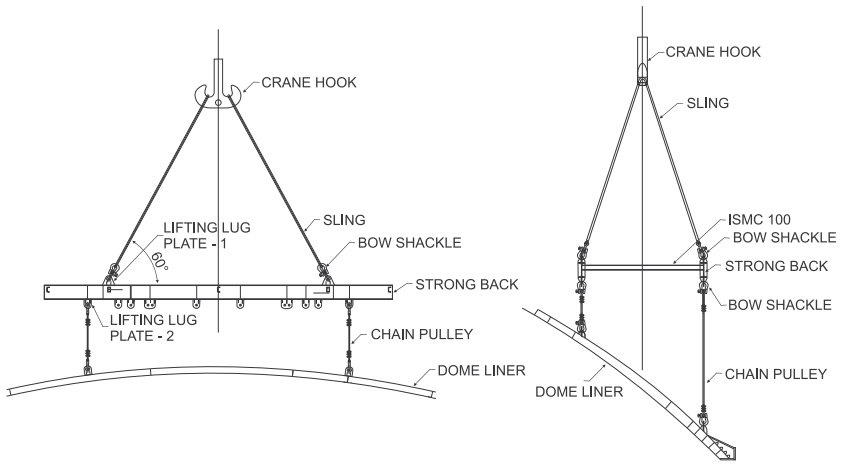


Figure 6: Handling of panels during fabrication and erection process

Besides complexity in the connections of the members, it was also a challenge to form the members at lifting hook locations.

One of the lifting points at the junction of panel 8B and panel 9B was coming exactly at the joint. Circular members around SG opening were coinciding with the circumferential member. Circular members were required to be continued by dividing meridional members.

There were three options available to solve the problem:

1) Splicing the members at the junction of the panels.

   But due to design constraints, the splicing of the members was not possible in both the panels.

2) To keep the members as dummy and to replace them with new permanent continuous members after erection of both the panels.

   But, problem in this arrangement was that all the meridional members which were notch-cut and fixed with circular members needed to be removed while replacing with new continuous permanent members.

   In this area, while removing the members, plate in attachment with it would get free. To regain the required curvature after removal of members and plates was very difficult. Also, the safety issues because of the removal of plate and beams were increased.

3) To place continuous members in one of the panels and to place temporary in other.

   In this case, we placed permanent member in 9B and temporary in 8B. 8B panel was erected first and 9B placed later. While erecting 9B, temporary members were removed and lateral movement of 9B was made during erection.

Some members were removed while replacing. The free plate was supported on a jig-like arrangement (specially made) for 8B panel. This arrangement led to satisfy design requirement by keeping circular member as continuous, without splicing, and temporary arrangements were required only for one panel.

Fabrication of the panels involved a lot of work, with diversity in each ring, and was completed in

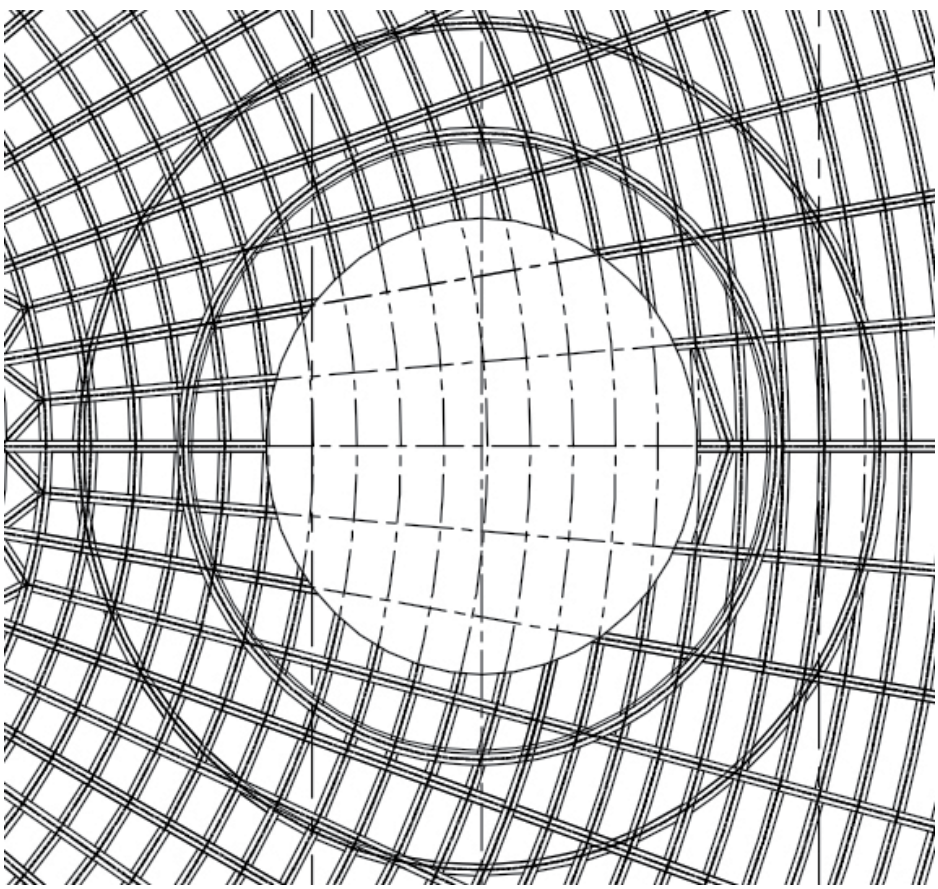


Figure 7: Strengthening arrangements around SG opening (Plan)

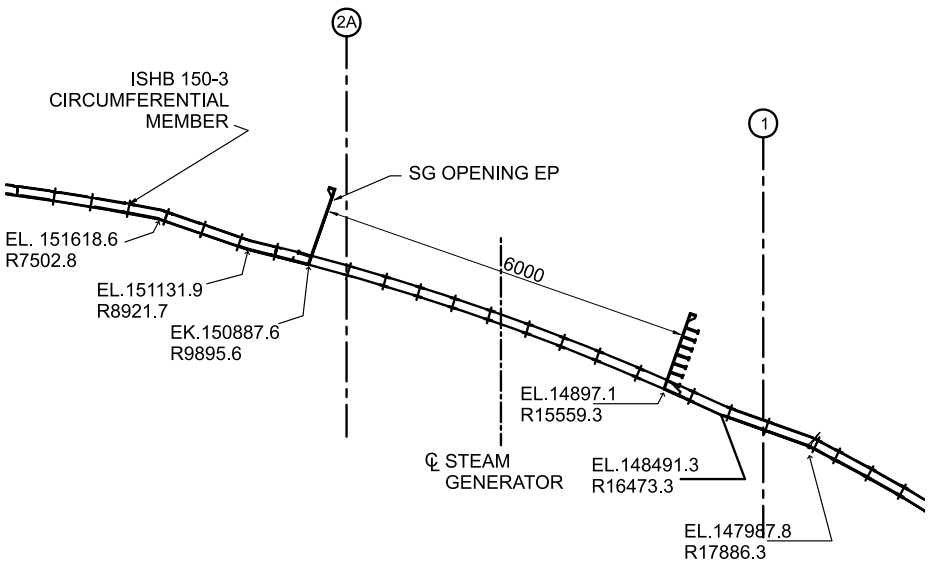


Figure 8: Strengthening arrangements around SG opening (Section)

stipulated time achieving desired quality. Successful completion of fabrication was a challenge for all the stakeholders involved in the fabrication.

The salient points on the panel fabrication works are listed below:

1) Thirty-three jigs were fabricated by making use of ISMB-150. Almost around 4.5 km of ISMB-150 was bent to different profiles, which were later cut and assembled.

2) Almost every plate was cut to the required dimension from the raw material, which involved the cutting of around 3 km in length, which included both straight and radius cut.

3) In every panel, a minimum of 50 wedges were used to lock the plates to the jig. Every junction of the plate was so locked that 100% contact was maintained between the 6-mm plate and the jig.

4) There were 5000 joints prepared with notch-cutting with very tight tolerances.

5) Extensive amount of welding was involved as detailed below.

4 MT of weld metal deposit were performed to complete the entire welding. The details of all the welding involved in the fabrication of the IC dome liner as a single unit are given below.

Type of joint	Length in km
Fillet of 4 mm	9
Fillet of 5 mm	7
Fillet of 6 mm	4
Fillet 8 mm	1
Fillet 10 mm	5
Groove with bevel 37.5 for 10-mm plate	3
Groove with bevel 37.5 for 25-mm plate	0.5
Double Groove with bevel 37.5 for 25-mm plate	1
Total length:	**30.5 km**

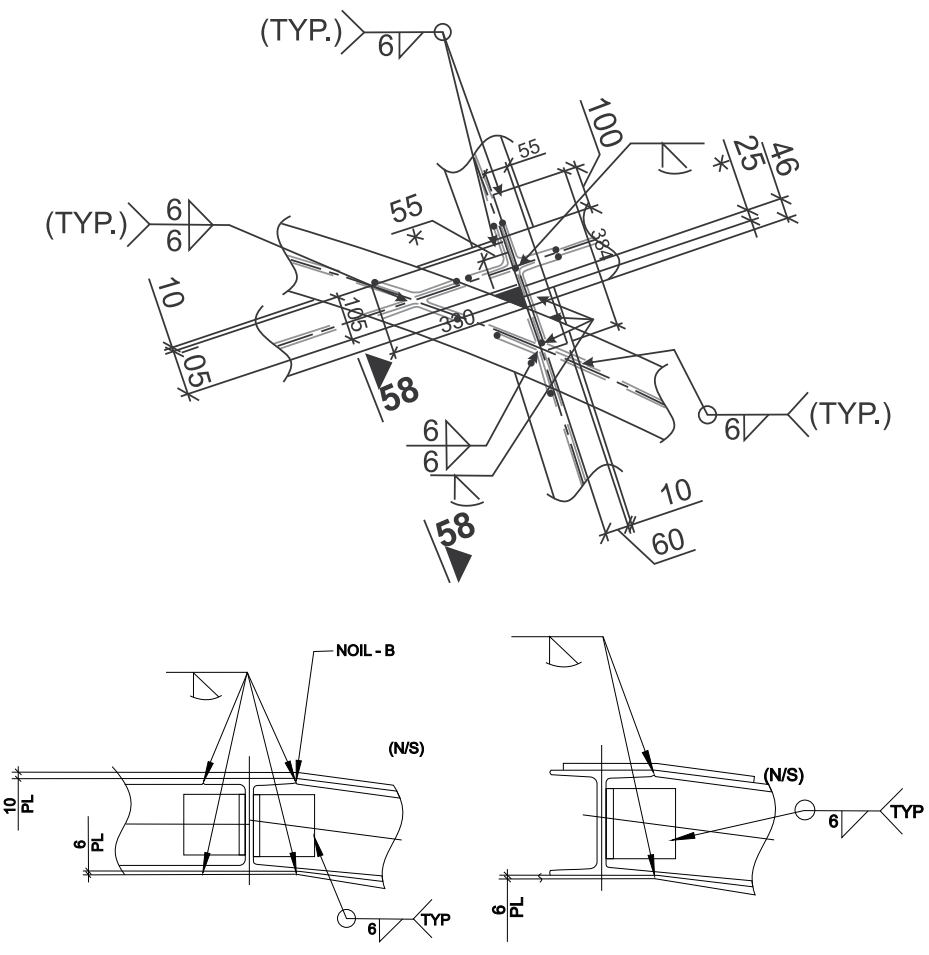


Figure 9: Sketch showing three members meeting at one location.

In order to perform the above-said job in stipulated time period with required quality, about 150-200 workers were deputed, including highly skilled supervisors, fitters, welders and other supporting staff.

Transportation

Evener beams

In order to control the distortions induced during handling from concave to convex jig and from convex jig to transportation trailer, evener beams were used which evened the handling loads in the members, ensuring minimum distortions/deformations in the members.

Figure 10: Photo showing built-up beams instead of ISHB to avoid congestion

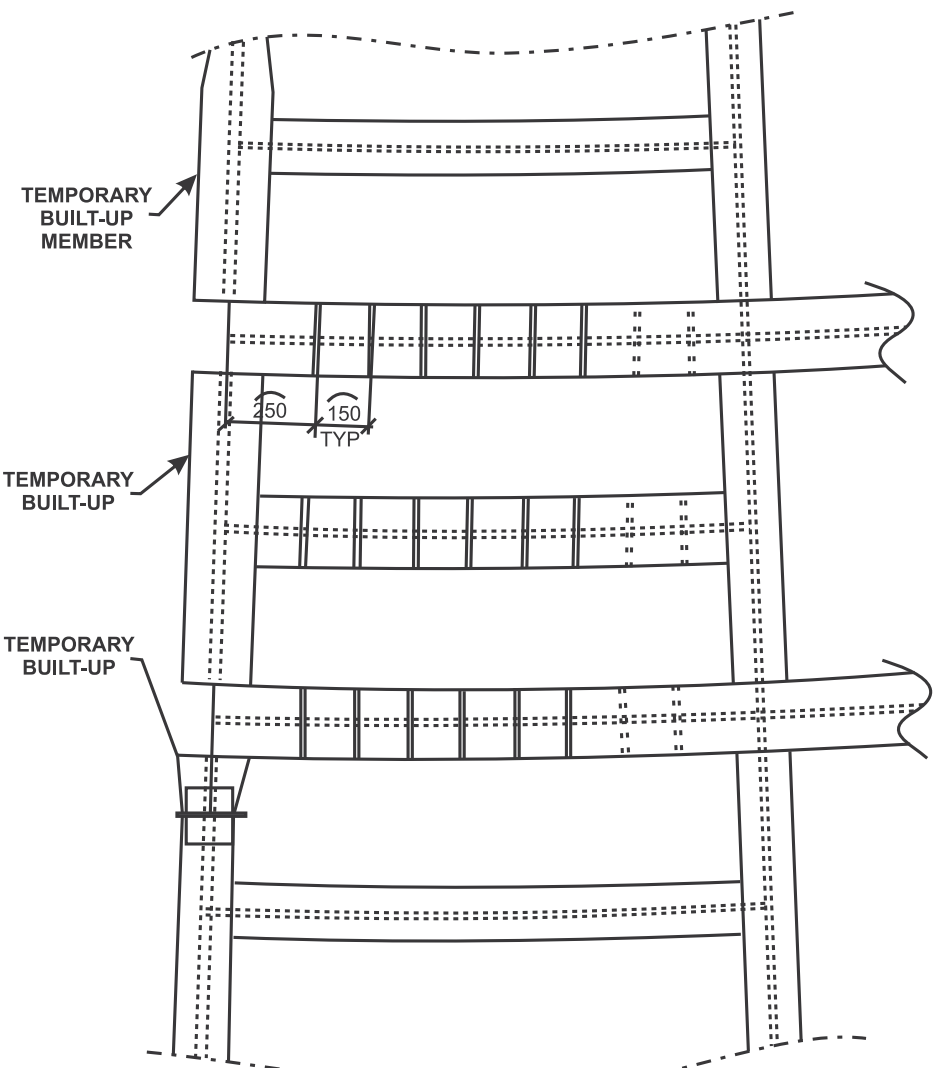


Figure 11: Sketch showing built-up member at lifting locations

Arrangement and sizes of the panels

Amongst the panels described in the Table 'Description of the Panels', the combined panel of 3rd and 4th rings having the size of 11.2 m (length) x 1.57 m (top width) x 6.07 m (bottom width) was the most difficult and challenging job to handle (from concave to convex and from convex to trailer). Taking advantage of SG opening available at the bottom of the panel, it was kept diagonally on the trailer for symmetric loading on both sides, allowing optimum use of area available on trailer.

Assembly

Assembly area preparations, cranes, supports and alignment

The place for assembly was so chosen that it was best suited for a heavy-duty crane configuration (capacity: 1350 T) and to avoid fouling with other structures constructed, existing tower cranes, during slewing and marching of this crane along with dome.

Crane configuration as shown in Fig. 13 was decided for erection. The lifting capacity worked out to be 373 MT (excluding crane hook) at 44-m radius, which was more than the total load to be lifted.

Description of the panels												
Tier	No. of Panels	Degree	25 degree panels dimension in m			20 degree panels dimension in m			30 degree panels dimension in m			
			L (Bottom)	L (Top)	Height along curve	L (Bottom)	L (Top)	Height along curve	L (Bottom)	L (Top)	Height along curve	
1st ring	16	20 & 25 alternate	10	8.43	4.8	8.09	6.93	4.8				
2nd ring	16	20 & 25 alternate	8.43	6.07	6	6.75	5.05	6				
3rd ring	8	30 degree							6.07	4.28	6	
4th ring	8	30 degree							4.28	1.57	5.2	
Crown	1	360 degree							6m dia. 360 degree			
Combined 3rd & 4th	4	30 degree							6.07	1.57	11.2	

With this crane configuration, the vertical clearance between the bottom of the crane hook to the crown of the IC dome worked out to be more than 20 m. With an angle of 55° of the lifting sling with the horizontal plane, the elevation of the bottom of the crane hook was EL 172.922 m and the elevation of the IC dome crown was EL 152.50 m. With these arrangements, there was no fouling of the IC dome assembly with the main boom. With this configuration, there was a 20-m clearance available.

Considering this configuration (Fig. 14), a best suited place was selected near 'turning pad A' as shown in Fig. 15.

The assembly area was leveled and compacted. Around the periphery, EPs were embedded to facilitate the seating of dome liner panels (D1A to D16A). Stools were provided at 144 locations exactly as provided in the ring beam. At these 144 locations - 02 Plate EPs were embedded in RCC and all the EPs were checked for planar radius, planar angle (stool-to-stool distance along circumferential direction in horizontal plane) and elevation, before concreting. In the concreted area of assembly, EPs were embedded at junction of panels (to enable alignment of the panels).

A total of 144 stool with the same configuration (dimensional details) as of ring beam stools were fabricated and erected on EPs in assembly area. On top of the stool, fixing and wedge arrangements were made for alignment of panels.

For the ease in movement of manpower inside the dome assembly, approach was given by lowering the ground level at one location.

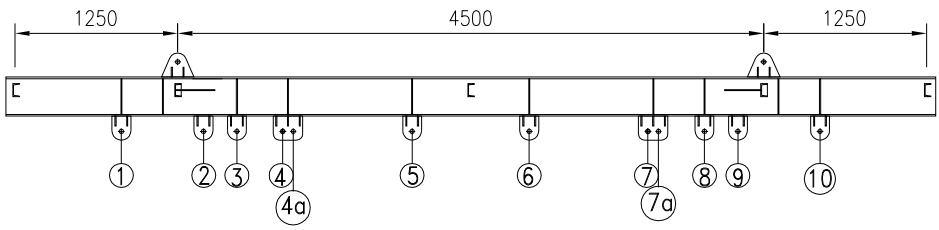


Figure 12: Sketch showing the evener beam suitable for different type of panels

For supporting the panels in the

Figure 13: Handling of SG area panel(large panel)

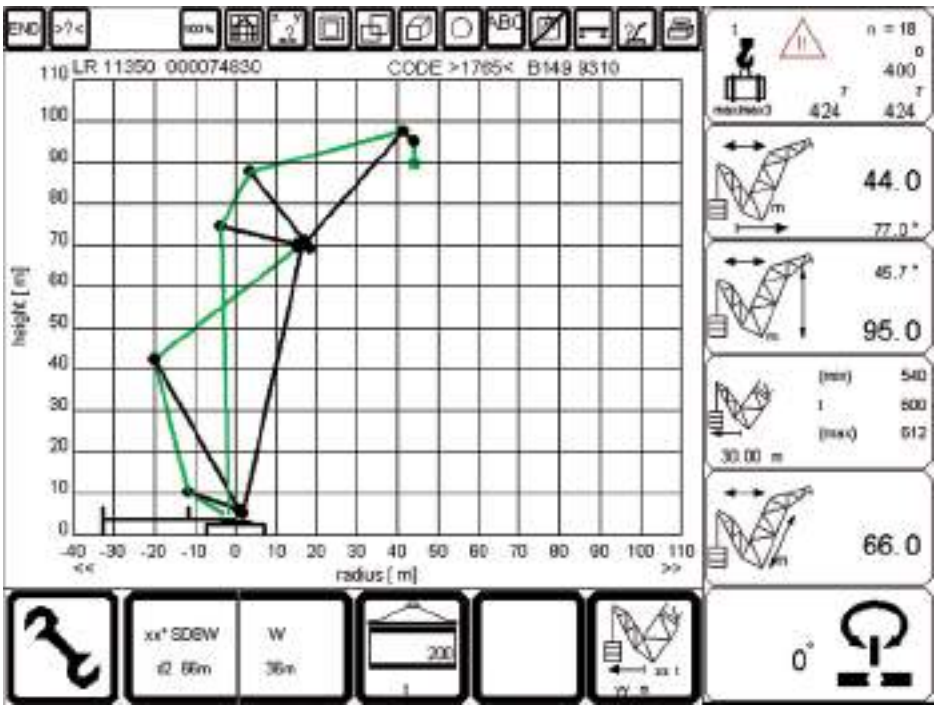


Figure 14: Lifting capacity of the crane LR11350 with configuration

assembly area, heavy duty towers were used. These towers were erected to perform two functions:

- For supporting of the panels
- For aligning the panels with the help of spindles of towers present at top

Timber packings with the same profile of dome liner were specially fabricated and were used for uniform resting of liner on steel beam during alignment and welding.

Sequence for assembly of the panels was decided in such a way that erection of the panels could be performed by making use of 40-MT mobile crane. Very limited area was available for erection of the panels. Hence, the sequence of panel erection was decided in such a way that the crane could make way to reach within assembly area, enabling maximum number of panel erection using 40-MT crane capacity. The detailed sequence of assembly is shown in Fig. 20.

A specially designed evener beam was used for erection of the panels from trailer to the anticipated position in assembly area. It was a challenge to attain the required slope of the panels to match the curvature during erection.

For aligning the panels, spindles of heavy-duty tower, chain pulleys and turn buckles were used in order to achieve the required radius and elevations. Fine-tuning and perfect matching of plates and backing member of panel-to-panel joints was achieved carefully by making use of mechanical wedges (clamps and keys).

During the alignment of the panels, pre-cambering was maintained to take care of welding shrinkages.

After erection and alignment of three consecutive circumferential IC dome panels, radius at the required elevation of top, middle and bottom of each panel at four

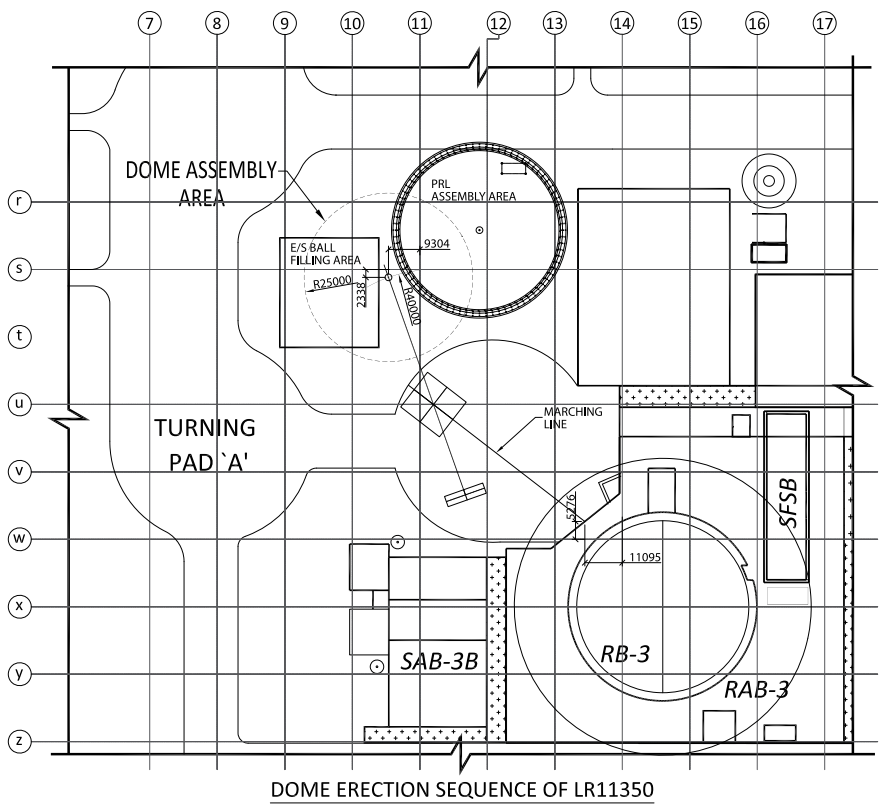


Figure 15: Location of dome assembly area

Figure 16: Stool at assembly area

locations in circumferential direction were checked with the help of Total Station.

After ensuring required parameters, welding of meridional joint of the middle panel was carried out.

Welding sequence

For controlling distortion induced due to welding, sequential welding was performed.

SG EP erection and alignment

It was decided to erect SG EP in the assembly area after thorough deliberations on the subject. The diameter of the EPs was 6 m and the height was 1.25 m and were aligned with a 10-mm-thick plate along the periphery. Each EP weighed around 6 MT. The two EPs were located at north and south.

During fabrication of EPs, precautions were taken to maintain included angle of the bottom flange (350-mm wide and 16-mm thick) to cylindrical portion. Along with this diameter, ovality, position of lugs, stiffeners and marking of opening for pockets were ensured with respect to designated center, which was permanently marked on the EP. Along with this, temporary members were placed inside the opening forming a grid-work of ISHB-150. These were so located that they matched with the locations of meridional and circumferential members outside the opening.

This EP had a bottom flange with a width of 350 mm and a thickness of 16 mm. A step of 6 mm x 50 mm was made in the flange so that after erection, square butt welding could be performed with liner backing member. Meridional and circumferential members in the vicinity of SG EP were required to be welded on the cylindrical portion of the EP. Hence, it was decided to keep these members free during the fabrication of the panel and were later removed during the erection of SG EP, and after the erection, these members were restored and welded. Due to this sequence of operations, execution of this critical job was very smoothly performed.

The details of all welding performed at assembly area to form as a single unit is given in below.

- Total no. of horizontal joints: 37
- Total no. of vertical joints: 52
- Total SG EP joints (6-m dia.): 2
- Total weld length (liner plate-to-plate weld assembly): 640 m (approximately)
- Weight of single panel ranges: 8 to 10 MT

Load testing

One of the major challenges was to load test the evener beam (lifting beam) by keeping the configuration of the slings exactly as per the final dome lifting. After thorough deliberations on the subject, it was decided to fabricate the secondary evener beam.

Main Evener Beam (lifting beam)

Main evener beam, which is also called top crane hook connector, is connected with the help of a pin (The crane hook has a slot to the fix the pin). During the erection of the Prefabricated Ring Liner (PRL), the same pin was used to lift the PRL. This pin is designed for a load of up to 3000 MT. The evener beam has 18 lifting points. The calculated weight of dome to be lifted was around 340 MT. After considering the

Evener (load lifting) beam and pin details

Weight: 12.36 MT
Designed for lifting: 720 MT
Pin capacity: 875 MT
(In double shear)

Figure 17: Depression in ground for men & material movement

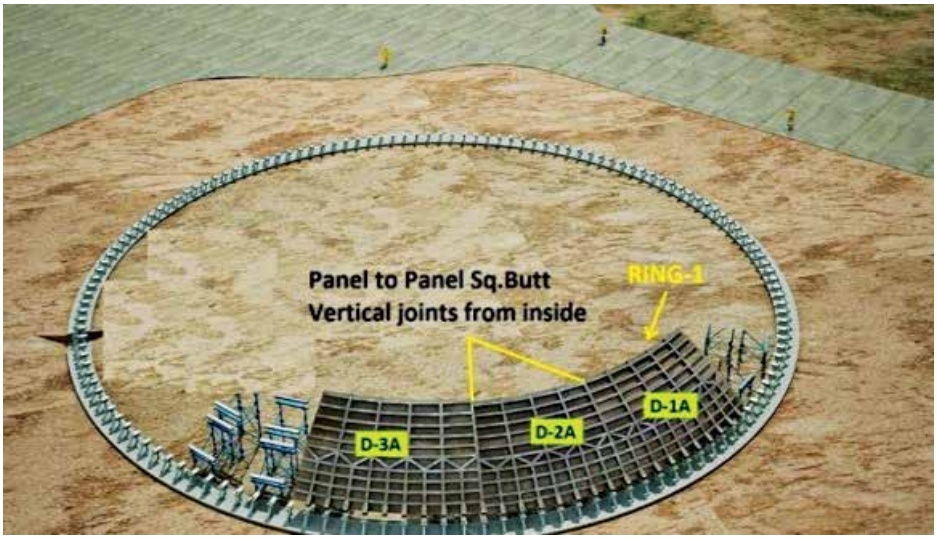


Figure 18: Assembly area with heavy duty towers with panels

weight of tools and tackles, evener beam and positive mill tolerances, the weight to be lifted worked out to be 355 MT. While designing the total system, worst case was considered (snapping of one of the slings).

Heavy-thickness plates were cut to required shapes and formed into three different modules. Preheating was performed before welding due to heavy thickness.

These three modules were later assembled to form a single unit, for which extreme precautions were taken to match the concentricity, distance, dimensional tolerances etc. in order to achieve smooth fixing of the pins into the holes.

Evener beam thus formed was heat-treated to diminish the residual stresses formed in the assembly and to achieve the original properties of the materials.

Lifting Pin

A 227-mm-diameter pin/bolt of class 12.9 was used for connecting evener beam to hook of the crane. This pin was forged and heat-treated for quenching and tempering for achieving an ultimate tensile strength of 1200 MPa.

Evener Beam Details

Maximum number of joints in the fabrication of the evener beam were full-penetration bevel welds.

Heavy thickness plates ranging from 40 mm to 63 mm were used.

A huge amount of welding (about 1.5MT) was performed.

A 40-mm plate was rolled from specialised party to achieve smooth rolling and to achieve close dimensional tolerances to the radius of 1.25 m.

As this member was most critical from the loading point of view, utmost care was taken for its welding. Highly experienced welders who could perform 6G welding were engaged for executing the job.

Secondary Evener Beam

For performing load testing of the primary evener beam, a secondary evener beam was designed. This evener beam was fabricated by using built-up sections with 16 mm (flange and 12 mm (web) plates having a height and width of 250 mm.

Secondary evener beam is formed as polygon with 18 sides having a maximum length of 13.5 m and an inner polygon having a maximum length of 6 m.

Load testing of the primary evener beam through secondary evener beam was successfully completed by using existing loads at the site. Secondary evener beam was design to suit the existing loads at the site. For optimum design of the secondary evener beam, load positions were staggered as shown in Fig. 26.

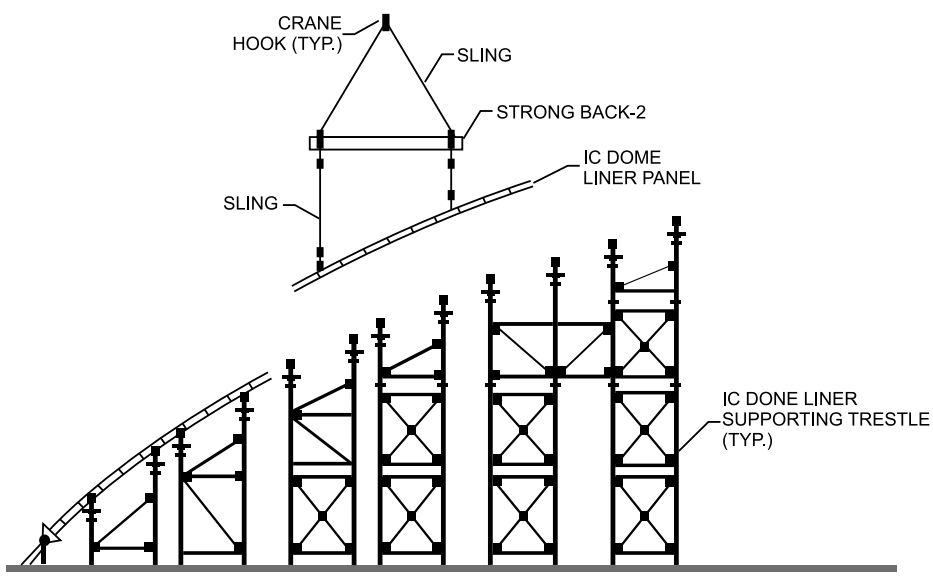


Figure 19: Arrangement of heavy-duty towers at assembly area

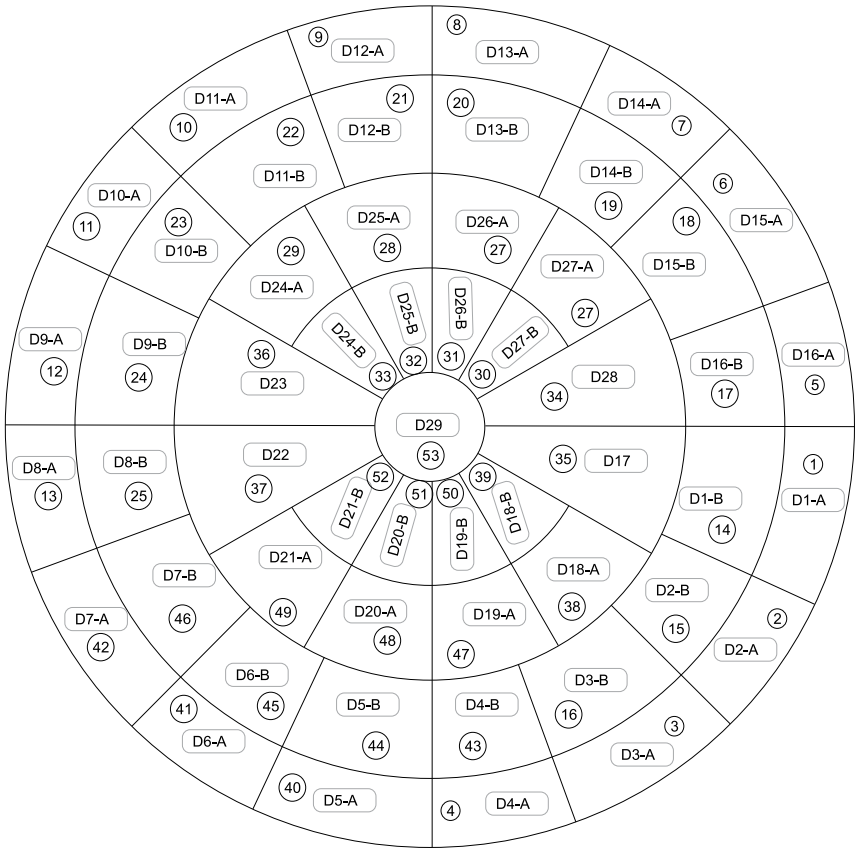


Figure 20: Sketch showing panel configuration during assembly

The loads available on the site ranged from 18 MT to 23.5 MT. Hence, necessary arrangements were made to compensate the load to match 23.50 MT by adding extra loads on the block. These loads were so positioned on the blocks that the centre of gravity was maintained.

Arrangements for Load Testing

The actual weight to be lifted was around 340 MT (excluding main evener beam but including tools and tackles). Considering a factor of 1.25, the evener beam was tested.

Load cells

Amongst the tools and tackles used, bow shackles of 55 MT had a built-in load cells in the pins. Those load cells indicated the load carried by them. Load cell system had a facility to record the loads in a remotely controlled unit. It had a range of about 120 m.

This was specially required to monitor distribution of the loads. If loads were not distributed as intended, turn buckles provided along with lifting arrangements were adjusted.

Testing of tools and tackles

For testing of slings, turnbuckles and bow shackles-cum load cells, the following sequence of activities were performed,

- Verification of material specification
- Calibration of load testing bed
- Fixing of tools and tackles
- Application of load
- Check for physical damage, percentage elongation, dimensional parameters.

Loads applied on the tools and tackles was up to the proof load,

Erection

The IC dome-liner backing member assembly was lifted as a single unit using 18 slings. The angle of inclination of the crane cable with the horizontal was kept at 55°as per design. The loading plane was so selected that it coincided with the plane of centre of gravity of the IC dome liner backing member system.

A 56-mm-diameter HYFLEX steel wire rope was used for lifting the complete IC dome as a single unit. The material of slings had a tensile strength of 1960 MPa and modulus of elasticity of 2.0 E + 05 MPa. The minimum breaking load of individual slings was 207 MT.

For permissible capacity of crane at a given radius, the limited wind speed as per crane manuals was 9 m/s. To be on safer side, the wind speed limit was restricted to 8 m/s, i.e. if there was a speed of wind more than 8 m/s, the dome assembly would not be lifted. For this purpose, wind data was collected for previous one month and continuous monitoring was done until the time the dome was lifted.

Lifting hooks

At the selected point of the lifting, both meridional and circumferential members were replaced with the built-up members, which are shown in Fig. 28.

It was necessary to limit the built-up section height to 150 mm only, as it had to match with the existing ISHB-150-3. Plate thickness was increased.

Meridional members at lifting location had a length of 2.4 m (Built-up sections) and there were three circumferential members adjacent to it on both sides. All these were replaced with built-up section.

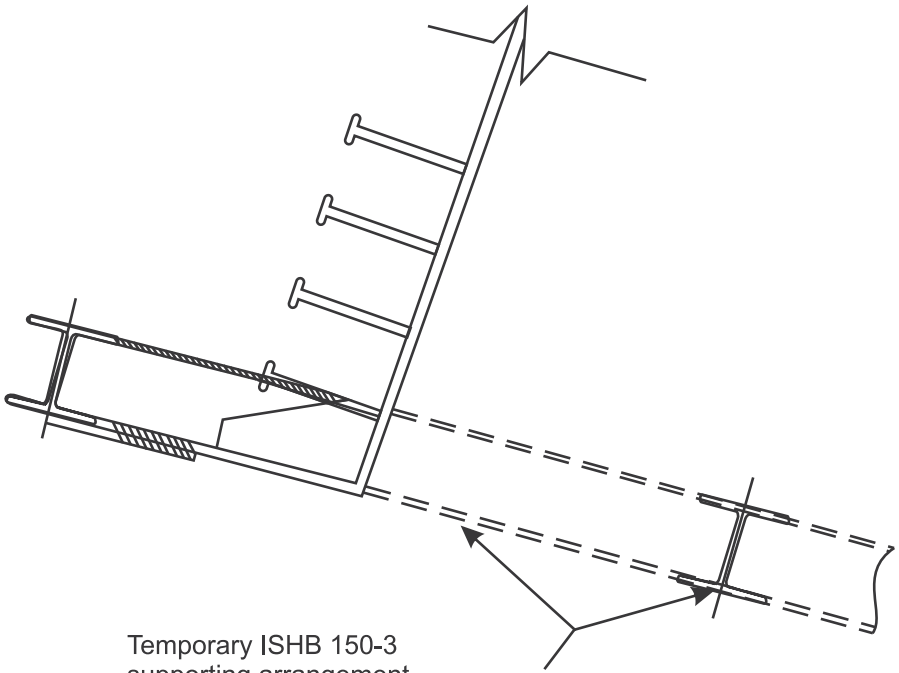


Figure 21: SG EP and its connection with dome members

Measurements

Assembly area

Readings of radius and elevation for individual panels were taken at four sections. At each section, three readings were taken, i.e., at circumferential members positioned at top, middle and bottom.

- After completion of the entire dome, the HD towers were detached and final readings were taken from the inside of the dome assembly area.
- The assembled dome was lifted about 1000 mm for 2 hours and the maximum loads on all 18 slings were monitored. Also other readings were taken.
- The assembled dome was lowered and rested back on the stools. Another set of readings were taken at the same locations where initial readings were recorded.
- SG EP locations were checked with respect to grid and recorded.
- All readings were well within the acceptable limits.

Ring beam

In Ring beam, stools were erected in Pour-2 of ring beam concrete. These stools would receive the dome seating plates. Hence, mapping was carried out and necessary correction was made.

Stools were checked for elevation, radius and circumferential stool-to-stool distance.

Ring beam liner was kept free at top for a height of 400 mm for flexibility for alignment purpose with the dome liner. This free portion was temporarilily stiffened by angles during the fabrication of ring beam panels.

To preform welding of dome to ring beam, brackets and platforms were erected. LD towers were erected on these platforms for making approach for welding.

Load testing of heavy-duty crane of capacity 1350 MT

Load testing of crane LR11350 was completed successfully a few days before the actual dome lifting. The carne was tested for a load of 415.7 MT.

Dry run

A dry run of crane was undertaken to rule out any surprises during actual dome lifting and to ensure smooth erection of dome.

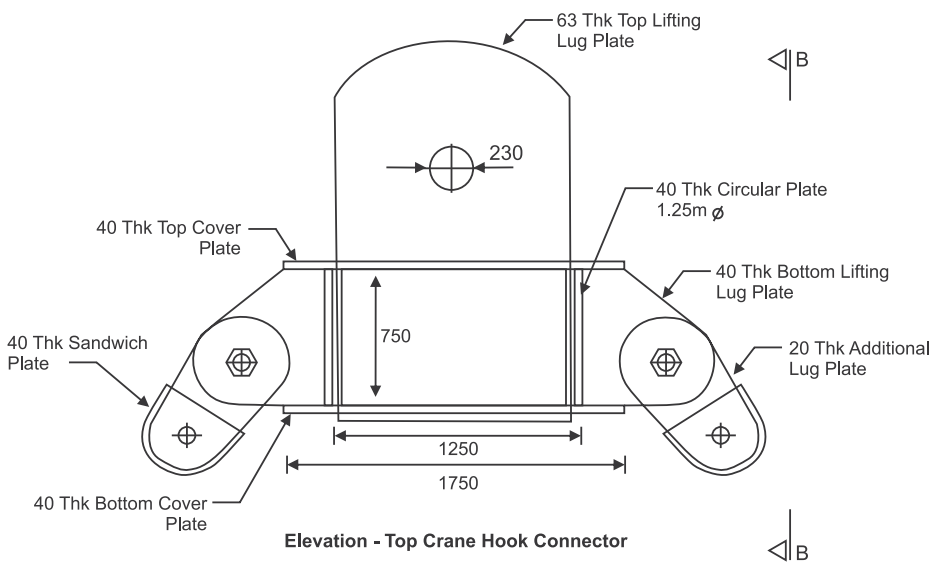


Figure 22: Details of Evener Beam

Figure 23: Evener Beam

The crane was set to the same configuration as it was required during actual lifting of the dome.

After setting crane parameters in the required configuration, slings were suspended from the hook. The length of slings was so placed that its height after suspending would match the bottom of the dome during actual erection.

A dry run was performed to set the path of the crane for actual lifting of the dome liner.

SG trestle

The dome was supported at the SG opening area from the top of SG enclosure wall (North and South) at EL 132000. The SG opening support consisted of four ISMB500 star column as vertical members braced with ISMC300. The vertical ISMB500 star columns were also diagonally braced in the horizontal direction. The vertical ISMB500 was supported on the top of 800-mm-thick SG enclosure wall.

SG trestle was fabricated in three parts. The first part (7-m high) was erected individually and the other two parts were preassembled on ground, which consists of trestle (8.5 m) and circular ring beam (8 m in diameter) and walkway platforms.

The total assembly was placed on its designated position with SGs in place, with a gap between the trestle to be erected and the SGs being hardly 150 mm.

Walkway platforms were provided for:

- Proper approach to weld stub columns on the circular ring beam.

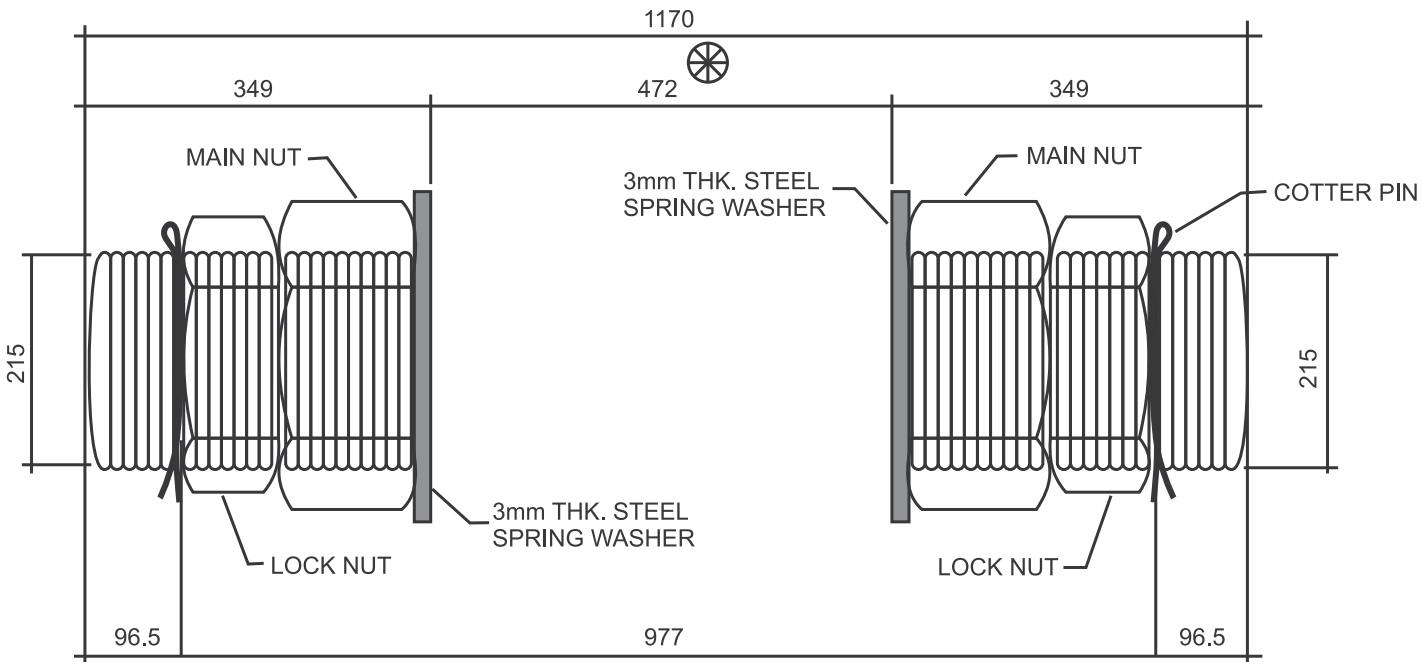


Figure 24: Pin details of 227 Ø PIN (Class 12.9 Grade)

Figure 25: Secondary Evener Beam

- Protecting Steam Generator when hot work is in progress, i.e., while welding the stub columns.
- Ensureing that while dismantling/ cutting stub columns after concreting, loose material would not damage SGs.

Assembly

CSS header, pipe support, platform support, etc. were erected after the completion of dome assembly.

HSCMS was also erected after the completion of dome assembly.

Grit blasting and painting

It was decided to perform grit blasting, primer panting and epoxy painting at the assembly area. This resulted into reduction of one handling operation, which in turn reduced use of resources, manpower and time for completion.

After completion of the entire assembly alignment and welding of dome panels, grit blasting and painting zinc silicate as primer with a dry film thickness (DFT) of 75 microns was carried out. After blasting and primer painting was completed, final painting was carried out, which included two coats epoxy paint to a DFT of 125 microns each (total 250 microns for 2 coats).

Documents prepared

As dome fabrication, assembly, erection and alignment was critical, all the related activities were thoroughly deliberated and the required procedures prepared and got approved before the execution.

The following list gives the procedure developed.

Work procedure for fabrication, welding, transportation, assembly and painting of IC dome liner.

Work procedure for measurement scheme of IC dome liner at fabrication, assembly area and after erection on Ring Beam.

Figure 26: Load testing of Evener Beam

Figure 27: Bow shackle with load cell

Figure 28: Slings arrangement for lifting of IC Dome

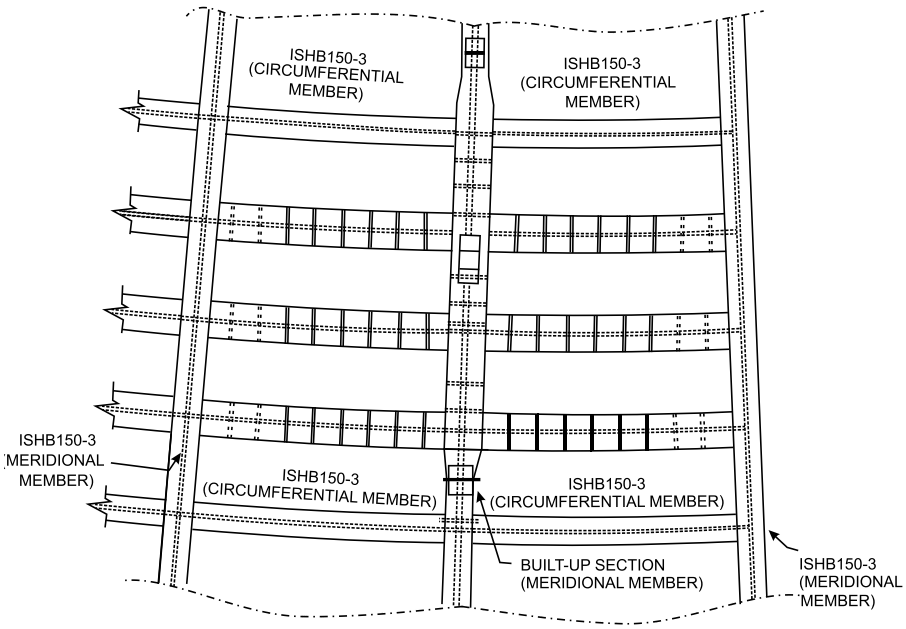


Figure 29: Sketch showing lifting hook detail

Crane configuration and capacity

Model: LR11350

Main boom length: 54 m

Luffing jib length: 66 m

Main boom angle: 77 degrees

Luffing jib angle: 45.7 degrees

Working radius: 44 m

Derrick counter-weight: 500 MT at the radius of 30 m.

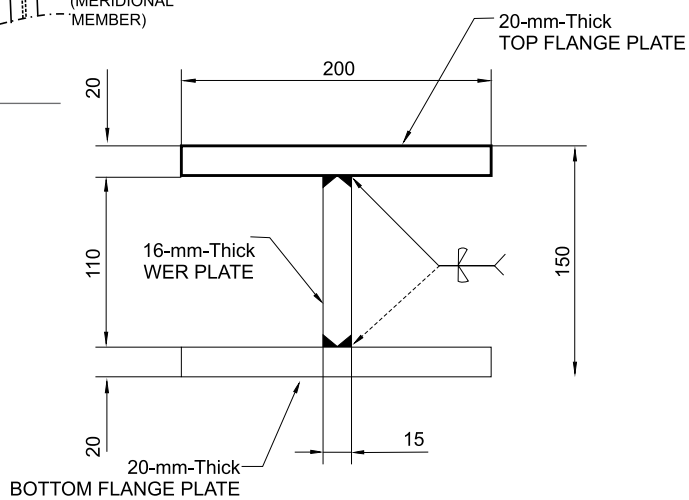
Work procedure for erection and alignment of IC dome liner.

Work procedure for erection and alignment of SG EP on IC dome liner at assembly area.

Method statement for load testing of tools and tackles for dome lifting.

Safe working procedure for assembly erection of dome liner

Job hazard analysis on assembly and erection of IC dome.



BUILT-UP SECTION (BS-1 & BS-2)

Figure 30: Sketch showing built-up beam

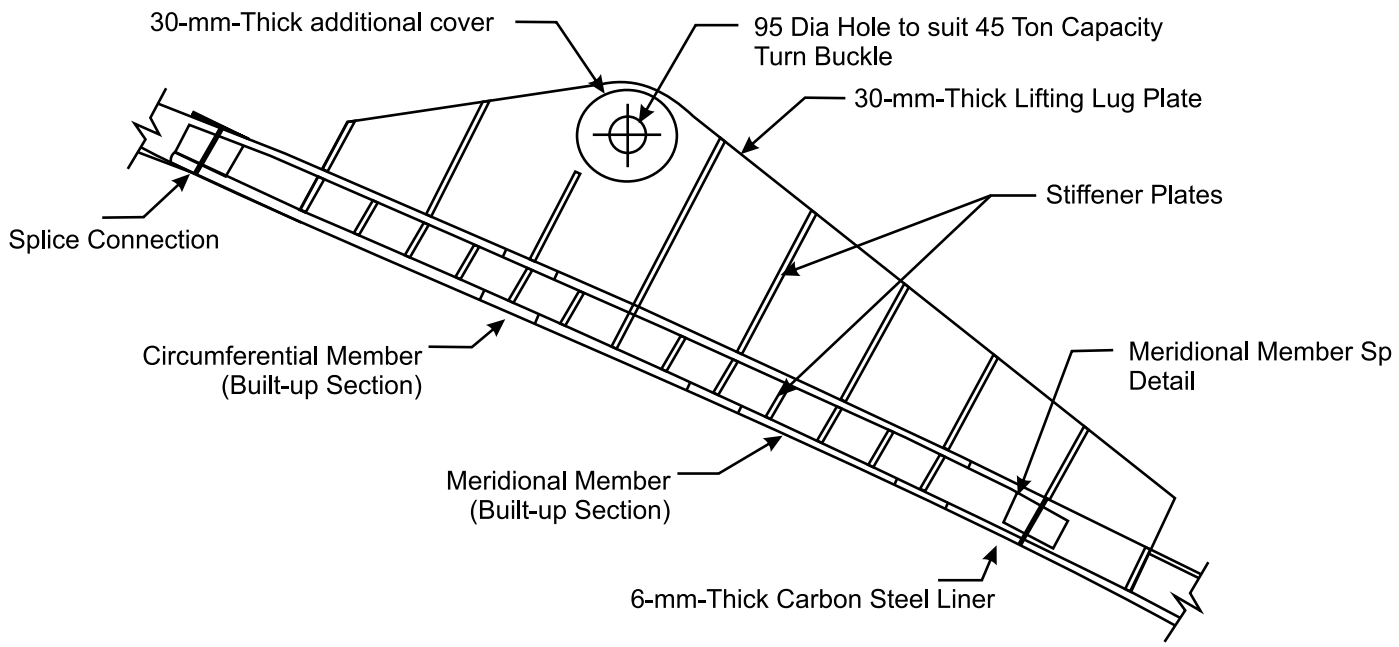


Figure 31: Sketch showing lifting hook details

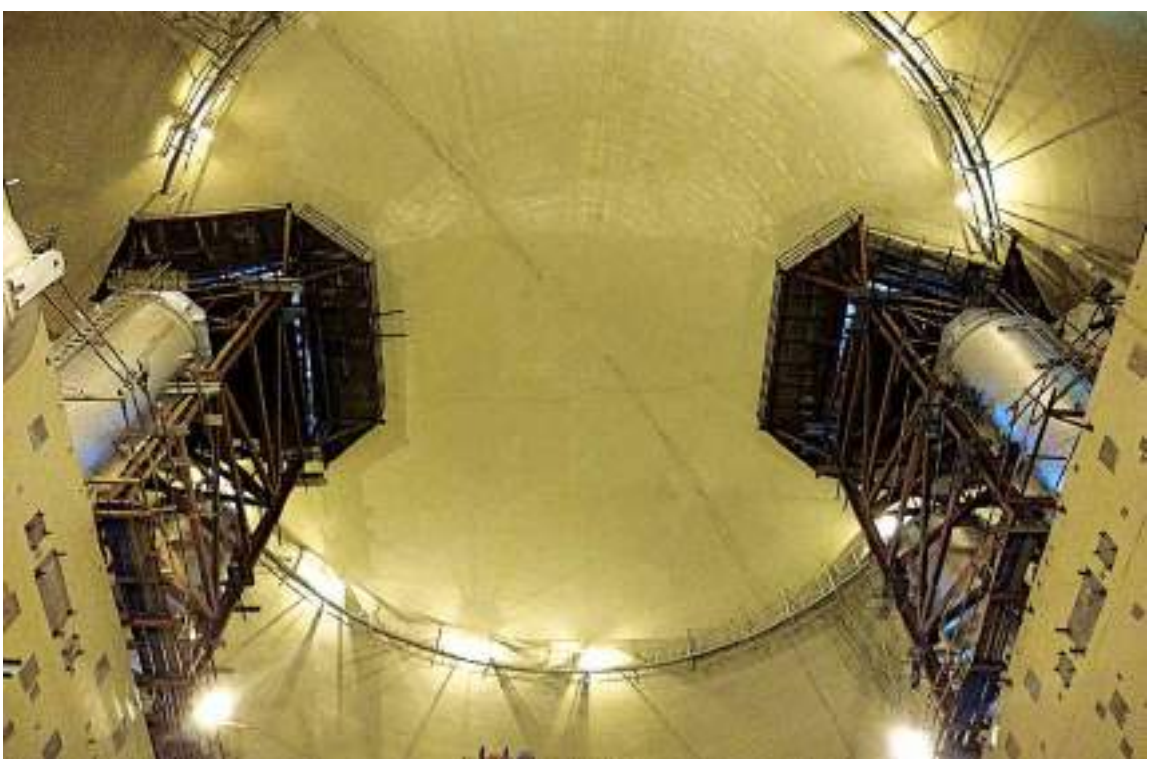


Figure 32: View from inside the reactor building showing IC dome liner with SG trestle in place

Figure 33: SG Trestle

Erection and accomplishment of the event.

The first-of-its-kind dome liner of 47.042-m diametre and 8-m height — a double-curvature segmental dome — with two large openings of 6-m diameter, weighing around 355 MT was lifted and erected as a single unit. The complete operation of lifting and erection of dome liner at a height of 44 m in Reactor Building-3 was completed in 1 hour 45 minutes, representing perfection in every field.

Lokesh Kumar, an Electrical Engineer, joined NPCIL in the year 1982 after the successful completion of one-year training from 25th batch of BARC Training School After completing his induction training, he worked for 2 years in Procurement Group of NPCIL, Mumbai and in the year 1984, he was posted to Narora Atomic Power Project (NAPP). Since then he has held different positions at various NPCIL units such as Project Engineer (Electrical), RAPP-3&4; ACE (Electrical), TAPP-3&4; and in Project Directorate of NPCIL, headquarters in the year 2006. He was instrumental in getting clearances and approval like environmental clearance from MoEF, siting and excavation consent from AERB and Financial and Administrative approval from Govt. of India. He also contributed a lot in the preparation of general conditions of various packages/works and for Construction Management manual. He was posted at KAPP-3&4 as Chief Construction Engineer in the year 2009 and designated as Project Director, KAPP-3&4, in 2011. He is currently working as Executive Director (Procurement), Headquarters.

Jagdish Singh Virdee, a Mechanical Engineer, joined 24th batch BARC Training School (in plant trainee). After the successful completion of one-year training at Nuclear Training Centre, RAPS, he was posted to RAPS-1&2 in mechanical maintenance section and later in the year 1987 he was posted to Narora Atomic Power Station (NAPS). He demonstrated his capability in successful commissioning and commercial operation of first indigenously-designed PHWR units at NAPS. He was then posted to Kaiga Generating Station as Senior Maintenance Engineer (Mechanical) in the year 1998. He was designated as Quality Assurance Superintendent at KGS-1 to 4 in the year 2005. In the year 2012, he was posted as Chief Construction Engineer at Kakrapar Atomic Power Project-3&4. Currently he is working as Project Director, KAPP-3&4.

M. Kotaiah, a Gold Medalist in B.E. (Civil Engineering), and M.E. (Structural Engineering), is from 32nd batch (First batch of Civil Engineering Trainees) of BARC Training School. After successful completion of training he joined NPCIL. At present he is in-charge for Civil works at KAPP-3&4. During his 27 years of service he has worked in all fields of Civil Engineering. He has worked at NPCIL HQ, Mumbai, KKNPP, KAPP-3&4 and Moscow. He has worked on many of the 'first-of-its-kind works' in Civil Engineering fields both at KKNPP and KAPP-3&4. He has published a book on pre-stressing works. He has received Outstanding Contribution Award, Excellent Contribution Award and Group Achievement Award from NPCIL. Currently, he is ACE (Civil), KAPP-3&4.

H.N. Ramesha, B.E. (Civil Engineering), joined Construction Group in Kaiga Generating Station after completion of one-year orientation course from 34th batch of BARC Training School. He was involved in the construction of Main Plant civil works of Kaiga-1&2 and later as a Project Engineer, at Kaiga units-3&4. He was posted to Kakrapar Atomic Power Project-3&4 as a Project Engineer in February 2010 and is responsible for construction of Main Plant civil Works.

Rajesh Kumar, B.E. (Mechanical Engineering), joined NPCIL at KAPP-3&4 as a Technical Officer in the year 2010 and was involved in mechanical works of construction of Main Plant Building. He was involved in fabrication in EP's, liner module, IC wall liner, D_2O distillation tower, Pre–Fabricated Ring Liner (PRL) from 7th lift onward in RB-3&4. He was involved in fabrication and erection of composite beam structure at El. 115m of RB-3 and RB-4. He was actively involved in fabrication, assembly and erection of KAPP-3 dome liner, which is first-of-its-kind in the world. Presently, he is mechanical in-charge in civil section of KAPP-3&4.

Planning, Integration & Operation of NPP in the Present Grid Regulatory Framework

Sandeep Sarwate, ACE (Transmission); K.P. Singh, Chief Engineer (E&T), NPCIL, HQ

1. Concept of grid

An electrical grid is an interconnected system of elements such as generators, transformers, reactors, transmission lines and the associated distribution network, which operate in synchronism. The Load Dispatch Centres keep a watch on grid operation and control grid frequency by regulating the generation as per load forecast, observing the critical lines loading pattern, critical nodes voltage pattern and ensuring system stability by inter-regional connectivity and load management. Geographically, India has been divided among the following regional grids:

i) Northern Region
ii) Western Region
iii) Southern Region
iv) Eastern Region
v) North-Eastern Region

2. Each region has its own Load Dispatch Centre known as Regional Load Dispatch Centre (RLDC). Also the States in a region have their own Load Dispatch Centres (SLDCs), which are subordinate to the concerned RLDC, which in turn reports to the National Load Dispatch Centre (NLDC). RLDC is the apex body to ensure stable and integrated operation of the power system for achieving maximum economy and efficiency in the operation of the concerned region. Every stakeholder of the system, i.e., generator, transmission licensee, sub-station and Discom etc. is obligated to ensure availability of real-time power system data in RLDC Control Room through a suitable telemetry system, preferably a fibre-optical network. It is binding upon all the constituents to comply with directives of RLDC in line with regulatory stipulations. A hierarchical set-up indicating "Grid Management" is shown in Fig. 1.

3. Power evacuation voltage

In order to design the main generator transformer, its circuit breakers and the switchyard bays, a decision about station power evacuation voltage is required. Earlier, the evacuation voltage for NPPs was 220 kV, which has gone up to 400 kV now. In future projects, the evacuation voltage may be 765 kV.

4. CEA Transmission Planning Criteria recommends the upper ceiling for transformation capacity connected to a single sub-station as stated below, i.e.,

For a 220 kV sub-station-500 MVA

For a 400 kV sub-station-2000 MVA

For a 765 kV sub-station-9000 MVA

5. Criteria for minimum number of evacuation lines from a nuclear power station

The evacuation voltage and the number of lines required for transmission of power from any station is arrived after conducting the Power System Studies in the time frame of station COD (Commercial Operation Dates). These studies are normally carried out by the CTU in consultation with Central Electricity Authority (CEA). As per the Transmission Planning Criteria, the number of lines required for NPP shall meet the N-1-1 criteria. This implies that system must have a redundancy of 2 nos. of lines. More than 2 line outage simultaneously would have impact on station generation.

6. Start-up power for NPPs

In the earlier schemes with evacuation voltage of 220 kV, the

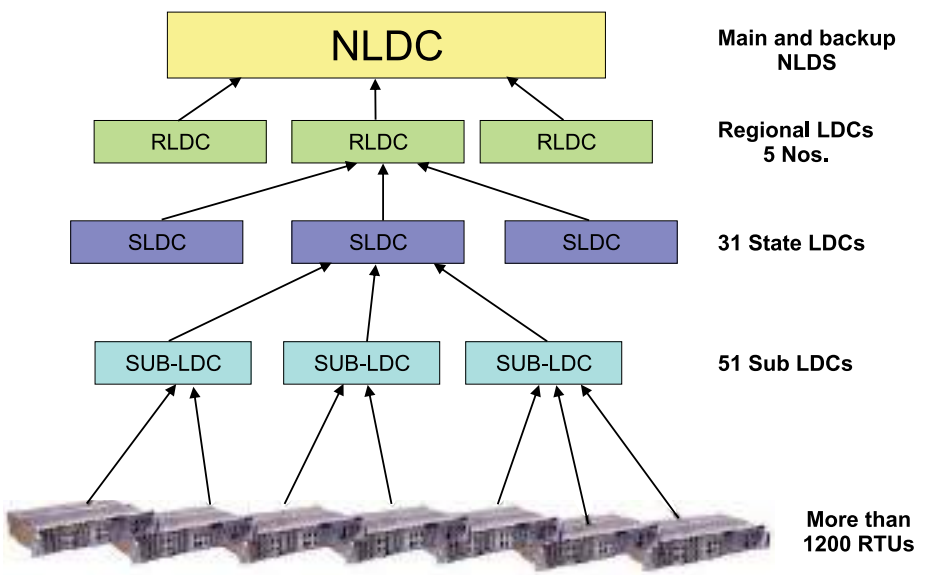


Figure 1: A hierarchical set-up indicating Grid Management

220-kV switchyard was utilised for both, i.e., for power evacuation and start-up. However, subsequent to the adoption of 400 kV as evacuation voltage, the start-up power continued to remain at 220-kV level, probably due to higher reliability and quick restoration to nuclear stations post grid collapse. The availability of 400-kV/6.6-kV ratio start-up transformers may also be the reason for retaining start-up power at 220 kV (Fig. 2).

7. Implementing Agency

7.1 Till the year 1990, the power evacuation network for NPPs was developed and implemented by the State Electricity Boards. For Tarapur Atomic Power Station units-1&2 (TAPS-1&2), the switchyard was operated and maintained by the Maharashtra State Electricity Board during the initial years of the plant operation.

7.2 However, from KAPS-1&2 onwards, the POWERGRID took over the mantle of implementing the power evacuation schemes associated with NPCIL.

7.3 Electricity Act 2003 allows the entry of private sector in Transmission sector. Accordingly, the work for construction and operation of transmission lines is now awarded through Tariff-Based Competitive Bidding (TBCB).

8. Approach towards planning of power evacuation scheme

CERC "Connectivity Regulation" lays down procedure for identification of power evacuation scheme. Accordingly, the generators are required to approach CTU with individual application for Connectivity and Long-Term Access (LTA) in the prescribed formats indicating proposed installed capacity, project schedule, fuel linkages, prospective beneficiaries, status of various statutory clearances such as land, water, environmental, etc. A brief about Connectivity and LTA is stated below:

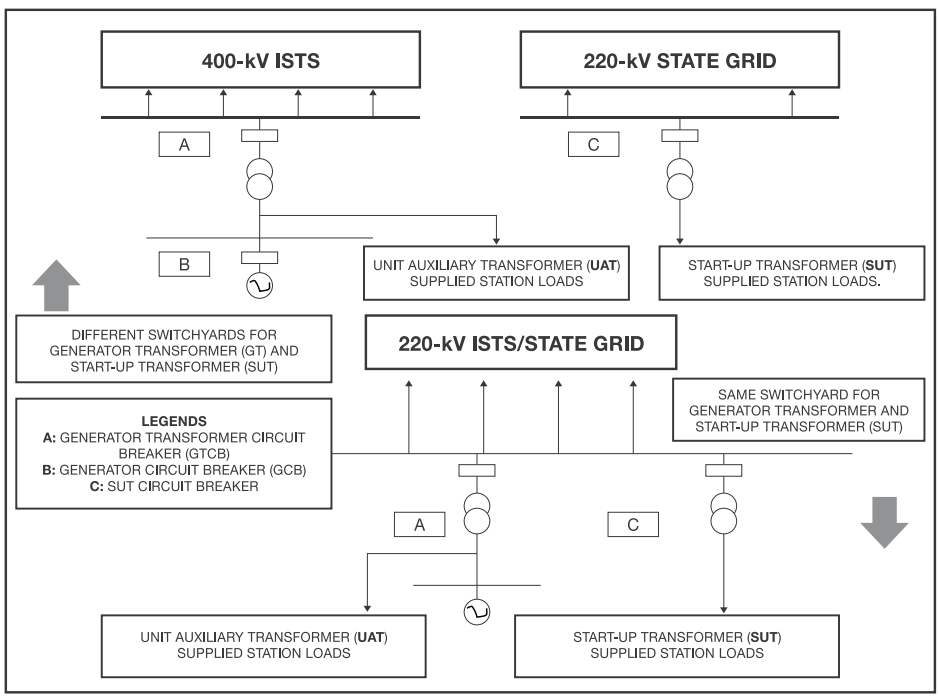


Figure 2: Energizing Station auxiliaries of Nuclear Power Plant via Start up Transformer

8.1 **Connectivity:** It implies the state of getting connected with ISTS. Under this, CTU may allow the upcoming generator to connect with a nearby sub-station. The grant of connectivity allows the generator to draw commissioning power including injection of infirm power. However mere connectivity does not fulfil the condition of adequacy of transmission system for transfer of power to target beneficiaries and grant of connectivity shall not entitle to interchange any power with grid unless it obtains Long Term Open Access.

8.2 **Long-Term Open Access (LTA/ LTOA)**

It indicates complete transmission scheme associated with the proposed generating capacity comprising of the following inputs i.e.

i) **Evacuation voltage (Switchyard voltage):** Input for design/ specifications of Generator Transformer.

ii) **Number of circuits along with Reactive compensation if any i.e. Bus reactor/Line reactor(s):** Input for Switchyard layout and number of bays.

iii) **Switchyard Short Circuit level:** Input for design/engineering of downstream Plant Auxiliary system.

8.3 Grant of LTA describes the complete power evacuation scheme associated with the project. While applying for LTA, the generator is required

to indicate the prospective beneficiaries to whom power is intended to be sold. If this information is not available, the target region for sale of power is to be indicated. Subsequently, CTU conducts the requisite system studies covering power evacuation voltage, number of lines, switchyard fault level, reactive compensation etc. These studies are further deliberated in the "Regional Standing Committee of Transmission Planning." Subsequently, final approval is given by the concerned Regional Power Committee (RPC), which is the apex body for Grid-related issues.

9. AERB SG-D-11 Requirements

The above said studies indicate the design parameters, i.e., evacuation voltage, fault level, number of bays, etc. to go ahead with system engineering and layout preparation. However, AERB SG D-11 mandates another set of studies to confirm that system stability is maintained in the prescribed contingencies to ensure availability of "off-site power".

The following transient studies are mandated

i) Loss of generating unit of NPP

ii) Loss of the largest generating unit of the grid

iii) Loss of the largest transmission line or inter-tie

iv) Loss of the largest load in the grid

v) Loss of a transmission line of NPP switchyard

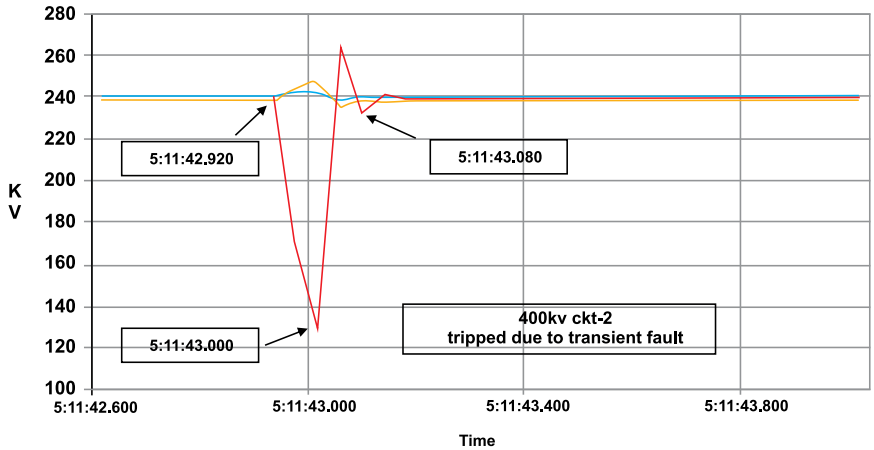


Figure 3: Successful auto reclosure plot by PMU (Voltage at bus connected to faulty line)

9.1 The studies also cover other scenarios such as N-1-1 contingency analysis, load throw off and subsequent voltage-rise studies and impact analysis of other transients as mandated by CEA Transmission Planning Criteria. These studies are procured from PGCIL under a separate contract by NPCIL.

10. Signing of Implementation Agreement (IA)

CERC Tariff Regulation mandates signing of an "Implementation Agreement" between the Generator and Transmission Licensee that identifies a SCOD (Scheduled Commercial Operation Date) acceptable to both the parties. The IA provides a mechanism under which the generator will compensate the transmission company by paying IDC/Transmission charges in case it is not available on the SCOD while the transmission system is available. Likewise, the transmission company agrees to arrange alternate scheme for evacuation from the generating station, in case its network is not available whereas the generator is ready. It may be stated that unless and until the IA is signed, the transmission company may not proceed with the tendering work for line construction.

11. Commissioning Power

As per the document "Approval of the procedure for drawl of Start-up Power" dated 12/8/2014 issued by Central Electricity Regulating Commission, the Commissioning power by the upcoming power plant may be drawn as per "Deviation Settlement Mechanism (DSM). Salient features of DSM are as follows:

i) The generator is allowed to draw commissioning power under DSM up to a maximum period of 21 months (15 months prior to expected date of synchronisation, and 6 months after synchronisation) from the date of commencement of drawl of start-up power from the grid. In case, start-up power is required beyond the specified period, the generator shall approach CERC for necessary permission.

ii) All the relevant switchyard equipment as per the connectivity granted, data and voice communication, GT/SUT tap positions (in line with RLDC directives) have to be commissioned as per the regulation.

iii) Generator should also pay the charges such as transmission charges, RLDC fees and charges as per the regulations.

12. Costing of Commissioning power

This can be split under "Carriage and Content Mechanism" as described below:

i) **Carriage Cost:** This refers to the charges towards the transmission network utilised for drawing commissioning power. This comprises Annual Fixed Charges of the network and will be dependent upon network topology.

ii) **Content Cost:** This refers to the charges of electricity utilised for commissioning activities. These are frequency linked, i.e., higher the frequency, the lower the rates, and vice versa.

13. Commissioning of Transmission lines/elements

It can be classified under following categories, i.e., a) Trial Operation b) Commercial Operation.

i) **Trial Operation:** As per CERC tariff regulation, trial operation in relation to a transmission system or an element thereof shall mean successful charging of the transmission system element thereof for 24 hours at continuous flow of power and communication signal from sending end to receiving end and with requisite metering system, telemetry and protection system in service, enclosing certificate from the concerned Regional Load Dispatch Centre.

ii) Date of Commercial operation in relation to a transmission system shall mean the date declared by the transmission licensee from 0000 hrs, of which an element of the transmission system is in regular service after successful trial operation for transmitting electricity and communication signal from sending end to receiving end.

iii) Rate of return of a new project shall be reduced by 1% for such period for a transmission line if found to be in commercial operation without prescribed protection, data telemetry or communication implements.

14. Operational Aspects: Nuclear power station vis-à-vis grid

Nuclear power plants (NPPs) are basically base-load plants and hence not designed to participate in frequency control due to limitations of fuel design. This aspect is very well recognised and documented in various "Governing Documents" pertaining to "System Operation" as stated below:

i) **Exemption from Free Governing Mode of Operation (FGMO):** Regulation 5.2 (f) of Indian Electricity Grid Code (IEGC) calls for implementation of FGMO for all thermal units of 200 MW and above and hydro units of 10 MW and above for a stable frequency regime. CERC Tariff Regulation (2014-19) stipulates that the rate of return of a new project shall be reduced by 1% for such periods as may be decided by the CERC, if a generating station is found to be under commercial operation without commissioning of FGMO. NPCIL units are exempted from participating in FGMO (Regulation 5.2 f (iii)).

ii) **Network Congestion:** The grid network is planned and implemented with finite capacity. However, due to network constraints, it is likely to face congestion, which may lead to overloading/ overstressing of the available network capacity. This, if not controlled in time, may have affect on grid stability. While the Transmission Planning Criteria allows a line to be loaded up to its thermal limits, in actual practice, as perceived by the system operator (the Regional Load Dispatcher), it has to be moderated considering the voltage profile and load angles

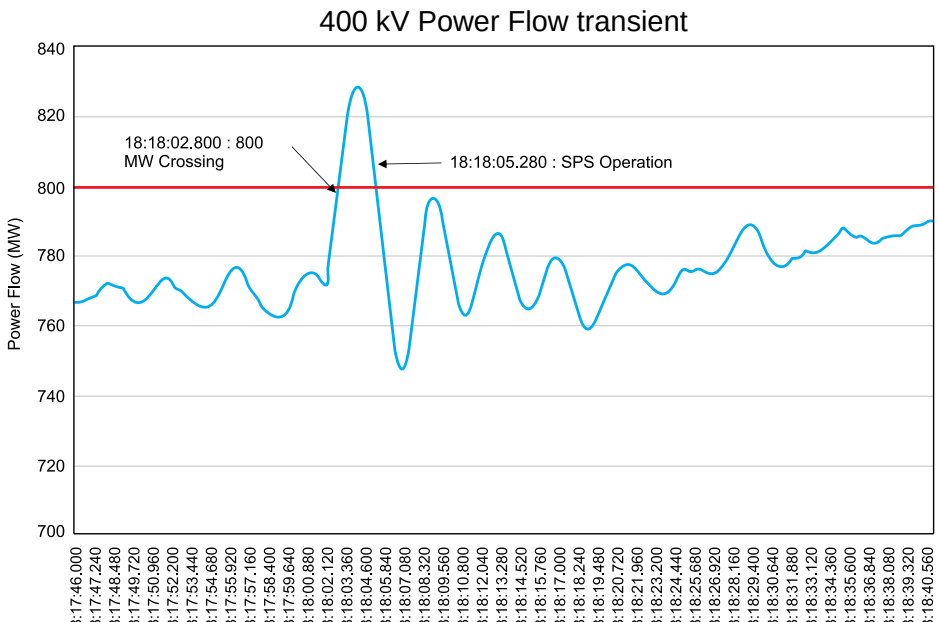


Figure 4: A sample PMU plot indicating operation of SPS

observed at that point of time. Under such situations, the Load Dispatcher may order regulation of generation/ loads requisitioned to the system, to restore the normal operating conditions. In such a situation, the transmission transactions already scheduled in the system may be curtailed as per following sequence in line with IEGC I.E.

a) Deviation from schedule (Unscheduled ones)

b) Short-Term Bilateral Transactions

c) Short-Term Collective Transactions

d) Medium-Term Transactions

e) Long-Term Transactions

iii) Generators having Long-Term Access (including NPCIL stations) have maximum right for utilising the evacuation corridors. Others, i.e., Medium Term, Short Term, Deviation from schedules, etc. are allowed only after ensuring that due capability is existing in the network and may be denied the access for power injection or drawls.

iv) **Restoration of Grid and off-site power:** Quick restoration of "Grid Supply" or "Off-Site Power" to Nuclear Power Station is a mandatory requirement to ensure reactor core cooling and maintaining it in a safe shutdown state. These requirements have been covered in IEGC and relevant stipulations are as follows:

a) Detailed plans and procedures for restoration of the regional grid under partial/total blackout shall be developed by RLDC in consultation with NLDC, all Users, STU, SLDC and RPC Secretariat and shall be reviewed/updated annually. Regulation 5.8 a) of IEGC.

b) List of generating stations with black start facility/ inter-state/inter-regional ties, synchronising points and essential loads to be restored on priority, shall be prepared and be available with NLDC, RLDC and SLDC. Regulation 5.8 of IEGC.

c) Providing start-up power to NPP units has been recognised as a priority in the document "Black Start Restoration Procedure" prepared by different RLDCs, in deference to IEGC stipulation.

d) Hydel and gas power plants with low start-up power requirement are identified for grid restoration and extend the required Start up power to nearby NPPs.

e) Availing of start-up power (Bottom-up Approach): This calls for identification of black start sources available in the grid, a list of which is available with the RLDC. Generating stations having self-starting facility (such as hydro) should be started first and small islands should be formed. These islands can be integrated later at pre-determined locations having synchronisation facilities. This approach is preferred in a system having a fair amount of generating stations with black start facilities such as hydro and gas turbines.

f) Availing of start-up power (Top Down Approach): On the contrary, in a system having limited amount of black start facilities, need may arise to import the "Start-up Power" from a nearby region. It may involve transaction over a long line and create problem regarding charging current and high voltages.

g) Some important principles while restoring the loads are as follows:

- Achieving load generation balance through minimum and essential loads such as NPPs, Traction
- Radial loads should be picked up first
- Balanced loads should be picked up first
- Bypassing the Under Frequency relays till adequate loads are restored

h) Managing Reactive Power: During system restoration, the load is expected to be low and this may lead to high charging current that may cause high system voltages, which may not be advisable. Operational feedback indicates following problems arising out of high voltages during

system restoration, i.e.:

- Failure of lightning arresters/CVTs
- Tripping of transformers due to over fluxing

i) The following points have to be kept in mind to control high voltages i.e.

- Charging of shorter lines first
- Switching off capacitor banks
- Taking bus reactors in service
- Converting line reactors into bus reactors
- Operating generators at minimum voltage level to facilitate MVAR intake
- Avoiding energising of high voltage lines/ cables
- A transmission line from a generating station should be charged from the other end and synchronised at generating end. If the line holds, it indicates that the line is healthy

15. Narrowing down of operational frequency bandwidth

Grid operation at a constant frequency not only improves the overall equipment and systems efficiency but also the grid stability. With the continuous intervention of CERC, which is the "Apex Grid Regulator", the normal operation frequency band has been narrowed down progressively as shown in the table given below.

S. N.	Frequency Range	Date
1.	49-50.5 Hz	Till March 31, 2009
2.	49.2-50.3 Hz	With effect from Aptil 1, 2009
3.	49.5-50.2 Hz	With effect from May 3, 2010
4.	49.7-50.2 Hz	With effect from September 17, 2012
5.	49.9-50.05 Hz	With effect from January 6, 2014 till date

This has played a key role in stabilising the grid and improvement in the performance of NPPs in India. Due to stable grid operation, NPCIL units have operated continuously for more than 300 days on 25 occasions.

16. Future Design/Engineering-related challenges in planning of grid connectivity

This can be described under following categories i.e.

a) **Adopting the same voltage for drawl of start-up power and evacuation:** As indicated above, presently, NPPs are being designed and implemented with twin switchyards, i.e., one each for power evacuation and for start-up power to feed station auxiliaries using Start-up Transformers. This involves additional financial implications not only for implementation of separate switchyards, buildings and panels but also the lifelong Operation and Maintenance (O&M) activities. It has been observed that some of 220-kV lines trip frequently for want of adequate maintenance, as they are owned by the transmission utility of the host state. This puts undue stress on O&M as well as on protective equipment. More so, procuring additional RoW for start-up power lines is becoming increasingly difficult. Drawl of commissioning power at 220 kV is also costly as compared with drawls at 400 kV through DSM. If Start-up Power Transformers can be designed with 400/6.6 kV voltage ratio, this will do away with the need for 220-kV switchyard and associated 2 nos. of 220-kV lines. There is a need to establish that restoration time of offsite power to NPPs through the 400-kV lines after grid collapse will be within the acceptable time frame, considering the advanced and additional core cooling systems provided for the new NPPs.

b) **Improvising transient stability of the system:** All-time availability of transmission lines is desirable to ensure smooth power evacuation and operation of the units. Tripping of more than one line simultaneously or one after the other poses a challange for normal plant operation. Most of the line faults are transient in nature and occur between single phase to ground. Enabling Single Phase Auto Reclosure (AR) in transmission lines improves the line availability to a great extent and may save the units from tripping, specially during rainy season when there is large vegetation growth near transmission corridor. Single Phase Auto Reclosure is designed to trip only the faulty phase, while other two healthy phases remain in service. Dead time of 1 second is normally provided for transient fault clearance and Reclosure of the tripped single phase of the line. However, if the fault is permanent in nature, the other two phases will also

trip along with the tripping of faulty phase after auto reclose. Commissioning of Single Phase Auto Reclose scheme on transmission lines is a regulatory requirement.

The AR scheme has been implemented / being implemented in NPCIL stations in NPCIL stations and it is operating successfully. However, frequent tripping of lines may call for frequent operations of scheme, which may put the equipment under undue stress. Thus maintenance of transmission lines should be heightened. A plot captured from PMU indicating successful Auto Reclosure on 400-kV line is given in Fig. 3. Here it can be seen that subsequent to a fault on Red phase, voltage of this phase goes down, whereas for Blue and Yellow phases, voltage remains stable. Fault on R phase clears after 80 ms and accordingly voltage picks up and stabilises, thus restoring the line to its pre-transient condition.

c) **System Protection Schemes (SPS):** Grid connectivity of nuclear power units, though planned and implemented with prescribed redundancies, may suffer from evacuation constraints under certain situations. Under such scenario, the available power evacuation capacity from an NPP may not be adequate to support the generation, which may affect the stability at the NPP end. The IEGC stipulates System Protection Scheme (SPS) to reduce the generation at a rapid rate to ensure system stability. Though NPPs are generally exempted from such actions.

A sample PMU plot indicating operation of SPS is given as Fig. 4. It can be seen that on 400-kV line, power flow has to be controlled below 800 MW (red line), which was set as an upper limit for this line. The loading of this line is controlled by:

a) Automatic backing down of generation at different generating stations

b) Automatic load shedding in relevant region

17. Summary

Over the past one decade, grid regulation and operation has assumed lot of importance and significance due to its impact on public life and safety. The generation has come out of the licensing regime and is adding to the grid at faster pace than expected. The regulations are becoming more stringent and grid management is becoming more complex. Knowledge about the prevalent regulations and new design approaches will go a long way to economise the project cost and plant reliable operation.

Reference

1) The Electricity Act 2003

2) The Indian Electricity Grid Code (IEGC): do

3) CERC Tariff Regulation (2014-19)

4) CERC (Deviation Settlement Mechanism and Related Matters) Regulation

5) Glossary of Terms related to Transmission and Grid Activities

   (Web page of Transmission Group)

6) Procedure to identify and implement power evacuation schemes associated with NPPs

   (Web Page of Transmission Group)

Sandeep Sarwate, an Electrical Engineer, joined NPCIL in 1988. Currently he is working as ACE (Transmission) in Operation Directorate. His scope of activities involves finalisation and timely implementation of power evacuation schemes and review of electrical transients associated with nuclear power plants. He has represented NPCIL in 'Regulatory Hearings' conducted by Central Electricity Regulating Commission (CERC), the apex grid regulator.

KP Singh, Chief Engineer (E&T), is heading the Electrical and Transmission group in Operations Directorate at headquarters. After completing B.Tech. in Electrical Engineering, he joined the 25th Batch of BARC Training School in the year 1981. He worked at TAPS-1&2 in operations, maintenance and technical services sections for about 24 years prior to joining the Operations Directorate at headquarters in the year 2006. He has a long experience in O&M practices followed on electrical equipment, up-gradations, condition monitoring and repairs. He is the Member Secretary of Standing Task Force for Electrical Systems (STFES) at headquarters since February 2008. He is also member of Technical Coordination Committees (TCC) of Regional Power Committees.

Online Dry-Out System for Power Transformer

P. Mohan, SME (E); T.P. Rangababu, SO/G (EM); I. Seshu Babu, SO/E (EM), MAPS

Insulation plays a key role in determining transformer's lifecycle. In addition to high temperatures and oxidation processes, moisture is the primary health concern for the cellulose-based insulation system. Laboratory ageing experiments with paper in oil indicate that degradation rate is nearly proportional to the water content, at least within the range of water content that it is realistic to encounter in transformer windings. Maintaining low water content in cellulose and oil substantially prolongs transformer's life expectancy.

Many studies have been carried out on the equilibrium between water in paper and water in oil. The most important conclusion is that at all realistic temperatures, the bulk of the water will reside in the solid insulation and the moisture content in the oil is indicative of the moisture content in the solid insulation at a given temperature at equilibrium as shown in Fig. 1. This has several important implications. Most importantly, it means that drying a transformer by drying the oil alone will be a very inefficient and time-consuming process.

Transformer 2-52210-UT-2, 16.5kV/ 7kV, 15/25 MVA, was in service from 1985 at Madras Atomic Power Station (MAPS). The moisture content in oil was 30 parts per million (ppm). However, it was well below the limit. After conventional filtration, oil moisture would be 7-8 ppm, and within a span of three months (oil sampling frequency) the oil moisture content reached 30 ppm. This observation prompted that cellulose moisture was diffusing to oil to maintain equilibrium. To estimate the level of moisture content in cellulose, DIRANA (FDS) test was conducted on UT-2 in 2013, which indicated a wet transformer 4.9% of weight of cellulose. As part of ageing management, vacuum drying was planned to remove the excessive moisture, but due to site constraints, heating cycles could not be performed. Only cold cycles were performed. Moisture removal with cold cycles was little effective, since unit is synchronised and taking UT-2 offline was not possible.

Over the years, the water content increased due to hygroscopic binding of air moisture as well as cellulose and oil degradation due to oxidation. The air cell type conservator was replaced in 2013 to prevent the access of air moisture. However, these processes cannot be entirely prevented. Conventional methods with short-term use of conventional oil purification systems do not reduce moisture to the necessary extent.

Let us consider a simplified case to illustrate the difficulties of drying a large transformer by continuous drying of the oil by degassing. Let us assume we have a large transformer, with 10,000 kg of cellulose and that we want to reduce the water content in the solid insulation from 3% down to 1%. This means that we want to remove 200 kg of water. Let us further assume that we have a constant average temperature of

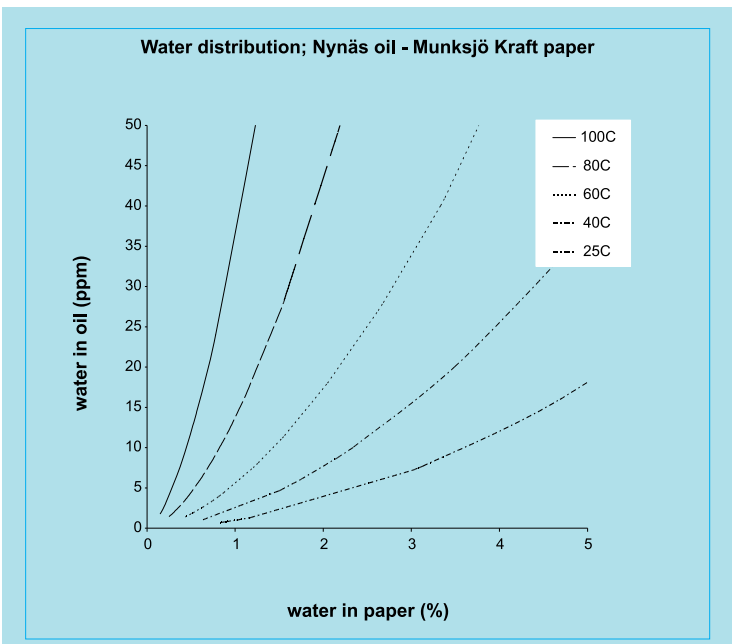


Figure-1: Water in oil vs. water in paper equilibrium curves from ASEA 1972 study

40°C. We would then have water content in the oil of 15 ppm. If we reach the desired end-point, we would, at equilibrium, find approximately 2 ppm in the oil. If we have during the whole treatment average water content of 7 ppm (very optimistic, considering the slow transport of water from thick structures) and treat 3,000 kg of oil per hour with a degasser removing all the water from the oil (also very optimistic), then we would remove 0.021 kg per hour, or 0.5 kg per day. It would then take 400 days of round-the-clock drying of oil to achieve the set goal, even with the very optimistic assumptions made in this example. In reality, the time would surely take much longer. It is more likely to take few years, with a vacuum degasser tied up full-time, and during that period there would be no possibility to do DGA with any accurate interpretation.

In online drying method, transformer oil is continuously passed through cartridges during operation. The sieve material contained in the cartridges adsorbs the moisture. The dried oil is then fed back into the transformer. Now the state of equilibrium has shifted, deposited. Water molecules diffuse from the cellulose insulation into the insulating oil, and the moisture content throughout the transformer drops. The drying process takes place in two phases. During the first phase, the water content of the oil is quickly reduced (2-3 days). This substantially improves the breakdown voltage. The second phase is determined by how much moisture is further diffused out of the solid insulation after being precipitated from the oil. The flow of moisture decreases steadily along with the relative humidity

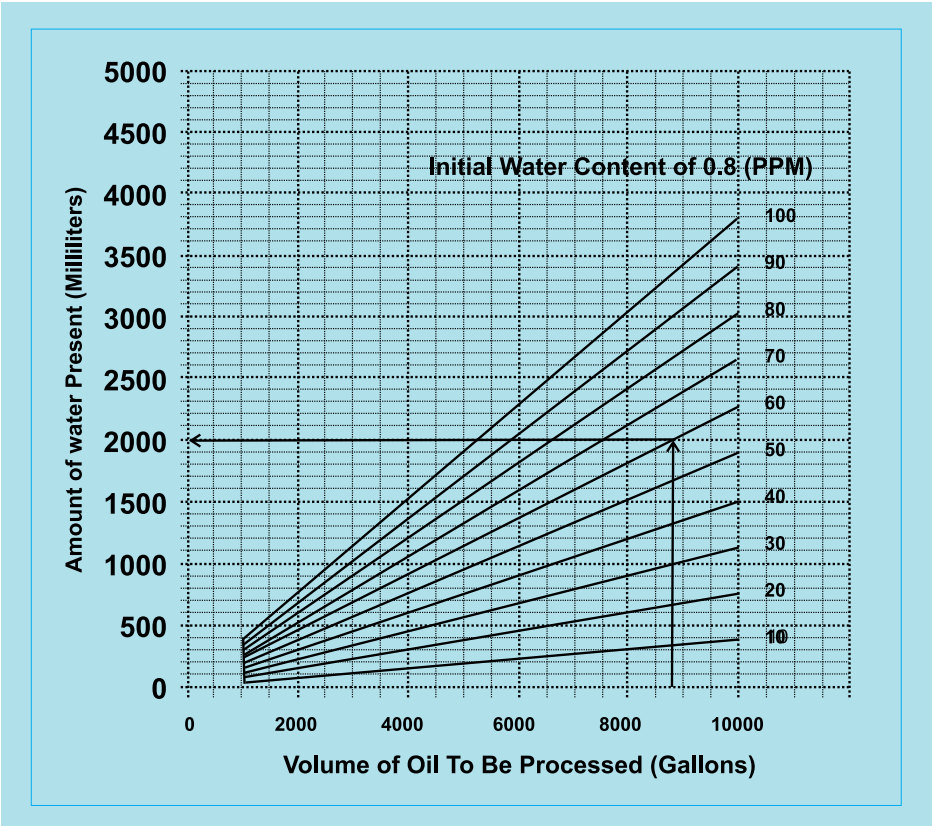


Figure-2: Estimation of water content for the given volume of oil & moisture content

concentration. After removal of the drying system, the transformer settles at a new equilibrium value.

M/s PTss-Velcon make online transformer dry-out system and model TDS5FV4X was procured for drying out UT-2 while in service. This dry-out system is designed to allow a transformer under load to dry itself out. A quantity of 4 numbers of Velcon SD-1107 superdri dissolved water removal filters are installed in the filter vessel. Through this filter vessel oil is processed at the rate of 1200 litres per hour maximum. The filtering system removes the dissolved water from oil to less than 10 ppm and includes particle removal capabilities with 0.5-micron filtration. The process does not affect dissolved gases in oil and does not remove oil oxidation inhibitors.

The online dry-out process is designed for safe, unattended 24-hour operation. The system is connected to UT-2 by using the transformer connection valve as supplied to the system, and oil is returned by the system to a top-fill connection valve. The number of cartridge change-outs required to dry out the transformer installation to an acceptable level (<1%) will vary according to the rate at which the transformer insulation sheds its moisture.

SD-1107 Superdri Cartridges can adsorb 620 ml of water at 5 GPM flow rate (refer to Fig. 3). The number of cartridges required can be estimated by knowing the water content to be removed from oil (refer to Fig. 2). Unlike ordinary filters, Superdri Cartridges cannot be monitored for capacity or performance by differential

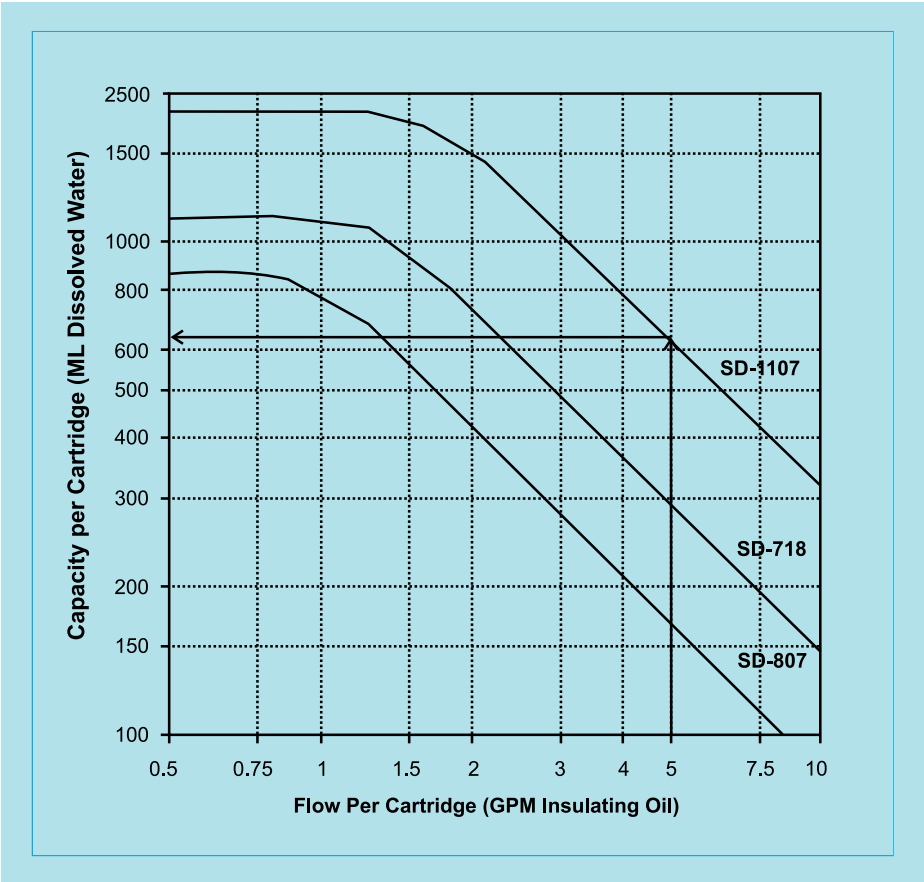


Figure-3: Determination of amount of water a single cartridge will remove at a set flow

pressure. Regular effluent samples are analysed by inline moisture sensors such as Doble DOMINO for moisture content to know the performance of cartridges. If the inlet and outlet moisture content becomes same or out of range, the system indicates that the cartridges are exhausted. However, confirming a manual sampling and analysing for moisture content before exercising the cartridge replacement is desirable.

P. Mohan, Senior Maintenance Engineer (Electrical), joined MAPS in the year 1982. He was involved in the initial commissioning of unit-2 PHT system, moderator system, RB ventilation and auxiliary cooling system electrical equipment and GT-2. During the EMCCR of MAPS-1&2, he was associated with the upgrading of the electrical system. In 2013, he was involved in the replacement of GT-2 with a new transformer and its commissioned with online DGA and online bushing monitoring system.

Panduranga Babu T., SO/G, joined MAPS in the year 1982 in Electrical Maintenance section. He has been involved in internal inspection/servicing and maintenance of power transformers GT-2, UT-2 & SUT-2, commissioning of 260 MVA GT-2, introduction of on-line monitoring facilities for GTs with online DGA & HV bushing monitor, rewinding and upgrading of station auxiliary transformers and replacement of 230kV ABCBs with SF6 CBs in indoor switchyard.

Seshu Babu I., SO/E, is an Electrical & Electronics Engineering graduate. He joined MAPS NTC in 2005. He was involved in the commissioning of TAPS-3 electrical systems, commissioning of 260 MVA GT, introduction of online monitoring facilities for GTs with online DGA & HV bushing monitor, RLA testing of main generator, rewinding and upgrading of station auxiliary transformers. He has received 'Young Scientist Award' in the year 2011.

Ice Plugging on 250 NB Size Pipeline in Moderator System at KAPS

L.K. Jain, the then Site Director, KAPS; V.K. Jain, Station Director; Y.B. Bhatt, Operation Superintendent;
A.K. Bhole, TSS; P.K. Patel, Scientific Officer/D, KAPS-1&2

Kakrapar Atomic Power Station (KAPS) has achieved one more milestone of ice plugging on 250 NB (10 inch) size pipeline in moderator system for replacement of moderator pump-2 discharge valve 3211-MV-7.

Introduction

The ice plug isolation technique is very useful when system boundary is not isolable and draining is not feasible or possible. In this technique, a section of pipe is frozen from outside with liquid nitrogen with ice is formed inside the pipe with system fluid itself to provide process isolation. The basic requirements of this technique are to have the pipe full of water and there should not be any flow through the pipe.

Initially this technique was used all over the world for smaller pipe sizes (up to 100 mm diameter). At Nuclear Power Corporation of India Limited (NPCIL) also, this technique is being used for a long time. After various technical developments, research, innovation and experience, now this technique is used for higher pipe sizes also. Traditionally, a metallic icebox is used to create cavity for pouring liquid nitrogen around the pipe. The fabrication, installation, space constraints and leakage of liquid nitrogen, etc. are the main limitations with metallic icebox.

The technical ideas were sought from the vendors and company situated at abroad using this technique. Subsequently, KAPS successfully adopted the method of formation of ice plug by wrapping the copper tube on pipeline as coil and supplying liquid nitrogen through copper tubes. The wrapping of copper coil on pipe eliminates all the limitations of metallic icebox. This technique was adopted for the first time at KAPS in the year 2005. From 2005 onwards, all ice plugs at KAPS were formed with copper coil wrapped on pipe surface.

Summary

During the draining of Moderator Hairpin Heat Exchanger-2 (HX-2) for carrying out in-service inspection (ISI) by eddy current testing (ECT), 3211-MV-7 was observed to be passing and could not be rectified from outside. Further upstream valve was also observed slightly passing.

For attending the passing of 3211 MV-7, it was noted that this activity could cause internal exposure as passing water would find its path directly to MV-7 upstream elbow portion due to field orientation of suction pipe from top of the pump. Moderator system tritium activity was 1189 MBq/ml (32 Ci/litre).

After reviewing the construction drawings and field survey, ice-plug at the 3211-MV-7 upstream line on horizontal portion was planned. First an ice plug was formed on test set-up having identical pipe size, material and layout exactly matching the field. The result of the mock test ice plug were reviewed, a detailed plan was prepared and an ice plug was formed at upstream of 3211-MV-7. Moderator HX-2 was drained and 3211-MV-7 replaced with tested spare valve. Moderator

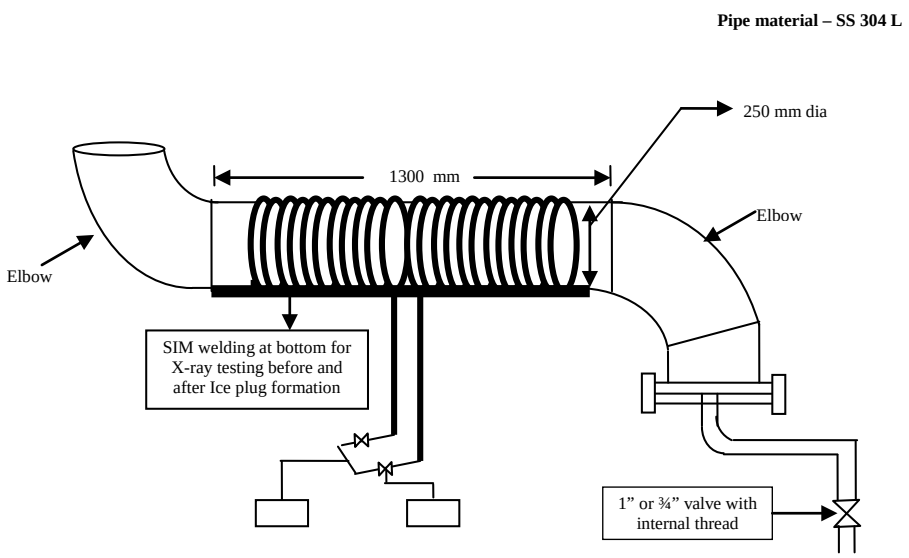


Figure 1: Detailed sketch of test piece

HX-2 was flushed with virgin heavy water (D_2O, approximately 3 tonnes). Subsequently, moderator HX-2 drying and ECT activity were completed. MV-7 inspection was carried out and it was observed that seal disc was not seating properly on sealing ring.

Mock-Up Setup

Moderator system pipe at upstream of 3211-MV-7 is 250 NB, SS 304L, Schedule 10S (4.19 mm thickness), with longitude seam welding at 6 o'clock position. As per pipe layout, upstream of MV-7 is 250 NB elbow and 1300 mm horizontal length of pipe.

The 250 NB diameter spool piece test setup was fabricated in workshop as per fabrication details worked out in the procedure. Radiography of seam weld was carried out prior to starting the ice plug as a baseline data. The radiography report was found normal and no defect was observed. Ice plug formation on test set-up was carried out at TB-2 unloading bay at EL.100 m in open atmosphere with normal ambient temperature. Two nos. of 10-mm-size, 10-feet insulated copper tubes were used to feed the liquid nitrogen from container to wrapped coil. A 10-mm-diameter copper tube was wrapped on 250 NB diameter pipe in coil form. The length of copper tube coil mounted on pipe was 30 inch (L=3D, 15-inch length on either side from the centre of the test piece, totalling 32 inch length). Total turn of copper tube mounted on pipe was 75 turns. Two liquid nitrogen containers, each having 500-litre capacity, were connected to the copper tube at the centre of test setup coil length.

Demonstration of Ice Plug Formation

Ice plug test mock-up was carried out for performance checking of ice plug formation. The liquid nitrogen supply was fed from centre and it was flowing in both directions of the centre point. The pipe surface temperatures were monitored at four different places at the bottom of the centre of wrapped coil, top position at both the ends of coil and downstream bottom elbow near flange (replicating MV-7 location). These four temperature readings were monitored on continues basis throughout the job and recorded at 15-minute intervals on data sheet. Insulation blanket was installed in full length of copper coil to avoid heat transfer from coil to atmosphere. The test set-up was filled with water.

Figure 2: Before pouring liquid nitrogen in test piece

Figure 3: After pouring of liquid nitrogen in test piece

Figure 4: After formation of ice plug in test piece

Figure 5: Ice-plug pressure hold test in test piece

Figure 6: Image of temporary Blank

The pouring of liquid nitrogen in the copper tubes was started. Pipe surface and water temperature was 30°C prior to starting the liquid nitrogen flow. Water level was checked inside the open end of top elbow pipe to monitor the expansion in volume of water. It was observed that ice formation on pipe internal surface was started after one hour of liquid nitrogen pouring. Formation of ice inside the pipe was assessed by means of drop in temperature on test set-up and by inserting rod from the top open end of top elbow.

After seven hours, the centre of ice plug closed. Flow of liquid nitrogen was maintained for further two hours to increase the length of ice plug at the centre to around two feet. At this moment, the temperatures at centre bottom / bottom elbow end side / top elbow end side / near bottom elbow flange were -41/-29/-16/13°C.

The drain valve at bottom flange was open and around 50-100 ml water came, but due to paucity of venting, further water did not come. This confirmed the successful formation of ice plug. In case of actual ice plugging at the upstream of MV-7, hold-up water at the downstream of ice plug would be easily getting drained through moderator HX-2 drain path.

The ice plug was pressure-tested by air from the bottom elbow drain point.

Air pressuring arrangement, i.e. PRV, pressure gauge and isolating valve, was made at the drain point bottom elbow. Air pressure was applied to the ice plug to check its strength. In the first step, 5.0 kg/cm^2 air pressure was applied for 30 minutes. In the second step, pressure was further raised up to 7.0 kg/cm^2 and held for 15 minutes. There was no pressure drop at bottom elbow, as well as no bubbling at the open end of top elbow was observed.

After completion of pressure test, liquid nitrogen flow was stopped and air pressure was removed from bottom elbow. During natural thawing of the ice plug, it was observed for three hours that the water column of top elbow was holding and no water was seeping to bottom elbow. After complete thawing of the ice plug, the complete setup was dismantled. Radiography of seam welding was repeated and found normal.

Mock demonstration of ice plug on test setup concluded that the ice plug formed after 8 hours of liquid nitrogen pouring. The length of plug was 24 inch at the centre zone. A total of 550 litres of liquid nitrogen was consumed during the exercise. The ice plug was pressure tested successfully at 5 and 7 kg/cm^2 for 30 and 15 minutes, respectively. During natural thawing, the ice plug was found holding water column of the top end elbow for at least three hours. There is no difference in the radiographs of pipe seam weld joint before and after ice plug formation.

Review of Ice Plug at Weld Joint

So far KAPS has carried out ice plugging successfully up to 200 NB size CS pipes. But the present requirement was to form the ice plug on 250 NB size SS 304L, Schedule 10S, with longitude seam welding at 6 O'clock position. Normally, ice plug is always formed away from weld joint. The details were discussed with the designer at HQ and Materials Science Division expert of BARC. The BARC expert shared their report 'Low temperature thermal aging of austenitic stainless steel welds: Kinetics and effects on mechanical properties'. It is observed in the report that low temperature aging has very little effect on tensile properties of both SS 304L and 316L welds, as compared to changes in toughness and hardness of ferrite phase. The expert opined that as the moderator system operates at temperatures lower than 80°C, there would be no degradation of ferrite in the weld due to long-term operation of the reactor.

The ice plug report of test setup was sent to the designer and their review comments were obtained. Based on a comprehensive review between the station and HQ, it was finalised to carry out repair work of MV-7 with formation of ice plug at moderator pump-2 discharge line.

Preparation for Ice Plug Activity in the Field

In order to take up the activities of formation of ice plug and

replacement of moderator MV-7, a detailed plan and procedure were prepared. A contingency plan was prepared for handling any abnormal situation and collection of D_2O.

Three different teams for ice plug formation and moderator HX-2 draining, mechanical maintenance team for MV-7 removal and replacement job as well as handling of any abnormal condition as per contingency plan were formed. All the action plans and procedures were discussed and deliberated in daily management meetings.

Two 30-m-long, 10-mm-diameter copper tubes were wrapped around 250 NB diameter pipe in coil form at moderator pump-2 discharge pipe. The length of copper tube coil mounted on pipe was 30 inch (L=3D, 15 inch length on either side from the centre of ice plug). The total turn of copper tube mounted on the pipe was 75 turns. Two self-pressurised liquid nitrogen containers, each having 500-litre capacity, were connected to the copper tubes at centre by a thermal insulated copper tube for pouring liquid nitrogen into the coil from EL. 100 m RB.

In order to create space for ice plug formation and working on 3211-MV-7, moderator pump-2 discharge line vertical support was removed temporarily. One temporary additional support was provided from the top platform to support discharge pipe at elbow location. Backup air supply accumulator to 3211-MV-7 was disconnected and removed from the field to create free space. The 3211-MV-7 actuator was removed so that valve could be removed easily from its position. An arrangement was made for jacking of top and bottom flange of 3211-MV-7 for easy removal and installation of new MV. All the nuts of 12 studs used for holding 3211-MV-7 between two flanges were opened half-turn and closed back (one by one) to ensure easy opening during actual replacement job. MV-7 radiography was carried out and it was ensured that disc was in the closed position for removal of MV-7 after ice plug activity.

One spare valve was prepared and tested in VTF for its healthiness. One special blank with draining arrangement from the top side was prepared for emergency use. This blank was ready with proper gasket fixed on both sides.

For monitoring of pipe surface temperatures, 5 thermocouples were mounted at the top and bottom of coil centre, the top side of both ends of ice plug and at the upstream elbow of MV-7. These five temperature reading points were hooked up to a display unit and a paperless recorder (PLR) for continuous monitoring. Additionally, a hand-held temperature-monitoring gauge was also available. A camera was also installed in moderator room near the ice plug arrangement for live display in main control room.

The liquid nitrogen was arranged in a large-capacity (7000 litres) cryogenic container. This container was parked at RB-1 MAL shutter and was ready for filling four self-pressurised 500-litre-capacity liquid nitrogen containers. Two containers always remained connected with inlet tube and two as standby for refilling and changeover process. The refilling of liquid nitrogen from big tanker to 500 containers was carried out at RB-1 MAL shutter.

All pre-requisites as per detailed ice plug plan and contingency plan were

Figure 7: Actual field setup in moderator room

Figure 8: Moderator pump-2 suction side layout

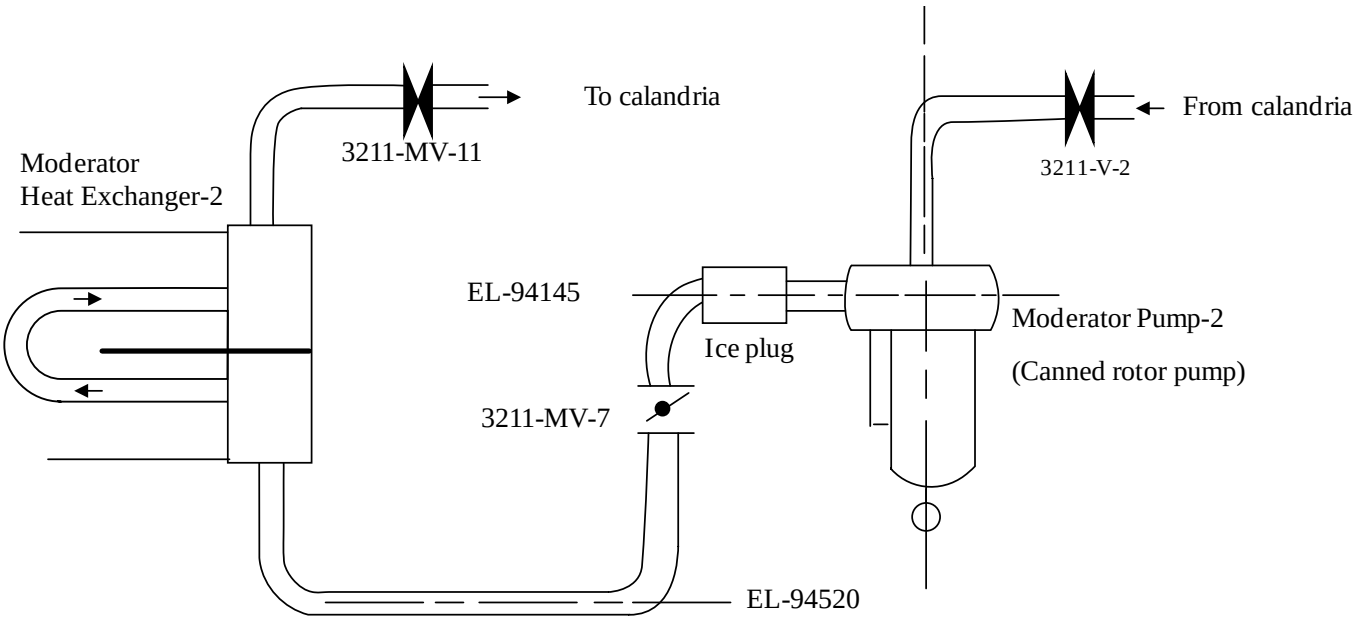


Figure 9: Flow circuit schematic diagram for moderator circulation

ensured. A station ALARA meeting was conducted and pre-job briefing was given to all the team members.

Ice Plugging in Moderator Room

3211-MV-7 was kept in close condition as per pre-requisites of ice plug formation. Moderator room ventilation was kept in purge mode. Vapour recovery dryer-3 was operated in moderator mode.

Liquid nitrogen pouring to ice plug arrangement was started. Readings from thermocouples, levels in liquid nitrogen containers and pressure in containers were monitored and recorded at 15-minute intervals. Atmospheric oxygen level was monitored in moderator room.

It was observed that ice formation on pipe internal surface was started after one hour of liquid nitrogen pouring. Formation of ice inside the pipe was assessed by means of drop in temperature at the centre and also at pipe ends. After 12 and 16 hours, temperature at the centre of ice plug was -60 to -80°C, respectively and at both ends, the temperatures were in the range of -15 to -22°C. An attempt was made to see the formation of ice plug. As soon as moderator HX-2 drain valve opened, the calandria bias level started falling. The pipe surface temperature of ice plug end toward 3211-MV-7 started increasing and reached in positive side. It indicated that complete ice plug was not formed at the centre zone of the ice plug.

All the activities were reviewed to identify the reasons. It was noted that the ice plug location was between moderator pump-2 discharges pipe and 3211- MV-7. The ice plug was positioned at higher elevation with respect to 3211-MV-7 downstream pipe, elbow and common discharge header of all three pumps as inlet to moderator HX-2. The cold water of ice plug region was circulating to the bottom discharge header due to density difference and it was delaying/not allowing the ice plug to form completely. This phenomenon did not occur in the test setup, as it was blank (simulated) at MV-7 flange.

After ensuring liquid nitrogen flow, frosting at the end of plug and monitoring of plug temperature, a further attempt was made. Temperature at centre of ice plug was -100°C and at both ends, the temperature was in the range of -20 to -22°C. This time, the calandria bias level remained steady. The frost formed on pipe surface toward 3211-MV-7 remained intact and did not melt. This was the moment to confirm that ice plug was formed, the plug was closed at centre and that further activities could be continued.

Subsequently, moderator HX-2 was drained as per plan. 3211-MV-7 was opened to remove the hold-up D_2O of upstream of valve. D_2O recovery team members were kept poised in VP suit. With all due precautions and protection in place, the 3211-MV-7 studs were removed one by one as per procedure. A slight gap was created between the valve and top flange using jacking arrangement. There was no water from the opening, except a few drops on MV-7 seat and flange. Valve was removed from its position. A spare tested valve with actuator was installed. A close monitoring of liquid nitrogen flow was ensured

during opening and replacement of MV-7. The close monitoring was being done from the main control room through CCTV arrangement.

Subsequent to the replacement of 3211-MV-7, liquid nitrogen supply was stopped and the ice plug was allowed for natural thawing. A total of 4000 litres of liquid nitrogen was consumed in formation and maintaining the ice plug. This entire activity was completed in 26 hours.

There is a dedicated team in KAPS O&M adopting this technique of isolation by ice plugging. The team members have vast experience in formation of ice plug on various sizes. Earlier also, the same team successfully formed ice plug in 200 NB pipe at TAPS-1&2, having line pressure of 4 kg/cm^2 in 2012.

Conclusion

The successful formation of ice plug on 250 NB line it is a historic milestone for KAPS-1&2 and for NPCIL. This methodology has helped in the reduction of shutdown period as well as of internal uptake from tritium.

It is a beginning for future isolation practices. It has demonstrated that critical isolation activities on higher-size pipelines on important systems like PHT system and moderator system can also be performed successfully.

L.K. Jain, B. Tech (Mechanical), joined 22nd batch of BARC Training School in the year 1978 and after completion of training, he joined Rajasthan Atomic Power Station and worked in various positions of Mechanical Maintenance Head, Maintenance Superintendent, Technical Services Superintendent. Subsequently, he was posted as Chief Superintendent at Narora Atomic Power Station in the year 2007. Recognising his outstanding contribution in field of innovative maintenance, the Department conferred him 'Unit Level Recognition Award' in the year 2000. Indian Nuclear Society also conferred INS Medal in the year 2001. He joined as a Site Director, Kakrapar Gujarat Site in November 2011. He is currently working as Executive Director (QA) at NPCIL, HQ.

Vijay Kumar Jain, BE (Mechanical), joined 25th batch of BARC Training School in the year 1981 and after completion of training, he joined Rajasthan Atomic Power Station and worked in various position in Operation Group and promoted as Operation Superintendent and Technical Services Superintendent. Subsequently, he was promoted as Chief Superintendent, RAPS-3&4 in the year 2010. Recognising his outstanding contribution in field of Operation and Resource Optimisation, Department conferred him 'NPCIL Excellence Award' in the year 2008. Presently, he is holding the post of Station Director, KAPS-1&2 since May 2013.

Y.B. Bhatt, BE (Mechanical), joined 31st batch of BARC Training School in the year 1987 and after completion of training, he was transferred to MAPS. He has worked as Reactor and Turbine Engineer in MAPS. He joined Kakrapar Atomic Power Station in year 1991 and worked in various positions in Operation Group like Control Engineer, Asst. Shift Charge Engineer and Shift Charge Engineer. He has also worked as Head of Waste Management Plant and EMCCR. Subsequently, he was promoted as Operation Superintendent, KAPS-1&2 in the year 2014. Presently, he is holding the post of Operation Superintendent, KAPS-1&2 since January 2014.

Ajay Kumar Bhole, BE (Mechanical), joined the 32nd batch of BARC Training School in 1988. After completion of the induction training, he joined KAPP. He has held various positions of Control Engineer, ASCE, SCE and STE (C) and STE (N). His work domains include RCA and development of corrective action, OE coordination and dissemination, FAC, SAMG action plan and training, and liaison on regulatory aspect. He is recipient of NPCIL High Performance Annual Awards under the category of 'Special Contribution Award' in the year 2009. Presently, he is TSS, KAPS-1&2.

Paresh Kumar Patel, DME (Mechaical), joined KAPS in the year 1989 in QA section in construction division. He carried out inspection of calandria tube and coolant tube rolling activity of Unit-1. He has performed welding inspection, hydro testing of various circuits and hot conditioning of KAPS. After completion of KAPS-1&2 construction phase, he joined commissioning group in planning and worked for 2 years. After completion of commissioning activity he joined operation section in 1996. From 1996 he is in operation section. His current assignment is procurement of all operation consumables, general arrangements and as document cell in-charge. Presently, he is holding the post of Scientific Officer/D, KAPS-1&2 since February 2008.

India's first twin unit 540 MWe nuclear plant at Tarapur is at an advanced stage of completion. **Manjit Singh** et al present the development and design details of some of the most crucial system.

Design and Development of Drive Mechanisms for Adjuster Rods, Control Rods & Shut-off Rods of TAPP-3&4

Manjit Singh, Head, Division of Remote Handling and Robotic (DRHR), BARC

Introduction:

Division of Remote Handling and Robotics (DRHR), Bhabha Atomic Reseach Centre (BARC) and Nuclear Power Corporation of India Ltd. (NPCIL) had entered into Memorandum of Understanding (MoU) for design and development of drive mechanisms for adjuster rods, control rods and shutoff rods of Tarapur Atomic Power Projects-3&4.

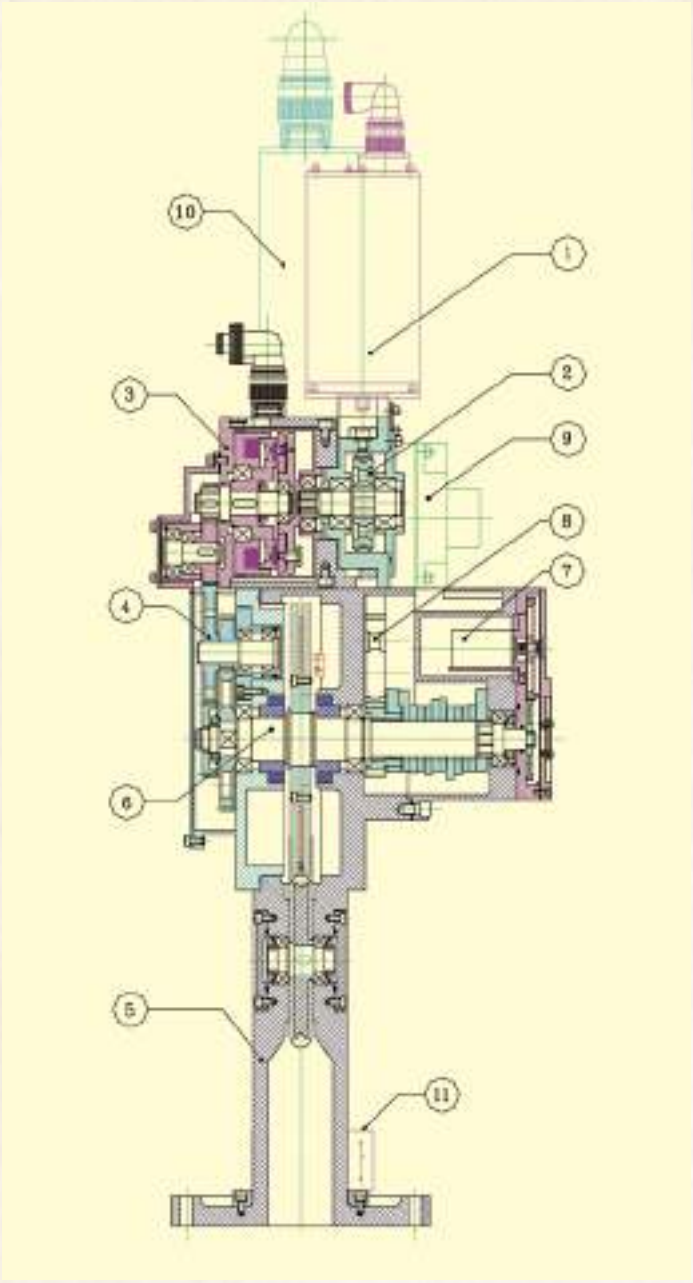
DRHR, BARC has designed cable winch drive mechanisms for adjuster rods, control rods and shut-off rods of TAPP-3&4 incorporating a number of advanced features. These mechanisms are significantly different from the mechanisms used in Dhurva, Kamini and 220 MWe Pressurised Heavy Water Reactors (PHWRs). The prototype drive mechanisms have been tested on full-scale test station at BARC for design validation. The design drawings and technical specifications for production of drive mechanisms have been issued to NPCIL.

Functional Requirements: The drive mechanisms are designed to meet the following functional requirements:

- Raising, lowering and holding of rods
- Position indication and limit position indication
- Scram characteristics
- Size constraints
- Environmental conditions
- Remote engagement/ disengagement
- Limited reactivity addition capability
- Fail-safe, non-reverse scram characteristics
- Service life requirements
- Trips, alarms and indications to check safe operation and healthiness

Number of shut-off rods	:	2 : 28
Number of control rods	:	4
Number of adjuster rods	:	17
Reactivity worth of shut-off rods	:	72 mk
Total travel of shut-off rod / control rod	:	6600 mm
Weight of shut-off rod / control rod	:	50 Kg
Time to raise shut-off rod / control rod (at max speed)	:	150 ± 10 sec
Total length of shut-off rod / control rod	:	5500 mm
Reactivity addition rate during withdrawal of rods	:	0.33 mk/sec
Max linear speed during withdrawal of shut-off rod/control rod	:	56.5 mm/sec
Drop time for 5940 mm (90% travel) of shut-off rod (*)	:	1.8 sec ± 0.1 sec
Speed variation of adjuster rods / control rods	:	Upto 1 : 10
Weight of adjuster rod	:	15 Kg
Time to raise adjuster rod at max speed	:	70 ± 10 sec
Drop time for 5940 mm (90% travel) of control rod	:	4 sec approx.
Partial drop distance for stepback function of control rod	:	Anywhere upto 100% drop
Max ambient temperature for mechanisms	:	65°C
Max radiation field for mechanisms	:	10 R/hr
Applicable code	:	ASME Section III, Sub-sec.NB for OBE & SSE

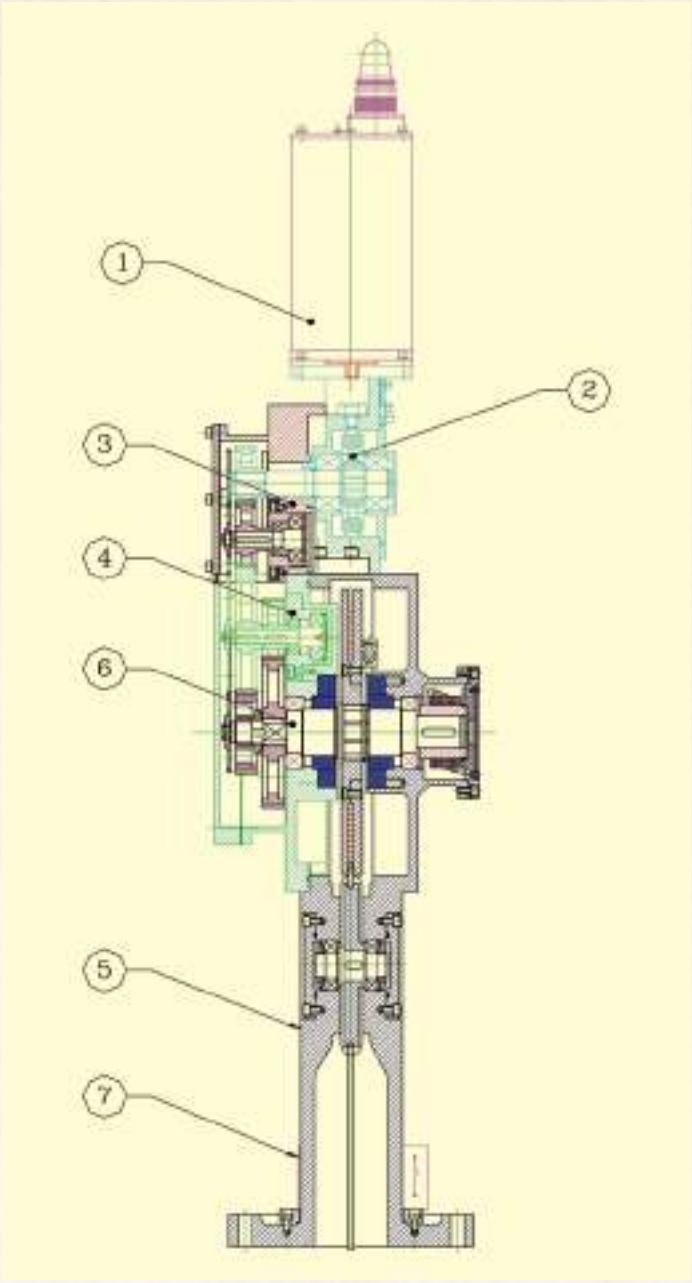
(*) Excluding signal processing and actuation delay



Sub-assemblies

1. Motor sub-assembly
2. Worm gear sub-assembly
3. Electromagnetic clutch sub-assembly
4. Reduction unit-1 sub-assembly
5. Mechanism housing sub-assembly
6. Sheave shaft sub-assembly
7. Potentiometer sub-assembly
8. Reduction unit-2 sub-assembly
9. Hydraulic dashpot sub-assembly
10. Limit switch sub-assembly
11. Reed switch sub-assembly

Shut-off Rod/Control Rod Drive Mechanism



Sub-assemblies

1. Motor sub-assembly
2. Worm gear sub-assembly
3. Potentiometer sub-assembly
4. Reduction unit sub-assembly
5. Mechanism housing sub-assembly
6. Sheave shaft sub-assembly
7. Reed switch sub-assembly

Adjuster Rod Drive Mechanism

Signing of MoU between BARC and NPCIL

- Reliable, non-dependent on external power source for safety action
- Minimum periodic maintenance

Basic Design Specifications: The basic design specifications for the drive mechanisms are as follows.

Shut-off Rod/Control Rod Drive Mechanism

During normal reactor operation shut-off rods/ control rods are held through electromagnetic clutches for fail-safe operation. On deenergisation of clutches, the rods fall freely under gravity. The drive mechanisms for shut-off rods and control rods are identical. The shutoff rod element contains an orifice at its top end, which comes into action at 80% downward travel of the rod and limits its free fall speed. The control rod element contains an orifice at its bottom end to limit its free fall speed. The hydraulic dashpot is designed to gradually reduce the speed of shut-off rod/control rod during 90% to 100% downward travel.

Adjuster Rod Drive Mechanism

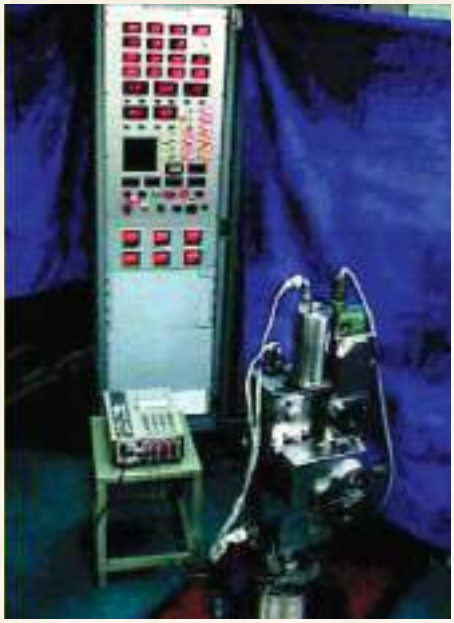
The adjuster rod drive mechanism is designed for raising and lowering of adjuster rods at controlled speeds and does not contain electromagnetic clutch or hydraulic dashpot.

Salient Design Features

The salient design features of drive mechanisms are as follows:

- 28 shut-off rods constitute the Primary Shutdown System. 4 control rods and 17 adjuster rods constitute Reactor Regulation System. The unavailability of the Primary Shutdown System shall not exceed 10^{-3}/year.
- Heavy water moderator is used for cooling of shut-off rods, control rods and adjuster rods. A perforated guide tube surrounds each shut-off rod, control rod and adjuster rod. The guide tubes for shut-off rods and control rods are identical.
- The drive mechanism is flange mounted on top of guide tube extension and it forms part of pressure boundary for heavy water moderator system.
- The drive motors in the drive mechanisms operate on 3 phase, 220 Volts, 50 Hz supply. The drive motors for control rods and adjuster rods are designed for variable speed (10% to 100%).
- Simplified absorber element design to facilitate easy inspection and replacement of wire rope used for attaching the absorber element to the drive mechanism.
- The electromagnetic clutch operates on 90 Volts DC. Clutch design and torque capacity suitable to permit partial release of shut-off rod from parking position for checking healthiness of drive mechanisms. Clutch design and torque capacity also

Test Rig for Qualification of Spiral Spring, Rotary Switchgear and Potentiometer



Full Scale Test Station

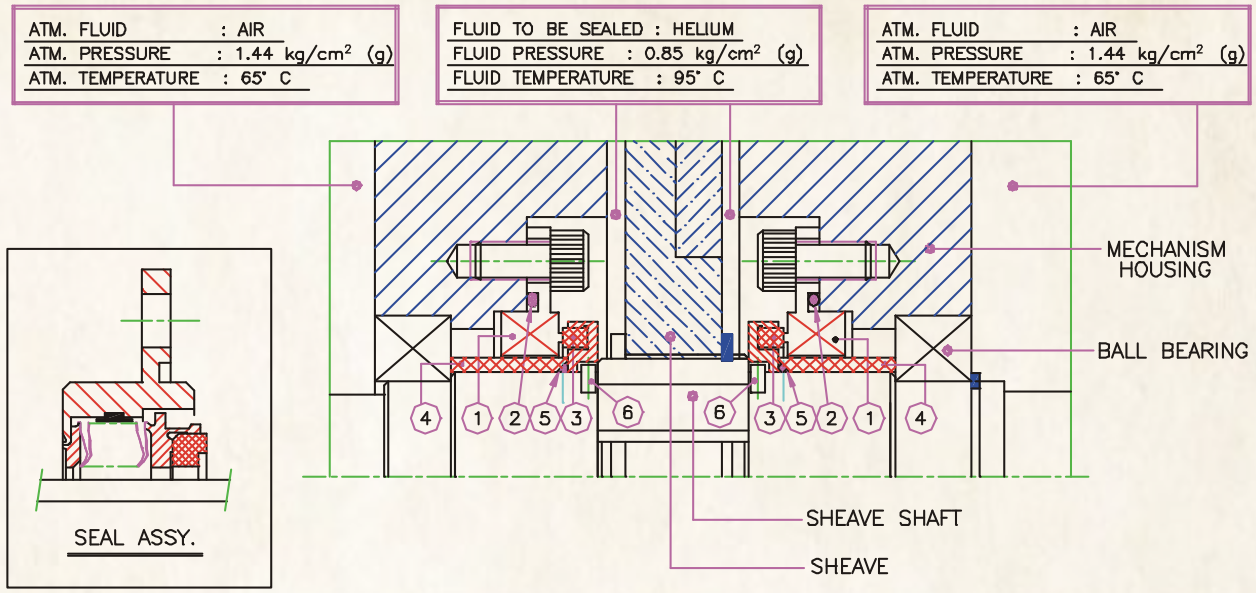
suitable to permit re-arresting control rod after release for reactor stepback function.

- 90% free fall of shut-off rod/ control rod (without dashpot) for highest reliability and consistent performance. Maximum free fall speed of shutoff rod element is limited through the use of an orifice at its top end (orifice is effective during 80% to 90% downward travel of shut-off rod). Maximum free fall speed of control rod element is limited through the use of an orifice at its bottom end.
- Hydraulic dashpot incorporates an oil window connected to low pressure side. Above the oil level, window has adequate space for expansion of oil at high ambient temperature.
- The conventional single vane replaced by double vane to balance forces on dashpot shaft arising from high oil pressure during damping action.
- A screw for controlling oil bypass from high pressure side to low pressure side for adjusting damping characteristics of dashpot.
- Modular design of drive mechanism layout to permit in-situ maintenance/replacement for individual sub-assemblies e.g. motor and worm gear, clutch, dashpot, switchgear, potentiometer etc without opening moderator pressure boundary.
- Better lubrication for gears, bearings, pick-up rings and spiral springs for long wear life.
- Rope sheave in place of rope-drum to eliminate chances of wire rope coming off the drum groove.
- Provision of single turn triplicate potentiometer on dashpot shaft to monitor retrieval of spiral spring while the rod is being raised. Raising of the rod will get inhibited in case of unsatisfactory retrieval of dashpot shaft. Rationality checks on potentiometer signal shall be done to detect potentiometer failure.
- Provision of multi-turn dual potentiometer to monitor continuous position of rods. Rationality checks on potentiometer signals shall be done to detect potentiometer failure.
- Provision of rugged triplicated rotary switchgear unit to monitor shutoff rod drop time for 90% fall.
- Gear reduction trains for potentiometer and limit switches are eliminated
- Provision of one set of triplicated reed switches (directly actuated) to indicate shut-off rod fully 'out' position and other set of reed switches for motor supply cut-off.

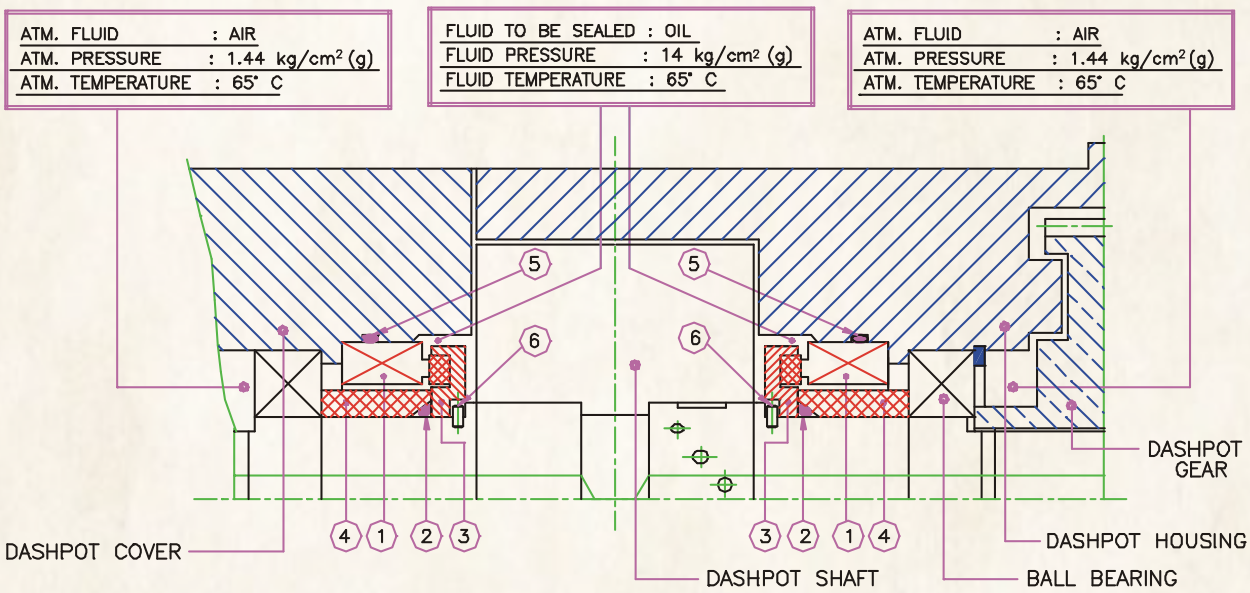
Design Testing of Prototype Units

- Effect of initial accelerating spring on rod drop dynamics
- Optimisation of orifice in shut-off rod element for rod drop dynamics
- Optimisation of orifice in control rod element for rod drop dynamics and clutch resetting
- Effect of hole in guide tube stopper plate on rod drop dynamics
- Effect of perforations in the guide tube on rod drop dynamics

Seal Test Rig



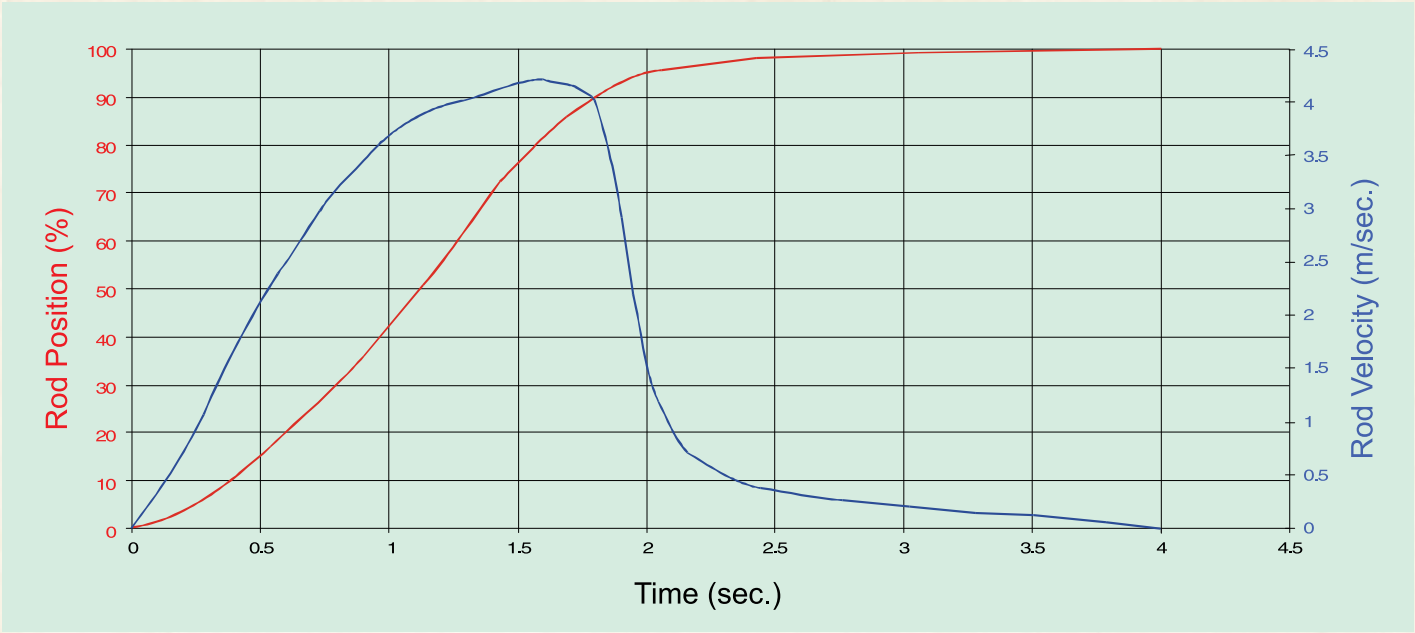
MECHANICAL SHAFT SEALS FOR SHEAVE SHAFT



MECHANICAL SHAFT SEALS FOR HYDRAULIC DASHPOT

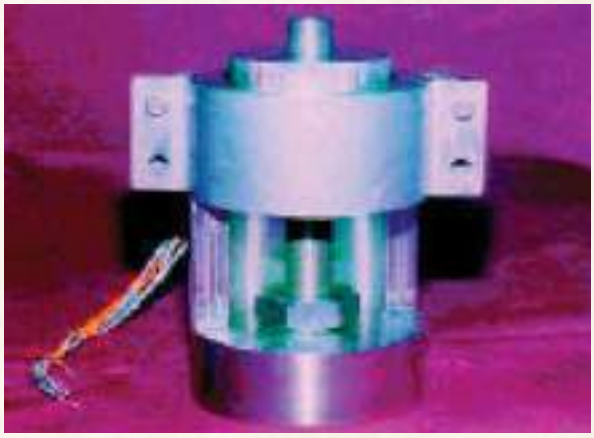
S.No.	DESCRIPTION	MATERIAL
6	ANTI–ROTATION PIN	S.S.316
5	'O' RING	VITON
4	SLEEVE	S.S. 17–4 PH
3	MATING RING COMPOSITE (ROTATING)	T.C.+TITANIUM
2	'O' RING	VITON
1	SEAL ASSY. (STATIONARY)	CARBON FACE

Seal Test Rig



Drop Characteristic of Shut-off Rod for TAPP-3&4

Reed Switch Assembly - Parts



Fixture for checking actuation of Reed Elements

Reed Switch Assembly - before posting

Test console for qualification of Reed Switch Assy.

- Effect of water level variation in calandria on rod drop dynamics
- Optimisation of partial release characteristics of shut-off rod for on-line testing
- Effect of moderator cross flow on rod drop dynamics
- Effect of dashpot by-pass screw adjustments on rod drop dynamics

Qualification of Special Hardware Items on Test Rigs

- Simulated testing and qualification of dynamic shaft seals used in sheave chamber and dashpot for 50,000 cycles.
- Simulated testing and qualification of spiral spring, rotary switchgear (Limit Switch) and potentiometers for 104 cycles.
- Simulated testing and qualification of reed switch unit for 106 cycles.
- Qualification of drive motor and electro-magnetic clutch.
- Qualification of wire rope & its crimped terminals.

Status of Development:

- Mark-I shut-off rod (SOR) drive mechanism has been tested on fullscale test station for 1000 drops.
- Mark-II SOR has been tested on fullscale test station for design validation and optimization of scram characteristics.
- Mark-II SOR has also been successfully tested for more than 5000 drops on full-scale test station for reliability testing.
- On-line testing of SOR P-II has also been successfully completed for more than 3000 cycles. During online testing, rod was held at park 'UP' position and the voltage to EM clutch was reduced to zero for short testing is in progress. The partial release for CR has been provided for stepback function.
- **Swaging of wire rope with end terminals:**

  The wire rope crimping with end terminals was carried out using portable pneumatically operated cable swager. This equipment has been specially procured for control mechanism application. Equipment also has a cable pull tester unit, which is a self-contained hydraulic unit, used for testing the swaged terminal. The swaged joint is tested at 60% of rated strength of the wire rope. Recently, 12 sets of wire rope assemblies for CIRUS shut-off rods have been supplied by DRHR, BARC. The swaging method was qualified by carrying out load testing and after getting successful test results for three consecutive samples.

  Presently, wire rope crimping (for control mechanism application in all the nuclear power plants) is done using a die and a manually operated press. Other end of the terminal is further welded. The wire rope crimping using pneumatically operated cable swager eliminates welding and gives consistent results.
- Further testing at high ambient temperature is in progress.
- Testing of Adjuster Rod Drive Mechanism on full-scale test station is in progress.

Mr. Manjit Singh is Head, Division of Remote Handling and Robotic (DRHR), BARC, Trombay, Mumbai. He has done B.E. (Electrical) with Honours from Punjab University in May 1972. He joined BARC Training School in 1972. Mr. Manjit Singh is a recipient of Dr. Homi Bhabha award for securing 1st rank in BARC Training School. He has also received 'Technical Excellence Award-1997'. Mr. Manjit Singh has pioneered the development of remotised tools for in-service inspection of coolant channel of 220 MWe PHWRs in India. He has been responsible for the design, development and supply of BARCIS Systems to NPCIL. Mr. Manjit Singh has pioneered the development of cable winch type control mechanisms for use in research and power reactors in India. He has been responsible for the design and development of Shut-off rod drive mechanisms for Dhruva, Safety plate drive mechanims for KAMINI and Shut-off rod drive mechanisms for NAPP. He has also been responsible for the design and development of shut-off rod/adjuster rod and control rod drive mechanisms for TAPP-3&4.

The other team members are Messrs. **D.N. Badodkar, N.K. Singh, N.S. Dalal, M.K. Mishra, G. Veda Vyas and C.B. Kothari** of DRHR, BARC, Mumbai.

[This article was originally published in Nu-Power Vol. 16 No. 1-2 (2002). The author's introduction has been reproduced as it appeared in the original article in the year 2002.]

Hall of Nuclear Power

National Science Centre, Delhi

Dr. Jitendra Singh, Minister of State (Independent Charge), PMO, Department of Atomic Energy (centre) inaugurating the Hall of Nuclear Power at National Science Centre, Delhi along with senior officials of DAE, NPCIL and National Science Council

'Hall of Nuclear Power'

Inaugurated at National Science Centre, Delhi

A Fabulous Permanent Exhibition on Nuclear Power

A fun way to learn about science is to visit a science museum. Each year, lakhs of people visit science centres across the country. Utilising this platform, a permanent exhibition on nuclear power, named ***'Hall of Nuclear Power – Atoms Serving the Nation',*** *has been established in the national capital.*

Nuclear power – electricity without pollution

Our nation is emerging as a leading economic force globally. To drive economic growth, we need a steady, sustainable and dependable supply of electricity to light up our homes as well to energise our industries. What is equally important is the fact that environment-friendly sources of energy have become an undeniable necessity, to save the planet. Nuclear power is one such mainstream source of generating clean electricity without polluting the planet.

Environmental concerns and climate compulsions make it necessary for us to choose energy sources that do not involve greenhouse gas (GHG) emissions. This is because atmospheric emissions of GHGs like carbon dioxide (CO_2) are primarily responsible for global warming and the resulting climate change. Nuclear power is based on fission of atomic nucleus, involving conversion of a tiny amount of nuclear mass into a huge amount of energy, and does not use fossil fuels or any form of chemical combustion. Therefore, nuclear power generation does not involve

emission of GHGs, which is how it helps mankind in fighting global warming. Also, there is no emission of other harmful gases such as sulfur dioxide (SO_2) and oxides of nitrogen (NOx). Nuclear power is non-polluting, environment-friendly, reliable, cost-effective as well as sustainable for centuries.

Hall of Nuclear Power at Delhi

In India, science museums are visited by lakhs of people, especially young aspiring students. Utilising this popular platform, Nuclear Power Corporation of India Limited (NPCIL), in collaboration with National Science Centre, Delhi, which is the northern headquarter of National Council of Science Museums, threw open a permanent exhibition gallery on nuclear power, at the Centre in January 2016. The gallery, named ***'Hall of Nuclear Power – Atoms Serving the Nation'***, was dedicated to the nation during the silver jubilee year of the centre.

This permanent exhibition on nuclear power in Delhi is the third of its kind in the country set up by NPCIL through collaborative efforts. The first one is at Nehru Science Centre, Mumbai and another one is at Chennai. NPCIL organises visits of school children to nuclear power gallery at Mumbai round the year. Similar initiatives are also envisaged for galleries at Chennai and Delhi. Several more such 'Nuclear Power' galleries are planned for locations across India.

The gallery was inaugurated by Dr. Jitendra Singh, Hon'ble Minister of State (Independent Charge), PMO, Dept. of Atomic Energy on January 16, 2016. The guest of honour was Dr. Sekhar Basu, Chairman, Atomic Energy Commission and Secretary, Department of Atomic Energy. Among other dignitaries present on this occasion were Mr. Kailash Chandra Purohit, the then Chairman & Managing Director, NPCIL; Mr. N. Nagaich, Director (Human Resources), NPCIL; Mr. G.S. Rautela, Director General, National Council of Science Museums (NCSM); and Mr. D. Rama Sarma, Director, National Science Centre, Delhi.

The expansive nuclear power gallery is spread over an area of about 700 sq. m., with over 60 permanent exhibits, covering various aspects of nuclear energy, with prime focus on nuclear power plant safety and applications of nuclear technology for human welfare. Nuclear power generation, its basics, and non-power uses of nuclear energy and radiation technology are depicted at the gallery.

The permanent gallery focuses on key advantages of nuclear power and its suitability for India. What's more, the gallery also addresses generally prevalent misconceptions and myths surrounding nuclear power and radiation.

In developing the 'Hall of Nuclear Power', the goal was to create a genuinely interesting experience for the visitors. For this, the principle of 3 E's – *Entice, Enthuse, Explore* – has been employed for providing a blend of high-impact edutainment.

The gallery is replete with the state-of-the-art exhibits, employing latest technology and innovative gadgetry, which takes the user interaction and experience of visiting the gallery to a new level.

For a more meaningful engagement, latest multimedia techniques have been employed at the gallery to create focal points of sharp interest, among which are: 2D and glasses-free 3D displays, animations with voice-over commentary, informative films shown on monitors played automatically as the visitor approaches the exhibit, an information-packed film demystifying nuclear power that runs continuously in a mini theatre to provide a rich immersive experience, as well as interactive digital kiosks, quiz consoles and an interactive virtual Q&A exhibits in which nuclear experts appear live through pepper ghost holographic projections to answer visitors' queries.

At the 'Ask Budhiya' exhibit, the popular comic figure 'Budhiya' – a well-informed common man – addresses misconceptions and myths about nuclear power and radiation, by appearing right in front of the visitors – virtually. In this lively interactive audio-visual treat, Budhiya debunks myths and misconceptions surrounding nuclear power, in a question-answer format.

There is also a semi-dynamic, interactive miniature model of a nuclear power plant with relevant voice-over commentary, to reveal to the visitor the inner functioning of a nuclear power plant. Also, an exhibit in the form of a simplified, scaled-down cut-section depicts the calandria vault, where calandria – the heart of a nuclear reactor – resides. Visitors can also take a highly informative virtual tour of a nuclear power plant in a mini theater.

A display dedicated to pioneers of radioactivity introduces the visitors to researchers such as Wilhelm Röentgen, Henri Becquerel, Marie Curie and Pierre Curie, Ernest Rutherford, James Chadwick and Enrico Fermi, who ushered the world in a nuclear age. A bust of Dr. Homi Jehangir Bhabha creates a life-like presence of the 'Father of Indian Nuclear Power programme'. The accompanying exhibit outlines his life, his work, and how he was pivotal in setting up the nuclear establishment of the country. Another section of this multi-panel exhibit reveals little-known aspects

GLIMPSES OF THE GALLERY

Mr. N. Nagaich, Director (Human Resources), NPCIL (centre) explaining the exhibits to Dr. Jitendra Singh, Minister of State (Independent Charge), PMO, DAE (right) at National Science Centre, Delhi. Mr. Sekhar Basu, Chairman, AEC and DAE Secretary is also seen in the photograph (2nd from left)

of his personality – Bhabha's intense love for music and painting.

India's three-stage nuclear power programme is explained in a comprehensive yet easy-to-understand manner, highlighting the mega role that the nuclear fuel thorium is poised to play in power generation in the coming years.

The journey of uranium fuel from mining to processing to fuel bundle fabrication is depicted pictorially with supporting explanations, while fuel bundles and some reactor structural components are displayed using actual blank samples to give the visitor a real-life feel of some of the most vital components of a nuclear power reactor.

'Radiation – Our Constant Companion' is an exhibit that explains to the visitor how we are all exposed to natural background radiation all the time and everywhere on the earth. A comparison provided in this exhibit tells us the amount of natural radiation from several sources in day-to-day life against the radiation dose from the operation of a nuclear power plant, which is extremely low, indeed negligible and well below the statutory and regulatory permissible limits.

Non-power applications of nuclear energy and radiation

Nuclear energy is a boon to mankind. Apart from power generation, nuclear energy and radiation have several non-power applications that are used in day-to-day life. An exhibit at the gallery is dedicated to these applications, such as the use of radioisotopes in cancer treatment, medical diagnosis, space exploration, submarine propulsion, research, agriculture as well as a wide variety of industrial uses.

In addition to the above highlights, the gallery has several more graphical displays that convey vital information creatively. The lucid and crystal-clear approach used for information delivery makes the visit to this permanent exhibition a memorable experience and invariably leads to greater retention of information – which, ultimately, is the goal of the entire effort.

Amritesh Srivastava

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

Flag-off Event of "Atoms on Wheels" at Bhavnagar, Gujarat

As a long-term strategy of Nuclear Power Corporation of India Limited's (NPCIL) public awareness campaign to educate the masses at grassroots level about the usefulness, viability and safety of nuclear energy, an on-ground educative and innovative initiative "Atom on Wheels" undergoing progressive deployment in 6 states of India like Madhya Pradesh, Gujarat, Maharashtra, Andhra Pradesh, Haryana and Rajasthan in a phase-wise manner under NPCIL's Rural Integration Programme. The activities have already been conducted in Haryana, Rajasthan and Madhya Pradesh, and in continuation to that, now this campaign is organised in Gujarat. To begin with, this mobile exhibition was flagged-off at Bhavnagar district of Gujarat by Mr. R.P. Chaudhari, Additional Collector, Bhavnagar, in the presence of Mr. N.P. Gandhi, SO/G, Mithi Virdi Project and Mr. Amritesh Srivastava, Manager (Media & Corporate Communications) and in-charge of "Atom on Wheels" programme. Other senior officials of NPCIL, Bhavnagar and District Collectorate were also present on the occasion.

"Atom on Wheels" is a special awareness drive to be undertaken in and around 240-250 villages near the proposed power plant site in Bhavnagar. The core objective of the campaign is to invite various sections of people to visit the exhibition and help them understand various applications of nuclear energy, its benefits, scientific and mainly the safety aspects. The exhibition is designed in a very distinct and lucid way to dispel various myths and apprehensions about nuclear energy, its usage and its impact. The mobile vehicle is fabricated with 15 exhibits and panels coupled with LCD and projectors to show various public awareness films on different themes related to nuclear energy. The entire activity will be carried out over a period of 4 months.

[NPCIL HQ News Desk]

NPCIL Participates in IITF–2016

NPCIL participated in the 36th India International Trade Fair (IITF)–2016 during November 14-27, 2016 organised by India Trade Promotion Organisation (ITPO) at Pragati Maidan, New Delhi. The two-week-long trade fair was inaugurated by Mr. Pranab Mukherjee, President of India.

NPCIL had set up its exhibition stall in the Ministry of Power pavilion. The pavilion was awarded Silver Medal for Excellence in Display category.

NPCIL stall showcased interactive model and attractive displays to highlight the beneficial aspects of nuclear power and address concerns related to the safety of nuclear power plants and radiation etc. This platform was also utilised for the promotion of "Hall of Nuclear Power" at National Science Centre, New Delhi by displaying special panels on it.

NPCIL's resource persons at the stall, with an interactive, miniature, semi-dynamic NPP model

During the two-week period, nearly 6 lakh persons visited NPCIL stall and their queries on various aspects of nuclear power were answered satisfactorily by resource persons from NPCIL headquarters, Narora Atomic Power Station, Rajasthan Rawatbhata Site and Noida Office.

[NPCIL HQ News Desk]

NPCIL Schools Navi Mumbai Medicos on Effects of Radiation

Continuing the series of Doctors' Meet programme to educate medicos on various aspects of radiation, including inconsequential radiation doses and below-average prevalence of cancers around nuclear plants, a seminar was conducted at MGM Medical College, Kalamboli in Navi Mumbai for post-graduates of Radiology Department.

About 25 medicos participated in the seminar. NPCIL resource persons discussed various topics like ionising and non-ionising radiation, the existence and sustenance of life amidst natural and man-made radiation, beneficial aspects of radiation and medical interventions during radiation emergencies.

Medicos attending seminar session

[NPCIL HQ News Desk]

Public Awareness Programme at Adi Utsav

A public awareness programme was carried out by Chutka Madhya Pradesh Atomic Power Project (CMPAPP) site during Adi Utsav organised by Mandla district administration at Ramnagar, Mandla from April 10 to 11, 2016.

Adi Utsav celebrates the rich art, culture, history and tribal traditions in and around the district. Mr. Shivraj Singh Chauhan, Chief Minister of Madhya Pradesh, MLAs and other dignitaries attended the Utsva. More than 50,000 people from around Mandla participated in the Utsva.

People from areas in the vicinity of Chutka Madhya Pradesh Atomic Power Project visiting the NPCIL exhibition stall

The CMPAPP site along with Information Centre, Narayanganj participated in the festival and set up an exhibition stall. Displays and exhibits carrying pictures, messages and scientific information on the benefits of the project were installed. Films on Budhiya and comics were also screened on computer. About 2000 people visited the exhibition. Various informative NPCIL publications, Budhiya comic books, DVDs, etc. were distributed.

[NPCIL HQ News Desk]

Workshop on Nuclear Energy at Ankola

Workshop in progress

A one-day workshop on 'Nuclear Energy and its Uses to Mankind' was organised by the public awareness committee, Kaiga Site at Gokhale Centenary College, Ankola in Uttara Kannada district of Karnataka on April 1, 2016. About 140 students and 10 faculty members attended the programme. The college is one of the leading educational institutions in the coastal Karnataka region.

[NPCIL HQ News Desk]

Young students eagerly learning about nuclear power at the MAPS stall

Awareness Programme at SCSVMV University

Department of Mechanical Engineering of Sri Chandra-sekharendra Saraswathi Viswa Mahavidyalaya (SCSVMV) University, Kancheepuram, in Tamil Nadu organised a Science Exhibition 'SCITECH EXPO 2016' during April 21-22, 2016 within university premises. This was arranged to create science awareness among general public and school, college and university students. Various R&D and scientific organisations participated in this event. As part of NPCIL's public outreach programme, Madras Atomic Power Station (MAPS) along with Environmental Survey Laboratory participated in the event by setting up a stall. Exhibits, boards and banners highlighting the nuclear power safety, radiation protection, natural background radiation, environmental safety, etc. were displayed at the stall. Physical models of reactor building and fuel bundle were also exhibited.

Around 2500 students and members of public visited the stall. They were briefed about the operation of nuclear power plants, importance of nuclear energy for future energy security, and the three-stage nuclear power programme of India. Specific queries of students were addressed by MAPS resource persons.

[NPCIL HQ News Desk]

MoU Signed for Nuclear Power Gallery at Bhubaneswar

Mr. N. Nagaich, Director (HR), NPCIL (3rd from left) and Mr. Subhendu Pattnaik, Dy. Director, PSP (right) exchanging the signed MoU documents

As part of public awareness strategy, Nuclear Power Corporation of India Limited (NPCIL) has been creating permanent galleries on nuclear power at various Science Centers across the country. On the same lines, to establish a permanent gallery at Pathani Samanta Planetarium (PSP), Bhubaneswar, a Memorandum of Understanging (MoU) between NPCIL and PSP was signed on March 9, 2016 by Mr. N. Nagaich, Director (Human Resources), NPCIL and Mr. Subhendu Pattnaik, Deputy Director, PSP.

Earlier, nuclear power galleries have been set up in Mumbai, Delhi and Chennai, while there are many more planned to be set up in the country in the coming years, including at Bhubaneswar.

[NPCIL HQ News Desk]

Seminars at Navi Mumbai

Under the NPCIL's Lecture Series in Educational Institutions, two more seminars were conducted recently, engaging the minds of the young generation from two streams – engineering and management. At Pillai College of Engineering, Panvel on August 10, 2016, around 100 final year students were addressed by NPCIL's team on the topic "Is nuclear technology safe and sustainable?" In their introductory messages, faculty members emphasised various aspects of safety of nuclear power plants, noting further that nuclear power plants are designed for utmost safety and that they can withstand man-induced as well as natural calamities.

Lecture underway at Pillai College of Engineering

In the seminar at ITM, Kharghar on August 13, 2016, the topic discussed was "Strategies for Managing the Nuclear Energy Sector." Issues related to the planning, monitoring, continual improvement and expansion of nuclear power were discussed with M.B.A students, who were glad that in the planning of the country's energy security, nuclear power plays the role of providing clean, green, viable and sustainable contributor. Around 100 students and faculty members attended the lecture.

[NPCIL HQ News Desk]

Seminar in progress

Public Awareness Seminars at Surat and Vadodara

A seminar 'Indian Nuclear Power Programme and Radiation – A Fact of Life' was organised by Kakrapar Gujarat Site, NPCIL, at Mahavir Swami College of Engineering & Technology, Surat, Gujarat on January 19, 2016. The aim of the seminar was to draw the attention of student community towards nuclear power as a safe, economical, environmentally benign and sustainable source of electrical energy.

The seminar consisted of two lectures. The one on "Indian Nuclear Power programme" was delivered by Mr. Sunil Kumar, the then Training Superintendent, Kakrapar Gujarat Site, wherein he covered topics such as global energy scenario, need for nuclear power, three-stage Indian Nuclear Power Programme, functioning of a nuclear power station, radiological and safety features of a nuclear power station, and waste management.

Dr. A.K. Patra, Head, Environmental Survey Laboratory (ESL), Kakrapar Gujarat Site delivered a lecture on "Radiation - A Fact of Life and Environment Impact Assessment around Kakrapar Gujarat Site". Dr. Patra, gave a demonstration of radiation measurement to the participants by measuring the naturally occurring gamma radiation inside the seminar hall.

The seminar was attended by 108 students and faculty members of Electrical Engineering Department.

On similar lines, Kakrapar Gujarat Site also organised a public awareness seminar on Indian Nuclear Power Programme 'Radiation – A fact of life and DAE – Society Benefits' at Parul Institute of Engineering and Technology, Vadodara (also known as Baroda), Gujarat on April 26, 2016.

The seminar was attended by 50 students and faculties of different departments.

[NPCIL HQ News Desk]

Media professionals at the Turbine Hall of NAPS-1&2 during their visit

Visit of Media Professionals to NAPS

Nuclear Power Corporation of India Limited (NPCIL) organised a visit of senior media professionals to Narora Atomic Power Station units-1&2 (NAPS-1&2) during December 9-10, 2015, under the public awareness programme of NPCIL. During the programme, the focuss was sharing information about the functioning of nuclear power plant and the safety aspects of nuclear power generation. The visiting media professionals were briefed about the proactive management, immaculate planning, efficient working, adherence to specifications and procedures as well as stringent safety culture in place at NPCIL's power plants.

Mr. D.S Choudhary, Station Director, NAPS provided a brief on the station, which was followed by a detailed presentation covering various safety aspects of the nuclear power plants (NPPs). It was also shared with the media professionals that radiation level is periodically measured in the surrounding areas of NAPS-1&2 by the Environment Survey Laboratory (ESL), to ascertain various health parameters. They were also communicated about the various types of radioactive wastes and waste management. It was also highlighted in the presentation that radiation received from NPPs, by the people residing in the vicinity, is insignificant in comparison to the natural background radiation and well below the permissible regulatory limits.

On the following day the group made a visit to the Information Centre, where various interactive models depicting working of NPP, fuel and structure of reactor core were demonstrated to them. The visiting group was also taken inside the Control Room and Turbine Hall, where they were briefed about the entire process of electricity generation. They also visited the wetland and exclusion zone to witness the rich biodiversity around the plant. During the trip, they raised many queries, such as about radiation, safety of Indian nuclear power plants, effects of earthquake and tsunami on power plants, etc., which were addressed by senior officials with facts and figures.

[NPCIL HQ News Desk]

Workshop on Nuclear Power and Radiation at Ajmer

Students attending the workshop

Under the public awareness outreach programme of NPCIL, a one-day workshop on nuclear power was organised during National Science Day celebrations at Government Women Engineering College, Ajmer, Rajasthan. The workshop was conducted on February 26, 2016 by NPCIL RR Site as part of curriculum of engineering college. The workshop included lectures on nuclear power and understanding radiation. About 260 final-year engineering students and professors participated in the mega event.

Mr. Sanjay Mathur, SO/F delivered the lecture on "Nuclear Power - Safe amd Clean" and Mr. Rakesh Vashishtha, Station Health Physicist, RR Site unit-1&2 delivered the lecture on "Understanding Radiation". Booklets and pamphlets on nuclear power and green caps were distributed to participants. The programme concluded with interactive session.

[NPCIL HQ News Desk]

Workshop for Journalists at RR Site

Under the long-term, structured public awareness programme of NPCIL, a workshop for journalists was organised on February 18, 2016 at Vikram Nagar Seminar Hall, Rawatbhata Rajasthan Site (RR Site). A total of 45 state and national-level journalists from Rawatbhata, Chittorgarh and Kota participated in the workshop.

The inaugural speech was delivered by Mr. T.J. Kotteeswaran, Site Director, RR Site. He briefed on the three-stage Indian Nuclear Power Programme and explained the various aspects of nuclear power generation and its safety and environment-friendliness.

The visiting group of journalists bidding farewell after the workshop at RR Site

Mr. Vineet Kumar, Station Director, RR Site Unit-1&2 delivered a speech on "RR Site at a glance" and highlighted the major achievements of RR Site.

Through lectures and question-answer session the fact that nuclear power is safe and clean source of electricity and that radiation is part of our life was shared with the media professionals.

[NPCIL HQ News Desk]

Invited Talk on 'Nuclear Power' at Amity University

Under "INSPIRE" programme of Department of Science & Technology, Govt. of India, invited talk on "Nuclear Power: An Inevitable Option for Clean & Green Future" was delivered at Amity University, Noida Campus on January 20, 2017 by Mr. Amritesh Srivastava, Senior Manager (Media / Corporate Communications), NPCIL. Hundreds of students from various schools and colleges of Delhi participated in the event. On this occasion, information about various aspects of nuclear energy was shared with the students and various doubts and apprehensions related to nuclear power were dispelled. The objective of this programme is to inculcate scientific temper amongst the students and to motivate them to pursue scientific innovation and research. Many scientists, officials and science communicators across the premiere institutions pan-India participated in the event and shared their vast experience with the students.

Students at the lecture programme

[NPCIL HQ News Desk]

Two-day Lecture Programme at KV, Delhi Cantonment

As a part of public outreach activity in schools, a two-day lecture programme was organised at Kendriya Vidyalaya No. 3 in Delhi Cantonment during August 1-2, 2016 for students of class X, XI and XII. Lectures were held at two venues simultaneously and in two shifts. A total of 626 students along with their teachers participated in the lecturers.

The students were given an overview of the working of nuclear power reactors. They were also briefed about types of radiation, omnipresence of radiation and how it is a constant companion of life. Students also learned about various application of nuclear energy and radiation in agriculture, industry and health as well as about the role of Environmental Survey Laboratories in monitoring the environment around nuclear power plants. A quiz was also conducted for the students and teachers. Booklets and pamphlets elucidating nuclear power were distributed among the participants and these were also made available for the school library.

Glimpses of close interaction with the students

[NPCIL HQ News Desk]

Lecture at Inter College in Shikarpur, Bulandshahr

Recently, NPCIL was invited to a workshop sponsored by the Sanskrati Department of Govt. of India on "Development of Scientific Thoughts" at Surajbhan Saraswati Vidya Mandir Inter College, Saraswati Vihar, Shikarpur in Bulandshahr district in Uttar Pradesh. At the event, organised on July 30, 2016, the public awareness team of Narora Atomic Power Station (NAPS) presented a lecture on nuclear power, describing key safety features employed in the design of a nuclear power plant, important systems of nuclear power plants, as well as measures implemented and precautions taken during the operations of a nuclear power plant. The participants were explained the reasons behind the fact that nuclear power plants do not pose any health hazard to people or environment.

The mega public awareness session in progress

In all, about 750 students and teachers along with officials attended the event.

[NPCIL HQ News Desk]

Student being demonstrated an interactive miniature nuclear power plant model

Science Expo-2016 at Nagpur

For NPCIL, Raman Science Centre at Nagpur has been the preferred venue for reaching out to a large audience fot disseminating public awareness messages. The centre attracts schools and colleges not only from Nagpur town, but also from distant places in Vidarbha and adjoining M.P, year after year.

At the SCIENCE EXPO-2016 held from January 9 to 13, 2016, NPCIL set up its exhibits with an interactive model of nuclear power plant along with other means of sharing information, such as informative posters, pamphlets, books based on the comic character 'Budhiya', etc. The stall depicted the green nature of atomic energy, while allaying apprehensions and concerns related to safety of nuclear power and radiation.

The annual science lecture of NPCIL at the exposition has now become a star attraction, and this year also NPCIL resource persons delivered one to a group of around 250 students and teachers drawn from several schools and colleges.

Around 70,000 visitors were briefed on the positive aspects of nuclear power during this 5-day event.

[NPCIL HQ News Desk]

Science Fiesta-2016

Inquisitive students learning about nuclear energy and its many applications at the Science Fiesta

Inculcating a scientific temperament, infusing a spirit of rational thinking stands the Goa Science Centre bang opposite the confluence of the Mandovi with the Indian Ocean. It is here, at the annual Science Fiesta, where all the top scientific institutions and organisations of the state disseminate their knowledge to the visitors in the most interesting ways through displays and face-to-face conversations.

NPCIL's exhibition at the venue was installed by JNPP's team with the aggregated campaign from February 26-29, 2016, being a collaborative venture between JNPP and CP&CC Directorate. Minister of S&T, Goa, Ms. Alia Saldahna visited the NPCIL interface and conversed with the team on various aspects of nuclear power generation.

The highlight of the campaign was NPCIL's scientific representation delivered to an assemblage of over 200 students from over 20 institutions and the Nuclear Power Quiz sponsored by JNPP invoking the participation of 25 gifted students from an equal number of schools.

Collector, North Goa and Director, National Institute of Oceanography awarded the prizes to winners of various contests, including the Nuclear Power Quiz contest on the closing day.

Over 10,000 citizens from Goa, Maharashtra and Karnataka regions were educated on the beneficial aspects of atomic power during this campaign.

[NPCIL HQ News Desk]

Interactive Seminar and Site Visit of Future Journalists of Mumbai University Hosted by JNPP

A group of around 50 post-graduate students of the Department of Communication & Journalism, Mumbai University, led by Dr. Sundar Rajdeep, HOD, Department of Communication & Journalism, Mumbai University visited the Information Centre at Ratnagiri and Jaitapur Nuclear Power Project (JNPP) site during October 21-22, 2016.

A full-day seminar was arranged by JNPP in collaboration with NPCIL's CP&CC Directorate on the first day.

Mr. P. Mohan Chief Engineer, JNPP Site made a detailed presentation on the suitability of the JNPP site, land acquisition, compensation status, approvals from government and regulatory bodies, status of Rehabilitation & Resettlement agreement with State Government, pre-project activities, and works in progress as well as other related topics like business & development opportunities for local residents.

The students were curious to know about various issues ranging from compensation and resettlement to spent-fuel management and economics of nuclear power.

A site visit was organised on the next day, and the future journalists were shown the safe elevation of the site and the various features of the project were explained.

In an open session following the site visit, facts about the JNPP project were shared with the students, covering

Young journalism students during their JNPP visit

topics such as the land acquisition act, disbursement of compensation, technology, assured fuel supply, waste management, cooling water discharge to sea and how it was inconsequential to marine life, biodiversity of western ghat with specific reference on Shri Gadgil Committee report, etc.

Dr. Rajdeep acknowledged the scientific approach of NPCIL, right from site selection to implementation of the project. The site selected for JNPP is totally barren and the fact was appreciated that no family is dislocated for the project.

[NPCIL HQ News Desk]

Social Welfare Activities by Kakrapar Site

As a part of corporate social responsibility, Kakrapar Atomic Power Station (KAPS) undertakes various welfare activities continually for the development of the neighbouring communities. Some of the welfare activities undertaken recently were:

Eye camp for nearby villagers

An eye camp was organised by KAPS Hospital in association with Tejas Eye Hospital, Mandvi, for the benefits of nearby villages during February 21-23, 2016. A total of 266 patients were examined by ophthalmologists, out of which 90 patients were screened for cataract surgery with implantation of intraocular lens. Five patients had ratinal and corneal conditions. The rest of the patients underwent refraction (also known as refractometry) for correction, out of which 110 patients were given refraction spectacles. Patients were also given free medicines, eye drops, etc. upon discharge.

Doctors conducting eye examination on patients at the camp

Financial assistance for establishing Glaucoma Unit

As part of the mission for providing quality healthcare facilities to people in surrounding areas, KAPS extended a financial assistance of ₹ 73,10,000 to Tejas Eye Hospital, Mandavi, for setting up a glaucoma unit. The unit has been named as 'Anumathak Glaucoma Unit'. This state-of-the-art unit is first of its kind in south Gujarat. The unit which was donated on July 13, 2016 has started providing services to economically underprivileged patients in this area. The hospital provides specialty services at concessional rates and even at no cost.

A close-up view of glaucoma unit

The instruments installed in the Glaucoma Unit are:

- Topcon Operation Microscope OMS 710 with assistance microscope and Accessories
- Topcon Slit lamp with SL-D701 with Digital camera DC-04 and Accessories
- Heidelberg retinal tomograph (HRT) unit HRT-03 with Lenovo PC assembly
- Ultrasonography by Microscope APPASAMY
- I-cARE Tonometer–TA-01 with accessories

An Assortment of accessories for schools

KAPS distributed a variety of musical instruments, sports kits, stationery kits, playground equipment for children, study benches and platforms to 16 different schools of villages located around Kakrapar plant site. The project spurred interest and capabilities of school children in the area of sports and music.

[NPCIL HQ News Desk]

Distribution of music instruments, stationery kits and sports kits to Nalanda High School, Moticher

Children enjoying the playground equipment at Primary School, Anumala

Dedication of "Dr. Homi Bhabha Anumathak Sanskritik Bhavan"

Mr. BC Patani, District Magistrate & Collector, Tapi (3rd from right) inaugurating the assembly hall in the presence of senior officials of Kakrapar Gujarat Site.

A view of Dr. Homi Bhabha Anumathak Sankritik Bhavan

Dr. Homi Bhabha Anumathak Sankritik Bhavan, an assembly hall, constructed by NPCIL's Kakrapar Gujarat Site at Uttar Buniyadi Kanya Vidyalaya premises in village Bedkuvadur, was dedicated to the public on September 07, 2016 by Mr. B.C. Patani, District Magistrate & Collector, Tapi. Mr. L.K. Jain, Kakrapar the then Site Director along with other senior NPCIL officials and sarpanches of nearby villages were present on the occasion. A total of 100 teachers from 23 schools of adjacent villages, viz., Moticher, Nanicher, Vankla, Unchamala, Bedkuvadur and Kanza were also felicitated for their services rendered to the society.

[NPCIL HQ News Desk]

MoU Signed for Construction of Intra-Village Roads

MoU documents being exchanged after signing

NPCIL's Kakrapar Gujarat Site signed a Memorandum of Understanding (MoU) for construction of intra-village roads in the village Kanja under its Corporate Social Responsibility (CSR) programme on November 28, 2016. This tripartite MoU for construction of 550 metres of intra-village roads was signed between Chairman, CSR Cell, Kakrapar Gujarat Site, Sarpanch-Gram Panchayat and Executive Engineer – Panchayat (R&B) division, Tapi. The construction work will be taken up by Panchayat (R&B) division, Tapi.

[NPCIL HQ News Desk]

Chutka Site Distributes Accessories to Specially-Abled Persons

NPCIL's Chutka Madhya Pradesh Atomic Power Project (CMPAPP) organised 'Free Distribution Camp' for providing assistive devices to the specially-abled persons of at Bebaliya village of Narayanganj tehsil in Mandla district on March 29, 2016. The beneficiaries, identified and listed in the assessment camps conducted earlier in surrounding villages of proposed Chutka site, were informed telephonically to avail of the opportunity. In addition, the publicity of the camp was made through pamphlets, banners, advertisements in local newspapers, etc. The camp was organised in association with State Govt. District Administration programme 'Khand Stariya Antyodaya Mela' and M/s Artificial Limbs Manufacturing Corporation of India (ALIMCO). During the camp, assistive devices such as soft cervical collars, conventional tricycles (right and lrft-hand propelled), cerebral palsy chairs, aluminium axilla crutches, walking sticks, folding braille canes, behind-the-ear digital hearing aids, MSIED Kits (for mentally challenged), rollators (rolling walkers), ankle-foot orthosis, etc. were distributed. NPCIL made small but vital contribution to the lives of 56 beneficiaries.

Beneficiaries at the distribution camp

[NPCIL HQ News Desk]

NAPS Donates Ambulance

Dr. Deepak Ohri, Chief Medical Officer, Bulandshahr, receiving the keys of ambulance from Mr. D.S. Choudhary, Station Director, NAPS

As part of CSR activities, Narora Atomic Power Station (NAPS) presented a brand-new high-roof ambulance to Chief Medical Officer, Bulandshahr on January 4, 2016 in a ceremony at NAPS plant site. The ambulance goes a long way towards fulfilling a vital need for the village communities in Debai tahesil, and also augment emergency health care services to the residents of Narora area.

[NPCIL HQ News Desk]

Once plenty, only a few thousand Indian Vultures exist in the wild now. In last two decades, lakhs of vultures were wiped out by diclofenac – an anti-inflammatory drug used in cattle

Indian Vulture

Scientific Name: Gyps indicus

IUCN Red List: *Critically Endangered*

Physical Characteristics

The Indian Vulture or Long-billed Vulture is one of the nine vulture species found in India. It is about 90 cm long, about half the size of a six-feet human. But when it spreads its wings, the bird measures more than six feet across. It has pale tawny body and wing coverts with black head, neck and tail. The white ruff at the base of its neck is noticeable. Its hook-like bill is pale yellow. Both male and female look alike. Like most other vultures, the Indian Vulture too has a bald head. It is believed that the feather-free head of vultures help them to feed the carcass easily and to tuck in their heads under the wings to maintain the body temperature.

Distribution

A resident bird, the Indian Vulture is found in India and Pakistan. In India, it is seen in central, west and north west parts of the country. The Rawatbhata region where the

With its broad wings, the vulture soar high on thermals. High in the sky, it glides effortlessly, keeping an eye on the ground for food. When it spots a carcass, the bird descends gradually on it in a circular path.

Rajasthan Atomic Power Station (RAPS) is located and its nearby places are home to the Indian Vultures.

Ecology

It inhabits a wide range of habitats like forests, open areas, cultivated lands, villages and towns.

Food

The Indian Vulture is a scavenger that feeds exclusively on carrion. By feeding the rotting organic matter which otherwise would spread infectious diseases to other living things, the Indian Vulture actually helps maintain a clean environment. With its strong digestive system, it can even digest the bacteria that causes anthrax.

Breeding

It nests in colonies mainly on cliffs, and lays single egg every year.

Threats

Besides the common threats like habitat degradation that affects most birds species, the vultures face an exceptional problem that took them almost to extinction. In the mid 2000, a stark decline of Indian Vultures and other Gyps vultures was noticed. After an intensive research, it was found that diclofenac, an anti-inflammatory drug used to treat domestic animals, has been the cause. The drug, which remains inside the carcass of a livestock, affects the kidneys of the vultures and causes death. Lakhs of vultures died in last twenty years and what is left in the wild now is only a few thousands. The bird has been classified as Critically Endangered by the International Union for Conservation of Nature (IUCN).

Text and Photograph:
J. Devaprakash

The author is Senior Manager (Mass Media), NPCIL.
He is also a keen bird watcher and an amateur wildlife photographer.

CMD's Page

प्रिय साथियों,

आप सभी के साथ पहली बार रूबरू होते हुए मुझे हार्दिक प्रसन्नता हो रही है। जलवायु परिवर्तन की वैश्विक चुनौती का सामना करने में परमाणु ऊर्जा के महत्वपूर्ण योगदान से जुड़ी तमाम जानकारियों को आपसे साझा करते हुए काफी खुशी का अनुभव हो रहा है।

पेरिस के वैश्विक जलवायु सम्मेलन के पश्चात भारत एवं अन्य देशों ने पेरिस समझौते को 'रेटिफाय' कर दिया है। जलवायु परिवर्तन को नियंत्रित करने के लिए यह एक ऐसा ऐतिहासिक समझौता है, जिसे व्यापक वैश्विक सहयोग का एक मज़बूत आधार कहा जा सकता है। अपनी इन्हीं विशेषताओं की वजह से 'वैश्विक जलवायु सम्मेलन' में परमाणु ऊर्जा को चौतरफा समर्थन मिला। इसके महत्व को समझते हुए भारत के माननीय प्रधानमंत्री जी ने वैश्विक जलवायु कार्यक्रम के समर्थन में आगे आकर, समझौते को आगे ले जाने के लिए सराहनीय कदम उठाया। स्वच्छ ऊर्जा के स्रोतों को अधिक गतिशीलता से अपनाने के लिए भारत ने निःसंदेह रुप से कई योजनाएँ बनाई हैं, जिनमें से परमाणु ऊर्जा एक अग्रणी भूमिका को प्रशस्त करेगा।

कुडनकुलम साइट को रशियन फेडरेशन के साथ तकनीकी सहयोग से 6 वीवीईआर-टाइप रियक्टर्स के स्थल चुनाव के लिए सैद्धान्तिक स्वीकृति प्रदान की गयी है।

एनपीसीआईएल हमारे देश के करोड़ों नागरिकों को स्वच्छ, सुरक्षित और प्रदूषण रहित विद्युत की विश्वसनीय ढंग से आपूर्ति करने के लिए परमाणु ऊर्जा के शांतिपूर्ण उपयोग की राह पर नित्य सफलतापूर्वक आगे बढ़ रही है और हम अपने देश के नागरिकों को भरोसा दिलाना चाहते हैं कि एनपीसीआईएल इस कसौटी पर खरा उतरने के लिए पूरी तरह से तैयार है।

आपको इस बात से अवगत कराते हुए मुझे बेहद प्रसन्नता हो रही है कि 10 अगस्त, 2016 को देश के सबसे बड़े ऊर्जा उत्पादन संयंत्र, कुडनकुलम परमाणु बिजली घर (केकेएनपीपी-1) की 1000 मेगावाट क्षमता वाली इकाई-1 को भारत और रूस की मित्रता एवं सहयोग को समर्पित किया गया। तत्पश्चात 15 अक्टूबर 2016 के दिन 1000 मेगावाट क्षमतावाली इकाई-2 को भारत और रूस की साझेदारी को समर्पित किया गया।

कुडनकुलम परमाणु ऊर्जा परियोजना की 1000 मेगावाट क्षमता की (केकेएनपीपी-2) की दूसरी इकाई और देश का 22 वाँ 'परमाणु ऊर्जा रियेक्टर' 29 अगस्त, 2016 को दक्षिणी ग्रिड से सिंक्रोनाइज्ड किया गया और अब यह इकाई जनवरी 21, 2017 से शत-प्रतिशत क्षमता पर बिजली का उत्पादन कर रही है। यह इकाई शीघ्र ही व्यावसायिक रूप से कार्यान्वयन आरम्भ करेगी। इस प्रयास से देश में परमाणु ऊर्जा उत्पादन की क्षमता बढ़कर 6780 मेगावाट तक पहुँच जायेगी। यह संयंत्र दक्षिणी ग्रिड को विद्युत की आपूर्ति करने के साथ ही करोड़ों घरों को भी रोशन करेगा।

कुडनकुलम साइट को रशियन फेडरेशन के साथ तकनीकी सहयोग से 6 वीवीईआर-टाइप रियक्टर्स के स्थल चुनाव के लिए सैद्धान्तिक स्वीकृति प्रदान की गयी है। केकेएनपीपी इकाई-3 एवं 4 को सरकार द्वारा पहले से ही स्वीकृति प्रदान की जा चुकी है। इन रियेक्टरों के लिए साइट पर उत्खनन का काम लगभग समाप्ति की कगार पर है और कंक्रीट की पहली ढलाई के साथ निर्माण की योजना इस वर्ष के आरम्भ में की जायेगी।

परमाणु बिजली घर सुरक्षा और परिचालन में लगातार उत्कृष्ट प्रदर्शन करने में अग्रणी हैं और वित्तीय वर्ष 2015-16 में 37456 मिलियन यूनिट विद्युत का उत्पादन किया गया है। वर्तमान वित्तीय वर्ष 2016-17 में 31 जनवरी, 2017 तक 32796 मिलियन यूनिट विद्युत उत्पादन किया गया है। वर्तमान वित्तीय वर्ष 2016-17 में जनवरी 2017 महीने में 14 इकाइयों ने शत प्रतिशत उपलब्धता गुणांक प्राप्त किया है।

हमारे लिए यह बहुत ही गर्व की बात है कि पिछले कुछ वर्षों में भारत ने प्रेशराइज्ड हैवी वाटर रिएक्टर (पीएचडब्ल्यूआर) की तकनीक में सफलता के साथ दक्षता हासिल की है। तकनीक के इस क्षेत्र में हमारी क्षमता व्यापक है। हमने 540 मेगावाट पीएचडब्ल्यूआर की क्षमता को बढ़ाकर 700 मेगावाट कर दिया है। वर्तमान में प्रत्येक 700 मेगावाट क्षमता के 4 स्वदेशी पीएचडब्ल्यूआर-राजस्थान के रावतभाटा में 2 (आरएपीपी-7 और 8) और गुजरात के काकरापार में 2 (केएपीपी 3 और 4) का निर्माण कार्य विभिन्न चरणों में हैं।

देश में परमाणु ऊर्जा की क्षमता में वृद्धि करने तथा उसे सुविधाजनक बनाने के लिए सरकार द्वारा कई महत्वपूर्ण कदम उठाये गये हैं, उन कदमों में से एक महत्वपूर्ण कदम भारतीय बीमा कंपनी जनरल इंश्योरेन्स कॉर्पोरेशन-रीइंश्योरर (जीआईसी-आरई) द्वारा इंडियन न्यूक्लियर इंश्योरेन्स पूल (आईएनआईपी) की शुरुआत की गयी है।

विद्युत उत्पादन में निरंतर वृद्धि हो यही हमारा मुख्य प्रयास है। 1000 मेगावाट यूनिट के 2 वीवीईआर (एलडब्ल्यूआर) और 700 मेगावाट की 2 पीएचडब्ल्यूआर परियोजनायें, कुडनकुलम साइट और हरियाणा के गोरखपुर साइट पर शुरू हो रही हैं।

ग्रीनफ़ील्ड साइटों से संबंधित भूमि अधिग्रहण का कार्य मध्य प्रदेश के चुटका, राजस्थान के माही बांसवाड़ा, आंध्र प्रदेश के कोवाडा और गुजरात के मीठी विर्दी साइटों पर विभिन्न चरणों में हैं। इन साइटों पर जन-जागरुकता अभियान और पूर्व-परियोजना की गतिविधियाँ बेहतरीन तरीके से कार्य कर रही हैं।

देश में परमाणु ऊर्जा की क्षमता में वृद्धि करने तथा उसे सुविधाजनक बनाने के लिए सरकार द्वारा कई महत्वपूर्ण कदम उठाये गये हैं, उन कदमों में से एक महत्वपूर्ण कदम भारतीय बीमा कंपनी जनरल इंश्योरेन्स कॉर्पोरेशन-रीइंश्योरर (जीआईसी-आरई) द्वारा इंडियन न्यूक्लियर इंश्योरेन्स पूल (आईएनआईपी) की शुरुआत की गयी है। परिचालन में ऑपरेटरों के साथ-साथ आपूर्तिकर्ताओं के लिए बीमा पॉलिसीज़ की व्यवस्था की गयी है। आवश्यक अधिनियम के तहत एनपीसीआईएल ने एक ऑपरेटर के रुप में 1500 करोड़ रुपये का पॉलिसी कवर लिया है। इस प्रयास से परमाणु ऊर्जा विस्तार संबंधी समस्याओं को हल करने में सहायता मिली है, साथ ही देश में परमाणु ऊर्जा परियोजनाओं की स्थापना के लिए एक सरल मार्ग प्रशस्त हुआ है।

पर्यावरण का हमारे जीवन में बहुत ही महत्वपूर्ण स्थान है, इसलिए प्रकृति का संरक्षण करना हम सबकी प्राथमिकता होनी चाहिए। इस पहल को आगे बढ़ाने की दिशा में पहले से ही एनपीसीआईएल में कई कार्यक्रम चलाये जा रहे हैं। गंगा से लुप्त होते कछुओं को बचाने के लिए जैव विविधता के संरक्षण के कई महत्वपूर्ण प्रयास किये जा रहे हैं। इसके अलावा बटरफ्लाई गार्डन की स्थापना, प्रवासी पक्षियों के लिए मड-फ्लैट का निर्माण, एविफौना यानि पक्षियों के संरक्षण के लिए क्षेत्र सर्वेक्षण के आयोजन किये जा रहे हैं। इसके साथ ही हम अपने प्रत्येक संयंत्र में स्थापित नेचर क्लब के माध्यम से जैव विविधता संरक्षण के महत्व के बारे में लोगों को भी जागरुक कर रहे हैं।

सर्वांगीण विकास ही हमारी कम्पनी का मुख्य उद्देश्य है। सामाजिक विकास के साथ-साथ देश की सेवा ही हमारी प्राथमिकता है और यह ज़िम्मेदारी हम बखूबी निभा रहे हैं। स्वच्छ और किफ़ायती ऊर्जा के उत्पादन के साथ-साथ, हम ऊर्जा संयंत्रों के आस-पास के क्षेत्रों में रहने वाले लोगों के जीवन स्तर को भी सुधारने में निरंतर प्रयासरत् हैं। अपने इस कदम को आगे बढ़ाते हुए एनपीसीआईएल अपनी निगम सामाजिक दायित्व (सीएसआर) पहल के तहत अपने सभी परमाणु बिजली घरों एवं परियोजनाओं में स्थानीय लोगों के जीवन को बेहतर बनाने के लिए शिक्षा और स्वास्थ्य संबंधी कार्यक्रमों का आयोजन करती रही है।

एनपीसीआईएल लोगों को परमाणु ऊर्जा के बारे में वास्तविक जानकारी प्रदान करने में विश्वास करती है। यही कारण है कि एनपीसीआईएल अपने सभी साइटों और कॉर्पोरेट कार्यालय में बहुआयामी-राष्ट्रव्यापी जन-जागरुकता कार्यक्रम करती है। इस महत्वपूर्ण पहल के तहत ज्ञान-प्रसार के विभिन्न कार्यक्रमों का आयोजन किया जा रहा है, जिसमें प्रर्दशनी, नीति और राय निर्माताओं के साथ बातचीत, व्याख्यान और स्कूल एवं कॉलेज के विद्यार्थियों, शिक्षकों और आम जनता के लिए संयंत्र-यात्रा जैसे कार्यक्रम शामिल हैं। यह सभी कार्यक्रम रोचक, सरल एवं अपने में अनूठे हैं और लोगों के मन से परमाणु ऊर्जा से जुड़ी तमाम भ्रांतियों को दूर करने में काफी कारगर सिद्ध हो रहे हैं।

अपने इस कार्यक्रम को अधिक-से-अधिक लोगों तक पहुँचाने के लिए एनपीसीआईएल ने विज्ञान प्रसार (विज्ञान और प्रौद्योगिकी विभाग, भारत सरकार) और राष्ट्रीय विज्ञान संग्रहालय परिषद जैसे कई पेशेवर संस्थाओं के साथ भागीदारी की है। हमने मुंबई, दिल्ली और चेन्नई में स्थित विज्ञान केन्द्रों में परमाणु ऊर्जा पर स्थायी प्रदर्शनी की स्थापना की है। जिनमे लाखों दर्शक और ख़ास तौर से विद्यार्थी आते हैं और लाभान्वित होते हैं। इसके अलावा, अंतर्राष्ट्रीय और स्थानीय व्यापार मेलों के माध्यम से परमाणु ऊर्जा को बढ़ावा देने के साथ ही नये व्यापार के रिश्तों की शुरुआत भी की है।

सुरक्षा की कटिबद्धता और स्थानीय समुदायों के साथ जमीनी स्तर पर जुड़कर हम निरंतर सफलता की नित नई ऊँचाइयाँ छू रहे हैं। यही कारण है कि एनपीसीआईएल को राष्ट्रीय सुरक्षा परिषद, भारत (एनएससीआई) द्वारा सुरक्षा पुरस्कार, इंस्टीट्यूट ऑफ़ पब्लिक एंटरप्राइज द्वारा कॉर्पोरेट विजिलेंस पुरस्कार, ग्रीन टेक सीएसआर पुरस्कार और पब्लिक रिलेशन्स सोसायटी ऑफ़ इंडिया (पीआरएसआई) के राष्ट्रीय पुरस्कारों से सम्मानित किया गया है।

वास्तव में परमाणु ऊर्जा विद्युत उत्पादन का एक स्वच्छ, हरित और महत्वपूर्ण स्रोत है, जो विश्व स्तर पर कार्बन उत्सर्जन को बड़े पैमाने पर नियंत्रित करके, जलवायु परिवर्तन को रोकने में एक महत्वपूर्ण योगदान दे रहा है। समाज की भलाई और ग्रीन हाउस गैस उत्सर्जन को सीमित करने के साथ-साथ ऊर्जा सुरक्षा की दोहरी चुनौती का सामना करते हुए भारत समुचित परमाणु प्रौद्योगिकी को अपनाने में निरंतर प्रयासरत् है और जनहितकारी परमाणु ऊर्जा कार्यक्रम अपने लक्ष्य की ओर निरंतर आगे बढ़ता ही जा रहा है। आशा है कि हम आने वाले कुछ समय में इन सभी चुनौतियों का सामना करते हुए विश्व पटल पर अपनी सफलता का परचम लहरा सकेंगे। इन्हीं विचारों के साथ मैं आप सभी से इस उम्मीद से अनुमति लेता हूँ कि नया वर्ष आपके जीवन में समृद्धि और खुशहाली लाये।

सादर

एस. के. शर्मा

Through the Lens

Dr. Homi J. Bhabha, the architect of India's three-stage nuclear power programme, at the podium of the United Nations (UN) assembly in Geneva, giving the opening speech of the First UN Conference on the Peaceful Uses of Atomic Energy in 1955.

Image Courtesy: ITER

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
Total		**5780**	

**Owned by DAE*

Projects Under Commissioning

KKNPP-2**, Kudankulam, Tamil Nadu	VVER	1000	

*** Full-power operation on January 21, 2017*

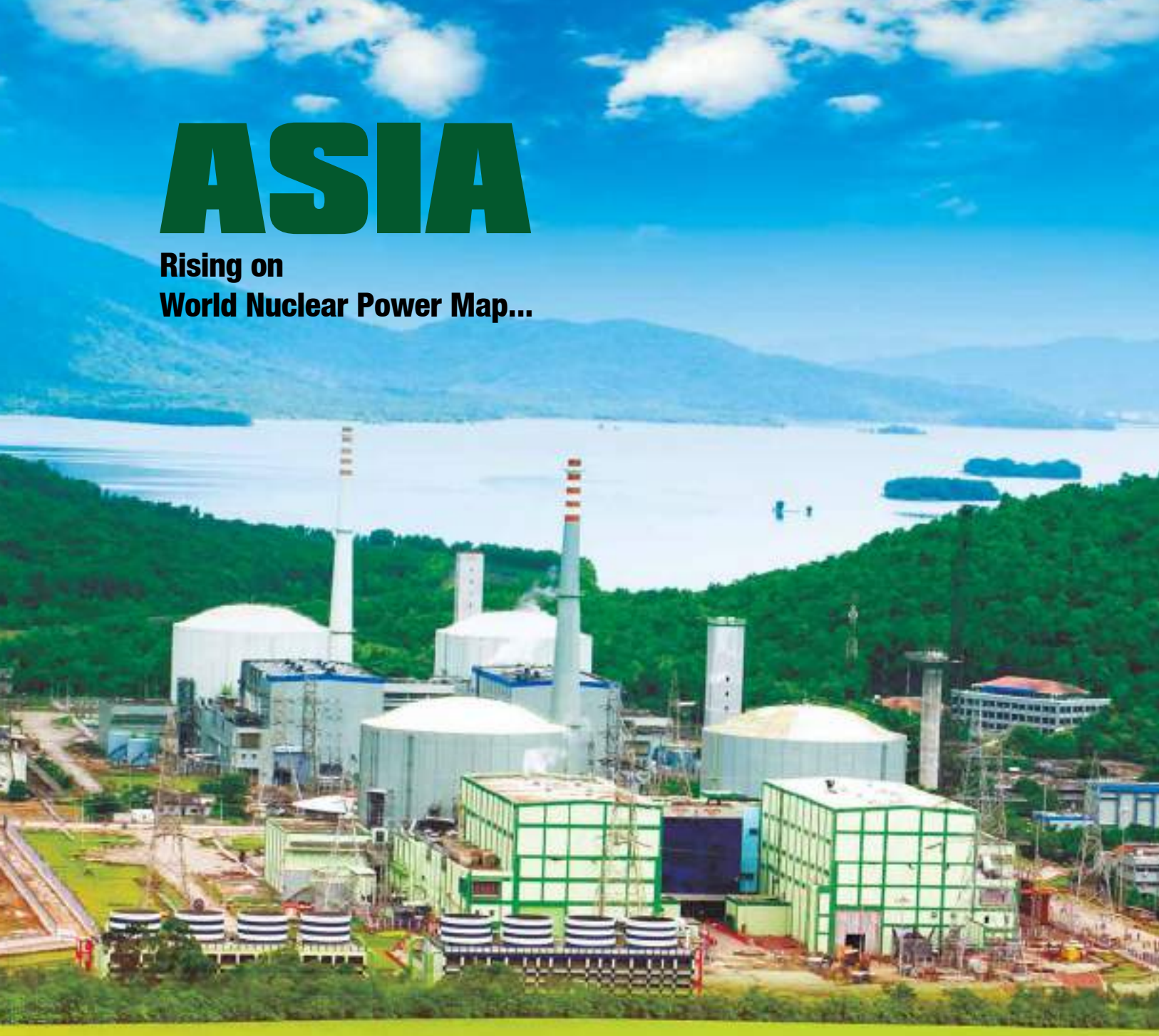
Projects Under Construction

Project	Capacity (Mw)
KAPP-3&4, Kakrapar, Gujarat	2x700 PHWRs
RAPP-7&8, Rawatbhata, Rajasthan	2x700 PHWRs
Total	**2800**
PFBR***, Kalpakkam	1x500 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 60 units currently under construction in the world, two-thirds (41 units) are in Asia. Similarly, of the 164 units planned world over, 103 will be set up in Asia.