# INDIAN NUCLEAR SOCIETY

# INS News Letter

Vol 20 Issue 03 November 2020



## Contents



## OBITUARY

20.9.1952 – 24.9.2020

**Dr. Sekhar Basu**, a renowned nuclear scientist, was Chairman, Atomic Energy Commission and Secretary to the Government of India, Department of Atomic Energy (DAE) from October 2015 to September 2018. Prior to his assumption of charge as Secretary, DAE, he was holding the position of Director, Bhabha Atomic Research Centre (BARC) from June 2012 to October 2015. Earlier he worked as Project Director of Nuclear Submarine Programme and later as the Chief Executive of the Nuclear Recycle Board in the same institute. Dr. Basu, a dynamic engineer of exceptional abilities, played major role in establishing India as a lead country in various domains of nuclear science and engineering.

Dr. Basu, born in 1952 at Muzaffarpur in Bihar, did his schooling from Ballygunge Government School, Kolkata and graduated in Mechanical Engineering from VJTI, University of Mumbai in 1974. After completion of one year of BARC Training School programme in nuclear science and engineering, he took up the responsibility of the development of nuclear submarine propulsion plant and was responsible for achieving success in the same. Subsequently, he took up activities related to India's nuclear recycle plants. Under his leadership, the plant operations were streamlined and based on operational experience he took up a very major challenge of design & construction of Integrated Nuclear Recycle Plant, which is first of its kind in India. His untiring efforts in this field have brought perfection in technology and given major boost to the programme.

Dr. Basu accelerated the pace of Nuclear Power deployment, Uranium Exploration and Mining, Healthcare and Mega science projects. He played a key role in obtaining government approvals for Ten Pressurized Heavy Water Reactors (PHWRs) and Two Pressurized Water Reactors (PWRs). This is a major boost towards increase of installed capacity of nuclear power stations.

Dr. Basu was an extremely competent technologist with an ability to integrate multi-disciplinary activities and develop multiple state of the art technology systems. He was awarded Padma Shri by the Government of India in 2014. One of the last projects in which he had taken keen interest was to develop the technology of cyclotron for medical isotope production.

It is with great sorrow, we announce the sad demise of Dr. Basu in the early hours of 24th September 2020 in a hospital in Kolkata. Dr. Basu was undergoing treatment for COVID-19.

Department of Atomic Energy

## From Editor's Desk

It is a matter of great relief that a declining trend has been observed in the COVID active cases as well as in fatalities registered in the country during last few weeks. However, this Pandemic has already taken a toll of 1.2 L country men which includes many DAE personnel and INS members. Our beloved former Chairman AEC, Sh. Sekhar Basu too unfortunately succumbed to COVID in the early hours of 24$^{th}$ Sept.' 2020 in a hospital in Kolkata. INS prays for the peace of all the departed souls.

Finally, EC (2020-2022) assumed charge on 5$^{th}$ Oct.' 2020 (with an MOU signed between the outgoing and incoming EC office bearers). There are plethora of administrative / accounts related issues which the EC has started addressing from the day one. Decision has also been taken to start the INS webinars and members can look forward to the announcement of the first webinar.

With the criticality of first 700 MWe PHWR (KAPP-3) on July 22, 2020 at Kakarpar, Gujarat, India has achieved a new milestone in its indigenous PHWR program. It shows the commitment of NPCIL towards the national policy of '*Atmanirbhar Bharat*'. Shri A.K.Balasubrahmanian, Director (Technical), Nuclear Power Corporation of India Limited has given a vivid account of the journey of PHWRs in the country from 1964 onwards. It is heartening to observe that several improvements in the design and safety features were incorporated in this journey based on our own experience of 530 PHWR years. I would like to thank Dr R.B. Grover, Emeritus Professor, Homi Bhabha National Institute for kindly agreeing to be the Guest Editor for this issue.

October is the month of announcements of Nobel Prizes. A compilation of the Prize winners for 2020 by Dr Indira Priyadarsani has been included in this issue. Within the country, prestigious "Shanti Swarup Bhatnagar Awards 2020 "were announced on 26$^{th}$ Sept. INS would like to congratulate all the awardees and in particular Dr Kinshuk Dasgupta of Materials Group, BARC for his work on carbon based nanomaterials and composites leading to the development of Bhabha Kavach, a light weight import substitute ballistic resistance jacket for the Indian armed forces..

I would like to urge once again all the members to send their views on the NL to insvkmeditor@gmail.com . It will help us tune the contents as per their feedback. I would like to thank the Authors, Editorial Board members and EC members for their whole hearted support in the publication of the NL. INS wishes all members safe and joyful festive season and a very happy New Year.

**Vijay Manchanda**

## From Guest Editor's Desk

Pressurized Heavy Water Reactors (PHWRs) are the mainstay of the Indian Nuclear Power Programme. The PHWR programme started with the setting up of two reactors, 220 MW rating, at Rawatbhata. After setting up a series of 220 MW reactors, the size was increased to 540 MW. Now NPCIL is moving to set up a series of 700 MW reactors, with the unit-3 at Kakrapar, having already achieved first criticality. Sh. A. K. Balasubrahmanian, Director (Technical), NPCIL, provides information in detail about the 700 MW PHWR in the lead article.

Let me share my views about the role of nuclear energy in India's electricity mix. Per capita electricity generation in India is lower than the world average. The Human Development Index (HDI) is an index developed by United Nations Development Programme to monitor the wellbeing of citizens of various countries. It is a composite index combining three indicators: life expectancy, education, and per capita income. A plot of HDI versus per capita electricity consumption indicates that initially HDI increases with per capita electricity consumption, and then saturation sets in. To have a high HDI that is about 0.9, a country needs to have per capita annual electricity consumption of about 5000 units. Consumption in countries having tropical climate such as Malaysia and Thailand is already close to this number. India cannot be different.

India's population is estimated to peak at 1.6 billion by the middle of this century. Taking transmission and distribution losses at the minimum technically feasible level of about 7%, India needs a total annual generation of about 8700 billion units. This may be compared with generation (from utilities and captive power plants) of about 1600 billion units in the year ending on 31.03.2020.

How to generate 8700 billion units per annum? Imperative of climate change calls for deployment of all low carbon technologies and that includes hydro, nuclear, solar and wind. One comes across opinions advising moving to a frugal way of life and managing only with generation from renewable energy, but ground reality is different. Gross electricity generation in India has seen Cumulative Average Growth Rate (CAGR) of 5.49% during 2009-10 to 2018-19, and flattening in recent times is a temporary phase. Despite claims by some regarding India being a power surplus country, about 40 million households are still without electricity, and erratic power supply is forcing households to go in for backup solutions as load shedding is a recurring feature in several parts of the country. Looking at the increasing sale of air-conditioners, refrigerators and other electrical appliances, increasing demand for cold storages, increasing level of urban pollution calling for a shift to electrical vehicles, structural changes in the economy favouring a shift to the use of electricity in industry, and anecdotal evidence pointing to rebound effect working to gnaw part of the gains achieved by improvements in energy efficiency, one can forecast four to five percent CAGR in the demand for electricity over three to four decades.

Hydro, solar and wind can at best provide about a quarter of the target demand of 8700 billion units. The rest has to come from nuclear and coal. The country has to ramp up generation by nuclear so that generation by coal can be ramped down.

Sh. A. K. Balasubrahmanian provides an overview about the programme to set a series of 700 MW units, which is a step toward ramping up nuclear generation. Despite ongoing pandemic, NPCIL engineers have managed to achieve first criticality in the 700 MW unit at Kakrapar. Many more similar units will come up in future.

**R B Grover**

Dr. R B Grover is working as an Emeritus Professor in the Homi Bhabha National Institute (HBNI) and was its first Vice Chancellor (2005-2016). He is a member of the Atomic Energy Commission. He was Principal Adviser in the Department of Atomic Energy during 2010-13. He was conferred with a Padma Shri in 2014 .

### Founders Day

Department of Atomic Energy (DAE) celebrated this year's founder's day in a special way on October 30. Shri K N Vyas, Chairman, AEC and Secretary to Govt. of India, inaugurated the Technology Development cum incubation centers at BARC, RRCAT, IGCAR VECC and IPR .The entire programme was conducted on line and transmitted live on you tube.

## DAE contributions in national mission to meet the challenges of COVID Pandemic

DAE with its multidisciplinary expertise and broad technological base has been actively developing materials and processes to meet the challenges of COVID-19 pandemic. Some developments are summarized here.

1) **Chlorophyllin for treatment of COVID-19**: Covid 19 is associated with severe depletion of immune cells, increased inflammation, and death of epithelial cells (pneumocytes). Since chlorophyllin was shown to improve immunity , reduce inflammation , prevent death of epithelial cells and also inhibit other viruses like hepatitis C virus, polio virus and HIV, it was proposed for possible treatment of COVID-19. Phase 1 clinical trials of chlorophyllin have been initiated on mildly symptomatic as well as severe cases of COVID-19 patients with approval of Kasturba Hospital for infection diseases, Tata Memorial Hospital, and Director General Indian Council of Medical Research. Preliminary results are encouraging.

**2) IOT based COVID beep:** ECIL developed a watch like wearable device COVID-BEEP for remote monitoring of the COVID-19 patients. It measures vital parameters of the patients such as body temperature, blood oxygen level, heart beat, respiration rate, ECG and blood pressure and transmits them to an IoT gateway which in turn sends the data to cloud / private server in an appropriate format. The data can then be accessed by the doctor on either his mobile phone or computer through Wifi, LAN or WAN. The prototype has been tested on patients in ESIC Medical College Hyderabad.

**3) Capture of Virus by Self-Assembled Carbon Nanotube based Filters**: Size of the SARS-CoV2 virus is in the range of 80-160 nm while the average pore size of CNT-wool is below 100 nm. In comparison , N-95 masks have a pore size of 300 nm. It is envisaged that CNT wool will be very effective in trapping SARS-CoV -2 virus and therefore better suited to make face masks. A patent has been filed for BARC developed floating catalyst chemical vapor deposition technique which enables self assembly of CNTs to form into sheets of wool.

**4) Serological Survey to Assess Prevalence of COVID -19 in Mumbai** : Tata Institue of Fundamental Research , in a joint venture with Translational Health Science and Technology Institute, Faridabad, University of Chicago, Duke University, ATE Chandra Foundation, Mumbai, Kasturba Hospital, Mumbai under the aegis of NITI Ayog and in partnership with BMC has undertaken a serological survey of 10,000 randomly selected asymptomatc residents of Mumbai , both in slum and non slum areas. Preliminary results indicated that in slum areas antibodies were detected in 57% of the population which is close to the herd immunity.

5) **Development of RT-PCR based KIT for COVID-19:** In response to the present COVID-19 pandemic, BARC has developed an RT-PCR kit for detecting the SARS-COV 2 virus. The detection in this kit occurs by the use of oligonucleotides primers and probes specific to two different and highly conserved regions of the viral genome. The kit was assembled and standardized using virus derived synthetic DNA fragments. After initial validation of the kit at Kasturba Hospital for Infectious Diseases, Mumbai further validation for deployment for clinical use is in progress at National Institute of Virology , Pune. The kit costs about Rs 400/-.

## Shanti Swarup Bhatnagar Prize for Science and Technology 2020

The prestigious S. S. Bhatnagar Prize in Engineering Sciences has been conferred upon Dr. Kinshuk Dasgupta of BARC, recognising his outstanding contributions in the area of large-scale synthesis of carbon nano-tubes leading to the development of light-weight bulletproof jacket also known as the Bhabha Kavach.The jacket material developed by Dr. Dasgupta, is a low-cost import substitute AK-47-HSC bullet resistant level III+ material and has been inducted into the armed forces.

**Editor**



## 700 MWe Indian Pressurized Heavy Water Reactor

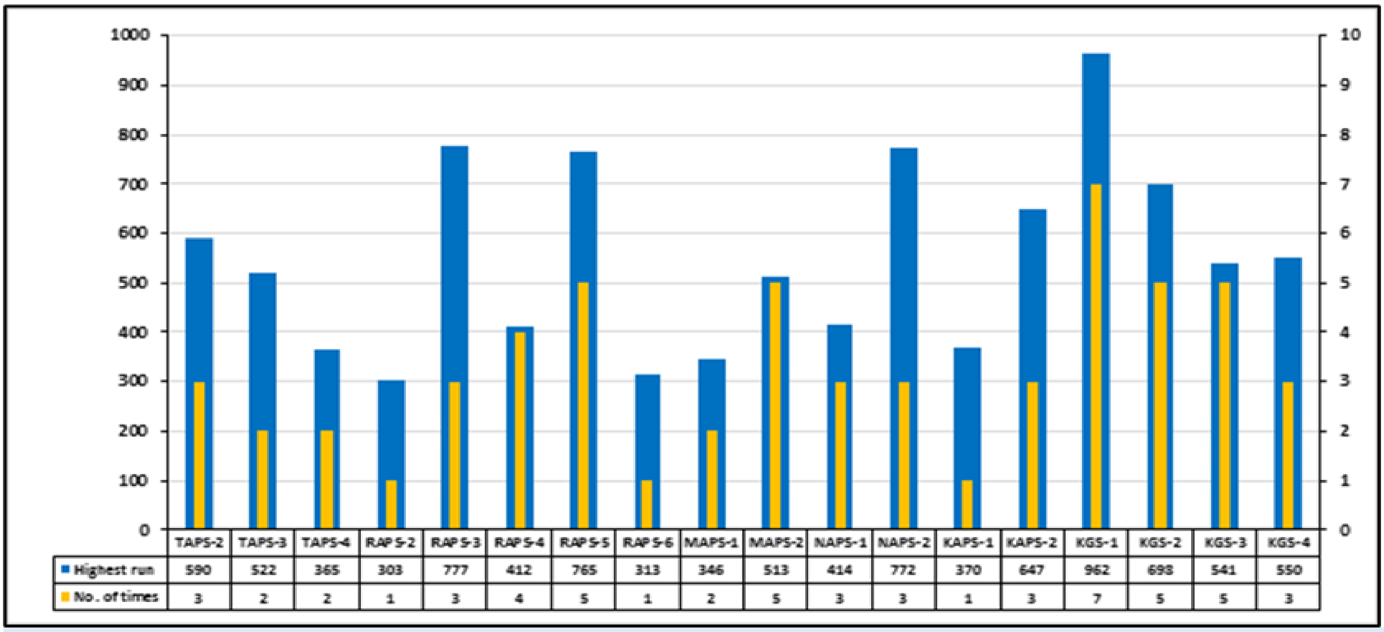
Responsibility of design & engineering, construction, commissioning and operation of Nuclear Power Plants (NPPs) for the first stage of Indian Nuclear Power Programme is with Nuclear Power Corporation of India Limited (NPCIL). Over the years, NPCIL has developed a unique status of an *all-rounder* in setting up NPPs in the country, with expertise in all facets – siting, design & engineering, stress analysis & seismic qualification, safety analysis, procurement, quality assurance, construction, commissioning, operation, maintenance, waste management, ageing management, refurbishment & modernization and plant life extension. The scientific and technical expertise gained within NPCIL and various units of the Department of Atomic Energy (DAE), along with the capability of Indian industries to support the national nuclear power programme gives India, a total '*Atmanirbharta*' in this high-end technical field.

The members of Indian Nuclear Society (INS) are well familiar with the contributions made by various DAE Units and the potential established in them over years to carry the programme forward. However, for very young members of INS, a brief mention of the route travelled so far to reach 700MWe is also included.

### The Journey up to 700 MWe PHWR

The construction of India's first nuclear power station at Tarapur (Maharashtra) consisting of two Boiling Water Reactors (BWRs) by General Electric, USA on a turnkey basis, was commenced in the 1960s. The main objectives of setting-up these units were to prove techno-economic viability of nuclear power, to obtain experience in operation and maintenance of nuclear power plants and to demonstrate technical viability of operating nuclear power stations in the Indian regional grid system. All the components of the power plant and nuclear fuel were imported and the role of Indian industries was limited to certain construction, erection and service contracts. These reactors were handed over on completion to DAE for operation & maintenance and commenced commercial operation in 1969.

As Pressurized Heavy Water Reactors (PHWRs) were part of the first stage of Indian nuclear power programme, India and Canada started a collaboration in 1964, to set up a twin unit PHWR power station in Rajasthan, for which Canada furnished nuclear designs and also supplied all the main equipment for the first unit. Indian responsibility was construction, installation and commissioning. For the second unit (RAPS-2), manufacture of many of the reactor components was taken up




Continuous Operation of PHWR Units for more than 300 days
(data updated up to October 05, 2020)

in India and the import content was reduced considerably. The first unit started commercial operation in December 1973. Canada withdrew support for the plant in 1974 after the Pokhran test and India carried out remainder of the design, construction and commissioning work of the second unit of RAPS.

The period following 1974 demonstrated the strength of scientific and technical capability created in the country by DAE. In 1980s, two 220 MWe PHWRs (MAPS-1&2) were constructed near Madras (now Chennai). From the Madras Atomic Power Station (MAPS) consisting of two units, MAPS-1 and MAPS-2, at Kalpakkam, Tamilnadu, India started carrying out all facets of the work for setting a PHWR on its own. Compared to RAPS-1 and RAPS-2 design, which were based on the Canadian Douglas Point reactor, certain design changes were incorporated at MAPS. These include replacing dousing tank with suppression pool for vapour suppression to limit the containment peak pressure during loss of coolant accident and partial double containment. Also, in the backdrop of problems with the end shields in RAPS unit-1, the end shield material was changed from 3.5% Nickel Carbon Steel to SS 304L for MAPS-2.

After gaining experience in setting up of RAPS and MAPS, a standardized design of 220 MWe reactor was developed. This incorporated major design modifications in terms of two independent fast acting shut down systems, high pressure emergency core cooling system, integral calandria and end shields, water filled calandria vault and double containment with modified vapour suppression pool. Four such reactors, two each at Narora, Uttar Pradesh and Kakrapar, Gujarat were set up. Eight more 220 MW PHWRs, with some more modifications such as locating the steam generators fully inside the primary containment, complete pre stressed concrete construction for primary containment with dome and a compact site layout, were set up at Kaiga and Rawatbhata subsequently.

In parallel, design and development of larger size 540 MWe PHWR unit was taken up in 1980s. The experi-

Kakrapar, Gujarat Site – (L) 2x220 MWe PHWRs and (R) 2x700 MWe PHWRs ence of design, construction and operation of 220 MWe units provided significant inputs in the design of 540 MWe PHWRs. These reactors consist of certain features and systems, which were demanded by their larger size. Construction of two 540 MWe units at Tarapur was commenced in the year 2000. The construction of these units in a record time in line with international bench mark and later smooth commissioning and successful operation confirms maturity achieved in design, development,

| 700 MWe PHWR Projects | |
|---|---|
| Under Construction | Sanctioned in Fleet Mode |
| KAPP-4 (Kakrapar, Gujarat) | GHAVP-3&4 (New site, Haryana) |
| RAPP-7 (Rawatbhata, Rajasthan) | KGS-5&6 (Kaiga, Karnataka) |
| RAPP-8 (Rawatbhata, Rajasthan) | Chutka-1&2 (New site, Madhya Pradesh) |
| GHAVP-1&2# (New site, Haryana) | Mahi Banswara- 1 to 4 (New site, Rajasthan) |
| *#: Excavation completed. Regulatory review is in final stage of completion for consent for first pour of concrete.* | |

construction and commissioning of nuclear power plants in the country.

While describing this glorious journey of about 530 reactor years of safe operation of Indian NPPs so far, it is a matter of national pride to mention that the first NPP in India (consisting of two boiling water reactors, at Tarapur Atomic Power Station) has completed 50 years of safe operation (worldwide, there are only three more reactors to achieve this milestone), and almost all of Indian PHWR based NPPs have logged long continuous operation (see figure below), for example Unit-1 of Kaiga Generating Station logged 962 days of continuous operation.

With 540 MWe PHWRs, NPCIL gained experience of design and operation of larger PHWR units. Recognizing that the reactor core of 540 MWe, with 37 element fuel bundles, has potential to generate higher fission power, ensuring safety margin, it was decided to design a reactor of higher fission power using the same core. This endeavor culminated in the design of a reactor with 2166 MW thermal power and 700 MW electrical output.

The practice well established over the years during growth of the nuclear power programme to update the design, safety features, project execution and other state of the art technological inputs was adopted for 700MWe Units also. As a number of 700 MWe PHWRs are planned, proactive initiatives have been taken for forward looking design changes, also taking into account, feedback received from previous projects. Standardization of design, engineering, upgrading safety analysis and management systems has been attempted in a manner that these remain valid for implementation of number of such units in the fleet mode in coming time.

India's first 700 MWe PHWR (KAPP-3) attaining criticality on July 22, 2020 is a landmark in the saga of indigenized nuclear reactor technology. This unit is a forerunner to five more units under construction and another ten units sanctioned and to be implemented in fleet mode.

Readers of this paper from INS are well familiar with the basic features of Indian PHWRs and how they have evolved over time with entirely indigenous efforts of DAE and Indian industry. The following, while making passing remarks to the predecessor 540MWe, and over all plant specific requirements for increased power to 700 MWe PHWR, places emphasis on some examples of additional evolution in engineering process, design, safety systems and project management for 700MWe units lined up now. Some of the challenges faced in project implementation will also be referred.

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The basic design of 700 MWe PHWR is similar to 540 MWe PHWRs. Design activity for 700MWe units was actively initiated after 540MWe units at Tarapur were put in operation successfully in the year 2005. Feedback was gathered systematically from construction, and operation teams regarding design, construction, project management, equipment performance including operation and maintenance activities specifically from the 540MWe Units as also from all other operating Units. An exclusive think tank and design group was given responsibility to work out overall design specifications, data book and overall conceptual design to be achieved and to estimate quantum of work for detailed design, development and analysis. The Group included experts from each system of the plant and with members having field engineering, operation and maintenance experience to provide practical inputs desired in the product for ease of construction and O&M. The broad boundary conditions thus worked out were followed later by individual design sections in their area. Major processes followed and the design outcomes in some of the main nuclear systems of plant are covered below. The design includes a number of 'First of A Kind systems/features', which, for the immediate attention of the reader are identified as ***'FOAK'*** in the subsequent write up.

## Engineering of the Project- In-house expertise and strength

The design and engineering work involved for 700MWe project was to make changes in equipment design and process control means/algorithms etc., commensurate with the increased power of the unit. Apart from these, following broad targets were also planned and executed for engineering the project:

- Design and engineering of all systems within nuclear island for KAPP 3&4 to be carried out by NPCIL in-house. Almost all design and engineering of nuclear systems, auxiliary systems, civil buildings, electrical systems to be designed in-house for an integrated approach and preparing younger team for series of plants to follow. All the Systems, Structures and Components (SSCs) were designed, analyzed and qualified meeting the requirements of design and Regulatory codes.

- Feedback gathered on design, construction, project management, equipment performance including operation and maintenance activities from the previous 540MWe Units as well as from all other operating Units to be utilized.

- Review and updating all equipment technical specifications in line with current industry standards and experiences in manufacture/supply and quality control during previous procurement or from operational feedback.

- Minimizing variety of equipment used by different designers of system and using identical components where feasible so as to simplify procurement, maintenance efforts and life management during operating life.

- Observations from previous projects regarding any imported components etc., by contractors. Proactive action to develop almost all of them in India.

- Current Regulatory requirements to be met as well as emerging directions in regulatory expectations both at AERB and internationally to be considered. Also, included the lessons learnt from earlier Regulatory reviews and to enhance analytical and experimental validation of certain design and safety features.

- Contracting conditions for procurement of equipment and components and project execution to take into account feedback from contracting agencies, finance groups as well as utilizing the advice and feedback from other power PSUs. Attempt to make other reputed contractors to take up nuclear work.

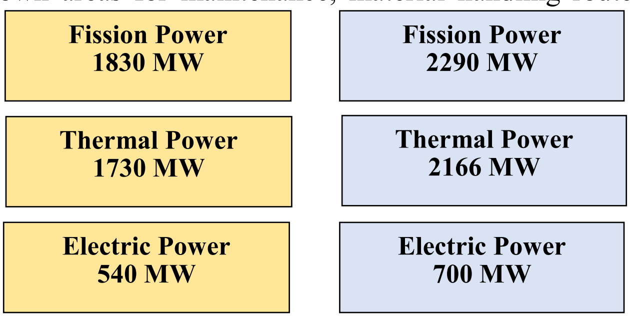
- Engineering using a 3D platform and a LAN based document management system to be adopted to evolve a clash free layout and to facilitate recording and prompt communication of all documents, drawings etc., with inbuilt version control.

Integrated detailed engineering of the plant was adopted in a virtual 3-D environment for the first time for KAPP-3&4 with the integration of 2D intelligent data base and 3D data base so as to prepare a standardized document base for all upcoming 700MWe units. There were difficulties to begin with like non availability of commercial software to NPCIL, customization of the 3D software as per NPCIL requirements, lack of experienced consultants and in-house capability in NPCIL with the involved processes for a large project. However, determined sustained efforts by all involved led to completion of the work. In-house capability as well capability among consultants is now available for these processes for a complex project like NPP.

Intelligent data base of plant components, specifications for different SSCs and other information required for 3D modelling and extraction of construction deliverables are now available as a part of 3D database for 700MWe Units.

For KAPP 3&4, construction deliverables in nuclear island like civil drawings, piping layout drawings, cable tray layout drawings, ducting layout drawings, support drawings and schedule, bill of quantity for procurement were extracted from centralized 3D data base.

3D modelling permits virtual construction for interference study. The 3D model incorporates layout of equipment, piping, tubing, cables, ducts, junction boxes, lay down areas for maintenance, material handling routes,



approach for inspection etc. The overall model is available in an integrated manner to ensure clash free construction, plan construction sequence and ensure proper access for subsequent operation and maintenance. The model was used extensively in all stages of project management. The walkthrough facility of the 3D modeling software was utilized extensively by O&M personal at site for formulating system testing schemes, commissioning strategies and procedures. The model is retained live with all the subsequent modifications routed through it after updation of the same.

For balance of the plant like turbine island and other utility systems of KAPP 3&4, engineering was done by EPC contractors.

Further, a Project / Product Lifecycle Management (PLM) software, also known as Total Engineering Support System (TESS) has been implemented from KAPP 3&4 onwards for managing entire project lifecycle information through all the stages like pre-project, engineering, procurement, construction, commissioning and operation & maintenance of the plant from a central repository. PLM has automated document and drawing release process, seamlessly using electronic workflow, simultaneously at Headquarters and at Project sites.

All drawings and documents are issued and available in TESS-PLM, which is accessible to all engineers of design & engineering, procurement, quality assurance, other engineers of headquarters and all construction sites through intranet (LAN). Thus, engineering document preparation, its issue for use, updation/revisions, storage and retrieval across the project organization is online.

## 700 MWe PHWRs – Major advances in design and safety features

In 700 MWe PHWRs, system design has capability for mitigation of beyond design basis events. Such events, known as design extension conditions in the current regulatory requirements, are explicitly addressed by providing mitigating systems and features.

The core design of 700 MWe is same as that of 540 MWe PHWR, but the energy extracted is uprated 25 % by allowing partial boiling (above ~ 85% full power) to the extent of 2 to 3 % quality at the exit of coolant channel (***FOAK***). Flow balancing and power distribution in channels have been done to ensure uniform quality at the exit of coolant channels. The increase in nominal maximum channel power from 5.5 to 6.5 MW contributes 18% more power output and additional 7% is achieved by modified burnup zones for achieving higher flux flattening. The 700 MWe reactor core is designed to produce 2290 MW of fission power and 2166 MW of thermal power to coolant.

### Reactor Core

The reactor core in 700 MWe PHWR is same as in 540 MWe PHWRs, consisting of calandria, two end shields, coolant channel assemblies and the reactivity devices. In the core, there are 392 coolant channel assemblies each consisting of Zr-2.5 % Nb pressure tube, kept concentric to its calandria tube by four tight-fit garter springs with end fittings at either end. Pressure tubes are connected to end fitting by zero clearance rolled joint to minimize residual stresses. These coolant channel assemblies pass horizontally through end shields and project out of calandria vault in order to facilitate feeder connection and on-power refueling. The coolant channels are separated with a lattice pitch of 28.6 cm for optimum neutron moderation. Each pressure tube contains twelve numbers of 0.5 m long, 37 elements Natural Uranium fuel bundles.

While the broad features and sizing of components in the reactor are same as in 540 MWe units, certain changes in feeder sizing, feeder layout, end shields and pressure tube manufacturing have been made as brought out below.

In order to limit the two-phase pressure drop from channel exit to outlet header, feeder sizes have been increased as feasible in 700 MWe PHWRs. To achieve the layout of feeders of increased diameters and to maintain desired gaps between feeders, thickness of end shields has been marginally reduced. Consequential marginal increase in radiation fields is taken care by augmentation of shielding of viewing window wall which is opposite to each end shield. Under shutdown conditions, radiation fields in FM vault are within acceptable limits. Also, stresses in end shields are estimated to be within acceptable limits.

There is sufficient performance data generated for Zr-2.5%Nb alloy pressure tubes developed and manufactured earlier and in use in all PHWRs now. While the performance has been satisfactory, as a part of further improvement in the diametrical creep characteristics of the pressure tubes, Technical Specifications of the material and texture of the finished pressure tube have been revised following extensive studies. This required changes in manufacturing route of the pressure tubes at Nuclear Fuel Complex (NFC). Trial fabrication by the new route was subjected to testing of large number of samples by NFC and BARC for qualification of the new manufacturing route of pressure tubes for 700 MWe (and now for 220MWe replacement pressure tubes too). The modified fabrication process is expected to further extend life of pressure tubes in PHWRs.

## Reactor Regulation and Shutdown

Reactor regulating system and reactor shutdown systems in 700 MWe PHWRs are generally similar to 540 MWe PHWRs. For large sized PHWRs, starting from 540 MWe units, the reactor is required to be controlled in several local regions known as zones. This is achieved by Liquid Zone Control Units. In addition, control rods and adjuster rods are provided for reactivity control in normal operating conditions.

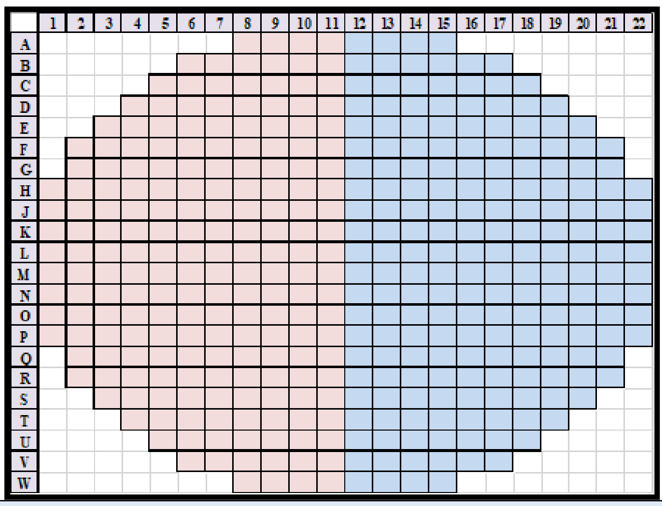
Two fast, independent, physically separate shutdown systems, working on diverse principles, ensure reliable fulfilment of shutdown function; with each system acting alone capable to safely shutdown the reactor from all operational states as well as postulated accident conditions. The first consists of spring-assisted gravity-driven cadmium shut-off rods and the second system employs injection of gadolinium nitrate into the calandria.

Three Pitch Long Self Powered Neutron Detector

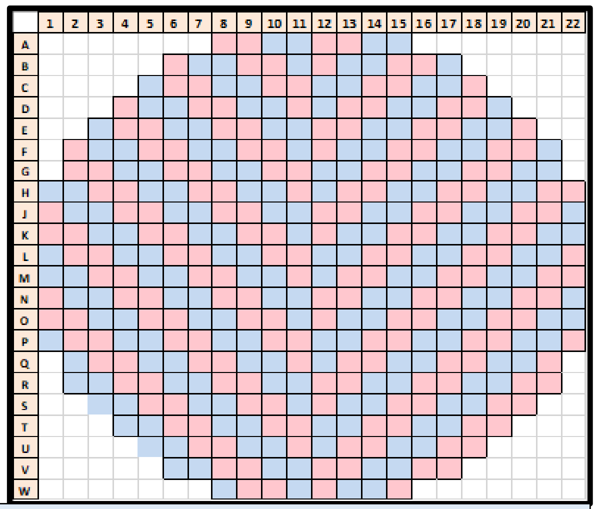
Extensive in-core instrumentation based on Self Powered Neutron Detectors (SPNDs) is provided for control and protection purpose. Various reactivity devices are used for control and protection of the reactor. These devices, together with the associated instrumentation, automatically maintain the reactor power at pre-set levels and shut down the reactor on sensing identified parameters exceeding the set limits.

In 700 MWe PHWRs, to ensure that local power remains within limits and thereby to maintain fuel safety, a new protection in the form of regional overpower trip (***FOAK***) is provided on both shutdown systems. Reactor physics simulations have been carried out earlier for 540 MWe reactor and now for 700 MWe reactor considering various configurations of reactivity devices, that are possible in the operating reactor core, to make appropriate choice of locations for detectors (SPNDs) belonging to the shutdown systems.

For control and protection of large PHWR, ex-core detectors are not reliable because they measure only leakage fluxes. Degradation of spatial power control or non-uniform refuelling may result in zone powers, Channel Power Peaking Factors and bundle powers beyond their desired values. Large numbers of SPNDs have been provided for detecting these conditions and to give signal for control/protection function for the desired action. These detectors are rugged by design and have long life in the harsh reactor environment. These do not need external power supply like other conventional detectors. Since partial boiling in channels is envisaged at power levels above ~85 % FP, channel outlet temperature measurement is not available for zone power estimations for flux tilt control in 700 MWe. Instead, signals from a number of vanadium SPNDs in Flux Mapping System (FMS) and associated algorithm provide the zonal powers required by the reactor regulating system (RRS) for spatial power control. It also provides information to RRS for initiating reactor setback when Channel Power Peaking Factor (CPPF), zone power and bundle power envelope exceed their respective set points.

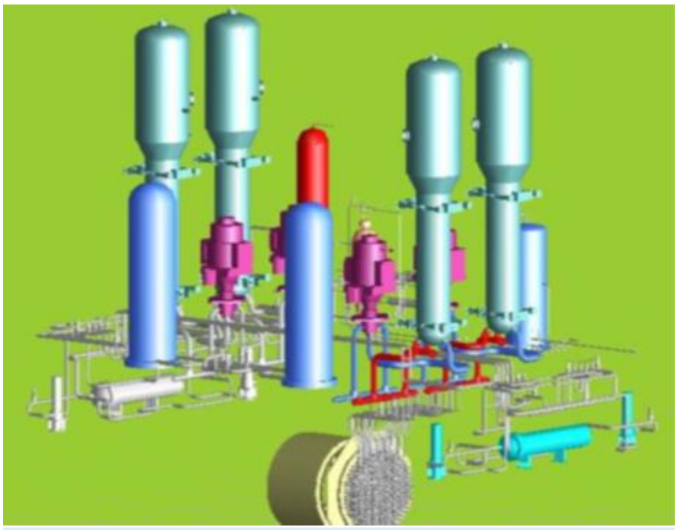


Different Loop in Radial Half (540 MWe)



Interleaved Loop Design (700 MWe)

Two Loops of Primary Heat Transport System (540 MWe and 700 MWe)



Primary Heat Transport System

The set points are chosen such that enough operating margin from trip level is available and the technical specification limits on bundle and channel powers are complied with.

Taking into consideration the operating experience of smaller length SPNDs in 540 MWe, Integral 3-pitch long Inconel SPNDs (***FOAK***) were developed. 3-pitch long SPNDs (see figure below) indicate regional average and are not affected during refuelling or by any local perturbation. Feedback on life limiting causes experienced in SPNDs initially used in 540 MWe prompted NPCIL to develop and implement solutions to enhance reactor life of SPNDs and to minimize radiation dose to maintenance personnel during replacement of SPNDs.

## Primary Heat Transport System

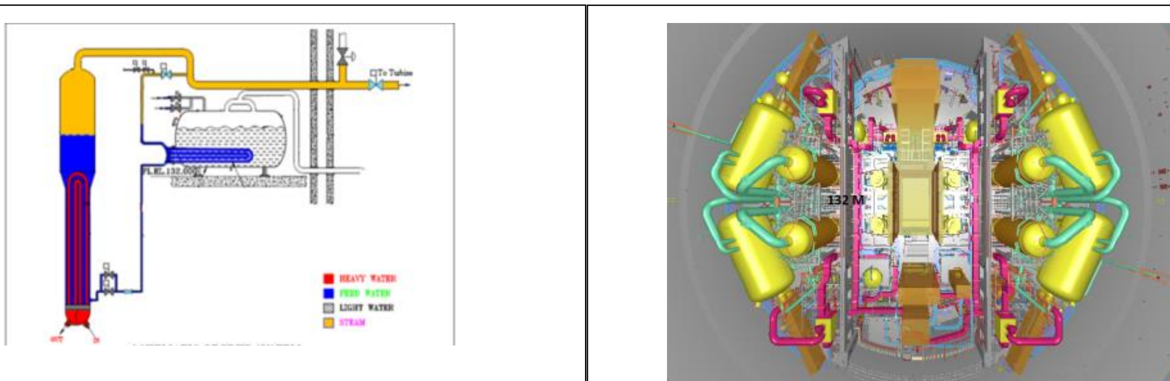
The primary heat transport system has two independent and identical loops of figure of eight. In 540 MWe PHWR, coolant channels in each vertical half of the reactor are served by one loop. 700 MWe has these loops feeding alternate channels (see figure below). This is done by adopting interleaving of feeders, as against distribution in two vertical halves. Each loop has two steam generators and two circulating pumps. This arrangement, which is introduced for the first time (***FOAK***) in any PHWR in the world, is aimed to minimise positive void coefficient of reactivity by uniformly distributing coolant voids resulting from the postulated event of loss of coolant. Interleaving of feeders has made feeder layout more complex than it has been. Alternate feeder is connected to a different header. Feeder lengths have increased and also the length of Headers has increased.

**Core Cooling – Safety in all conditions**

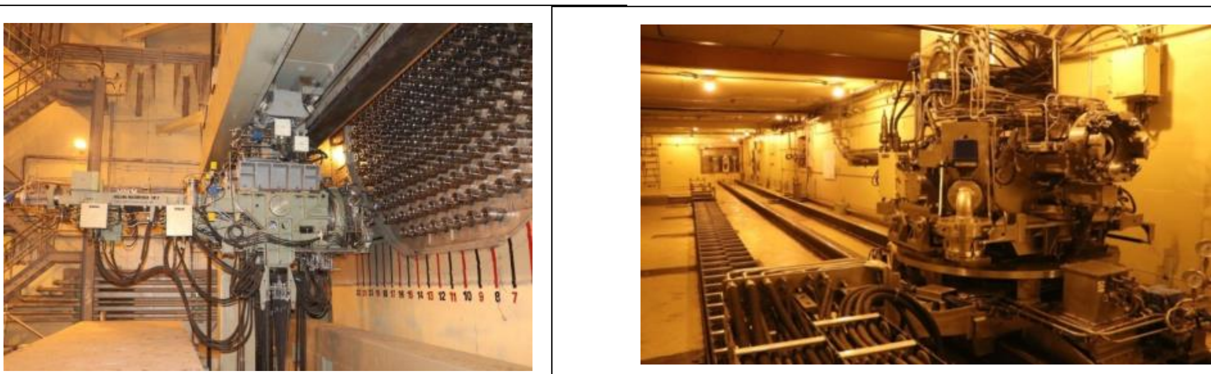
The Primary Heat Transport (PHT) system is designed to ensure adequate cooling of reactor core under various plant states. In normal power operation, PHT system extracts and transports the heat generated in the fuel to the Steam Generators (SGs). Steam produced in SGs is utilized by turbine generator for electric power generation.

Steam Generators for 700 MWe have been designed in-house and use appropriately forgings procured earlier as bulk purchase for more 540 MWe Units. It was seen that SG manufacturers have been importing SG tubes for earlier plants. NPCIL initiated proactive action to prompt industry to manufacture large size nuclear grade forgings and extra-long SG tubes in the country. Nuclear Fuel Complex (NFC) manufactured the 30m long SG tubes on orders received from SG manufacturer. Forging set up has produced SG shells as part of a trial order. Large size nuclear grade forgings made in India for SGs, Pressurizer etc. will be available from now onwards for all nuclear projects. Forgings of certain size of PWRs can also be made now in the country.

Due to elevation difference between the core and steam generators (see figure above), natural circulation of the coolant permits passive core cooling under shutdown conditions (with no forced circulation). Shutdown Cooling System is provided for cooling down primary coolant to low temperatures under reactor shutdown. With the objective of simplifying operating procedure for 700 MWe PHWRs, Shutdown Cooling System is designed to be valved in at full pressure and temperature of PHT



Passive Decay Heat Removal System



Fuelling Machine (L) and Mobile Transfer Machine (R)

system (***FOAK***).

Emergency Core Cooling System is provided for core cooling in the event of any breach of PHT pressure boundary. ECCS is built on 2x100% redundancy with single failure criterion for each loop and consists of high-pressure light water injection, followed by long term coolant water recirculation.

For catering to station blackout situation, Passive Decay Heat Removal System - PDHRS (***FOAK***), capable of removing decay heat for 8 hours, is provided (see figure below). This system removes decay heat by preserving water inventory in steam generators. It works on the principle of natural circulation and hence does not require any motive power to function once the system is taken into service. There are four PDHRS condensers, each connected to a steam generator. Core cooling is achieved by recirculating the steam from SG through the PDHRS Condenser and sending the condensed water back to the Steam generator. Beyond 8 hours, heat sink in the system can be augmented by fire water system without relying on station power. While incorporating PDHRS in the design of 700 MWe PHWRs, the feature of fire water injection into steam generators is retained, which acts as a back up to PDHRS.

**On-power Refuelling and fuel transfer scheme – Pro-active on operator convenience**

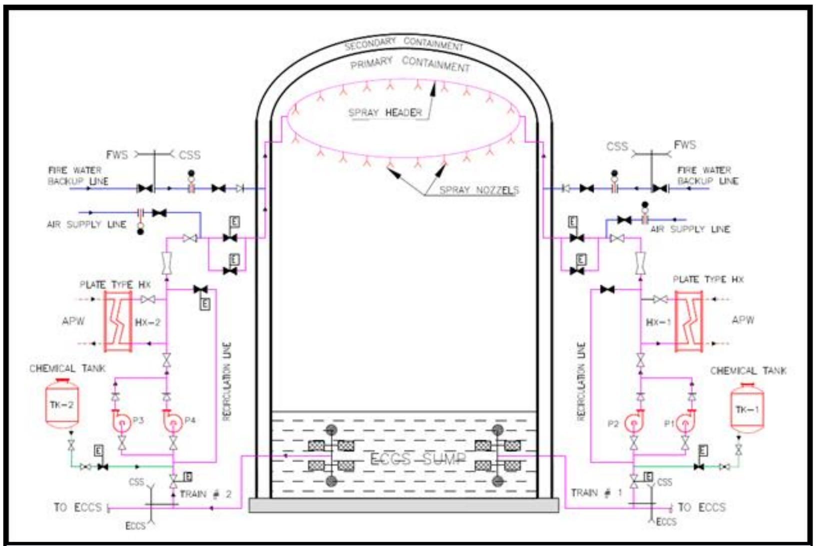
Because of low excess reactivity available in natural uranium fuel, replacing the fuel on regular basis, while the reactor is producing power, is necessary for sustained operation of the PHWRs. An on-power, remote controlled Fuel Handling system is provided for refuelling, which is carried out by two identical and remotely operated fuelling machines (see figure below), working in unison, at either end of the coolant channel. Refuelling rates during equilibrium operation stage (about 600 days after fresh core load), on an average is approximately two fuel channels to be refueled daily. Refueling rate in pre-equilibrium phase is higher. To meet the higher refueling rate requirement in 700MWe unit, the fuel transfer system aiding loading of fresh fuel into the fuelling machines and receiving spent fuel from fuelling machines for onward discharge to Spent Fuel Storage Bay (SFSB) has been redesigned.

In the fuel transfer system of 700MWe, a low pressure light water equipment, Mobile Transfer Machine - MTM (***FOAK***) has been introduced to carry out new fuel as well as spent fuel transfer operations (see figure below). It is a common equipment which serves both the fuelling machines. Use of MTM and locating the SFSB adjacent to reactor building has enabled deletion of Shuttle system along with its Shuttle Transport Tubes, associated deep trenches / ducts and complex water hydraulic system. In the new scheme, transfer of irradiated fuel from Reactor Building (RB) to SFSB is through a short length discharge port, connecting the RB and SFSB. Further, use of light water in MTM has eliminated heavy water

Containment Liner Erection

Electrical Penetration Assemblies

from the Fuel Transfer System. For this, snout level draining provision is incorporated in the fuelling machine and MTM. For housing and movement of MTM, a fuel transfer tunnel, made up of super heavy density concrete (***FOAK***) is provided inside reactor building. A tray loading machine is used in SFSB to facilitate the direct loading of irradiated fuel in the storage tray, in auto mode.




Containment Spray System

With incorporation of new scheme, total number of equipment in fuel transfer system is about one third of that in 540 MWe PHWRs. The new scheme is envisaged to simplify operations, requires less maintenance & surveillance efforts and will have lower man-rem burden during O&M. Further, automation of tray loading operation will drastically reduce personnel occupancy in the generally hot and humid environment in the bay area.

Spent fuel removed from the reactor core is stored in SFSB till the fuel bundles are cooled and transported to the reprocessing plant. Even though the new scheme for FT system requires less personnel occupancy in Spent Fuel Building, design temperature of bay water has been reduced compared to earlier reactors. Spent Fuel Building is totally enclosed and not exposed to direct sunlight. It will reduce the heat load along with the optimized volume of Spent Fuel Building for effective ventilation.

### Containment and related Features

Just as in previous units, the reactor and associated systems are placed inside the reactor containment, consisting of Inner and Outer containment structures having an annulus in between. Inner Containment (IC) structure houses the nuclear reactor and its associated systems and is one of the most important structures of a NPP. The Inner Containment is designed considering the maximum possible internal over pressurization due to the identified design basis accident, i.e. postulated main steam line break. The double containment as used in standardized 220MWe units and 540MWe along with associated engineered safety features provide effective confinement of releases even in credible beyond design basis events. However, the containment of 700MWe units has been further improved to take care of the likely emerging trends in regulatory requirements in future. As a part of major improvement in the design of IC structure of 700MWe with respect to earlier 220 MWe and 540 MWe NPPs, a carbon steel liner (***FOAK***) has been introduced on its entire inner surfaces consisting of walls, dome and the cellular raft to make the system almost leak tight (see figure below). The liner for the walls and dome is of integral type and for other surfaces it is add-on type. In 700MWe Indian PHWRs, factory

Typical External Hook-up Connections in Indian PHWRs built and qualified, indigenous, Electrical Penetration Assemblies (***FOAK***) have been installed, which are special cable sealing arrangement for passage for power cables and control cables from / to reactor building providing barrier against release of radioactivity to the environment (see figure below). These features have led to marked improvement in the leak tightness of the containment.

Passive Catalytic Hydrogen Recombiner Device (PCRD) and Containment Filtered Venting System (CFVS)

With increase in volume of building covering high enthalpy systems (Volume V1 as it is called in previous reactors), suppression pool concept became much less effective. In 700MWe PHWRs, Inner Containment is provided with an additional Engineered Safety Feature (ESF), Containment Spray System -CSS ***(FOAK)*** to cool the containment and clean up air borne radioactive iodine in case of postulated loss of coolant accidents (see figure below). This is in addition to other ESFs associated with the containment for cleanup of the secondary containment and controlled discharge from primary containment in caseThe inner structures, like the Fuelling Machine Vault ceiling have been provided with large opening modified to permit passive mixing of hydrogen in total volume, in case it gets released in beyond design basis accident scenario. Certain other additional safety features are discussed further.

## Additional Safety Features

The current regulatory requirements call for consideration of beyond design basis events in the form of design extension conditions. This requires incorporation of systems to handle events, more severe than design basis accidents. Accordingly, 700 MWe PHWR design incorporates such additional safety features or systems. It may be added here that almost all these additions to design were conceived before accident happened at Fukushima Daiichi NPP in Japan.

Design provisions were made in 700 MWe PHWRs to inject water through fire water system into identified plant systems (i.e. PDHRS, steam generators, ECCS, CSS, calandria, calandria vault). Additionally, to address safety in the condition of non-availability of designed power and water systems, provisions, known as hook up points (***FOAK***) have been made to inject water to identified systems from outside the reactor building. Water from any suitable on-site source can be injected into the identified systems through hook up points using mobile pumps or fire tenders. Adequate inventory of water is always stored at site in seismically qualified structures for a minimum period of seven days. of a requirement.

One design feature introduced is the provision of hydrogen recombination devices, called, Passive Catalytic (hydrogen) Recombiner Devices - PCRD (***FOAK***). These devices at strategically placed locations inside the reactor building will help in limiting hydrogen concentration, which is postulated to get generated as a result of metal water reaction between zircaloy and steam at high temperature conditions resulting during design extension conditions (see photograph below).

In using the previously described feature of water addition, the injected water gets converted into steam in removing the heat from the system. In case the cooling of containment is insufficient for a prolonged period this steam results in pressurization of the containment. In order to reduce containment pressure, and thereby maintaining integrity of the containment, Containment Filtered Venting System - CFVS (***FOAK***) is provided (see photograph below). This system, as per accident management guidelines, is to be brought into service close to the design pressure of the containment.

Air cooled Diesel Generator sets (***FOAK***) which can be started and operated without any auxiliary support are provided for the management of total loss of offsite and on-site power supplies for extended periods. These DG sets can supply power to instrumentation for monitoring plant parameters and emergency lighting. The output rating of these DG sets is designed to cater to operate a small capacity pump for transferring water, if required, under such conditions. The machines are kept poised all the time at a location qualified for beyond design basis site specific parameters like ground motion and flood.

As a part of accident management, new systems, Hydrogen and Steam Concentration Monitoring System-HSCMS (***FOAK***) and Severe Accident Parameters Monitoring System-SAPMS (***FOAK***) are provided.

Plant Layout

Onsite Emergency Support Center – OESC (***FOAK***) is relatively a new concept being adopted worldwide. A self-contained structure qualified with beyond design basis site specific parameters with respect to seismic and flood conditions is built near the NPP to accommodate about 100 persons for a period of about one week. The facility is adequately shielded for radiation and has all provisions to safely accommodate plant personnel without any external support. The facility is provided with diverse communication facilities. Adequate instrumentation qualified to function under harsh environment is available in the facility so that the essential plant parameters in real time can be monitored. The facility is envisaged to be used in case of beyond design basis events, which may also result from external hazard of such a magnitude that getting help from outside becomes difficult or impossible.

With the above additional safety features, the 700 MWe design caters to design extension conditions and meets the current safety requirement and also those envisaged in future.

## Structures

Design philosophy of civil structures of 700 MWe PHWR is evolved with a view to optimize and standardize structural design as per current national and international safety standards for ease in construction, maintenance and overall improved structural behavior. Reactor Building and Reactor Auxiliary Building are supported on a common raft ***(FOAK)*** for improved structural performance, particularly under seismic condition and other envisaged advantages. Need for providing rock anchors for a smaller size raft is eliminated. Just as other nuclear systems, the containment design and other structures have also been done in-house at NPCIL.

For locating the plant, maximum flood level is decided based on flood routing studies carried out by considering various postulated extreme events like precipitation of 1000 years Mean Recurrence Interval as per standard practice together with breach of upstream dam. Due to the above specified postulated event, engineering features are designed and implemented to limit maximum water level at site below safe grade elevation with adequate margin.

The main plant buildings/structures are grouped into safety related and non-safety related (conventional) based on the safety requirements of the system located inside the buildings/structures. Equipment related to nuclear steam supply such as calandria, steam generator, cooling system, associated safety system including control equipment are housed in nuclear safety related structures.

## Plant Layout

Plant layout for 700 MWe PHWRs is developed on the basis of twin unit module, with consideration of locating the common facilities centrally between the two units, without affecting the safety and functionality of individual units (see figure below).

Sufficient space is provided around the buildings for ease of construction of the two units in a phased manner and for erection of major equipment during construction.

In deciding the layout, radiation zoning of buildings was also considered. Building layouts are finalized considering basic layout requirements and Atomic Energy Factory Rules (AEFR) requirements. All safety related buildings are located within the Operating Island considering nuclear security requirements, access controls, vital area identification and segregation etc. Low trajectory turbine missiles, postulated to be generated from KAPP 3&4 and KAPS 1&2 are considered while finalizing the location and layout of safety related buildings of KAPP 3&4. Location of cooling towers is finalized to ensure unrestricted air flow for cooling.

## Electrical Systems

Major role of Electrical Power Supply System (EPSS) in 700 MWe PHWR is to provide electric power to the safety systems, safety related systems and non-safety systems as per the system requirement and evacuation of the generated electrical power to the power grid. Hence, EPSS as a safety support feature plays a major role in maintaining nuclear safety in different plant states.

Normal Power Supply System derives power from 220 kV or 400 kV off site grid or from the plant Turbo-Generator (TG). The Emergency Electric Power Supply System (EEPPS) is derived from normal power supply system and is backed up by on site emergency diesel generators (EDG) and battery banks.

EEPSS is divided into two independent divisions of power supply viz. Division-I and Division-II to feed redundant safety related loads in the plant. Each Division of power supply is completely independent of other Division. Normal Power supply to Division-I and Division-II EEPSS are derived from the Unit Transformers and Start Up Transformers respectively. To reduce the probability of common cause failure (internally generated fire and flood etc.), power supply equipment of Division-I and Division-II are located in physically separate buildings namely Station Auxiliary Building-A (SAB-A) and Station Auxiliary Building-B (SAB-B) respectively.

700 MWe unit is provided with 4x100% capacity EDGs. The rating and numbers of EDG sets are arrived based on safety related loads connected to each division, addressing single failure criteria, maintenance planning along with consideration of common mode failure cases etc. To cope up with station blackout, Class-III 6.6 kV inter unit bus ties are also provided (***FOAK***). These can be used if more than one DG is available in other unit to share some of the power supply to the affected unit. Aerosol based flooding system (***FOAK***) is adopted in 700 MWe as an improvement over the carbon di-oxide flooding fire protection system for EDGs provided in earlier units.

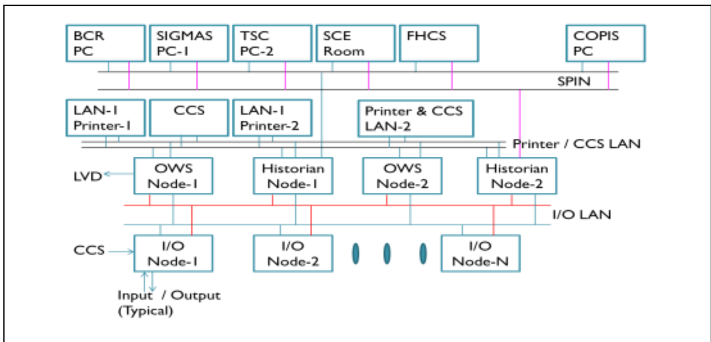
## Instrumentation & Control

C&I systems architecture has evolved in the past three decades. With the advent of microprocessors, computerization of individual systems started. Computer Based Systems (CBS) are referred as Digital Instrumentation & Control Systems (Digital I&C System-DI&CS) in present day terminology. Based on experience, feedback from user groups and recommendations of various Task Forces, a number of new features have been incorporated in the design of Control and Instrumentation architecture of 700 MWe. Systems were grouped function-wise or based on their purpose. Alarm function, Logic Control, Process Control, assimilation of functions pertaining to the process are combined at one place. Each group is provided with its own operator interface. Seated operation is introduced from 700 MWe PHWRs and hence, many of the controls from Main Control Panel are replaced with soft commands from operator interface. Systems which do not fit into grouping continue as Standalone Systems.

Distributed Control System (DCS) with soft controls is used extensively and security features like biometric authentication is provided. The I/O LAN of DCS are kept separate for each group avoiding Common Cause Failure (CCF). Large Video Screens are provided in Main Control Room for viewing operational parameters simultaneously by the entire crew in control room. The digital I&C system LAN of the plant is separate from the office LAN.

Hardware modules are standardized to reduce variety of hardware and the inventory of spares. To take care of obsolescence, hardware modules are developed with latest components and forward and backward compatibility is ensured. At the same time, hardware for protection is kept different to address CCF. NPCIL owns the proprietary information of in-house developed hardware modules and only manufacturing information is provided to prospective suppliers. Hardware modules are qualified for Electro Magnetic Interference. Software is also modularized to have uniform and quick development and to reduce the efforts required in Verification and Validation (V&V.) Common software is used in multiple systems in different configuration ensuring robustness of the software. Control Distribution Frame is eliminated to simplify cabling in control center. LAN is used in control systems of Turbine building for connection of smart field instruments. Process field bus (Profibus) based smart transmitter has been used from field to DCS as smart instruments for conventional side of the plant.

Safety systems are designed to be simple in nature. They are hardwired systems without any complex logics. Various systems are provided for performing functions of monitoring, control and protection under normal operating conditions, anticipated operational occurrences, design basis accidents and design extension conditions to meet the safety requirements in line with defense in depth philosophy.




C&I Architecture and Main Control Room

To avoid spurious actions, single failure criterion is met by following principles like independence, redundancy and diversity. Common Cause Failures have been thoroughly analyzed and appropriately addressed. Fail Safe feature of design is a salient feature in design which ensures that the effect of failure will be on safer side. In 700 MWe, systems are digitized entirely with the exception of safety critical functions generating trip alarms.

Main Control Room (MCR) is designed with ergonomic considerations to ease sensory impact on operators and thus reduce the probability for human errors. A Back up Control Room (BCR) is available in 700 MWe plant so that in the rare event of unavailability of MCR, essential functions like safe shut down of reactor, core cooling and monitoring of essential parameters can be carried out from BCR, which is located away from the MCR.

**Safety Analysis – Confirming safety**

As an integral part of licensing, deterministic safety analysis for the postulated events has been completed for 700 MWe PHWRs using indigenously developed computer codes. This exercise has confirmed that for postulated events, ranging from a frequent set of operational occurrences to unlikely accident conditions, the systems design is capable of safely mitigating postulated events and meeting regulatory requirements with margins. In line with the current regulatory requirements, safety analysis domain has been extended to cover those events, which are beyond the design envelope; and it has been established that such events can also be safely handled with the provided systems and accident management measures.

NPCIL Lab for Development of Computer Based Systems

With an integrated model of the plant, encompassing design features (such as PDHRS, two trains concept of safety and safety support systems), operational practices, components reliabilities and human actions; probabilistic safety assessment of the plant highlighted the design strengths as the stipulated probabilistic targets are met with large margins, which are more than one order better than the ones evaluated for earlier PHWRs. Further, the response assessment of containment safety features, hydrogen management systems and CFVS for extremely unlikely accident scenarios indicates that the design features for accident management ensure that the likelihood of release from the containment under accident conditions is very less and well within the accepted targets.

Based on radiological impact assessment, it is seen that with containment remaining intact, there is no requirement for displacement of neighboring population even in extreme emergency.

Certain other important safety related regulatory requirements were proactively taken up, like extensive equipment qualification and seismic margin assessment for earthquakes higher than the design level as mentioned below.

Equipment qualification (EQ) of mechanical, electrical, control & instrumentation (C&I) equipment for postulated service conditions which includes normal/ abnormal environments, 'harsh' accident environments, and seismic conditions were completed as part of design to ensure their capability in performing their intended functions in the prevailing environmental conditions, throughout the design life.

Seismic Margin Assessment (SMA) is carried out in NPPs to identify weak links in SSCs to avoid possibility of any cliff-edge effect due to their failure while experiencing earthquakes higher than the design level. SMA of safety related civil structures, mechanical, electrical and C&I equipment including piping systems is carried out based on conservative deterministic failure margin method and following national and international guidelines. This is a part of post design analysis and qualification of SSCs in 700 MWe reactor, which ensures adequate safety margins in carrying out basic safety functions viz. shutdown of reactor, decay heat removal and confinement of radioactivity

Full Scope Training Simulator

and also severe accident management for beyond design basis earthquake.

## R&D in Electronic Systems

NPCIL has established a Prototype Laboratory (TARA Lab) for development of Computer Based Systems. This prototype facility provides hardware configurations required for all systems of 700MWe along with field input signal simulation facility. The laboratory has facility for development of HMI software. The Laboratory also has various software development and testing tools required for development of embedded system hardware and software for Safety Class IB and lower safety class systems. Essential electronics test and measuring instruments are also available for measurement and diagnosis.

Testing of developed system software is carried out using these prototypes by developers / designers and test reports are generated for Independent Verification &Validation (IV&V). Validation of software which is to be deployed at site is carried out by IV&V teams using these prototype systems. This activity is necessary because some of the test conditions cannot be created and tested at site. After successful validation, the software is deployed at site. The prototypes, which are available at TARA lab are helpful for simulating problems faced at sites and for finding solutions quickly. This facility also reduces need of actual system software at the manufacturers place. At times, it is difficult to test systems at manufacturer's place due to various constraints.

Hydrogen Recombiner Test Facility
at R&D Center, Tarapur

TARA lab has around 80 embedded system panels of various configurations along with operator work stations and development & testing facility.

The prototype system laboratory along with highly specialized team of hardware and software engineers is used successfully for development and IV&V of hardware and software deployed in KAPP-3&4.

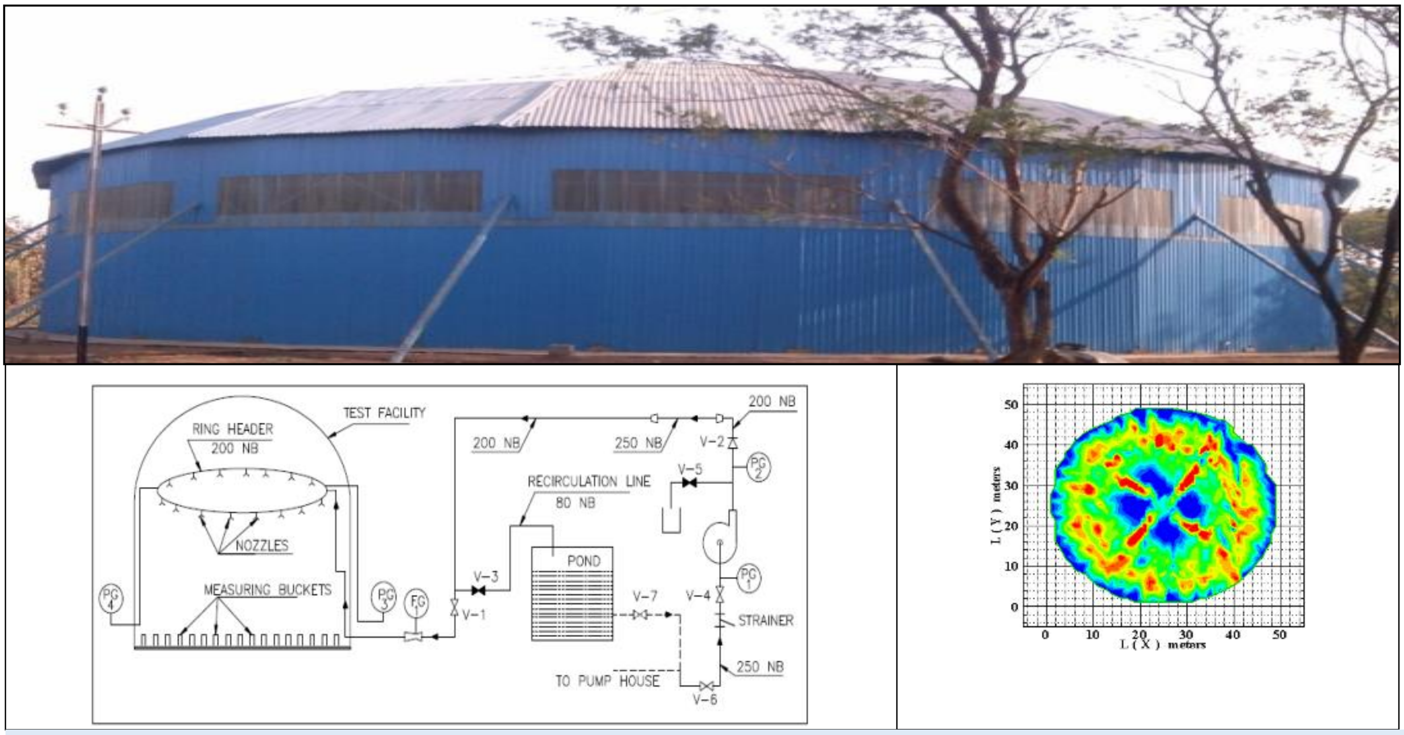
## Training Simulator

A full-scope replica nuclear power plant operator training simulator has been developed with KAPP-3 as reference plant and commissioned before the plant criticality. The simulator facility enables the operator to understand the operation of various process & control systems and overall integrated operation of the reference NPP including the complete refuelling operation. The simulator is capable of demonstrating end to end process of on power as well as shut down refueling. The Fuel Handling simulator is envisaged to perform in an integrated environment with the main plant simulator with coupled thermal hydraulics and reactivity behavior.

The Full Scope Training Simulator (FSTS) for 700 MWe commissioned at KAPP 3 incorporates comprehensive modeling of all plant systems operable from the control room along-with some systems that are field operated but relevant to operator training along-with replica operator interfaces (hard and soft) as in the actual control room environment.

The simulator response under all postulated plant conditions has been thoroughly checked and validated prior to releasing the simulator for training purpose. A Simulator Validation Team (SVT) was constituted comprising experts from design, analysis and operation of PHWR reactors. In order to minimize the commissioning time at site, validation of software part was taken up with soft Operator Interfaces at simulator development facility


TIP Drive System at Reactivity Devices Deck




Containment Spray System Test Facility Schematic and Observed Coverage

itself much before the installation of simulator hardware at site. Subsequently, after commissioning the Simulator Facility at KAPP site, the validation of simulator together with hardware was completed.

The Simulator is used for training main Plant and Fuel Handling operation personnel, to obtain initial licensing and subsequent renewal of license. Simulator Lesson Plans (LPs) were prepared for identified exercises covering routine and non-routine activities carried out by the Main Control Room crew. These LPs were qualified by the experienced operation engineers from main plant and Fuel handling together with SVT by repeated pre training trials prior to using them for imparting training. The Simulator training programme ensures that all plant operators who receive operator licenses get realistic "hands-on" training for normal operation and also for postulated transient and accident conditions.

### Technology Development

A dedicated group in NPCIL contributes to technology development (TD) and R&D related multi-disciplinary activities. The major TD domains are development of Remote Tool Systems, indigenization of materials / equipment / components and establishment of test facilities & conducting experiments. These capabilities were very well utilized for 700 MWe PHWRs.

Many Remote Tool Systems were developed to cater to the 700 MWe specific applications, which include a set of Pre-Service Inspection (PSI) Tools for Coolant Channel Pressure Tubes and Calandria Tubes (in association with BARC), Travelling In-core Probe (TIP) Drive System, etc.

Several new indigenized technologies were developed for KAPP-3&4 viz. Passive Catalytic hydrogen Recombiner Devices (PCRDs), factory built Electrical Penetration Assemblies, 3-Pitch Inconel Integral SPNDs, PDHRS, Containment Spray System (CSS), Glass to Metal Seals, Pre-fabricated Ring Liner of Reactor Building Inner Containment Wall steel liner, etc. Some of which are described below.

Various test facilities are established at NPCIL Corporate R&D Centre, Tarapur, to develop, qualify and validate 700 MWe related systems, tools and equipment. These facilities include Hydrogen Recombiner Test Facility (HRTF), which enabled development of PCRDs, 700 MWe Fuelling Machine Test Facility used for calibration and integrated testing of newly designed Fuelling Machine Heads, PDHRS Loop, CSS Test setup, etc.

### FOAK Qualification

In order to gain necessary confidence in the functioning of FOAK systems and features, development and experimental work was carried out at NPCIL facilities and at some national facilities. Some of the development and experimental work carried out include the following.

Rigorous testing of indigenously developed PCRDs was carried out at R&D Centre, Tarapur. Qualification tests of these devices were carried out up to 4% and 8% hydrogen in dry and under steam conditions. This activity was carried out in collaboration with Bhabha Atomic Research Center (BARC).

PDHRS functional tests were carried out in stages at IIT, Bombay, NPCIL R&D Centre, Tarapur and BARC. These tests included separate effect tests as well as integrated system performance tests. With test boundary conditions, simulation of tests in system thermal hydraulic computer code also showed good matching with the observed results.

To develop Containment Spray System nozzles, various experiments were carried out with single nozzle at different nozzle inlet pressures and nozzle orientations at R&D, Centre Tarapur. Based on these experimental data, single ring header with 108 nozzles layout was finalized. With this layout, a full scale mockup test facility was developed to measure the total spray coverage. Using experimentally validated model, about 88 % spray coverage of reactor building cross section could be obtained. To measure the droplet diameter, experiments were carried out at IIT Bombay with the help of same nozzles as actual used in CSS. Experiments were also performed for establishment of Iodine (elemental) as well as organic Iodine removal by CSS at IIT Bombay. These findings were also compared with USNRC correlation, which show very high conservatism in the used correlation for radiological dose assessment. Further experiments for the aerosol removal by CSS were also performed at R&D Centre Tarapur.

The CFVS design is validated by carrying out experiments on a scaled down experimental facility. In these experiments, Decontamination Factors (DF) for various forms of Iodine i.e. elemental, particulate and organic were determined at different thermal hydraulic conditions which are expected during CFVS operation.

Integral 3-pitch long Inconel SPNDs were developed and tested in-situ in TAPS-3&4, before deployment in 700 MWe PHWRs.

## Procurement and Construction – From drawings to reality

Procurement of systems, structures and components for KAPP 3&4 are managed through various supply, supply-cum-erection and Engineering, Procurement and Construction (EPC) packages. All long delivery equipment were ordered in advance and packages were ordered in a phased manner according to the time line as per the master control network. For KAPP 3&4, procurement of all critical & long delivery equipment and supply cum erection packages was through Indian vendors except turbine package. Nuclear equipment and components were manufactured and supplied by manufacturers who have earlier supplied similar equipment for 540 MWe and 220 MWe Indian Pressurized Heavy Water Reactors (PHWRs). All systems, structures and components within nuclear island are manufactured, supplied and executed based on the in-house design & engineering and construction deliverables issued by NPCIL. Balance of the plant like raw water systems, chlorination & demineralized water system, turbine package, secondary cycle systems including condenser cooling system, Induced Draft Cooling Tower (IDCT), Natural Draft Cooling Tower (NDCT), were executed as Engineering, Procurement and Construction (EPC) packages utilizing the capability available with Indian industries and consultants.

There were some delays in supply of equipment and construction on account of financial issues with the vendors. Further, from March, 2020 the impact of lockdown has affected the work related to further commissioning of KAPP-3 and supply of equipment, placement of supply erection / EPC contracts, engineering services work etc. for other projects. For a large programme, wherein activities at a number of projects are expected to run concurrently, there would be a requirement to bring in more number of industries and vendors.

## Preparing for future 700 MWe units – Standardization is the key

Layout of buildings, systems, structures, components (SSCs) and other plant engineering requirements like material movement path, tubing pull out space/ maintenance space, platforms for approach & maintenance, reserve volume for various purposes, accessibility space between services, sealing/shielding requirements etc. are detailed and standardized from GHAVP-1&2 onwards and same is developed in the integrated engineering environment in 3D engineering platform. Feedback from ongoing 700 MWe projects are captured and recorded in a centralized manner. Standardized layout of GHAVP 1&2 will be repeated for fleet projects except for site specific changes. Considering the standardized layout design of GHAVP 1&2, analysis and qualification of systems, structures and components will be carried out for the first rock site fleet project and resulting changes will be implemented in the 3D engineering platform. Standardized approach adopted for GHAVP 1&2 will reduce the engineering efforts for downstream fleet projects significantly. In addition to the type of construction drawings extracted from integrated engineering platform for KAPP 3&4, from GHAVP 1&2 onwards concrete forming drawings, EP fabrication drawings are also being extracted from 3D model. For GHAVP 1&2 and for all the fleet projects, input seismic parameters like DBGM and FRS are being finalized before taking up analysis, qualification and design of

SSCs.

From the experience of KAPP-3&4, project implementation model of GHAVP 1&2 is further refined by defining the scope of supply, supply cum erection and EPC packages considering nature of jobs, industry experience, size of the packages, expected duration of contracts, design & engineering competency with industry etc. From GHAVP-1&2 onwards, equipment specifications are standardized for adopting bulk procurement for fleet projects for cost effectiveness and simplifying procurement process. Specification of pipes, fittings, valves, control panels, junction boxes, distribution boxes etc. which are utilized for various systems & services are standardized for ease of procurement process, material management, from replaceability point of view etc. Efforts were put and currently many of the components/forgings etc. which were earlier imported are made indigenously with the help of Indian manufactures and equipment suppliers. Technical specification for the procurement of equipment, components, items etc., are prepared taking into account the feed-back of industry and approved quality assurance plans are included as a part of the tender specification for procurement of various SSCs. It is also ensured that accurate Bill of Quantities (BOQs) required for procurement through supply-cum-erection contracts are also made available before award of work. Construction drawings of various supply-cum-erection packages are made available well in advance compared to the construction front readiness. Supply milestones, site front release schedule, construction drawings release schedule etc., are defined in the tender for procurement of various packages in advance to avoid later on contractual issues and similarly other feedback of industries gathered through information exchange meetings etc. are also taken into account while formulating the tenders.

With standard design, postulated initiating events are same and as such safety analysis carried out for KAPP-3&4 will be standard and applicable for all future 700 MWe PHWRs. The only difference will be in terms of radiological dose assessment considering local meteorological conditions. It is therefore envisaged to prepare a generic accident analysis report for 700 MWe PHWRs. Similarly, Technical Specifications for Operation will also be standard for 700 MWe PHWRs, which is in line with the practice being introduced to have harmonized Technical Specifications for Operation of similar design NPPs.

## Summing Up

700MWe PHWR design incorporates various design and safety features and is an advanced, state of the art nuclear power plant. The design complies with the current national and international safety requirements. The design is an outcome of the vast experience in PHWR technology within NPCIL, DAE and Indian industries. With efforts taken to standardize the design, backed with Atmanirbharta in this proven technology, the country is poised for rapid addition of nuclear energy with a fleet of 700 MWe PHWRs.

*Acknowledgement*

*Successful implementation of the first 700 MWe PHWR at KAPP-3 is due to combined efforts of various groups in NPCIL/DAE. The author acknowledges the contribution made by all of them.*

*(Readers may post, queries on this paper, if any, through INS)*

**A.K.Balasubrahmanian**

Shri A.K. Balasubrahmanian is Director (Technical), NPCIL and has the overall responsibility for design, engineering, procurement, safety analysis, technology development, health and environment safety functions pertaining to Pressurised Heavy Water Reactors (PHWR) in NPCIL. He played a key role in implementation of the 540 MWe PHWRs and currently he is using his expertise for implementation of a large construction programme in India based on 700 MWe state-of-the-art PHWR

## Nobel Prizes 2020

Nobel prizes are the most prestigious honors awarded "to those who, during the preceding years, have conferred the greatest benefit to humankind". Five separate Nobel Prizes are awarded in the fields of Physics, Chemistry, Physiology or Medicine, Literature, and Peace. The peace prize is called "fellowship among nations".

Except for the Peace Prize, every year the Nobel Prizes are presented in Stockholm, Sweden, at the Annual Prize Award Ceremony on 10 December, the death anniversary of Alfred Nobel. The recipients' lectures are held prior to the award ceremony and each Nobel Laureate receives the prize from the hands of the King of Sweden.

In the past several nuclear scientists too received Nobel prizes, starting with Henri Becquerel, Pierre Curie, and Marie Curie's prize for the discovery of radioactivity, way back in1903. Nobel Prizes have been awarded for nuclear research and instrumentation in the fields of particle physics, nuclear physics /astrophysics, nuclear chemistry, nuclear power reactors and nuclear medicine.

The Nobel prizes for the year 2020 have been announced in October 2020. Because of the coronavirus pandemic, the committees are changing their approaches. Some of the events will not be held in Stockholm. Instead, medals and diplomas are to be distributed to the recipients in a digital ceremony.

## Physiology or Medicine

This year's Nobel Prize in physiology or medicine is awarded to three scientists Harvey J. Alter, Michael Houghton and Charles M. Rice who have made a very important contribution to the fight against blood-borne hepatitis, a major global health problem that causes cirrhosis and liver cancer in people around the world. Prior to their work, although the discovery of the Hepatitis A and B viruses had been significant, the majority of blood -borne hepatitis cases remained unexplained.

The Nobel Laureates' discovery of Hepatitis C virus is a landmark achievement in the ongoing battle against hepatitis viral diseases. Based on their discovery, highly sensitive blood tests for the virus are now available and these have eliminated post-transfusion hepatitis, thus greatly improving global health. Their discovery also allowed the rapid development of antiviral drugs directed at hepatitis C. For the first time in history, the disease can now be cured.

The brief information about Physiology Nobel winners is given below

**Harvey J. Alter** was born in 1935 in New York. He received his medical degree at the University of Rochester Medical School, and trained in internal medicine at Strong Memorial Hospital and at the University Hospitals of Seattle. In 1961, he joined the National Institutes of Health (NIH) as a clinical associate. He spent several years at Georgetown University before returning to NIH in 1969 to join the Clinical Center's Department of Transfusion Medicine as a senior investigator.

**Michael Houghton** was born in the United Kingdom in 1949. He received his Ph.D. degree in 1977 from King's College London. He joined G. D. Searle & Company before moving to Chiron Corporation, Emeryville, Cali-

fornia in 1982. He relocated to University of Alberta in 2010 and is currently a Canada Excellence Research Chair in Virology and the Li Ka Shing Professor of Virology at the University of Alberta where he is also Director of the Li Ka Shing Applied Virology Institute

**Charles M. Rice** was born in 1952 in Sacramento. He received his Ph.D. degree in 1981 from the California Institute of Technology. He established his research group at Washington University School of Medicine, St Louis in 1986 and became full Professor in 1995. Since 2001 he has been Professor at the Rockefeller University, New York. During 2001-2018 he was the Scientific and Executive Director, Center for the Study of Hepatitis C at Rockefeller University

## Physics

The Nobel Prize in Physics was awarded to Roger Penrose, Reinhard Genzel and Andrea Ghez for their discoveries that have improved understanding of the universe, including work on black holes. The award was divided as one half to Roger Penrose "for the discovery that black hole formation is a robust prediction of the general theory of relativity". The other half was jointly awarded to Reinhard Genzel and Andrea Ghez "for the discovery of a supermassive compact object at the centre of our galaxy. The discoveries of this year's Laureates have broken new ground in the study of compact and supermassive objects

The brief information about Physics Nobel winners is given below

**Roger Penrose**, was born 1931 in Colchester, UK. He obtained his Ph.D. in 1957 from University of Cambridge, UK. Professor at University of Oxford, UK. **Penrose** proved that black holes are a direct consequence of Albert Einstein's general theory of relativity. Einstein did not himself believe that black holes really exist; these super-heavyweight monsters capture everything that enters them. In January 1965, ten years after Einstein's death, Roger Penrose proved that black holes really can form and described them in detail. His work is still regarded as the most important contribution to the general theory of relativity since Einstein.

**Reinhard Genzel**, was born 1952 in Bad Homburg vor der Höhe, Germany. Obtained Ph.D. in1978 from University of Bonn, Germany. He was Director at Max

Planck Institute for Extraterrestrial Physics, Garching, Germany and also Professor at University of California, Berkeley, USA.

**Andrea Ghez**, was born 1965 in City of New York, USA. She did her Ph.D. in 1992 from California Institute of Technology, Pasadena, USA. Currently, she is the Professor at University of California, Los Angeles, USA.

## Chemistry

The Nobel Prize in Chemistry was jointly awarded to Emmanuelle Charpentier and Jennifer A. Doudna for their work on the development of Crispr-Cas9, a method for genome editing. Several groups are using CRISPR to change the DNA of livestock and crops. Others are using CRISPR as the basis of one-time therapies that could potentially offer cures to genetic diseases like sickle cell disease and muscular dystrophy. CRISPR has even been used to make simple diagnostic tests during the coronavirus pandemic." This year marks the first time the prize has been jointly awarded to two women. Charpentier and Doudna are just the sixth and seventh women to ever receive the prize in chemistry.

The brief information about Chemistry Nobel winners is given below

**Emmanuelle Charpentier** born in 1968 is a French professor and researcher in microbiology,genetics and biochemistry. She is the Founding, Scientific and Managing Director of the Max Planck Unit for the Science of Pathogens in Berlin. In 2018, she founded an independent research institute, the Max Planck Unit for the Science of Pathogens.

**Jennifer A. Doudna** was born in 1964. She is the Li Ka Shing Chancellor's Professor of Biomedical Science, Chair of the Chancellor's Advisor Committee on Biology and the Executive Director of the Innovative Genomics Initiative at the University of California, Berkeley. She is also an Investigator at the Howard Hughes Medical Institute. She is a former Associate Editor of ACS Chemical Biology and a current member of the Journal's Editorial Advisory Board.

**The Nobel Peace Prize** for 2020 was awarded to the World Food Programme (WFP) for its efforts to combat hunger, for its contribution to bettering conditions for peace in conflict-affected areas and for acting as a driving force in efforts to prevent the use of hunger as a weapon of war and conflict.

**The Nobel Prize in Literature** for 2020 is awarded to the American poet Louise Glück, Born: 1943, New York, NY, USA Louise Gluck is one of America's most celebrated poets

**Compiled by**

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DAE RRF at UM-DAE Centre for Excellence in Basic Sciences, University of Mumbai

## Nuclear News Snippets

https://powerline.net.in/2020/10/19/us-doe-approves-1-35-billion-for-small-scale-nuclear-reactor-project

The US Department of Energy (DOE) has approved $1.35 billion over 10 years for the building of the first US small-scale nuclear power project, giving a boost to a project struggling with cost overruns and delays.The DOE has pumped about $280 million since 2013 into the project involving 12 small reactors, slated to be built at its Idaho National Laboratory site. Employed NuScale's technology is regarded by some as a potential source of critical carbon-free power that grids will need to supplement intermittent sources like wind and solar.

https://powerline.net.in/2020/10/16/edf-plans-to-announce-new-epr-nuclear-reactor-by-mid-2021

French power company, EDF aims to unveil a new, cheaper-to-build version of its EPR nuclear reactor by mid-2021. EDF has faced costly delays in the construction of some plants, including its Flamanville 3 nuclear project in France which is more than a decade behind schedule. Other EDF projects include the planned Sizewell C nuclear plant in eastern England. Further, EDF is already building Britain's first new nuclear plant in more than two decades, Hinkley Point C, with backing from China's CGN.

https://powerline.net.in/2020/10/15/india-to-be-worlds-largest-market-for-battery-storage-by-2040

According to the International Energy Agency, India will become the largest market for utility-scale battery storage by 2040. In addition, India, which is working on adding 100 GW solar capacity by 2023, is also shifting focus towards storage-based projects to tackle the intermittency of power from solar PV. In February, Greenko and ReNew won 900 MW and 300 MW packages of a 1200 MW storage-based projects auctioned by Solar Energy Corporation of India (SECI).

https://powerline.net.in/2020/10/15/japan-launches-energy-policy-review-amid-global-push-for-greener-power

Japan has launched its latest three-yearly energy policy review, with the country grappling with a need to cut greenhouse gas emissions even as the public remains wary over nuclear power following the Fukushima disaster.

https://www.iaea.org/newscenter/news/how-to-improve-the-protection-of-patients-undergoing-frequent-medical-imaging

At a virtual meeting held by the IAEA during October 19 – 23, 2020, progress made to reduce radiation-related risks – while maintaining the benefits – for patients who need frequent medical imaging was discussed. Participants covered the impact and concrete actions needed to strengthen patient protection guidelines and technological solutions to monitor patient exposure history and took stock of global efforts to continuously enhance radiation protection of patients.

https://www.iaea.org/nuclear-power-and-the-clean-energy-transition/small-reactors-great-potential

With small modular reactors (SMRs) and microreactors (MRs) starting to become a reality, the face and reach of nuclear power is changing. SMRs and MRs provide low carbon energy like large nuclear reactors do, but they are smaller, more flexible and more affordable, so they can be used on smaller power grids and be built in hard-to-reach places where large reactors wouldn't be practical.

https://www.iaea.org/newscenter/news/world-food-day-2020-iaea-faos-joint-work-benefits-farmers-and-increases-food-security-worldwide

In 2020, more than 80 developing countries from all over the world have received support from the IAEA in partnership with the Food and Agriculture Organization of the United Nations (FAO) in improving food security and agricultural development with the use of nuclear and nuclear-related techniques. The Joint FAO/IAEA Programme of Nuclear Techniques in Food and Agriculture contributes annually to more than 250 IAEA technical cooperation projects and leads around 25 coordinated research projects towards increased global food security and sustainable agriculture.

https://www.iaea.org/newscenter/news/rosatom-technical-academy-becomes-first-iaea-collaborating-centre-in-three-programmatic-areas

Rosatom Technical Academy (Rosatom Tech) has become the first IAEA Collaborating Centre to extend its work with the IAEA into three different programmatic areas: nuclear sciences and applications, nuclear security and nuclear energy. Collaborating Centres work with the IAEA in specific technical areas, sharing knowledge and resources in the peaceful uses of nuclear energy to help governments achieve the United Nations Sustainable Development goals.

https://www.iaea.org/nuclear-power-and-the-clean-energy-transition/more-than-just-a-power-source

Hydrogen production through nuclear energy offers an opportunity to drastically cut carbon emissions while also boosting the profitability of the nuclear power industry. Nuclear power reactors can be coupled with a hydrogen production plant to efficiently produce both energy and hydrogen as a cogeneration system. For hydrogen production, the cogeneration system is fitted with components for either electrolysis or thermochemical processes.

https://www.iaea.org/newscenter/news/malaysian-nuclear-security-support-center-to-make-iaea-radiation-detection-equipment-available-regionally

The IAEA and the Atomic Energy Licensing Board of Malaysia (AELB) have established a pool of radiation detection equipment available for loan, backed by financial contributions from Japan, to support nuclear security training and detection capabilities at major public events in Asia and the Pacific. This is the first nuclear security equipment repository facilitated by the IAEA.

https://www.iaea.org/newscenter/pressreleases/iaea-mission-detects-no-radiation-increase-in-beirut-after-recent-blast

An International Atomic Energy Agency (IAEA) team of experts has not detected elevated levels of radiation in areas surveyed during a mission to Beirut which was carried out in the aftermath of the massive blast two months ago. There were no artificial radionuclides in the measurements, the team conducted during the visit in mid-September.

https://www.iaea.org/newscenter/news/nuclear-key-to-the-clean-energy-transition-conclusions-of-the-2020-iaea-scientific-forum

Nuclear power must have a seat at the table in global discussions over energy policies to curb emissions and meet climate goals, as technical and scientific advances open the door to better economics and greater public acceptance of this low carbon source of energy. These are some of the conclusions of this year's IAEA Scientific Forum, where ministers, scientists and other experts from industry and civil society came together for two days of talks on scientific and technological advances in nuclear power that could help drive the global transition to clean and sustainable energy.

https://www.iaea.org/bulletin/infectious-diseases/infectious-diseases-and-how-nuclear-science-can-help

Real time reverse transcription–polymerase chain reaction (real time RT–PCR) is the most accurate method to detect the COVID-19 virus. This nuclear-derived method is used for detecting the presence of specific genetic material of a pathogen, including a virus The FAO/IAEA Animal Protection and Health Laboratory has been helping countries use this technique to detect zoonotic (animal to human) diseases like COVID-19 and Ebola for decades.

https://www.iaea.org/newscenter/news/how-safety-and-security-regulators-addressed-challenges-during-the-covid-19-pandemic

Challenges faced and addressed by safety and security regulators during the COVID-19 outbreak were the focus of the discussion at the annual Senior Safety and Security Regulators' Meeting, held virtually on the sidelines of the 64th IAEA General Conference. While the IAEA had provided regulators and operators with a discussion platform to share their experience since the beginning of the pandemic, this session enabled a deeper understanding of actions taken to ensure nuclear and radiation safety and security, as well as the capacity to respond in case of a nuclear or radiological emergency during the pandemic.

https://www.iaea.org/newscenter/news/the-future-of-atoms-artificial-intelligence-for-nuclear-applications

The first ever IAEA meeting discussing the use of artificial intelligence (AI) for nuclear applications held virtually on the sidelines of the 64th IAEA General Conference, showcased the ways in which AI-based approaches in nuclear science can benefit human health, water resource management and nuclear fusion research. Open to the public, the event gathered over 300 people from 43 countries and launched a global dialogue on the potential of AI for nuclear science and the related implications of its use, including ethics and transparency.

https://www.iaea.org/newscenter/news/iaea-inpro-20-years-of-enhancing-nuclear-energy-sustainability

The IAEA marked 20 years of the IAEA International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), with participants at a virtual side event on the margins of the 64th IAEA General Conference. The event highlighted past INPRO successes and looked ahead to a future of support to countries facing changing energy needs and requiring innovative technologies

https://www.iaea.org/newscenter/news/iaea-nuclear-operators-forum-highlights-reactor-fleets-commitment-to-innovation

The 10th Nuclear Operators' Forum was held as an online event alongside the 64th IAEA General Conference, Panellists at the virtual forum, attended by 122 delegates, discussed challenges and solutions for ensuring innovation to advance the fleet's contribution of the fleet of 442 operating power reactors to a stable, non-polluting, low emission electrical grid.

https://www.iaea.org/newscenter/news/the-iaeas-nuclear-law-institute-a-decade-of-capacity-building-and-development-in-nuclear-law

The IAEA established NLI in 2011 as the first global training programme on nuclear law focused on supporting countries in drafting their legislation regulating the peaceful use of nuclear technology. By providing the framework for conducting these activities in a manner that adequately protects people and the environment, nuclear laws enable countries to fully benefit from nuclear applications and to implement their international obligations for the safe, secure and peaceful use of this technology.

https://www.iaea.org/newscenter/pressreleases/iaea-report-nuclear-power-to-continue-to-play-key-role-in-low-carbon-electricity-production

The International Atomic Energy Agency (IAEA) has released its latest projections for energy, electricity and nuclear power trends through 2050. Compared with the previous year, the 2020 projections are largely unchanged. Under the high case scenario, IAEA analysts expect an increase of global nuclear electrical generating capacity by 82% to 715 gigawatts. Under the low case scenario, it will fall by 7% to 363 gigawatts.

https://www.iaea.org/newscenter/news/covid-19-response-remains-top-iaea-priority-director-general-says

The IAEA has shipped more than 1260 consignments of equipment and supplies for detection and diagnosis of the COVID-19 virus to 123 countries in the largest operation in the Agency's history, Director General Rafael Mariano Grossi told the IAEA Board of Governors on 14th September, 2020. He also added that fighting the coronavirus will remain IAEA's top priority until the pandemic is finally defeated.

https://www.iaea.org/newscenter/news/international-day-of-clean-air-for-blue-skies-2020-how-nuclear-technology-can-help-ensure-clean-air-for-all

As the world marks the very first United Nation's International Day of Clean Air for blue skies (September 7), clean sources of power, such as nuclear energy, are in the spotlight. These energy sources can help meet global climate change goals and also reduce air pollution to protect people's health. Non-energy nuclear applications such as radiation technology play a significant role in cleaning up air pollution to meet regulatory requirements and to protect the environment.

https://www.iaea.org/nuclear-power-and-the-clean-energy-transition/what-is-the-clean-energy-transition-and-how-does-nuclear-power-fit-in

Nuclear power is the second-largest source of low carbon energy used today to produce electricity, following hydropower. During operation, nuclear power plants produce almost no greenhouse gas emissions. According to the IAEA, the use of nuclear power has reduced carbon dioxide emissions by more than 60 gigatonnes over the past 50 years, which is almost two years' worth of global energy-related emissions..

https://www.iaea.org/newscenter/news/robots-drones-and-artificial-intelligence-for-advanced-decommissioning-and-environmental-remediation-winners-of-the-iaea-2020-crowdsourcing-challenge

The IAEA has selected five best entries of the crowdsourcing challenge that sought original concepts or project outlines for advancing the decommissioning of nuclear facilities or environmental remediation of radiologically contaminated sites. Three of them focused on decommissioning and two on environmental remediation, ranging from characterization toolkits, through instruments for on-field measurements and collecting 3D radiation data to robots and artificial intelligence.

https://www.iaea.org/newscenter/news/new-nano paticles-hold-promise-for-radiopharmaceuticals -efficiency

Scientists working together through an IAEA Coordinated Research Project (CRP) have developed two new nanoparticles that hold promise for a new generation of nano size radiopharmaceuticals, which could dramatically improve early detection and therapy of various forms of cancers. They are expected to enter the last stages of preclinical studies this year.

https://www.world-nuclear-news.org/Articles/OPG-advances-towards-SMR-deployment

After lending strong support to provincial Canadian initiatives focused on small reactors, Ontario Power Generation (OPG) has selected three developers of grid-scale small reactors - broadly 25 to 300 MWe - for further evaluation in its program to deploy these. OPG operates six large reactors at Pickering and four at Darlington, total 6.6 GWe to produce about half of the province's electricity. It will now take forward engineering and design work with three developers of grid-scale small reactors: GE Hitachi (GEH), Terrestrial Energy and X-energy.

https://www.world-nuclear-news.org/Articles/German-lists-potential-radwaste-storage-sites

Germany's nuclear waste management organisation BGE has identified 90 areas covering 54% of the country as likely to be geologically suitable for a deep geological repository for high-level wastes, giving credible security for a million years as the radioactivity decays to backgrounds levels. They are in clay, salt and igneous rock. A decision is planned in 2031.

https://timesofindia.indiatimes.com/city/hyderabad/nfc-chief-allays-fears-over-nuclear-fuel-supply-says-new-facility-at-kota-by-2022/articleshow/77750335.cms

A new facility of the Nuclear Fuel Complex, with a capacity to produce 500 tonnes of nuclear fuel bundles, will come up in Kota, Rajasthan, in July 2022."We are planning to produce nearly 500 tonnes of fuel but we have made a provision wherein we can expand it in three years to produce 1000 tonnes," NFC chairman and chief executive Dinesh Srivastava told TOI . The fuel bundles, which will be produced at NFC-Kota, will serve the needs of the nuclear power reactors in the vicinity and also elsewhere.

https://energy.economictimes.indiatimes.com/news/power/edf-i2en-vjti-sign-pact-for-centre-of-excellence-in-maharashtra/78125216

EDF Group, a French company, will set up a centre of excellence in the civil nuclear sector in Maharashtra to work towards the implementation of the Jaitapur nuclear power project which will have the capacity to generate 9,600 megawatts of power. The centre will be built in partnership with I2EN, an outfit that brings together French stakeholders involved in nuclear education and training, and Veermata Jijabai Technological Institute, an education institute based in Mumbai. This centre will work towards the "development of all the skills necessary for the implementation of the Jaitapur project at the stages of design, procurement, construction, commissioning and operational activities."

https://rosatom.ru/en/press-centre/news/rosatom-will-develop-remix-fuel-fabrication-at-the-site-of-the-siberian-chemical-plant-in-seversk

Rosatom has approved a project to upgrade an experimental shop-floor for nuclear fuel fabrication at the site of the Siberian Chemical Combine (SCC), which is in Seversk, in the Tomsk region of Russia. The move will enable SCC to manufacture fuel assemblies with uranium-plutonium REMIX (regenerated mixture) fuel matrix for VVER-1000 reactors.

http://email.mg.nucnet.org/c

Communities that host nuclear power plants face "swift and severe" economic and social impacts following a plant's closure, according to a report by the Nuclear Decommissioning Collaborative.

The report, Socioeconomic Impacts from Nuclear Power Plant Closure and Decommissioning, examines the effects of nuclear power plant closures on surrounding host communities, along with the barriers to planning and mitigation, and offers recommendations to nuclear closure communities across the nation.

https://www.world-nuclear-news.org/Articles/Kepco-E-C-teams-up-with-shipbuilder-for-floating-r

Following Russia's pioneering work and based on South Korea's shipbuilding reputation, KEPCO's Engineering & Construction company signed an agreement with Daewoo Shipbuilding & Engineering to develop offshore nuclear power plants. KEPCO is developing the BANDI-60S as a 200 MWt/ 60 MWe reactor particularly for floating nuclear power plants.

**Compiled by S.K.Malhotra**

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

**INS News Letter is Published by S. P. Dharne on behalf of Indian Nuclear Society, Project Square, Anushakti Nagar, Mumbai – 400094, E- mail: indiannuclearsociety@gmail.com. Tel: 91-22- 2559 8327 & 2599 1097, Fax: 91-22-2557 6261, Website: www.indiannuclearsociety.com**