S.No. 12.2 (Annexure-9)

NUCLEAR POWER CORPORATION OF INDIA LIMITED
(A Government of India Enterprise)

PROJECT REPORT ON

MAHI BANSWARA RAJASTHAN ATOMIC POWER PROJECT - 1 TO 4

(MBRAPP - 1 to 4)

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EXECUTIVE SUMMARY

NPCIL is setting up 2800MWe Nuclear Power Plant (NPP) comprising of four PHWR (Pressurised Heavy Water Reactor) units of 700MWe each, namely MBRAPP-1 to 4, at Mahi Banswara in Banswara district of Rajasthan State. Location, topography, accessibility, rainfall, sources of water, and geological, seismological, meteorological and hydrological conditions are suitable for setting up the Plant. The Site for location of MBRAPP is surveyed, selected and recommended by Site Selection Committee constituted by Department of Atomic Energy, Government of India (GoI). The committee narrowed down on the site in accordance as the provisions laid down in the standard procedure prescribed by AERB for selection of site covering all studies, data, parameters which are necessary to meet the requirement to establish a nuclear power plant at a particular site. Based on recommendations of the Site Selection Committee, Government of India (GoI) has accorded 'in-principle' approval for setting up Nuclear Power Plant at Mahi Banswara, Rajasthan.

PHWR (Pressurised Heavy Water Reactor) based technology chosen for the reactor is proven, indigenously developed, and mastered without external help. The plant is designed with the latest state of the art technology so as to achieve radioactive releases from air and water route strictly within the permissible limits as stipulated by national and international regulators. Also conventional pollutants emitted from the plant operation in the form of air emissions, waste water and noise levels will be minimal.

NPCIL has 455 reactor-years of experience for safely and reliably operating such nuclear power plants. NPCIL will be responsible for setting up, starting from design, engineering, construction, commissioning, and operating to decommissioning the Plant after expiry of useful service life to long- term monitoring of the environment. In over four decades, NPCIL has fully mastered and implemented the various aspects of the technology, encompassing design, engineering, procurement, construction, commissioning, start up and operations of NPP. NPCIL has organizational culture and management systems for setting up NPPs in safe, efficient, responsible and sustainable manner, ensuring highest standards of safety and security. NPCIL has adequate and proven infrastructure in respect of waste management for proper and systematic planning and safe implementation of all waste management activities.

It is proven through assessment done on site-plant interactions by expert agencies on environmental studies that NPPs do not pose unacceptable radiological consequences to the environment and to the public at large. The environmental impacts identified by the studies are manageable and NPPs through site specific and practically suitable mitigation measures extenuate the impacts and comply with AERB stipulations with considerable margin. Further, a suitably designed monitoring plan is put into service during the operation phase to constantly monitor the effectiveness of envisaged mitigation measures.

NPP to be built in Mahi Banswara of Rajasthan State is safe to the public and to the environment and is capable of taking care of itself under normal condition or, under extreme accident condition. Proposed site has been chosen after survey of potential sites and evaluation against national criteria as stipulated by GOI/AERB. Aspects of site evaluation related to radiological safety and certain site characteristics relevant to the overall safety of the plant are considered in the design of NPP.

Safety has been NPCIL's continuous endeavour. In pursuit of providing best attention to safety, comprehensive and systematic safety assessments by multi-tier and multi-disciplinary review during each stage - design, construction, commissioning and operation of Nuclear Power Plants -

are carried out. The assessments are documented and updated periodically based on experience gained as well as from new developments. Verification by analysis, surveillance, testing and inspection is carried out to ensure that the physical state and the operation of the nuclear installation, continues to be in accordance with its design and applicable safety standards. Every event in the operating NPPs is reviewed and analyzed for corrective measures. The events reported internationally and their applicability to Indian NPPs is regularly reviewed. Analysis of events is done to establish their root cause. Accordingly the systems, procedures and aspects related to training and safety culture are further updated.

All through the process of design, manufacturing, construction and commissioning the Quality Assurance systems are implemented effectively to assure that implementation of safety principles has been given due priority. Quality Assurance is assured in Design of NPP, Manufacturing of Components, Construction of NPP, and Commissioning through efficiently developed Quality Management System Programme.

NPCIL management is committed to provide comprehensive and sustainable social development in the Plant neighbourhood. Under CSR (Corporate Social responsibility) programme NPCIL constantly invests in the NPP neighbourhood to improve quality of life of the local populace. The key human development verticals identified for the purpose are education, healthcare, and infrastructure development. The projects under the CSR programme are developed jointly in dialogue with village panchayats / District Administration, and are implemented through NGOs and / local bodies.

1.0 INTRODUCTION

1.1 Genesis of Atomic Energy in India

After India attained independence, in 1947, the Atomic Energy Commission was set up in 1948 for framing policies in respect of development of atomic energy in the country. The Department of Atomic Energy was established in 1954 with Dr. Bhabha as Secretary to implement the policies framed by the Atomic Energy Commission. Sir J.R.D Tata was one of the longest serving members in the Atomic Energy Commission and played a significant role in shaping the policies related to atomic energy program in the country.

The atomic energy program, which was initiated in a modest manner initially, has now grown as a wide spectrum, multi dimensional multidisciplinary with 63 organizations under DAE. The spectrum of these significant activities include R&D in Nuclear Sciences and Engineering, Exploration & Mining of Radioisotopes, Nuclear energy development and implementation, application of Nuclear Energy, Bio-Agricultural Research, Medical Sciences etc.

In India, nuclear energy development began with the objectives of peaceful uses of atomic energy in improving the quality of life of the people and to achieve self-reliance in meeting the energy needs. The commercial Nuclear Power program, started in 1969 with the operation of TAPS 1&2 (BWR), at Tarapur in Maharashtra, currently shares about 3% country's installed capacity. Thus nuclear power is, currently, playing a complementary role in meeting the country's energy demand. However, in long term, it is expected to play a significant role in meeting the huge electricity demand of the country.

1.2 About NPCIL

In the year 1967, Power Projects Engineering Division (PPED), a unit of Department of Atomic Energy (DAE), was formed and entrusted with the responsibilities of design, construction and operation of the nuclear power plants in the country. PPED was converted into Nuclear Power Board (NPB) in 1984 continuing under DAE. In September 1987 , with a view to shift nuclear power generation to commercial domain, NPB was converted under the companies Act-
1956, into Nuclear Power Corporation of India Limited (NPCIL) as a public limited company, under the administrative control of DAE, with the objective of undertaking the activities of design, construction, commissioning, operation & maintenance (O&M), life cycle management of nuclear power stations for generation of electricity in pursuance of the schemes and program of the government of India under the provisions of Atomic Energy Act, 1962. At this time of formation of NPCIL, the two units at each of the sites, namely Tarapur,-Maharashtra, Rawatbhata-Rajasthan, Kalpakkam-Tamil Nadu were under operation, two reactors each of 220 MW were under construction at each site at Narora in Uttar Pradesh, and Kakrapar in Gujarat. In addition to this, four pressurized heavy water reactors (PHWRs) comprising of 2X200 MW each at Kaiga-Karnataka and Rawatbhata-Rajasthan, were at initial stages of the preparatory activities. The assets of the erstwhile NPB, consisting of Tarapaur Atomic Power Station, Rajasthan Atomic Power Station (excluding unit-1), the Madras Atomic Power Station and all the projects then under construction (NAPP and KAPP) were transferred to NPCIL. NPCIL was also entrusted with the responsibility of operation of RAPS-1 on behalf of DAE.

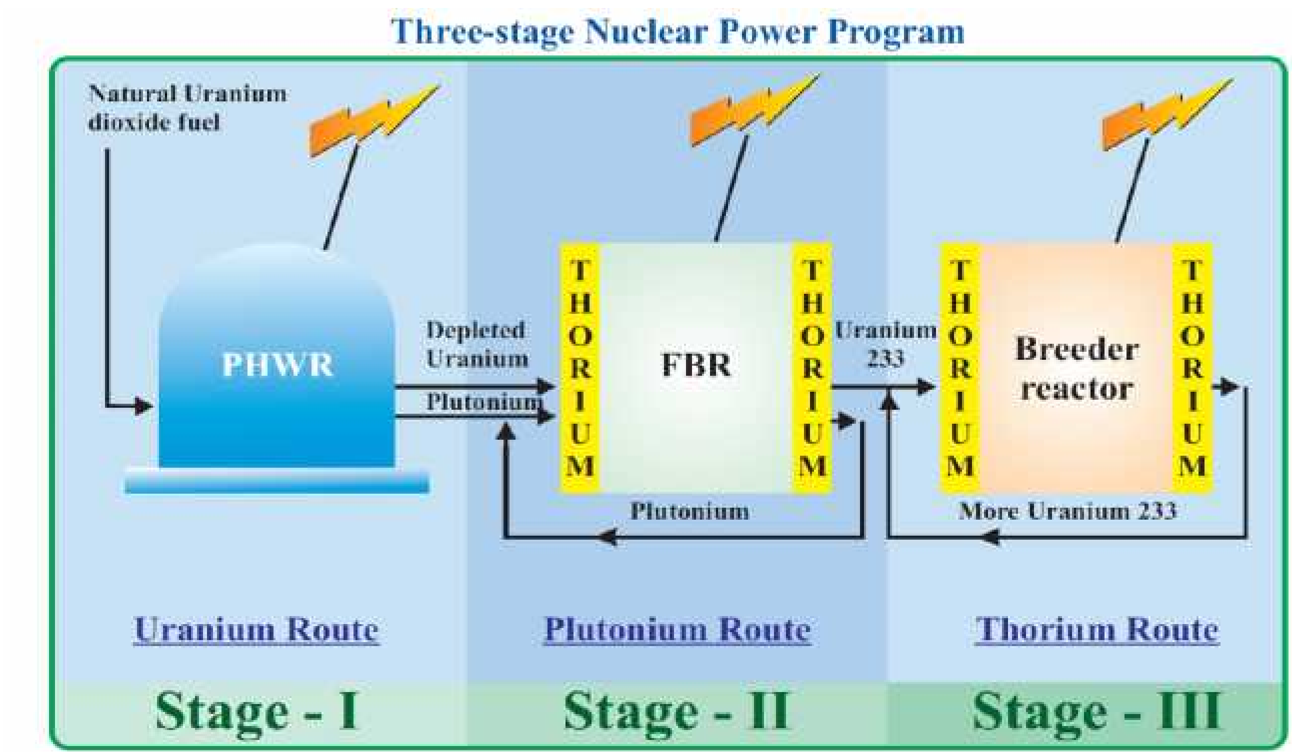
1.3 Indian Nuclear Power Program

The Indian nuclear programme was conceived based on, unique sequential three stages and associated technologies essential to aim at optimum utilization of the indigenous nuclear resource profile of modest Uranium and abundant Thorium resources. This sequential three-stage program is based on a closed fuel cycle, where the spent fuel of one stage is reprocessed to produce fuel for the next stage. The closed fuel cycle thus multiplies manifold the energy potential of the fuel and greatly reduces the quantity of waste generated.

The first stage comprises of Pressurized Heavy Water Reactors fuelled by natural uranium. Natural uranium contains only 0.7% of Uranium-235, which undergoes fission (splitting of Uranium atoms on absorption of slow neutrons) in the nuclear reactor to release energy (200Mev/atom). The remaining part in the natural Uranium, which is about 99.3%, comprises Uranium-238 which is not fissile (doesn't undergo the fission process with the slow neutrons like in Uranium-235), however it is converted to another fissile element Plutonium- 239 (Pu-239) in the nuclear reactor.

The second stage of the three stages Indian Nuclear Power Programme comprises of Fast Breeder Reactors (FBRs), which are fuelled by the fuel called as mixed oxide of Uranium-238 and Pu-239, obtained from the reprocessing of spent fuel of the first stage of PHWRs. In FBRs, Pu-239 undergoes fission (splitting of atoms by absorption of fast neutrons) producing energy, and producing Pu-239 by conversion of Uranium-238. Thus the FBRs produce energy and fuel, hence termed Breeders. FBRs produce more fuel than they consume. Over a period of time, Plutonium inventory can be built up by feeding Uranium-238.

In addition to the above, Thorium-232, which constitutes world's third largest reserves in India, is not fissile therefore needs to be converted to a fissile material, Uranium-233, by transmutation (a process of conversion of an element under radiation or, through radioactive decay process) in a fast breeder reactor. This is to be achieved through second stage of the program, consisting of commercial operation of Fast Breeder Reactors (FBRs).



Considering the sequential nature of the indigenous nuclear power program, and the lead time involved at each stage, it is expected that an appreciable time will be taken for direct Thorium utilization. Therefore, innovative design of nuclear power reactors for direct use of Thorium is also in progress in parallel to three-stage program. In this context, the frontier technologies being developed include the Accelerator Driven Systems (ADS) and Advanced Heavy Water Reactor (AHWR). The ADS essentially is a sub-critical system using high-energy particles for fission. One of the significant advantages of this system is small quantity of waste production. The quantity of waste in this system is greatly reduced in comparison to the existing reactors as Actinides produced in ADS are `burnt' out.

The AHWR is another innovative concept, which will act as a bridge between the first and third stage essentially to advance Thorium utilization without undergoing second stage of the three-stage program. It uses light water as coolant and heavy water as moderator. It is fuelled by a mixture of Plutonium-239 and Thorium-232, with a sizeable amount of power coming from Thorium-232.

India is also an active partner in the international experimental initiative on harnessing fusion power for the future, the ITER project. India is supplying several components for this experimental reactor.

1.4 Challenges faced enroute Development of Technology

The first stage program went through stages of technology demonstration, indigenization, standardization, consolidation and finally commercialization.

While the first stage began with 220 MWe reactors supplied by AECL, Canada, the subsequent PHWRs have all been indigenous. The Canadian assistance was withdrawn in 1974, even as the second unit of Rajasthan was under construction. It brought an international technology denial regime and isolation of the country from the rest of the world. Under such difficult and challenging circumstances, the Indian scientists and engineers rose to the occasion and with their untiring and innovative efforts, not only RAPS –1 but the design, construction and commissioning of the other unit too (RAPS-2) could be successfully completed.

Subsequently, MAPS units 1&2 were designed, constructed and commissioned with indigenous efforts. The design of 220 MWe PHWRs was standardized, and NAPS 1&2 & KAPS 1&2 were set up. Kaiga 1&2 and RAPS 3&4 were also set up with further improvements in design. The standard 220 MWe design was scaled up to 540 MWe and TAPP 3&4 (2x540Mwe) were set up, which are operating at full power. The 700 MWe PHWR design, using the same core of 540MWe, has been developed and construction of four such reactors are under construction two each at Kakrapar in Gujarat and at Rawatbhata in Rajasthan.

The country has developed comprehensive capabilities in all aspects of nuclear power from siting, design, construction and operation to decommissioning of nuclear power plants. Comprehensive multidimensional R&D facilities have been set up. Capabilities have also been developed in front and back ends of the fuel cycle, from mining and fuel fabrication to storage of spent fuel, reprocessing and waste management. Infrastructure for other inputs heavy water, zirconium components, control and instrumentation etc. has been established.

Excellent Human Resource and training infrastructure has been developed for the specialized skills needed for nuclear power.

At present 21 reactors with a capacity of 5780 MWe are in operation and Five with a capacity of 3800 MWe are under construction.

1.5 Development of Indian Industry over the period

At the time of country's independence in 1947 and for several years thereafter, the industry's capability was limited to manufacturing and supply of equipment for cement and sugar industry. The Indian industry exposure, manufacturing and supply of equipment for high technology requirements was quite limited. Whereas other developed countries at that time had well established industrial infrastructure and capability to manufacture equipment for defence and aviation industry. The nuclear industry development in those countries was a spin-off of the well established industry. The Indian industry development was initiated and achieved maturity with the development of nuclear technology. Large efforts have been put in by DAE and NPCIL to develop the Indian industry to achieve high standards in manufacturing of equipment for nuclear power technology. Currently, the Indian Industry capability in design, engineering and manufacturing of equipment is comparable to the international standards.

1.6 Achievements in Nuclear Power Technology

During the Calendar Year 2016, NPCIL recorded highest ever generation of 38781MUs (including 899.79 MUs infirm power from KKNPP-2) which was about 1.1 % higher than the generation of 38364 MUs in the last Calendar Year 2015. The expected generation for the Financial Year 2016-17 is about 39000 MUs including infirm power generation from KKNPP-2. the expected overall Plant Load Factor (PLF) and Availability Factor (AF) for all the reactors in operation were 79% and 81% respectively for the Financial Year 2016-17.

During the year 2016, KGS-3 achieved continuous run for more than a year (409 days). So far, this feat has been achieved 21 times by various reactors operated by NPCIL.

NPCIL's robust performance was achieved on the strength of excellent safety culture and healthy working environment nurtured by all employees at operating stations and Corporate Office. The Indian nuclear power plants have also performed at par with international benchmarks. At all operating stations of NPCIL, certified Environmental Management System (EMS) as per ISO-14001: 2004 and Occupational Health and Safety Management System (OHSMS) as per IS-18001: 2007 are maintained and regular audits (internal, external and management) were carried out for continual improvement.

1.7 Current Status on Indian PHWR Program

The first stage consisting of Pressurized Heavy Water Reactors (PHWR) has reached a state of commercial maturity and the second stage of Fast Breeder Reactors (FBRs) has been commercially launched with the construction of 500Mwe Fast Breeder Reactor (FBR) at Kalpakkam. The third stage systems (using U-233 – Thorium-232 obtained from spent fuel of second stage) have been developed at pilot scale. The development of commercial technology of third stage is under way currently. However, the commercial deployment of this technology is expected to take appreciable time.

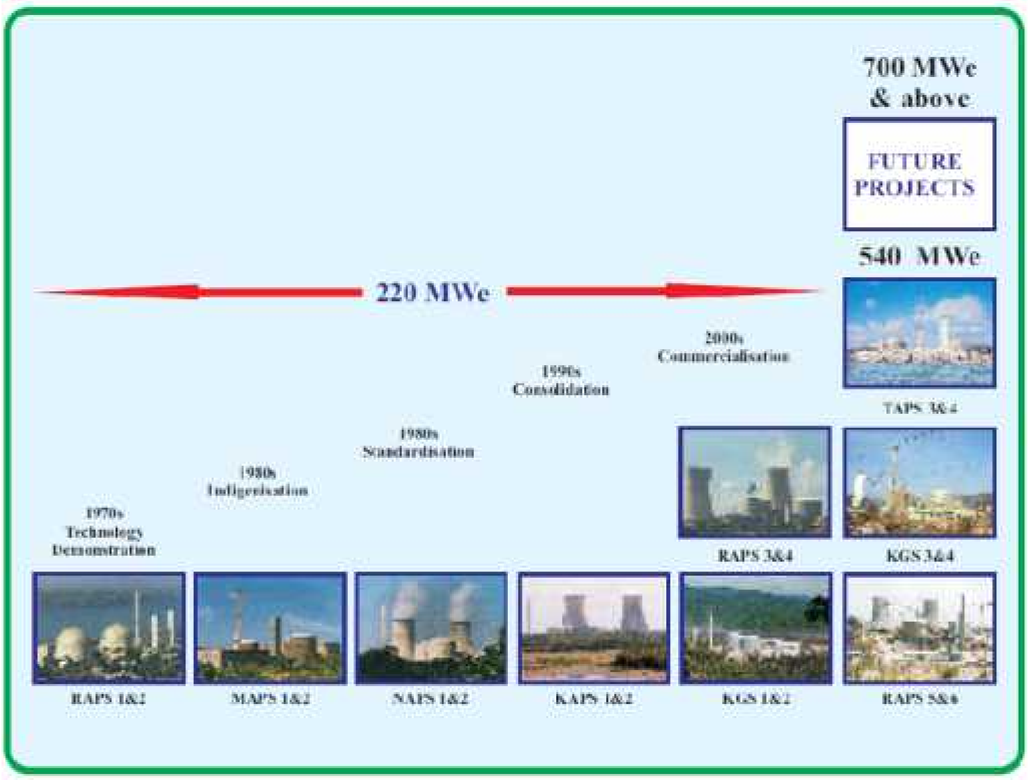


Fig-2: Current Status on Indian PHWR Program

1.8 Energy Scenario in India

India is not a very energy resource rich country. Currently, India's energy resource base status suggests the optimal mix of all the available energy resources to meet its growing demand of electricity which is projected to be about 800GW by 2032 and 1300GW by 2050.

Installed electrical generation capacity in 2012 was about 210 GWe in which the share of thermal power, hydro power, renewable, and nuclear power is about 66%, 19%, 12%, and 3% respectively. Energy is the prime mover of economic growth. Availability of energy with required quality of supply is not only the key to sustainable development, but also has direct impact and influence on the quality of service in the fields of education, health and , in fact, even food security. There is a big divide between the developed and the developing countries in per capita availability of energy.

The developed countries not only have significantly higher per capita energy consumption but also mainly depend on commercial energy. On the other hand, developing countries are highly energy deficient and also the large proportion of energy consumed is comprised of non commercial energy sources such as bio-mass. As per the projections made by International Energy Agency (IEA) , most of the developing countries are not expected to reach, even by the year 2030, the level of Energy development Index achieved by the OECD (Organisation for Economic Co-operation and Development) countries way back in 1971.

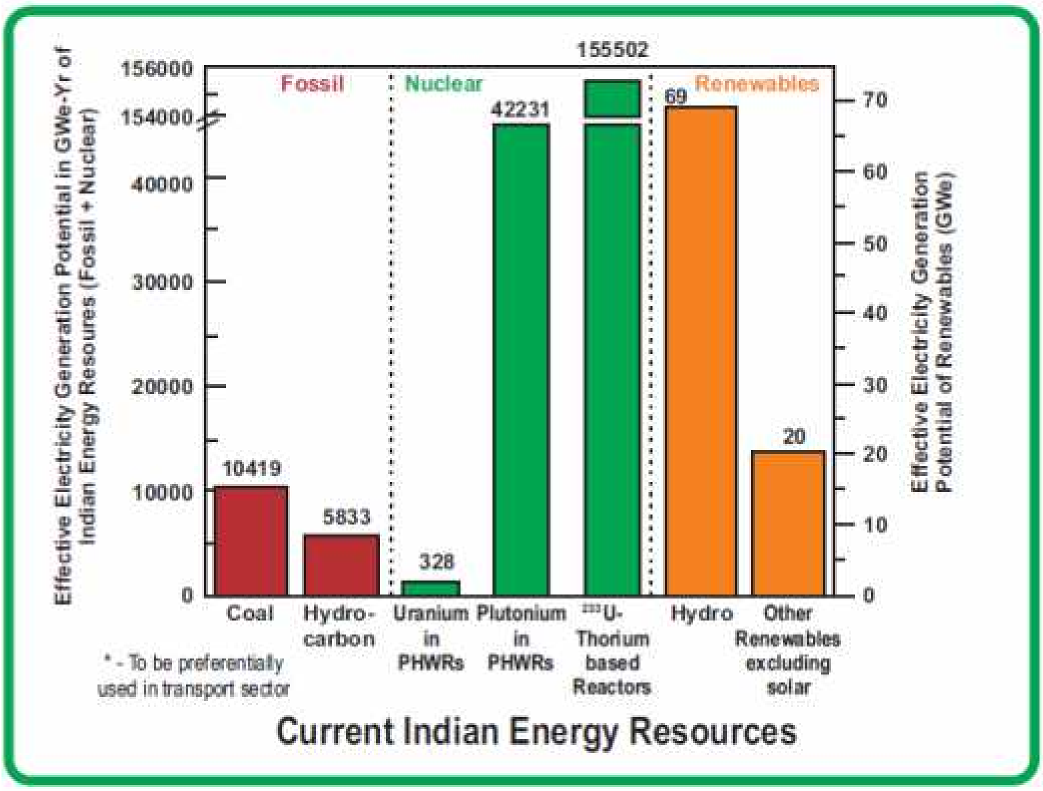


Fig- 3: Indian Energy Resources and Energy Generation Potential (Status in year 2012)

1.9 Glance at NPPs under operations, under construction and upcoming in the country

Table-1

Category of Units	Capacity (MWe)	Cumulative Capacity (MWe)	Present unit energy cost as on in paisa/kWh
Operational Units			
TAPS 1 & 2	2X160	320	93.88
RAPS-1 & 2	1x100 +	300	275.78 (Unit-2)
MAPS-1 & 2	2x220	440	199.64
NAPS-1 & 2	2x220	440	242.85
KAPS-1 & 2	2x220	440	232.04
RAPS-3 to 6	4x220	880	275.78 (Unit-3&4) 341.50 (Unit-5&6)
Kaiga (KGS) (Units 1,2,3,4)	4x220	880	300.25
TAPS-3&4	2x540	1080	283.44
KKNPP-1		1000	
Units under Construction			
KKNPP-1 & 2	1x1000	1000	
KAPP-3 & 4	2x700	1400	
RAPP-7 & 8	2x700	1400	
FBR, Kalpakkam	1x500	500	
Proposed For Construction			
Indigenous Reactors			
Gorakhpur, Unit 1 to 4,Haryana	4x700	2800	
Chutka, Unit 1&2, Madya Pradesh	2x700	1400	
Mahi Banswara,Unit 1 to 4	4x700	2800	
Kaiga, Unit 5&6,Karnataka	2x700	1400	
Bhimpur, Madhya Pradesh	4x700	2800	
FBR- 1 & 2	2x500	1000	
AHWR	1x300	300	
Reactors with Foreign Technical Cooperation			
Kukankulam, Unit 3 to	4x1000	4000	
Jaitapur Nuclear Power Park, Unit 1 to 6, Maharashtra	6x1650	9900	
Kovvada,1 to 6, Andhra Pradesh	6x1500	9000	
Chhaya Mithi Virdi, 1 to 6, Gujarat	6x1100	6600	
Haripur, Unit 1 to 6, West Bengal	6x1000	6000	

1.10 Road Ahead

Indian Nuclear power program, visualized by Dr. Bhabha in early fifties has been developed and successfully deployed with indigenous efforts, thus placing the country in elite club of countries possessing advanced Nuclear technology. The evolution and development of commercial Nuclear technology in the country has passed through several technological revolutions.

While developing and implementing the nuclear power program, the Indian industry capability in manufacturing and supply of high precision and specialized equipment has also been developed comparable to international standards.

The nuclear power has come of age with comprehensive capabilities in all aspects of nuclear power and is poised for a large expansion program. The challenge is to pursue the three-stage program, develop and commercially deploy technologies for utilization of thorium and ensure the country's long term energy security.

2.0 NUCLEAR POWER PLANT AT MAHI BANSWARA, RAJASTHAN

It is proposed to construct 2800 MWe Nuclear Power Plant (NPP) at Mahi Banswara in Banswara district of Rajasthan state consisting of four units of PHWR Reactors of capacity 700 MWe each. These units will be called Mahi Banswara Rajasthan Atomic Power Project Units -1 to 4, abbreviated as MBRAPP-1 to 4, and will be set up on the right bank of Mahi river at the upstream of Bajajsagar dam Reservoir in banswara district of Rajasthan state. It is about 520 Km by road from the state capital, Jaipur. The nearest railway station Ratlam is 60 km on Kota-Ratlam section of Western Railway. The nearest airport to the site is Udaipur at a road distance of 180 Km. The water requirements of the proposed MBRAPP–1 to 4 units will be met from Mahi Bajajsagar dam reservoir. Out of the total land required for the four units of 700MWe, area to be developed at site is 626 Hectares and that required for housing colonies of plant personnel is about 58 hectares.

The proposed 700 MWe PHWR reactors are indigenous and are similar to the ones currently under construction in Gujarat state (KAPP-3&4) and in Rajasthan state (RAPP-7&8). The proposed plant lay out of 700 MWe reactor will have single base mat on which Reactor building (RB), Reactor Auxiliary Building (RAB), Spent Fuel Building (SFB) and various other services required for reactor operation, will be built, and collectively will be called Nuclear Building (NB). The portion of nuclear building inside and including the secondary containment structure is called RB. The portion of NB housing the spent fuel storage bay including the tray loading bay is termed as spent fuel building (SFB).The portion of NB housing the Reactor Auxiliary Systems, PHT and Moderator Purification systems, D2O vapour recovery system and various service related structures such as maintenance shops etc. is called Reactor Auxiliary Building (RAB). The main plant buildings also include the control building (CB), Station Auxiliary Buildings (SABs) and Turbine Building (TB).

The reactor size and the design features of 700 MWe are similar to that of 540 MWe of TAPP 3&4 Units, except that partial boiling of the coolant up to about 3% (nominal) at the coolant channel exit has been allowed. The process systems have been suitably modified, over that of 540 MWe designs, for extracting the enhanced power produced in the core. Similar to TAPP-3&4 the reactor power is controlled using ionization chamber at low power (less than 15% FP) and through signal derived from Self Power Neutron Detectors (SPNDs) in the power range (higher than 5% FP). Both signals are used in the range 5-15% FP. Flux mapping system is used for correcting zonal power estimates derived from zonal control detectors (ZCDs).Bulk power estimates are corrected using selected channel temperature and flow measurements made on the primary side, up to approximately 85%FP.Above this the secondary side measurements are used to verify the thermal output of the core. Double Containment as used till now in all Indian PHWRs has been provided, to contain the radio active nuclides. The Primary containment is lined with carbon steel liner to reduce the leak rate.

3.0 PROJECT AT A GLANCE

- 400 kV substations will be provided to evacuate the generated power. This substation will be connected to different parts of Northern regions. For evacuation of 2800 MWe of power, 8 nos. of 400 kV lines would be needed, which include 2 nos. of 400 kV lines to cater to contingency conditions.
  - The latitude and longitude of the site are as follows:

    Latitude 23° 31' 46" N, Longitude 74° 35' 26" E .
- The proposed 4 units of MBRAPP and township will be accommodated within 626 Ha of land acquired for this purpose.
- Water for construction purposes will be drawn from Mahi Bajajsagar Dam Reservoir. 180 cusecs of water will be required for 4x700 MWe NPP, 127 cusecs will be consumptive use and balance 53 cusecs will be returned to the reservoir.
  - Siesmic, and other external events are considered in the design.
  - Natural Uranium Oxide is used as fuel.
  - Reactor is placed in double containment with carbon steel liner for the inner containment.
- Plant commercial life expected is 40 years, extendable up to 60 years or, beyond, and expected average plant load factor (PLF) is 80%.
- The estimated tariff from the project will be comparable and competitive with the contemporary thermal stations in the northern region.
- The safety of the MBRAPP is ensured by adopting the concept of defence-in-depth. This protection concept implies a system of consecutive series of physical barriers in the path of release of ionizing radiation and radioactive substances into the environment; and redundancy in equipment and control and other engineering features and managerial measures for protecting these barriers and maintaining their effectiveness. In addition there are engineered safety features such as Containment System, Containment Spray Cooling and air clean up System, etc. to mitigate the consequences of Design Basis Accident (DBA) like Loss of Coolant Accident (LOCA) + Loss of Emergency Core Cooling System (LOECCS).
- The physical barriers to contain radio nuclides comprise the fuel element matrix, fuel cladding, the primary pressure boundary, and the biological shields to attenuate ionizing radiation, and finally the containment (primary and secondary) to hold the releases from escaping into the environment, consequent to an accident.
- Pre-project activities viz., Property fencing, boundary wall work, topography survey, geo-technical and geo-physical investigation work, construction of approach and patrolling roads at site, construction of site offices, development of power evacuation plan, preparation of master plan for residential complex, arrangement of construction power supply and water supply for plant site and township, widening of access road to the plant, and permanent arrangement for water drawl for the plant and township will be taken up after possession of Land and will be completed in timely manner to put project infrastructure in place much before main plant construction.

4.0 TECHNICAL DETAILS

4.1 Salient site selection features

MBRAPP site comes under Choti Sarwan block of Banswara district of Rajasthan and it is about 30 km from Banswara town. The site has several favourable factors for locating 4x700 MWe PHWRs. Some of the major ones are summarized below:

- Availability of sufficient cooling water.
- Foundation conditions are favourable.
- Power evacuation is feasible for around 2800 MWe power from the site.
- Connectivity of the site via road and train

Some of the salient features of the proposed site for MBRAPP, in Banswara district of Rajasthan state:

Site Location: Land required for plant site and residential complex is being acquired together.

Water availability and drawl of cooling water from Mahi Bajajsagar Dam Reservoir has been assured for the Project by State Government of Rajasthan.

The site area lies in Seismic Zone-II in the Seismic Zoning Map of India (Fig.4).The Map showing the location of Banswara is shown in Fig-5. The seismo-tectonic study has concluded that there is no capable fault within five kilometers of the project site. The site is engineer-able from seismo-tectonic considerations.

The elevation of the plant site area in general varies from about RL + 296 m to RL + 316 m except few isolated hot spots. The average grade elevation of the plant site is about + 306 m.

Study to estimate design basis flood of MBRAPP considering all the potential sources of flooding at the plant site is being carried out by National Institute of Hydrology, Roorkee as per AERB codes and guides. Safe grade elevation will be finalized based on this study with appropriate drainage scheme at project area to avoid local flooding of nearby areas.

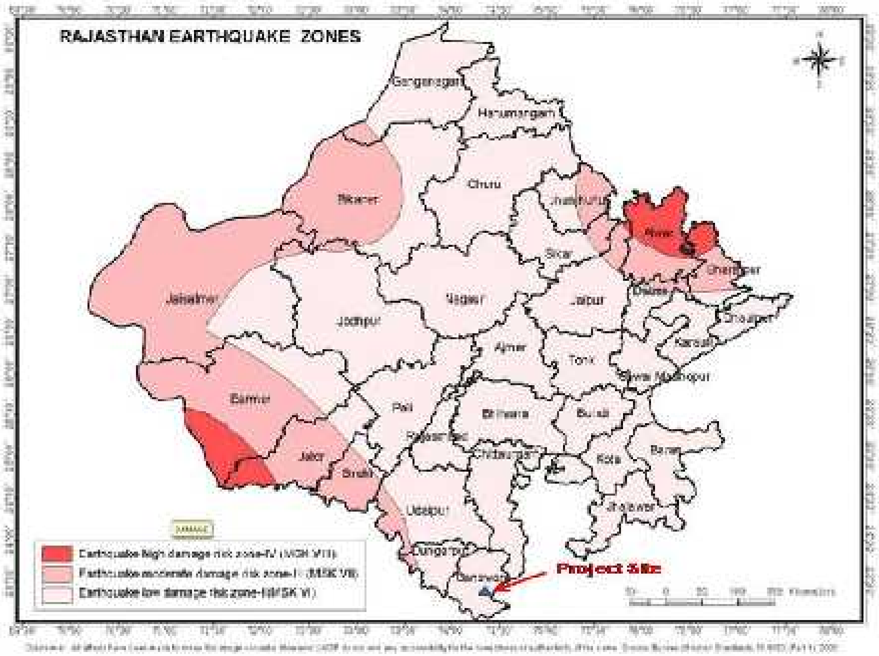


Fig.4- Siesmic Zone Map of India

Power evacuation scheme from the proposed plant is studied in detail considering transmission scheme, generation and load centers in the electricity network. Availability of adequate transmission links even during a grid disturbance is ensured. Possibility of operation in an islanding mode is also checked.

The current estimated population (year 2017) within the affected 6 number of villages (Bari, Sajwaniya, Rel, Adibheet, Katumbi and Khandia Deo) is about 8232. Project area is partly lying in these villages where habitation is scattered. Based on growth rate, population, estimated population in the project area is about 2568 (Year 2017). Estimated Population within natural growth zone is 34696.Population within 5 to 10 km except natural growth zone is 83416.

State Highway **SH10** passes about 1.5 km from the project site, connecting Khairwara-Dungarpur-Banswara-Ratlam. **NH113** connecting Nimbahara in Rajasthan with Dahod in Gujarat, passes about 6km from the site and runs through Banswara town. Banswara town is about 30km by road to the project site. The other national highway **NH3** passing through Ratlam connecting Phalghat, Indore and Dewas. Ratlam is about 60km away from the project site through road. The other nearest national highway, **NH8** passes through Khairwara at a distance of about 112 km from Banswara. Khairwara is connected to Banswara by **SH10** via Dungarpur. Location of MBRAPP-1 to 4 is shown in Fig -5.

It is ensured that the site has competent strata for transferring the design loads through the foundations.

The details of local geology are also considered for treatment of the founding strata if any and also for ensuring proper distribution of loads on foundations to prevent unacceptable differential settlements.

Fig-5: Location of MBRAPP-1 to 4

4.2 General Plant lay out

MBRAPP - 1 to 4, Site layout has been developed on the basis of twin unit modules of 700 MWe each, and taking care of current international safety standards. The twin unit module has the following principal features:

The layout is based on a unitized concept except limited sharing in some common facilities / systems (e.g fire water pumps).

All safety related systems and components have been appropriately grouped and placed in structures of the appropriate safety class.

Safety related buildings such as Nuclear Building (consisting of Reactor building, Reactor Auxiliary building and Spent Fuel Storage Bay), Control building, Station Auxiliary Buildings, SRPH, FWPH, SREH etc., are so located that they are outside the low trajectory turbine missile (LTTM) zone of turbines of MBRAPP-1&2 and MBRAPP- 3&4.

Seismic classes of equipment are housed in seismic-class structures. Consistent with this philosophy, Nuclear Building (NB), Control building (CB) and station auxiliary buildings (SABs) are designed for Safe Shutdown Earthquake (SSE).
For each Reactor unit, 4 numbers of Class-3 Power Emergency Diesel Generators (DGs) are housed in the two SABs (adjacent to respective RABs) in two separate groups with separate cable routing.

Separate Spent Fuel Building, which is part of NB, is provided for each reactor. Each SFB houses a Spent Fuel Storage Bay (SFSB), Tray Loading Bay (TLB) and fuel cask loading area. Spent fuel storage bay is founded on the common nuclear building raft and is developed with tank in tank concept.

The location of the stack is selected next to the waste management building so as to reduce the lengths of the large size active exhaust ventilation ducts coming out from the exhaust ventilation room located in the first floor of the waste management building.

The area between the two Reactor Buildings in Nuclear building houses the RAB, SFB, Change room, Labs, intake ventilation room, Back up Control room, etc.

There are separate buildings for active Mechanical workshop & Fuel Handling Maintenance facility, waste management facility and upgrading plant.

The twin unit module in the nuclear island has been so chosen that it will be possible to enforce single point entry in the radiation zones and follow radiation-zoning philosophy without undue inconvenience to the operating personnel as well as to the public.

With this concept the total movement of men and materials in the contaminated areas will be reduced substantially. Turbine Building, Station Auxiliary Building and Control Building are classified as Radiological Zone-1.

The layout is so developed that many underground piping, cables etc. will be run through the basements of buildings rather than using outdoor trenches and the length of tunnel and trenches has been kept to bare minimum.

The common service systems as well as the instrumentation and control and the electrical supply systems are centrally located and spread radially outwards in various directions to cater to the requirements of various buildings. This concept is adopted to cut down the total run of service pipes, cables etc.

Other aspects such as accessibility, maintainability and ease of construction have also been given due consideration in arriving at the plant layout.

Special provision of adequate space adjacent to the Reactor Building and Turbine building has been made to enable manoeuvring of the high capacity outdoor mobile crane during erection and handling of heavy equipment such as reactor components, steam generators and generator stator units etc.

The location of condenser cooling water pump house for twin units has been optimized considering the economic benefits in terms of reduced lengths of large size CW Piping. However, position of Induced Draft Cooling Towers and safety related pump house is governed mainly on the basis of turbine missile free area. Each unit is having two numbers of Natural Draught Cooling Towers (NDCT) and Induced Draft Cooling Towers (IDCT).

The switchyard is oriented to suit the power evacuation scheme, based on 400 kV transmission systems.

Like earlier projects, a D2O Upgrading Plant is provided to upgrade the heavy water collected from the RB vapour recovery systems, spills from various D2O systems etc. The waste management building and upgrading plant building has been kept adjacent to Nuclear Building (NB) to reduce O & M personnel requirement and also the common services of the main plant.

Active Laundry is in Nuclear building; personal decontamination (Showers & washroom) is also in Nuclear Building. Equipment decontamination facility is in Waste Management Plant (WMP).

Simplified diagram of a PHWR unit showing primary and secondary major process loops with power generation is given vide Fig.6.

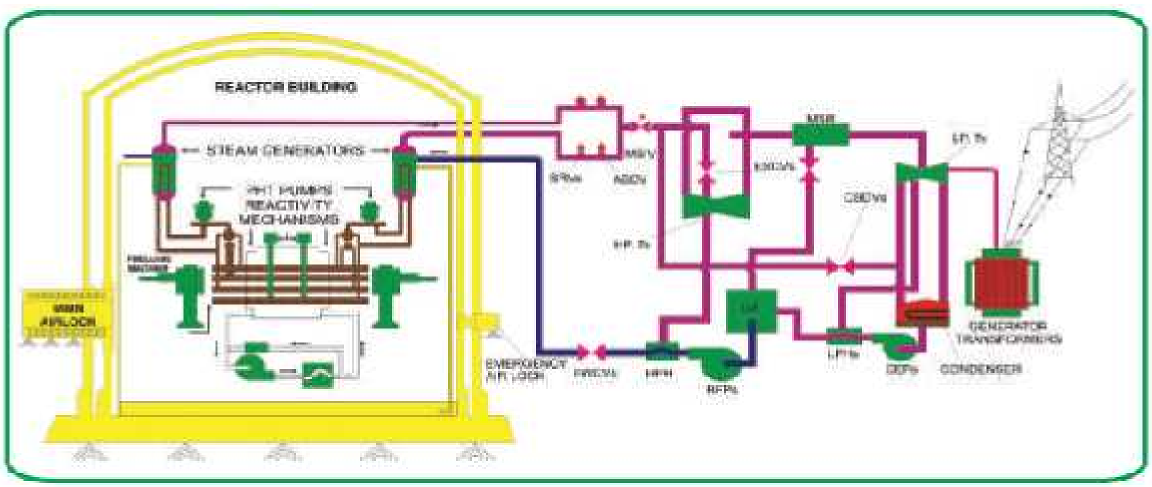


Fig- 6: Simplified diagram of a PHWR Unit.

4.3 Reactor systems

4.3.1 Reactor Fuel

The reactor chosen is of a Pressurized Heavy Water Reactor type (PHWR), using natural uranium dioxide fuel in the form of 37 rod clusters (bundles). The reactor generates about 2296 MW of total fission power out of which 2166 MW is delivered to the coolant. The primary heat transport (PHT) system consists of 392 horizontal coolant channels forming two independent loops.

4.3.2 Reactor Control and Protection:

The reactor is controlled to deliver the set demanded power. On-power refuelling takes care of the reactivity changes due to burn-up of fuel and build-up of fission products.

The core reactivity and spatial power distribution on a long-term basis are controlled by a planned scheme of regular on-power bi-directional refuelling. Fine control of reactivity and spatial power distribution are achieved by Reactor Regulating System (RRS). The worth of reactivity devices is augmented by Moderator Liquid Poison Addition System (MLPAS) controlled by RRS. The RRS provides supervised shut-off rod withdrawal during reactor start-up. Liquid Zone Control (LZC) system is the primary reactor control device. The power error / flux tilt error is the signal to actuate reactivity devices. The reactivity devices used in the control of the reactor are LZC, 17 nos. of stainless steel Adjuster rods, 4 nos. of Control rods each consisting of cadmium absorber sand witched between stainless steel tubes.

4.3.3 Design of Reactor shut down systems:

When certain plant parameters exceed operating limits and conditions, the shutdown systems trip the reactor by fast insertion of a large amount of negative reactivity into the core. Two independent and fast acting systems SDS #1 and SDS #2 capable of independently shutting down the reactor and maintaining it sub- critical are provided.

The design objectives of the shutdown systems are

Upon trip, to provide an initial negative reactivity insertion rate high enough to counteract all credible reactivity excursions.

Upon full insertion, to provide enough negative reactivity depth to ensure that the reactor remains sub critical following shutdown

4.3.4 Principal Mechanical Components:

Calandria:

Calandria is the reactor vessel containing heavy water as moderator and reflector, various reactivity controls, monitoring and shut down mechanisms, fuel and coolant channel assemblies. Abutting to the ends of the Calandria are two end shields, which are welded in-situ with Calandria to form an integral assembly, as shown in Fig-7.

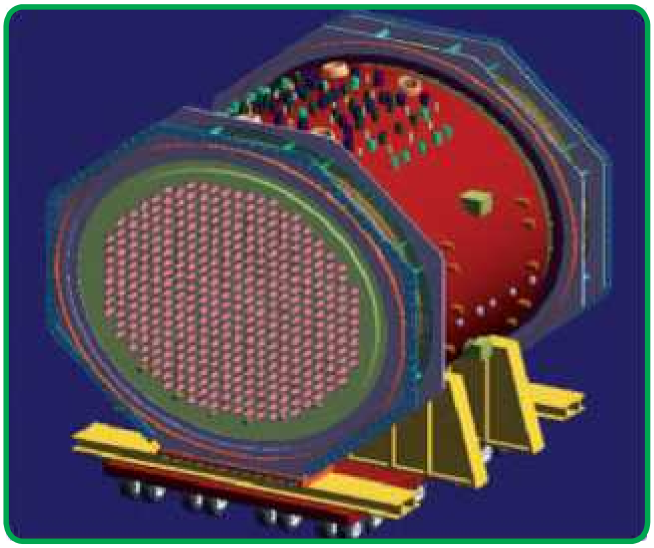


Fig-7: View of Calandria and Endshields showing coolant channels and penetrations

End Shields:

The end-shields, shown in Fig-7, provide shielding on the reactor ends to reduce the dose rate in fuelling machine vaults to an acceptable level, support and locate coolant channel assemblies and provide integral support to reactor assembly. The stainless steel end-shields are filled with10 mm diameter carbon steel balls and light water in 57:43 volumetric ratios, which provides adequate shielding properties. For cooling, the End shield water is circulated through external cooling circuit.

Primary Heat Transport System:

The Primary Heat Transport (PHT) system transports heat produced in the reactor core to steam generators to generate steam, which is fed to the turbine. The transport medium is pressurized Heavy Water.

PHT main circuit is arranged in two identical loops arranged in interleaving geometry. Partial boiling is allowed in the channels to the extent of obtaining a nominal quality up to 3 % at reactor channel exit. The two reactor outlet headers of the same loop are interconnected to avoid flow instability.

The heat transport system also includes following subsystems:

- Pressurizer, feed and bleed for pressure and inventory control.
- Relief system for over pressure protection.
- Fuelling Machine heavy water supply system to supply high pressure heavy water to the fuelling machines.
- Purification system for maintaining desired water chemistry and removal of corrosion products.
- Shutdown cooling system for removal of decay heat.
- Emergency Core Cooling System (ECCS) to maintain core cooling following a loss of coolant accident (LOCA).
- Inventory Addition and Recovery System (IARS) to maintain PHT inventory in the event of a

small leak, which is within the capability of primary pressurizing pump.

- Leakage collection system to collect, contain and transfer the collected heavy water and to provide venting and draining facility to the equipment.
- Service system to facilitate filling and draining of steam generator-primary coolant pump loop and header level control.
- Sampling system for monitoring the system chemistry.
- Passive Decay Heat Removal System (PDHRS) for decay heat removal during station blackout condition.

Pressurizer:

During power operation, Pressurizer carries out the function of PHT pressure control and Feed and Bleed systems carry out inventory control of main circuit through level control in Pressurizer. During low power operation or, when Pressurizer is isolated, Feed and Bleed systems carry out pressure control of main circuit.

Prssurizer is a pressure vessel (Surge tank) of a total capacity of 45m^3 with heavy water inventory of 30m^3 during full power operation. Pressurizer provides the necessary vapor cushion for PHT main circuit to reduce pressure variations due to transients involving swell and shrinkage in the coolant volume resulting from the operational transients. Pressurizer rides on PHT main circuit and keeps main circuit pressure with in operating limits. Upward pressure surges are mitigated by steam bleed valves, which relieve vapor from pressuriser to Bleed Condenser (BCD). Downward pressure surges are controlled by starting electric heaters provided in the pressurizer. Pressurizer is shown in the Fig-8.

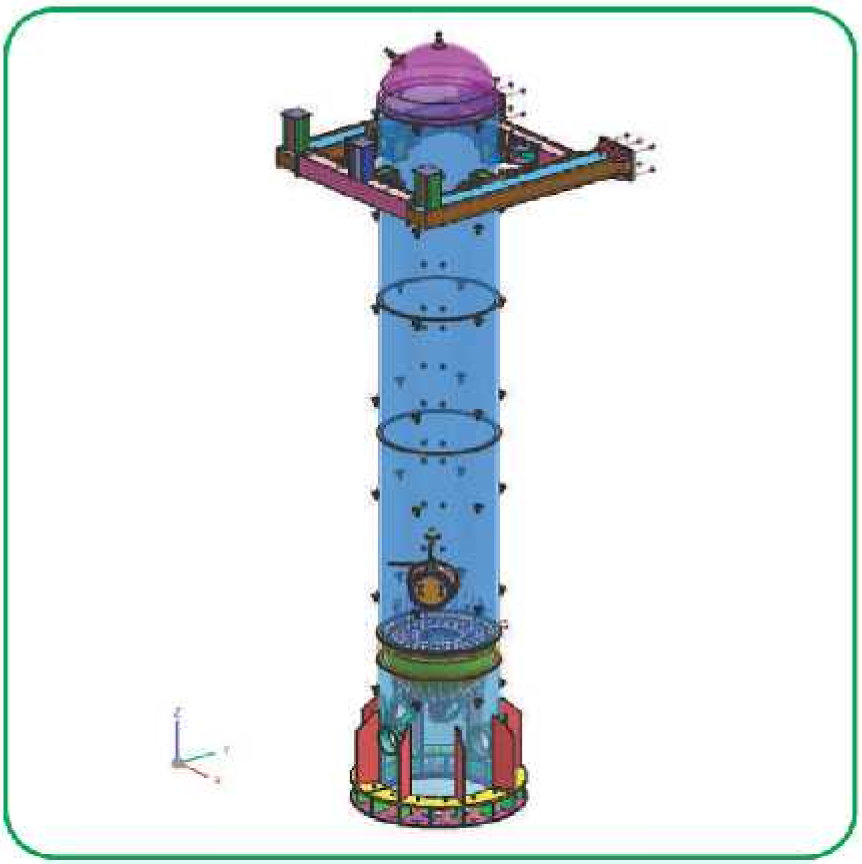


Fig -8: 700 MWe Pressurizer of 45 M^3 Capacity

Coolant Channel:

The gross coolant flow is 28.87 x 106 kg/hr based on the total power output and delta-T of 44°C across the core with primary quality of the order of 4 % (Max) at ROH.

The bi-directional fuelling adopted necessitates flows to be in opposite direction in adjacent channels to have fuelling in the direction of flow.

The main circuit coolant loop of figure of eight, i.e. series-parallel arrangement is chosen on the basis of:

- Lower heavy water hold up.
- Lower piping cost.

Fuelling machine (F/M) heavy water supply system:

F/M supply system comprises F/M supply pumps (2 x100% capacity), gas charged accumulators, three nos. of F/M supply filters and associated piping and valves for providing supply at different pressures. The return flow from F/M is cooled in F/M return cooler and returned to storage tank after purification.

Steam Generator (SG):

The SGs are vertical shell, natural circulation, and U tube heat exchangers with integral moisture separating equipment. They are also fitted with axial economizer to provide increased steam pressure. Fig-9 shows the view of SG at 700 MWe NPP. The reactor coolant flows through inverted U-tubes, entering and leaving nozzles located in the hemispherical bottom channel head of the SG. The bottom head is divided into inlet and outlet chambers by a vertical partition plate extending from the tube sheet. The heat conveyed by the reactor coolant is transferred to the secondary fluid through the tube walls of the tube bundle. On the secondary side the feed water is directed to the cold side of the tube sheet by an annular skirt in which feed water is injected by the feed water distribution ring.

Fig-9: Steam Generator of 700 MWe NPP

Primary Coolant Pump:

Primary coolant pump is used for coolant recirculation from SGs to reactor core and from reactor core to SGs, thus transferring heat from primary system side to the secondary side. Fig-10 represents the Primary Coolant Pump for MBRAPP Rajasthan Site.

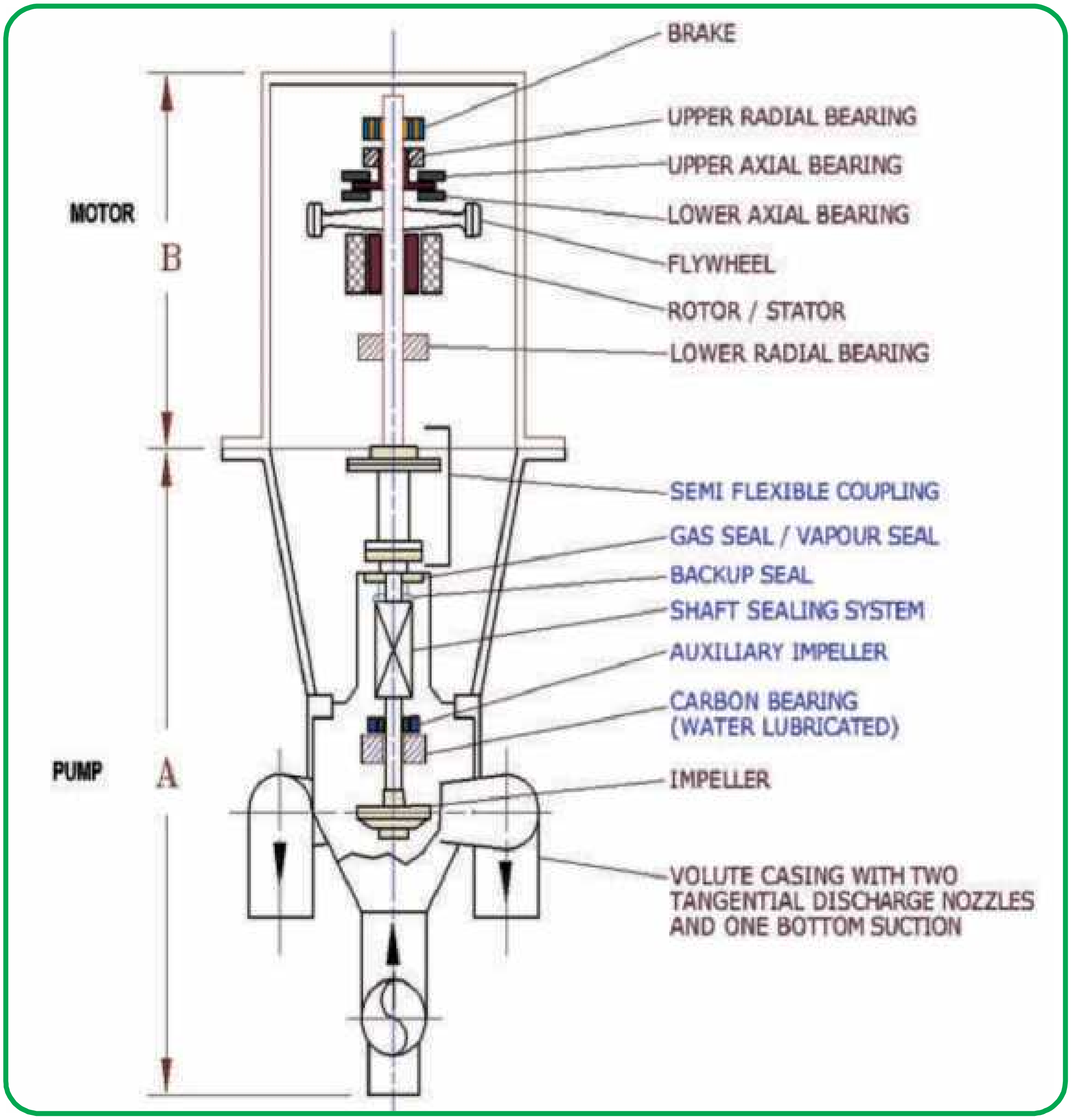


Fig-10: Primary Coolant Pump for 700 MWe NPP

4.3.5 Principal Fluid System:

During normal operating conditions the heat from the primary side is carried out by the primary heat transport fluid and is transferred to the light water in the Steam generators (secondary side).

During off normal conditions residual heat removal from the SG secondary side is ensured by series of engineered safety systems as per the requirement provided in the design. The shut down cooling system contributes for the residual heat removal from the primary side during shut down conditions. Emergency Core Cooling System (ECCS) is actuated as per the demand of the system to remove the residual heat from the core in case of emergency condition.

The engineered safety features provided as a first of a kind in its design for 700 MWe are as follows:

PDHRS (Passive Decay Heat Removal System):

The primary function of the Passive Decay Heat Removal System (PDHRS) is to ensure continued availability and recirculation of the inventory on the secondary side of the Steam Generators in the event of class IV failure, non-availability of Auxiliary Boiler Feed Pumps (ABFPs) or Station blackout and in the process ensure continued removal of decay heat from the core. The objective of providing PDHRS is to enhance reactor safety in the event of station blackout by ensuring continuance of thermosyphon cooling of the reactor through steam generators in the absence of makeup to the Steam Generator (SG).

Containment Spray System:

The objective of the Containment Spray System (CSS) is to remove the airborne Iodine following a loss-of- coolant accident (LOCA) by spraying water along with appropriate additives (i.e. Sodium hydroxide solution etc) into the containment. This spray also removes heat from the containment atmosphere and reduces the pressure of the containment thereby minimizing the driving force for leakage of fission products and consequent ground level releases. Containment Spray System (CSS) is designed to operate during accident conditions only.

4.3.6 Reactor Building and Supporting Systems:

Reactor Building Structure:

Reactor building (RB) consists of reinforced concrete cylindrical wall capped with reinforced concrete segmental dome, and a pre-stressed concrete inner cylindrical wall containment building with a 6 mm thick steel liner, and an annular space between the two buildings. The outer containment functions to protect the containment building from external hazards. RB houses Reactor core and portions of associated structures, systems, and components. In the event of a LOCA or Severe accident, the containment building prevents release of stored energy. The Reactor building is designed to withstand internal accidents as well as external hazards from the release of stored energy.

Reactor Building (RB), Reactor Auxiliary Building (RAB) and Spent Fuel Storage Bay (SFSB), collectively known as Nuclear Building (NB), are on single largest base mat, which ensures that overturning due to seismic events, tornadoes, fire, missiles, and aircraft hazard will never occur. The outer containment building is designed to withstand the potential effects of an external explosion.

Containment isolation system:

Containment isolation valve minimize the release of radioactivity to the environment in the event of an accident with fission product releases in the containment.

Other Safety Related Buildings:

Control building, Turbine building and Service Auxiliary Buildings are located on individual base mats. Diesel Generator Sets (DGs) are located in Service Auxiliary Buildings. Radio active Waste management building is located on individual base mat. The Safety related buildings include the new fuel storage building, the Reactor Auxiliary Building, Control building, Service Auxiliary buildings that house DG sets and the radio active waste management building.

4.3.7 Plant Water Systems:

The Plant Water System for MBRAPP-1&2/MBRAPP- 3&4 is provided for making up the losses (i.e., evaporation, drift, blow down and leaks) in the Cooling Tower based cooling water systems. Natural Draught Cooling Tower (NDCT) based systems are Condenser Cooling Water system and Auxiliary Service Water System. Induced Draught Cooling Towers (IDCTs) based system is Service water (SW) system for Active Process Water (APW) cooling and also to cool other safety related non active systems. 30 days storage reservoir (Emergency make up water pond) will be constructed.

Active Process Water System

Active Process Water (APW) system (a closed loop system) serves to remove heat from reactor process heat exchangers and dissipate to Service Water (SW) system through active process water heat exchangers. In the hierarchy of heat transfer, the reactor process system circuit forms the primary cooling circuit and the APW circuit forms the secondary cooling circuit. A tertiary circuit viz. SW system is provided for transfer of heat from APW circuit. SW circuit dissipates heat finally to the atmosphere via Induced Draught Cooling Tower (IDCT). The criteria for design of the system are to transfer the heat from reactor process heat exchangers to SW system, to provide water chemistry control, and also to provide an intermediate barrier to potential release of radioactivity to environment due to leakage in primary reactor process heat exchangers.

Service Water System

SW System is divided into two independent loops viz Loop-1 & Loop-2 with properly segregated equipment loads on each loop such that the heat load and flow requirement are equal to the extent possible. These equipments are segregated such that with one loop in service decay heat removal can be maintained and other loop can be under maintenance. The Service Water System dissipates the heat finally to the atmosphere via Induced Draught Cooling Tower (IDCT).

Condenser Cooling Water System

The condenser cooing water (CCW) system provides cooling water to turbine condenser. The warm return water from the condensers is cooled by natural draught cooling towers (NDCT) and re-circulated by condenser cooling water pumps in an open re-circulating loop. An independent CCW System is provided for each unit.

Auxiliary Cooling Water System

Auxiliary Cooling Water (ACW) system is a closed loop system using chemically treated DM Water designed to cater to the cooling water requirement of auxiliaries of secondary cycle like Boiler Feed Pumps (BFP), Condensate Extraction Pumps (CEP), Hydrogen Coolers, Lube Oil Coolers, Seal Oil Coolers, Air Evacuation Equipment and Steam Generator (SG) Blow down Coolers.

Auxiliary Service Water System

ASW System is an open recirculation system through NDCT catering to following cooling requirements; Reject heat from Auxiliary Cooling Water (ACW) System, which cools TG auxiliary equipment and cooling of chiller condensers of Chilled Water.

Fire Water System

The main plant area is provided with extensive hydrant and sprinkler system for minimizing the consequences of any fire hazard. High Velocity Water Spray System is provided for all transformers, turbine oil storage tanks, and day oil tanks. Medium Velocity Water Spray System is provided for cable vaults, cable trays and PHT pump motors. Indoor and Outdoor hydrants located suitably provide fire protection within and around the plant building. Water for personnel sprays in the Reactor Building is also supplied through fire water system.

4.3.8 Radio Active Waste Management:

Waste Management Plant of MBRAPP- 1 to 4 is designed to provide for segregation, safe handling, treatment, storage, monitoring and safe disposal of radioactive liquid & solid waste. The equipment, tanks and other facilities for handling the wastes is designed for the entire operating life of MBRAPP site.

Gaseous Waste Processing System:

The gaseous radioactive effluents from reactor and service building ventilation exhaust systems are passed through pre-filters and HEPA filters before discharging them through the stack. These gaseous effluents are continuously monitored for radioactivity content before discharging through stack. There are three gross β-γ activity monitors on each of the reactor building (RB) ventilation exhaust ducts (located in Service Building). These are connected to the Reactor Building containment isolation system logics for isolation (boxing up) of reactor building containment; in the event of two out of three β-γ activity monitors detect the activity level, on the Reactor Building exhaust duct, more than the pre-set values.

Liquid Waste Processing System:

During operation of the nuclear power plant, liquid wastes are produced by system drains, leakage, flushing and other processes. The design has liquid radioactive waste processing and storage system that performs the collection, short-term storage, processing and cleaning of the waste streams produced by let down, drainage, purge, venting, or leakage from system in the controlled area. The processed waste water is monitored during discharge. The discharge line is automatically isolated if an authorized limit is exceeded. Processed water discharged to the environment via the liquid waste processing/storages system will comply with applicable regulations of AERB

Solid Waste Processing System:

Near Surface Disposal Facility (NSDF), generally known as Solid Waste Management Facility (SWMF), is common for all the units of MBRAPP. Solid wastes after conditioning will be disposed off in the NSDF area in earth trenches/ RCC trenches/vaults/ tile holes depending upon their surface dose rate. NSDF is co-located within the exclusion zone for avoiding long-distance transportation of waste. An area admeasuring 400m x 250 m (1, 00,000 m2 (10 hectares)) will be reserved for NSDF. This facility will be located within the exclusion zone boundary. Conditioned solid waste, EMCCR waste and decommissioning waste will be disposed/ stored in this facility. Access road for movement of vehicle carrying the waste from WMP building to NSDF will be provided.

4.3.9 Turbine Building Design:

The Turbine Generator and Secondary Cycle System broadly constitute a safety related part and a non important to nuclear safety (NINS) part.

The safety related part of turbine generator and secondary cycle comprises of –

- Main Steam system from steam generators up to pipe anchor outside turbine building including Steam Generator Pressure Control (SGPC) scheme including steam discharge and relief system.
- Main feed water system from pipe anchor outside turbine building up to steam generators including SteamGenerator Level Control (SGLC) scheme.
- Steam generator blow down system from steam generators up to pipe anchor outside turbine building.
- Complete auxiliary feed water system.

The turbine building is independent of the nuclear island such that internal hazards in the turbine building remain confined. The building is located in a radial position with respect to the reactor building to provide protection from turbine missile impact.

4.3.10 Electrical System:

400 kV substations will be provided to evacuate the generated power. This substation will be connected to different parts of Northern regions. For evacuation of 2800 MWe of power, 8 nos. of 400 kV lines would be needed, which include 2 nos. of 400 kV lines to cater to contingency conditions.

Standby Power Supply System:

Standby Power Supply System consists of Class III, Class-II and Class-I power supplies. These Standby Power Supplies feed all the safety related loads of the Station. These are divided into Division-I and Division-II for distributing redundant safety related loads. The redundant loads are so distributed that each division can independently meet the emergency load requirements. Each division is independent and physically separated from the other. Power supply equipment of Division I and Division II are located in physically separate buildings, namely Station Auxiliary Buildings A & B respectively, to reduce the probability of common cause failures. In addition, Diesel Generator set and associated power distribution buses are further segregated within each SAB to ensure their independence and to minimize their simultaneous unavailability. These buildings are designed for Safe shut down earthquake (SSE) and Operating Basis Earthquake (OBE) conditions. These Station Auxiliary Buildings are located outside the turbine missile zone. All the safety related power supply systems are unitized. All Electrical supply sources and distribution equipment required for Class I, Class II & Class III Systems will be designed to safely withstand OBE & SSE conditions. In addition, one air cooled Diesel Generator of 200 KVA rating will be installed for each unit in MBRAPP.

4.3.11 Safety Aspects of Nuclear Power Plant:

Safety aspects of NPP can broadly be classified into three categories:

- Nuclear Safety
- Radiation Safety
- Industrial Safety

Nuclear Safety Aspect of Proposed PHWR:

Core Cooling

Multiple means are provided for core cooling under various plant states. These include main as well as backup systems.

Purpose	Device / Equipment
Under normal operating condition	
i) Power operation	
Primary	Primary coolant pumps
Secondary	Steam generators (SG) fed by main boiler feed pumps
ii) Hot Shutdown Condition	
Primary	Primary coolant pumps
Secondary	Steam generators fed by main/ auxiliary boiler feed
iii) Cold Shutdown Condition	
Primary	Shutdown Cooling Pumps
Secondary	Process Water in Shutdown Cooling heat exchangers.
Under accident condition	
i) Station Blackout	
Primary	Thermosyphoning
Secondary	Re-circulating steam generators secondary side inventory after cooling in passive decay heat removal system (PDHRS). As a backup, fire water supplied from diesel engine operated pumps independent of station power supplies can also be injected into PDHRS or

ii) Loss of Coolant Accident	Through Emergency core cooling system (ECCS) • 2 X 100 % trains of High pressure H_2O injection (Accumulator) • 2 X 100 % trains of Low pressure long term recirculation by ECCS pumps

Containment of Radioactivity

Type	Double containment with primary containment of pre-stressed concrete (with carbon steel liners) and secondary containment of reinforced concrete. Both are of dome shape.
Engineered Safety Features	Containment spray system – for containment cleanup and cooling after accident Secondary containment purge and recirculation system – to maintain negative pressure in secondary containment space Primary containment controlled discharge system- to reduce primary containment pressure on long term basis.

Emergency Power Supply Systems:

700 MWe PHWRs are connected to the grid through two separate systems of 400KV and 220 KV. Standby Power Supply System consists of Class-III, Class-II and Class-I Power Supplies. These Standby Power Supplies feed all the safety related loads of the station. These are divided into the Division-I and Division-II for distributing redundant safety related loads. The redundant loads are so distributed that each division can independently meet the emergency load requirement. Each division is independent and physically separated from the other. On-site emergency DG sets is classified as Class-III power supply system. Auxiliaries connected to this power supply system can tolerate short time power supply interruption (approximately two minutes). 4 numbers of 4000kW, 6.6kV diesel generator sets are provided. DG#1 and DG#3 are located in SAB-A and DG#2 and DG#4 are located in SAB-B. Each diesel generator set along with its auxiliaries is housed in independent rooms. Any one out of four diesel generator sets is adequate to meet the system demands under all postulated conditions. Onsite underground water proof fuel oil storage sufficient for 1 DG operation for 7 days at 4000 kW is always ensured.

Providing Ultimate Heat Sink:

Use of natural draft cooling towers that draw makeup water from Mahi-Bajajsagar Reservoir on Mahi River, have been used as heat sink.

Spent Fuel Storage And Cooling System:

In 700MWe PHWRs, Spent Fuel Storage Bays (SFSB), one for each unit, are located inside the reactor auxiliary building outside Reactor Building. It has the capacity to store spent fuel bundles of 10 years reactor operation and one emergency full core unload. These spent fuel storage pool is having tank in tank concept.

Design Basis flood level and Safe grade elevation

The severe most flooding is considered in deciding the safe grade. The maximum flood depth for this case is not uniform within the plant boundary and depending upon topography, the elevation of the plant site area in general varies from about RL + 296 m to RL + 316 m except few isolated hot spots. The average grade elevation of the plant site is about + 306 m.

Since Banswara site is an inland site, Tsunami is not postulated in the design.

Decay heat removal provisions:

Core cooling during loss of Class-IV power supply

During loss of Class-IV power conditions, reactor is shutdown automatically and core cooling is achieved by natural circulation of primary coolant system through steam generators. Heat removal from SG takes place initially through atmospheric discharge valves. After starting of the Emergency Diesel Generator (EDG) sets, Auxiliary boiler feed pumps supply feed water to SGs. Subsequently shutdown cooling system can be valved in and in this mode core cooling can be maintained for long period.

Core cooling during SBO:

In case of simultaneous loss of Class-IV and Class-III power supply, reactor is shutdown automatically and core cooling is achieved by natural circulation of primary coolant system through steam generators. 700 MWe PHWRs incorporates Passive Decay Heat Removal System (PDHRS) which cools and re-circulates SG secondary side inventory. PDHRS having 600 m^3 DM water inventory (4 x 150 m^3) can maintain SG inventory for about 6 hours without any make up. There is design provision to supplement PDHRS inventory by fire water system and this mode of cooling can continue for long period. In addition feature of fire water injection into SGs is also available as a back-up to PDHRS.

Design Basis Accident (DBA):

Safety analysis of various design basis accidents have been carried out including loss of coolant accidents (LOCA) covering a spectrum of primary coolant pipe break sizes. With ECCS available, acceptance criteria are met for all LOCA conditions. All equipments in ECCS system are provided with class III / II power supply. A sump with an inventory of 1100 m^3 is provided at the basement of the Containment to provide suction to ECCS pumps.

Containment Spray System (CSS) is available for post accident containment clean up and cooling to depressurize the containment. CSS pumps are provided with Class-III power. The CSS pumps also take suction from the ECCS sump.

Multiple Failure Conditions:

Safety analysis of various multiple failure conditions have been carried out (viz. LOCA with Loss of ECCS, LOCA with Failure of containment isolation) and the Radiological Impact Assessment shows that no counter measures in public domain are required in these cases.

Additional Design provisions

In addition to the design provisions explained above, following additional measures are provided:

Design Feature	Design Status for PHWR 700 MWe
Augmentation of services	
Water availability / utilization for various accident conditions	• SSE qualified onsite storage for 30 days for decay heat removal • Appropriate hook up arrangement with quick connectors to utilize the onsite water resources. • Fire tenders for the backup of diesel driven fire water pump.
Alternate power supply	• One air cooled DG set of 200KVA capacity is provided much above design basis flood level (DBFL).
Automatic Reactor Trip	• Automatic Reactor trip on Seismic event is provided.

Radiation Safety Aspect:

The primary means of preventing and mitigating the consequences of accidents is 'Defence In-Depth'. Defence in-depth is implemented primarily through the combination of a number of consecutive and independent levels of protection that would have to fail before harmful effects could be caused to people or to the environment.

If one level of protection or barrier were to fail, the subsequent level or barrier would be available. When properly implemented, defence in - depth ensures that no single technical, human or organizational failure could lead to harmful effects, and that the combinations of failures that could give rise to significant harmful effects are of very low probability. The independent effectiveness of the different levels of defence is a necessary element of defence in-depth.

Defence in-depth is provided by an appropriate combination of:

(i) An effective management system with a strong management commitment to safety and a strong safety culture.

(ii) Adequate site selection and the incorporation of good design and engineering features providing safety margins, diversity and redundancy, mainly by the use of:

(a) Design, technology and materials of high quality and reliability;

(b) Control, limiting and protection systems and surveillance features;

(c) An appropriate combination of inherent and engineered safety features.

(iii) Comprehensive operational procedures and practices as well as accident management procedures.

The strategy for defence in-depth is twofold: first, to prevent accidents and second, if prevention fails, to limit the potential consequences of accidents and to prevent their evolution to more serious conditions. Defence in- depth is generally structured in five levels. The objectives of each level of protection and the essential means of achieving them in existing plants are shown in Table 4. If one level were to fail, the subsequent level comes into play, and so on.

Table 2: Objective of each level of protection and essential means of achieving in existing plants

Level 1: Prevention of abnormal operation and	The objective of the first level of protection is the prevention of abnormal operation and system
Level 2: Control of abnormal operation and detection of	If the first level fails, abnormal operation is controlled or failures are detected by the second
Level 3: Control of accidents within the design basis	Should the second level fail, the third level ensures that safety functions are further performed by activating specific safety systems and other safety features.
Level 4: Control of severe plant conditions, including prevention of accident progression and mitigation of the consequences of	Should the third level fail, the fourth level limits accident progression through accident management, so as to prevent or mitigate severe accident conditions with external releases of radioactive materials.
Level 5: Mitigation of radiological consequences of significant releases of radioactive materials	The last objective (fifth level of protection) is the mitigation of the radiological consequences of significant external releases through the off-site emergency response. The efficacy of the mitigation measures will depend on their overall effectiveness and the speed of their implementation

Barriers to Radioactivity Release

The principle of defence in depth is implemented primarily by means of a series of barriers which would in principle never be jeopardized, and which must be violated in turn before harm can occur to people or the environment. These barriers are physical, providing for the confinement of radioactive material at successive locations. The barriers may serve operational and safety purposes, or may serve safety purposes only. A schematic of these barriers is shown in Fig-11 (a) and Fig- 11 (b).

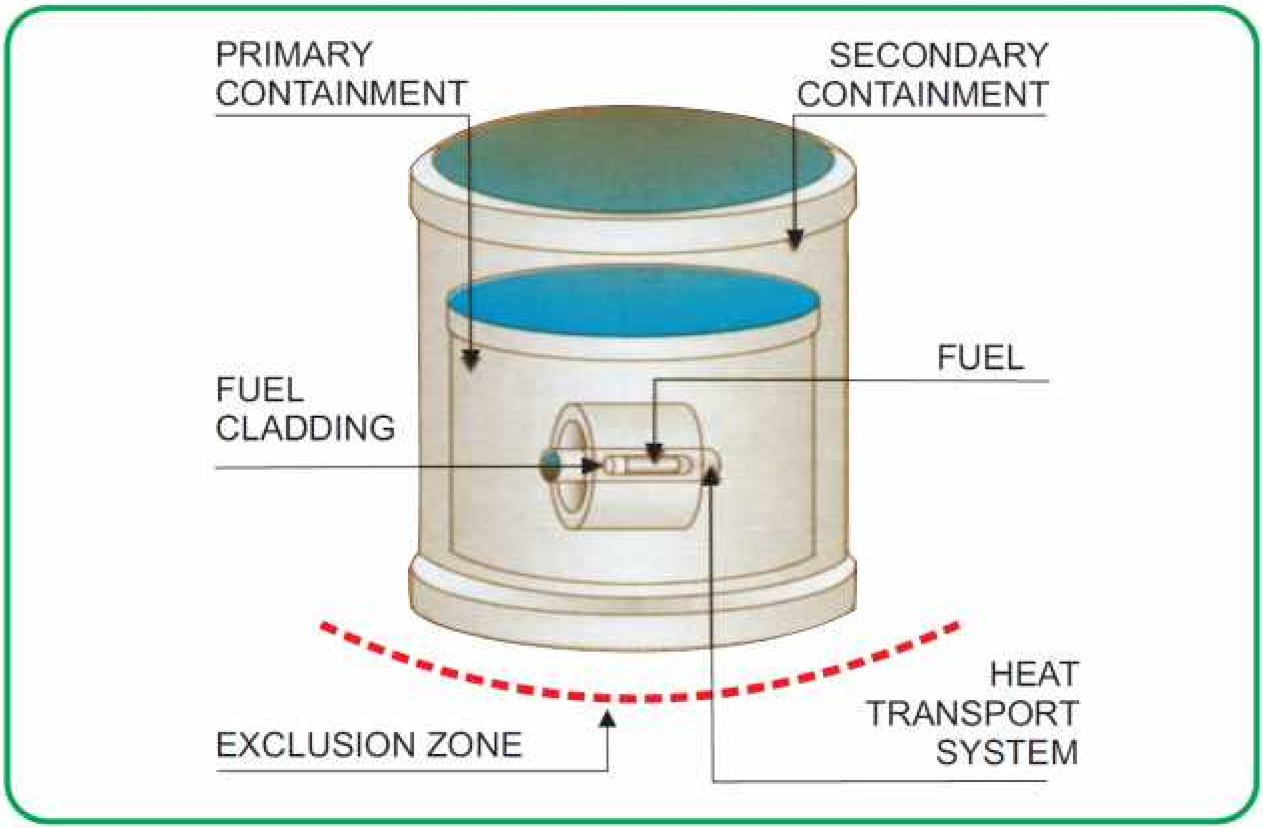


Fig-11 (a) : Representation of Barriers to Radioactivity Release

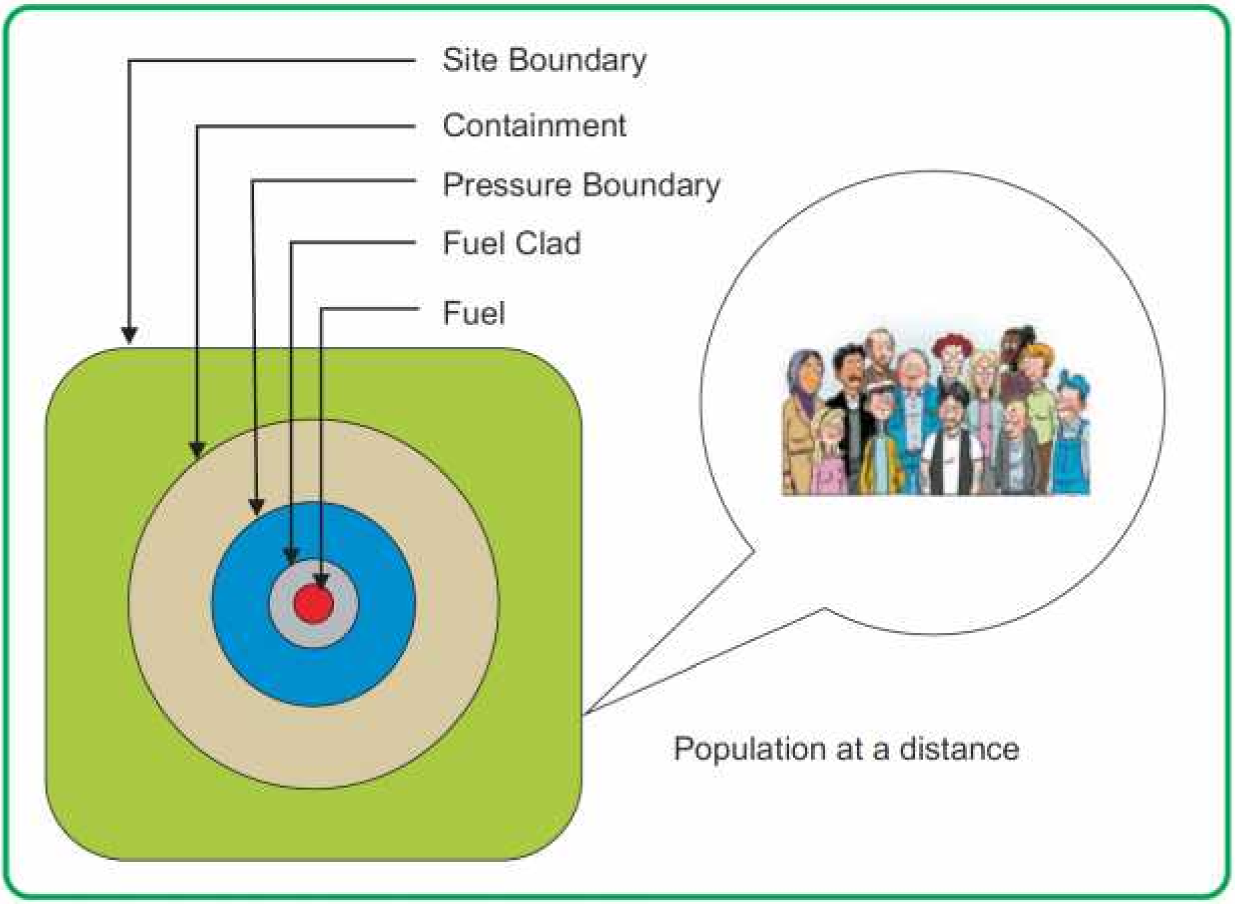


Fig-11 (b): Representation of Barriers to Radioactivity Release

Industrial Safety Aspects:

During construction and operation phase of the project, all the project activities are carried out as per the regulations covered under Atomic Energy (Factories) Rules 1996, Electricity Act and Rules, Explosives Act and Rules, Petroleum Act and Rules etc,. Complying to all safety and other statutory requirements is enforced during all the Project phases including operations. Necessary clearances from concerned authorities are built in the system and so total procedural compliance is ensured with prior instructions and oversight on the job.

5.0 PROJECT EXECUTION

NPCIL has mastered and re-engineered the Nuclear Power Projects execution methodology and strategies and achieved reduction in gestation period. The construction and commissioning of TAPS 3&4 and Kaiga-3 in 5 years with substantial cost savings further endorses this. The following fig-12 indicates the gestation time achieved in construction of nuclear power reactors in India is comparable to international standards.

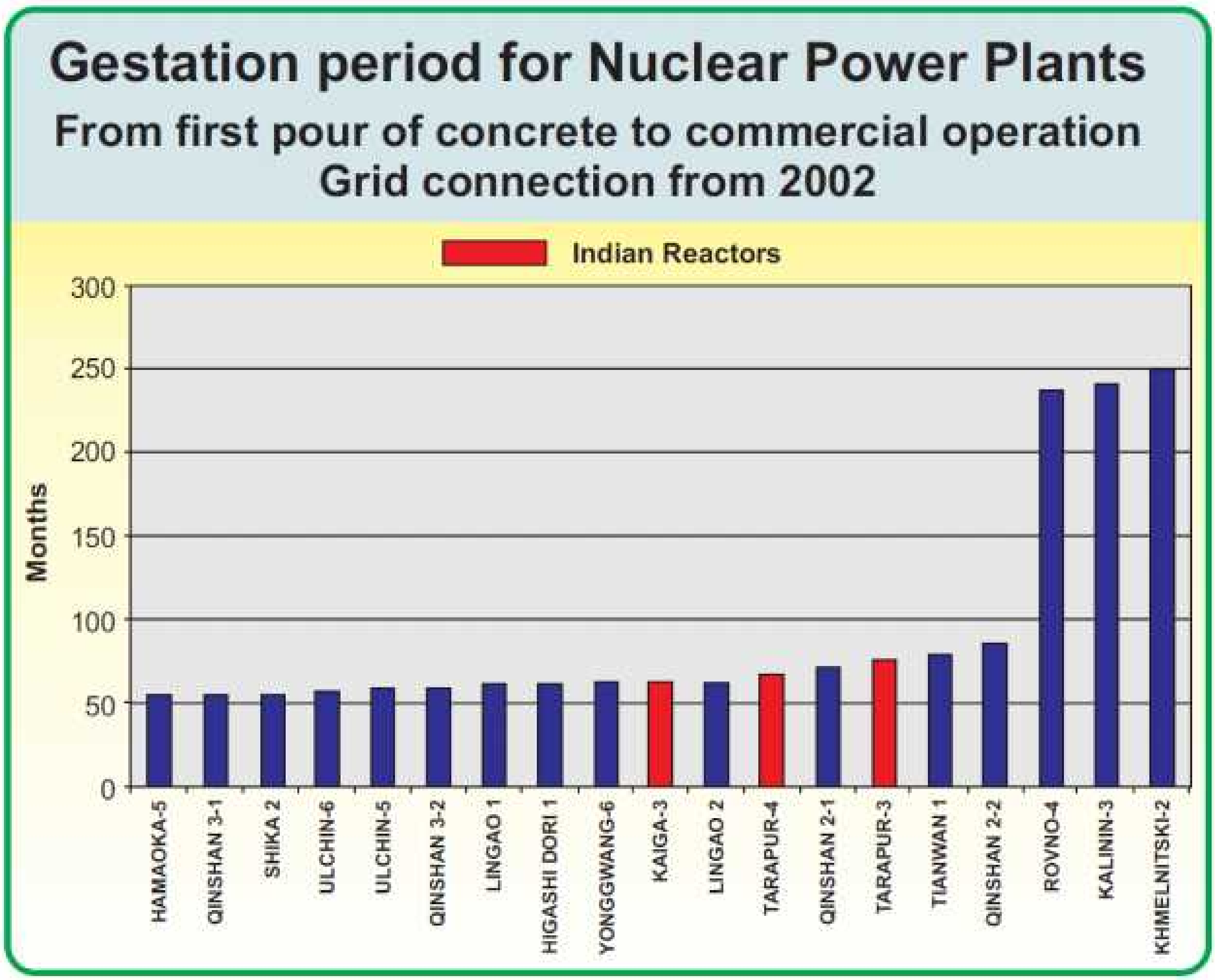


Fig-12: Performance achieved in NPP Construction in India vis-à-vis elsewhere in the world

6.0 QUALITY ASSURANCE:

NPCIL has established a "Corporate Quality Management System" and prepared "Corporate Quality Management Manual" which covers all Quality aspects viz. Preparation of Quality Assurance Manual and Quality Control Plans and Ensuring Quality Surveillance and Quality Assurance in all phases and activities of NPPs covering Design, Procurement, Manufacturing, Construction, Commissioning, Operation and Maintenance, and Decommissioning adopting processes to meet the specified requirements for quality, reliability and safety. All the provisions in the corporate quality management system are at par with International Standards complying with International Atomic Energy Agency and Indian Atomic Energy Regulatory requirements. NPCIL gives utmost importance to the quality culture in NPPs.

Fig-13: Quality Assurance in NPP- an Overview

7.0 POWER TARIFFS AND COSTS OF THE PLANT

The nuclear power tariffs are competitive with those of thermal power stations. The tariffs of one station TAPS 1&2 is 94 paise / kWh and that of three stations – MAPS, NAPS, KAPS about ₹ 2. In the year 2010-11 the average tariff of nuclear power stations was 272 paise/ kWh. The power tariff of the Plant is expected to be very competitive with those of other mode of generation.

As far as the costs of Indian PHWRs are concerned, the overnight costs of 220 MWe reactors at 2007 prices have been in the range of ₹ 6.2 to 6.5 crore / MWe, while that of 540 MWe reactors has been about ₹ 6.0 crore / MWe at 2007 prices. The overnight cost of the 700 MWe reactors at 2011 prices is estimated to be about of ₹ 8.19crore / MWe (excluding finance cost and escalation), which is comparable to other reactors in the world. Nuclear power in India has thus evolved into an economically competitive option for electricity generation.

8.0 ENVIRONMENTAL ASPECTS

Environmental monitoring is carried out by Environmental Survey Laboratory (ESL) around the plant areas within 30 Km beyond exclusion zone to ensure that the actual exposure of the members of the public is less than the prescribed limit set by AERB before the commencement of plant operation. The environmental survey laboratory (ESL) will have a full-fledged laboratory for analyzing radiological parameters.

For locating the radiological monitoring stations, the evaluation area was considered as 30 km around the proposed site. The project site is about 1.0 Km radius circle around each 700 MWe PHWR unit, the survey area were divided into four zones 1, 2, 3 and 4 (1.0 - 5 km, 5 - 10 km, 10 - 15 km, and 15 - 30 km, respectively). The 30 km radius circle was further divided into 16 circle-segments / sectors from A to P, taking the project site as centre.

The radioactivity content in the environment matrices is assessed during sophisticated radio-chemical analysis and highly sensitive instruments.

The critical pathways by which radiation exposure may arise to the public will be identified, taking into account the cropping patterns prevalent in the area, the nature of occupation and the food habits of the population groups living nearby, and so on. Based on this, an environmental sampling program will be formulated specifying (i) the matrices such as rice, vegetables, milk, fish meat, etc. that need to be considered for monitoring, (ii) the desired frequency or periodicity of sampling and (iii) the number of samples to be collected in a year.

In general, the samples collected by ESL include water samples in the villages around the plant within 30 Km radius, collection of vegetation sample, food samples, fallout indicators (goat's thyroid), sediments, etc., to identify any radioactivity in excess of natural occurrence due to operation of the plant.

The external gamma radiation levels will be monitored using integrating type dosimeters, namely the thermo- luminescence dosimeter (TLD). The list of locations in the surrounding areas where TLDs will be placed will be as per AERB. The measurement of accumulated exposure will be done for quarterly periods. These external ambient radiation levels are compared with normal background radiation levels (base line data prior to start of the plant).

Critical group of members of the Public and critical radionuclides are identified from the analysis of various samples collected and analysed by ESL.

Micro-meteorological conditions around the plant are assessed prior to start of the plant and during operation of the plant continuously to assess the impact of radiological conditions during any radiation emergency to initiate necessary correct measures if required. The external, internal and total doses to the members of the public will be monitored and estimated at various distances from the project as per AERB's requirements.

Results of the survey carried out by the ESL will be brought out in the form of annual reports and will be submitted to AERB for inspection and verification of compliance with regulatory limits on radiation exposure.

In addition, Indian Environmental Radiation Monitoring Network (IERMON) stations are installed all over India in strategic locations to obtain online ambient radiation levels and air activities and transmitted to Head quarters to BARC at Mumbai. This would be part of Global Environmental Radiation Monitoring Network (GERMON) Programme. India was a member country and a member of the scientific advisory committee of GERMON. Under this programme, data from a few selected stations would be made available to GERMON Head Quarters (called Coordinating and Collaborating Center (CCC)), situated in Paris, on a quarterly basis.

9.0 CSR INITIATIVES

NPCIL while expanding the nuclear energy has kept aim to contribute towards development of local community in the vicinity of the plants. Many social welfare programmes have been taken up in the past for the benefit of villagers. Recently Corporate Social Responsibility (CSR) has been included in a focused way and has been integrated with business plan of the company. Under CSR, NPCIL has identified three areas of human development verticals - Education, Health and Infrastructure Development. Various programmes like aids to schools, Scholarships/sponsorships to students, Construction of School buildings, Aaganwadis etc., under education; medical camps, mobile medical van, aids to Primary Health Centers, extension of hospitals, medical treatment and medicines (OPD services) for villagers etc. under health; drinking water facility, community hall, street lights, fishing facility, approach roads, bus stop sheds etc under infrastructures have been planned and implemented successfully.

NPCIL management is committed to contribute for improvement of the quality of life of local community and society at large. DPE (Department of Public Enterprises under Central Govt.) guidelines issued in March 2010 under which NPCIL has adopted a system of need identification, planning, implementation and evaluation of CSR activities. All concerned functional and unit heads have the responsibility to ensure effective implementation of the CSR activities / projects by taking the help of specialized agencies, trusts, NGOs etc.

All CSR programmes and projects embarked upon by NPCIL are implemented in timely manner and in consultation with the local Panchayats and District Authorities without placing any financial burden on them. CSR at NPCIL is a sincere devotion that stems out of genuine concern and the drive to provide comprehensive and sustainable social development in the plant neighbourhood.

MISSION OF NPCIL

"To develop nuclear power technology and to produce nuclear power as a safe, environmentally benign and economically viable source of electrical energy to meet the increasing electricity needs of country."

QUOTES.....

"As I flew over the Kaiga Project site a little while ago, I saw the beauty of lush tropical forests surrounding the magnificent domes of the two nuclear power reactors. This is the India of my vision: a nation that preserves its heritage even while marching forward and embracing the latest in science and technology for rapid development"

– A.B. Vajpayee

" NO POWER IS COSTLIER THAN NO POWER."

– Dr. Homi Jahangir Bhabha

"While there is vast natural Hydro-electric potential in the neighbouring states of Punjab and Himachal Pradesh, Haryana has no such natural potential which could be exploited for meeting the long term power requirements. Nuclear Power Plant will be of great help in meeting long term energy needs of the state."

– Anonymous

NPCIL

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