Status Report - BANDI (Korea, Republic of)

Downloaded on: Nov 17, 2026 2:27 PM CET
Published Date : Sep 09, 2024 9:38 AM CET

1. Overview

- ☐ **In Operation**
- ☐ **Under Construction**
- ☐ **Described in**

Link to PRIS	--

- ☑ **New Concept**

Number of Units	--
Year	--

Reference Plant

Name of Site	--
Link to PRIS	--
Net Power Output (MWe)	60
Gross Power Output (MWe)	--

1.1 Introduction

BANDI is the SMR of KEPCO E&C, named after a tiny firefly in Korean that emits bright green light in a deep forest in a summer night. Its reactor system is a so-called ‘block-type’ or semi-integral type, consisting of a steam generator (SG) block and a reactor vessel (RV) block. The two blocks are directly ‘nozzle-to-nozzle’ connected without large pipes, which leads to eliminating the large-pipe break loss of coolant accident (LBLOCA) from its design basis accident scenario. Compared to a fully integral one, the block-type system is said to have benefits of simpler design and manufacturing, easier surveillance and maintenance, and better scalability. Its safety is enhanced by fully passive safety systems without relying on offsite power sources or operator actions. As for applications, the primary target of BANDI is floating nuclear power plants that provide clean, safe, reliable and affordable energy for remote isolated communities. It can also be designed for carbon-free propulsion power of big merchant ships like bulky containers. KEPCO E&C is now working closely with a Korean global leading shipbuilding company on engineering and business planning.

1.2 Development Milestones

2012	Preliminary and basic studies for SMRs
2013	Government-supported R&D projects for key innovative element technologies of SMR
2016	Nuclear Steam Supply System (NSSS) conceptual design for maritime SMRs
2023	Overall design change
2023	NSSS, Balance of Plant (BOP), and floating system conceptual design for FNPPs
2025	Basic design for FNPPs
2026	Standard design and licensing review for FNPPs
2031	Projected construction

1.3 Design organization or vendor company

kwyi@kepco-enc.com

1.4 Links to designer/vendor website

www.kepco-enc.com

1.5 Design Description

1.6 Licensing Application Support Documents

1.7 Reactor Unit in PRIS

2. Category Fields

Table 1: ARIS Category Fields

ARIS Category	Value	Units of Examples
Current/Intended Purpose	Prototype/FOAK	e.g. Commercial – Electric/Non-electric, Prototype/FOAK, Demonstration, Experimental
Main Intended Application (once commercial)	Dispatchable, Off - grid / Remote, Mobile/Propulsion, Non-electric, Marine	e.g. Baseload, Dispatchable, Off-grid/Remote, Mobile/Propulsion, Non-electric (specify)
Reference Location	Floating-Fixed	e.g. On Coast, Inland, Below-Ground, Floating-Fixed, Marine-Mobile, Submerged-Fixed (Other-specify)

Reference Site Design (reactor units per site)	Single Unit	e.g. Single Unit, Dual Unit, Multiple Unit (# units)
Core Coolant	H2O	H2O, D2O, He, CO2, Na, Pb, PbBi, Molten Salts, (Other-specify)
Reactor Core Size (1 core)	30 MWth <= Thermal power < 1000 MWth	e.g. Thermal Power < 30 MWth, 30 MWth ≤ Thermal power < 1000 MWth, 1000 MWth ≤ Thermal power ≤ 3000 MWth, Thermal power > 3000 MWth
Reactor Type	PWR	e.g. PWR, BWR, HWR, SCWR, GCR, GFR, SFR, LFR, MSR, ADS
Reactor Size	SMR	e.g. PWR, SMR
Neutron Moderator	H2O	e.g. H2O, D2O, He, CO2, Na, Pb, PbBi, Molten Salts, (Other-specify)
NSSS Layout	Semi-integral	e.g. Loop-type (# loops), Direct-cycle, Semi-integral, Integral, Pool-type
Primary Circulation	Forced (2 pumps)	e.g. Forced (# pumps), Natural
Thermodynamic Cycle	Rankine	e.g. Rankine, Brayton, Combined-Cycle (direct/indirect)
Secondary Side Fluid	H2O	e.g. H2O, He, CO2, Na, Pb, PbBi, Molten Salts, (Other-specify)
Fuel Form	Fuel Assembly/Bundle	e.g. Fuel Assembly/Bundle, Coated Sphere, Plate, Prismatic, Contained Liquid, Liquid Fuel/Coolant
Fuel Lattice Shape	Square	e.g. Square, Hexagonal, Triangular, Cylindrical, Spherical, Other, n/a
Rods/Pins per Fuel Assembly/Bundle	240	e.g. #, n/a
Fuel Material Type	Oxide	e.g. Oxide, Nitride, Carbide, Metal, Molten Salt, (Other-specify)
Design Status	Conceptual Design	e.g. Conceptual, Detailed, Final (with secure suppliers)

Licensing Status		e.g. DCR, GDR, PSAR, FSAR, Design Licensed (in Country), Under Construction (# units), In Operation (# units)
Neutron Spectrum	Thermal	e.g. Fast, Thermal

3. Parameter Fields

Table 2: ARIS Parameter Fields

ARIS Parameter	Value	Units of Examples
Plant Infrastructure		
Design Life	60	Years
Lifetime Capacity Factor	>95	%, defined as Lifetime MWe-yrs delivered / (MWe capacity * Design Life), incl. outages
Major Planned Outages	< 1 month (refueling) per one cycle length	# days every # months (specify purpose, including refuelling)
Operation / Maintenance Human Resources	TBD	# Staff in Operation / Maintenance Crew during Normal Operation
Reference Site Design	Single or Dual Units (Flexible)	n Units/Modules
Capacity to Electric Grid	60	MWe (net to grid)
Non-electric Capacity	200 MWth heat at 300 ºC	e.g. MW(th) heat at x ºC, m3/day desalinated water, kg/day hydrogen, etc.
In-House Plant Consumption	TBD	MWe
Plant Footprint	TBD	m2 (rectangular building envelope)
Site Footprint	TBD	m2 (fenced area)
Emergency Planning Zone	Site boundary	km (radius)
Releases during Normal Operation	TBD	TBq/yr (Noble Gases / Tritium Gas / Liquids)
Load Following Range and Speed	20 – 100%, 5% / min	x – 100%, % per minute
Seismic Design (SSE)	N/A	g (Safe-Shutdown Earthquake)
NSSS Operating Pressure (primary side)	15.5	MPa(abs), i.e. MPa(g)+0.1, at core outlet

NSSS Operating Pressure (secondary side)	5.5	MPa(abs), i.e. MPa(g)+0.1, at secondary side outlet
Primary Coolant Inventory (incl. pressurizer)	48000	kg
Nominal Coolant Flow Rate (primary)	1210	kg/s
Nominal Coolant Flow Rate (secondary)	93.4	kg/s
Core Inlet Coolant Temperature	293	ºC
Core Outlet Coolant Temperature	322	ºC
Available Tempeature as Process Heat Source	300	ºC
NSSS Largest Component	RPV	e.g. RPV (empty), SG, Core Module (empty/fuelled), etc.
- NSSS Largest Component Length	13600	mm
- NSSS Largest Component Diameter	2800	mm
- NSSS Largest Component Thickness		mm
- NSSS Largest Component Weight	110	tonne
Reactor Vessel Material	SA508	e.g. SS304, SS316, SA508, 800H, Hastelloy N
Steam Generator Design	Vertical, Helical tube, Counter flow	e.g. Vertical/Horizontal, U-Tube/ Straight/Helical, cross/counter flow
Secondary Coolant Inventory	TBD	kg
Pressurizer Design	Integral (within SG block), steam	e.g. separate vessel, integral, steam or gas pressurised, etc.
Pressurizer Volume	12.4 / 8.7	m3 / m3 (total / liquid)
Containment Type	Dry (single)	Dry (single/double), Dry/Wet Well, Inerted, etc.
Containment Volume	1300	m3
Spent Fuel Pool Capacity and Total Volume	TBD	Years of full-power operation / m3
Non Electric Application		-

Core Delta Temperature	29	ºC
Fuel/Core		
Single Core Thermal Power	200	MW(th)
Refuelling Cycle	48-60	months or “continuous”
Fuel Material	UO2	e.g. UO2, MOX, UF4, UCO
Enrichment (avg./max.)	4.95 / 4.95	%
Average Neutron Energy	7.74E5	eV
Fuel Cladding Material	Zr-4	e.g. Zr-4, SS, TRISO, E-110, none
Number of Fuel “Units”	52 assemblies	Specify as Assembly, Bundle, Plate, Sphere, or n/a
Weight of one Fuel Unit	383	kg
Total Fissile Loading (initial)	588.7 kg U-235 in UO2	kg fissile material (specify isotopic and chemical composition)
% of fuel outside core during normal operation	N/A	Applicable to online refuelling and molten salt reactors
Fraction of fresh-fuel fissile material used up at discharge	52.4	%
Core Discharge Burnup	29.4	MWd/kgHM (heavy metal, eg U, Pu, Th)
Pin Burnup (max.)	35.5	MWd/kgHM
Breeding/Conversion Ratio	N/A	Fraction of fissile material bred in-situ over one fuel cycle or at equilibrium core
Reprocessing	None	e.g. None, Batch, Continuous (FP polishing/actinide removal), etc.
Main Reactivity Control	Rods, temperature	e.g. Rods, Boron Solution, Fuel Load, Temperature, Flow Rate, Reflectors
Solid Burnable Absorber	Pyrex (B2O3)	e.g. Gd2O3
Core Volume (active)	48	m3 (used to calculate power density)
Fast Neutron Flux at Core Pressure Boundary	2.61E8	n/(cm²*s)
Max. Fast Neutron Flux	6.52E8	n/(cm²*s)

Core Control Rod Absorber		-
Core Soluble Neutron Absorber		-
Safety Systems		
Number of Safety Trains	Active / Passive	% capacity of each train to fulfil safety function
- reactor shutdown	Passive	- / 100 / -
- core injection	Passive	- / 100 / -
- decay heat removal	Passive	- /100 / -
- containment isolation and cooling	Passive	- / 100 / -
- emergency AC supply (e.g. diesels)	N/A	- / - / -
DC Power Capacity (e.g. batteries)	72	Hours
Events in which Immediate Operator Action is required	None	e.g. any internal/external initiating events, none
Limiting (shortest) Subsequent Operator Action Time	72	Hours (that are assumed when following EOPs)
Severe Accident Core Provisions	IVMR	e.g. no core melt, IVMR, Core Catcher, Core Dump Tank, MCCI
Core Damage Frequency (CDF)	1E-7	x/reactor-year (based on reference site and location)
Severe Accident Containment Provisions	PARs	e.g., H2 ignitors, PARs, filtered venting etc.
Large Release Frequency (LRF)	1E-8	x/reactor-year (based on reference site and location)
Overall Build Project Costs Estimate or Range (excluding Licensing, based on the Reference Design Site and Location)		
Construction Time (nth of a kind)	24 months (months from ship construction including NSSS installation to fuel loading)	Months from first concrete to criticality
Design, Project Mgmt. and Procurement Effort	TBD	Person-years (PY) [DP&P]
Construction and Commissioning Effort	TBD	PY [C&C]
Material and Equipment Overnight Capital Cost	TBD	Million US$(2015) [M&E], if built in USA

Cost Breakdown	%[C&C]/%[M&E]	
- Site Development before first concrete	TBD	(e.g. 25/10) (30/40) (20/25) (20/10) (5/15) (----------) (to add up to 100/100)
- Nuclear Island (NSSS)	TBD	
- Conventional Island (Turbine and Cooling)	TBD	
- Balance of Plant (BOP)	TBD	
- Commissioning and First Fuel Loading	TBD	
Factory / On-Site split in [C&C] effort	80 / 20	%/% of total [C&C] effort in PY (e.g., 60/40)
Nuclear System		
System Steam Flow Rate		kg/s
System Steam Pressure		MPa
System Steam Temperature		ºC
System Feedwater Flow Rate		kg/s
System Feedwater Temperature		ºC
Reactor Core		
Active Core Height		m
Equivalent Core Diameter		m
Average Linear Heat Rate		kW/m
Average Fuel Power Density		kW/kgU
Average Core Power Density	4.17	MW/m3
Outer Diameter Of Fuel Rods		mm

4. Plant Layout, Site Environment and Grid Integration

SUMMARY FOR BOOKLET

A floating nuclear power plant of BANDI can carry either a single unit or multiple units in it depending on the customer's need. If there is a dual unit in a FNPP, two Containment Vessels (CVs), each having a reactor system inside, are arranged in a reactor compartment by applying separate arrangement requirements for each reactor to minimize consequences should an accident occur within the power

plant. For easier operation and maintenance, Each CV has equipment entrance, personnel airlock, and emergency personnel airlock. The auxiliary compartment is designed to protect the safety-related systems from natural phenomena by applying divisional arrangement and physical protection requirements for safety grade equipment. Turbine Generators (TGs), condensers, heaters, etc. are located in the turbine compartment.

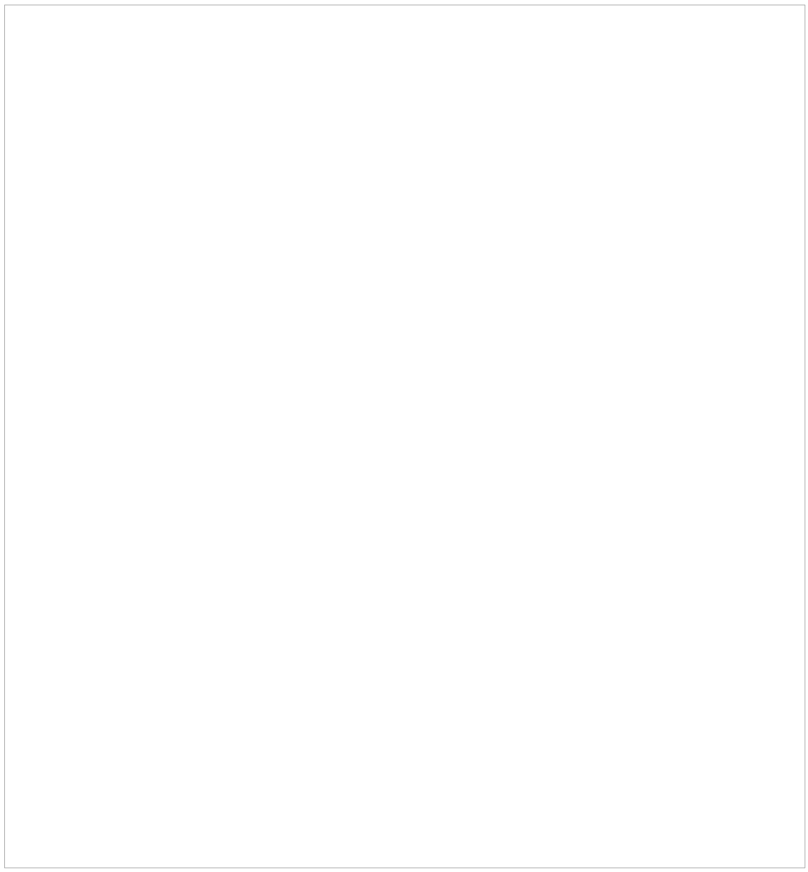


Figure 1. BANDI reactor coolant system and safety systems configuration.

4.1 Site Requirements during Construction

The plant layout of a typical BANDI floating nuclear power plant (FNPP) is shown in Figure 2, and its plane and section view in Figure 3.

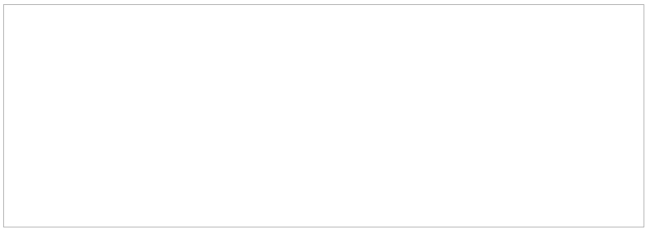


Figure 2. A typical plant layout of BANDI Floating Nuclear Power Plant.

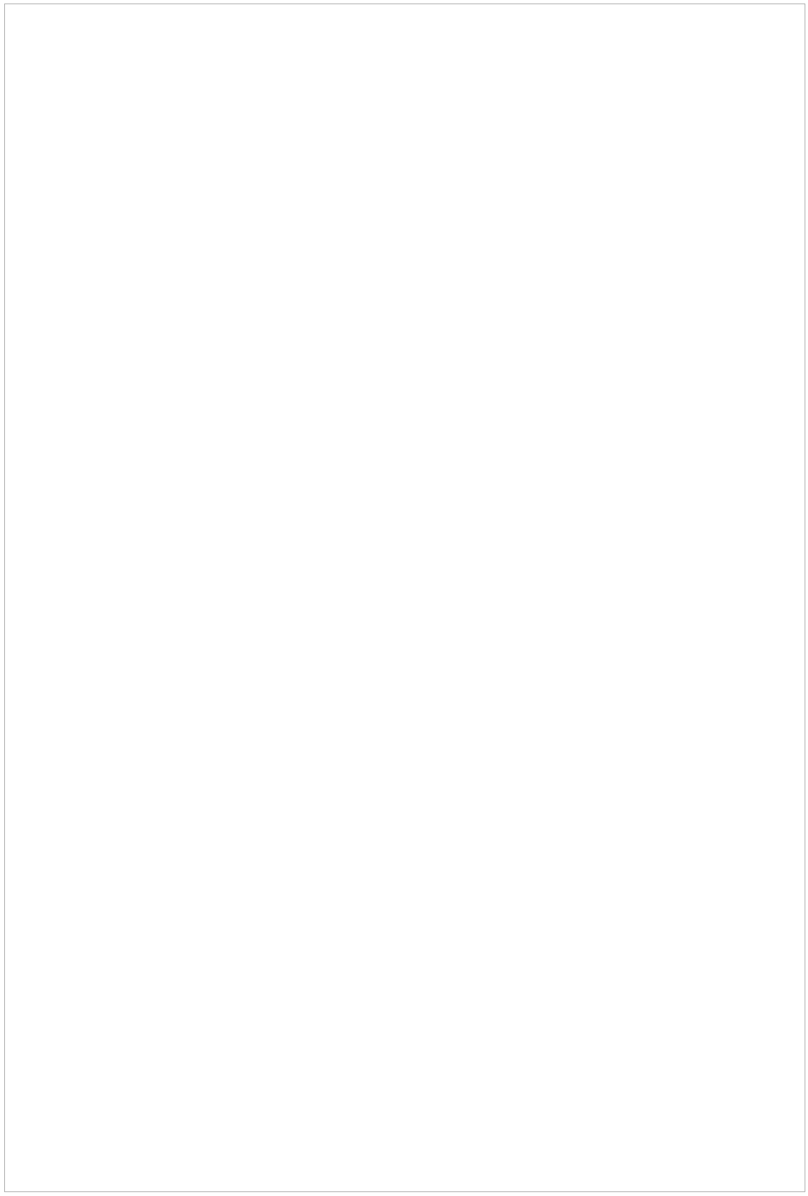


Figure 3. BANDI Floating Nuclear Power Plant: (A) Plane view and (B) Section view.

Reactor compartment

The reactor compartment contains two Containment Vessels (CVs), part of engineered safety features and associated auxiliary systems. The reactor coolant system (RCS) is enclosed inside the CV. The reactor compartment is located in the middle of the floating body, surrounded by the auxiliary compartment on the left and right sides. These systems are separated to minimize consequences in case of an accident. Each CV has equipment entrance, personnel airlock, and emergency personnel airlock. Passages for equipment transfer or operator movement are provided on the north and south sides.

Auxiliary compartment

The auxiliary compartment houses the facilities that are needed for the RCS to perform its normal functions and for the safety systems to achieve the safe shutdown in an accident. The storage and handling facilities for new and spent fuels are located on the right side of the auxiliary compartment. Seismic Category-I tanks and pumps, the Component Cooling Water (CCW) system, the plant cooling water system are on the left side. The auxiliary compartment can protect the safety-related systems from natural phenomena by applying divisional arrangement and physical protection requirements for safety grade equipment.

Turbine compartment

The turbine compartment is adjacent to the left side of the auxiliary compartment and encloses turbine generator, condenser, electrical system, and plant chilled water system. The turbine area is designed to secure the space for carrying in and out necessary equipment, and for connecting the secondary system to external electric line and onshore facilities.

Access control

The access control area is adjacent to the right side of the auxiliary compartment. Between the auxiliary compartment and the access control area, a space for land facility connection is secured. It also contains access controls to facilities and radiation areas, and provides living space for resident personnel.

4.2 Site Considerations during Operation

The BANDI FNPP is to be moored near the shore to transmit electricity and process heat to the land.

The BANDI FNPP can use sea water as an infinite heat sink for the passive residual heat removal.

4.3 Grid Integration

The BANDI FNPP is equipped with a system to transmit electric power to the local grid network.

The BANDI FNPP does not require off-site grid power in an accident since its safety systems are fully passive.

5. Technical NSSS/Power Conversion System Designn

SUMMARY FOR BOOKLET

BANDI is a semi-integral or block-type PWR in which the reactor vessel (RV) block and the steam generator (SG) block are directly connected, nozzle-to-nozzle, eliminating connecting pipes and thus large-pipe break loss of coolant accident from the design basis accident scenario. This type is said to be better for operational surveillance and maintenance than the integral type.

The BANDI reactor uses the conventional UO2 ceramic fuel enriched up to 4.95 % with 17x17 square array. 52 fuel assemblies are loaded in the reactor core, which are enough to generate 200 MW thermal power over 4~5 years without refueling.

The BANDI fuel handling system consists of refueling machine, in-containment vessel refueling pool, fuel transfer system, spent fuel pool, and spent fuel handling machine. During refueling operations, Containment Vessel Head (CVH), Reactor Vessel Closure Head (RVCH), Reactor Pressure Vessel (RPV) studs, In-Vessel Control Rod Drive Mechanism (IV-CRDM), and Upper Guide Structure (UGS) are removed and stored in designated locations.

SG with helically coiled heat transfer tubes is employed as a basic design, which requires less space

and is more capable of quickly following the load demand of the turbine than the conventional U-tube type.

The reactor containment system is composed of two main structures - Containment Vessel (CV) and Reactor Compartment. The CV of BANDI is a steel cylindrical type and its principal function is to confine radioactive materials that can be released during both normal and accident conditions including very unlikely severe accident. The reactor compartment encloses the whole primary systems and protects them from external hazards such as airplane crash.

The Instrumentation and Control (I&C) system is a fully digital system with data communication network and has a simple and compact structure suitable for BANDI. I&C design of the BANDI prevents software Common Cause Failure (CCF) by implementing its own diversity design in the safety system.

5.1 Primary Circuit

BANDI is a block-type or semi-integral PWR having one heat transfer loop. It consists of the reactor vessel (RV) block and the steam generator (SG) block which are directly nozzle-to-nozzle connected, eliminating large connecting pipes and thus large-pipe break LOCA from the design basis accident scenario.

Reactor Vessel (RV) Block

The RV block is similar in shape to a conventional PWR reactor vessel. The reactor pressure vessel (RPV) is a vertically mounted cylindrical vessel with a hemispherical lower head welded to the bottom of it and a removable hemispherical RVCH on the top of it as shown in Figure 4. Different from some conventional PWRs, there is no penetration on the RPV lower head by employing the Top-Mounted In-Core Instrumentation (TM-ICI) design which minimizes the possibility of lower vessel failure in case of a severe accident. Instead, the TM-ICI cables penetrate the RVCH along with the IV-CRDM cable sealing units, which also accommodate the power cables and the Control Element Assembly (CEA) position indicator cables. Another innovative feature is that conventional Core Makeup Tank (CMT) is substituted by the supplemental space inside the RVCH for the additional coolant storage.

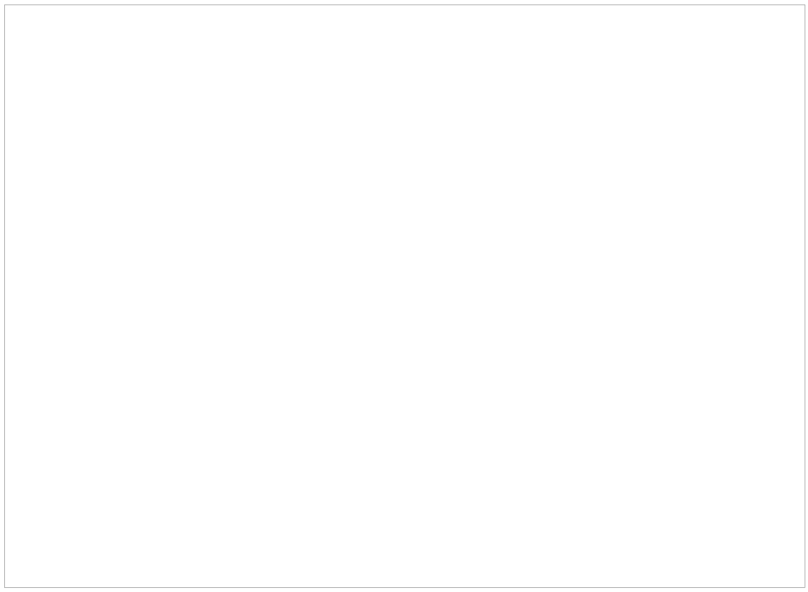


Figure 4. RCS configuration and cross sectional view of BANDI.

The cylindrical RPV excluding the RVCH and the lower head is divided into two parts by a flange connection. The RPV lower flange is a forged ring with a machined ledge on the inside surface to support the core support structure with the core in it. The RPV upper flange is joined to the lower flange by bolting and it also has a ledge to support some RVIs.

The outlet nozzle of RPV is directly connected to the inlet nozzle of SG block without piping. An added feature is the use of coaxial flow paths between RPV and SG so that both hot and cold coolant flow from and to the RPV run coaxially. The external nozzle-to-nozzle weld is designated as a part of vessel per ASME Sec. III. Subarticle NB-3300. This provides a very conservative design for this connection and a good basis for eliminating LBLOCA from design basis accidents. The Safety Recirculation Valves (SRVs) are attached to the RPV for a direct emergency coolant injection as a part of the Passive Emergency Core Cooling System (PECCS).

The life time of the RPV is extended to 60 years by the use of low carbon steel, which has lower contents of Cu, Ni, P, S compared to the design of a conventional PWR reactor vessel, resulting in an increase of brittle fracture toughness. The inner surface of the RPV is clad with austenitic stainless steel or Ni-Cr-Fe alloy.

The RVIs consist of core support structure, UGS assembly, IV-CRDM support structure, Lower Support Structure (LSS), and other internal structures. The core support structures such as Core Support Barrel(CSB) are designed to support the fuel assembly and guide the CEAs. The UGS, which consists of the fuel alignment plate, CEA shroud tubes and the UGS base plate, is removed from the RPV as a single unit during refueling process by means of reactor internals lifting rig. The IV-CRDM support structure is an assembly on which the IV-CRDMs are installed. The CSB, the UGS, and the IV-CRDM support structure are supported by the ledge of the RPV flange, and the LSS is supported at the bottom by the CSB.

All RVIs are manufactured of austenitic stainless steel except for the holddown ring, which is made of high-tension stainless steel. The holddown ring is located in the gap between the CSB flange and the IV-CRDM support structure flange. Therefore, it absorbs the load of axial direction caused by the Reactor Coolant Pump (RCP) mechanical vibration and the coolant flow.

The primary coolant flows from the RCP discharge of the SG block to the RPV inlet nozzle, passes through the annulus between RPV and CSB, RPV bottom plenum, core, in turn, and then finally flows out through the outlet nozzle of RPV connected to the inlet nozzle of SG block.

Steam Generator (SG) Block

The SG block is composed of a riser in the middle, helical tubes around it, a pressurizer on the top, and two RCPs at the bottom. When the primary coolant enters the SG block inlet nozzle, it flows up through the riser until it reaches the pressurizer bottom plate. Then the coolant flows downwards into thousands of helical tubes. After transferring the primary heat to the feedwater of secondary side, the coolant flows into two canned-motor RCPs again.

As shown in Figure 4, the helical type OTSG is employed in BANDI as the basic design. It requires less space than conventional U-tube type SG since there is no need for the dryer and the steam separator in the OTSG. Also it is known that OTSG is good for preventing the corrosion and for stable load following. When the load fluctuates in the power conversion system as the electricity demand changes, the degree of superheat follows the change so that the steam pressure of SG secondary side remains steady different from the U-tube type with saturated steam.

The pressurizer is integrated into the upper head of the SG block and divided by the pressurizer bottom plate. The Safety Depressurization Valves(SDVs) are attached on the pressurizer head to achieve the equilibrium of pressure after Small Break Loss Of Coolant Accident (SBLOCA). The pressurizer pressure is controlled by heaters and sprays, and its capacity is large enough to control the RCS volume by itself throughout 0~100% reactor thermal power.

There are two RCPs in the bottom plenum of SG block, which are selected as leak-tight canned motor design.

5.2 Reactor Core and Fuel

Reactor core

BANDI reactor uses a conventional UO2 ceramic fuel enriched up to 4.95 % in a 17× 17 square array fuel assembly. To produce 200 MW thermal power over 4~5 years, the reactor core is composed of 52 fuel assemblies as shown in Figure 5. Since BANDI does not use soluble boron, burnable absorber to control the excess reactivity over core life is loaded. The burnable absorber used in BANDI core is the Pyrex (B2O3) rod and in each fuel assembly it replaces 24 fuel rods with different boron concentrations. The numbers shown in Figure 5 represents the boron concentration in %. The center fuel assemblies have higher boron concentration up to 40% while the least, 5% of B2O3 is loaded in the outer fuel assemblies in order to flatten the radial power distribution. The burnup calculation showed that the BANDI core can operate for 4.79 years (57.5 months) with full power.

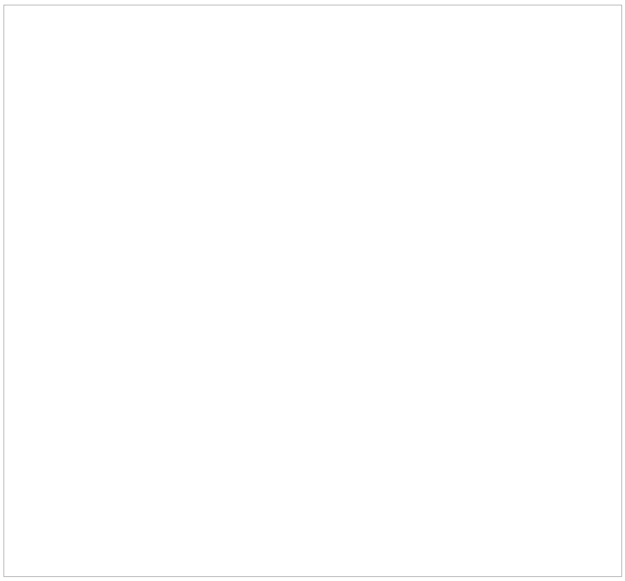


Figure 5. BANDI reactor core with burnable poison.

Reactivity control

As shown in Figure 6, the BANDI reactor core uses 40 control rod assemblies with 24 B4C control rods per assembly. In conjunction with the burnable poison, the control rod assemblies can provide enough negative reactivity to maintain shutdown with margin under the worst condition for the soluble boron free BANDI reactor core. There are two (2) control rod groups, 18 for regulating group and 22 for shutdown group. The control group is further grouped in 4 banks, R1 through R4, with 4 control rod assemblies per each bank

except R4 which has 6 assemblies. The shutdown group consists of 2 banks, 10 assemblies for S1 and 12 assemblies for S2. The remaining 12 fuel assemblies without control rod are reserved for the TM-ICI.

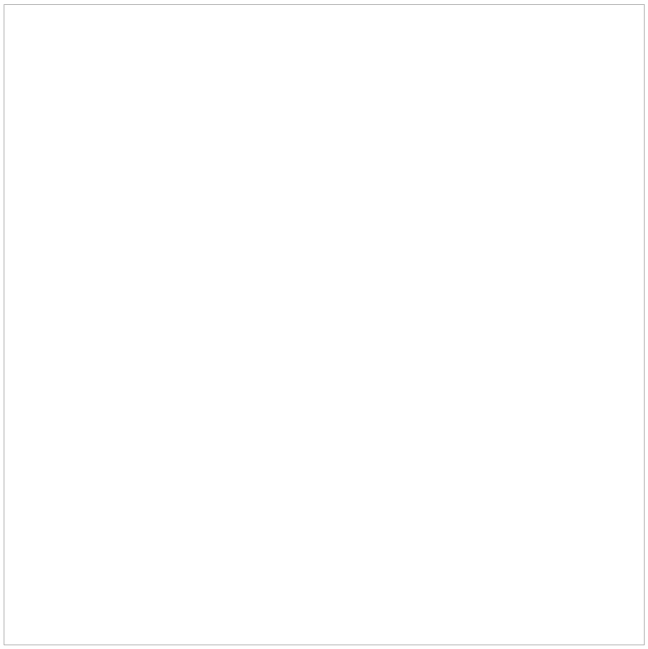


Figure 6. BANDI reactor control rod arrangement.

5.3 Fuel Handling

The BANDI fuel handling system treats the fuel assembly from initial receipt of new fuel assembly to shipment of a spent fuel assembly cask. The key aspects of the fuel handling system are the refueling machine, the in-containment vessel refueling pool, the fuel transfer system, the spent fuel pool, and the spent fuel handling machine. During the refueling operation, the containment vessel head, the RVCH, the RPV studs, the IV-CRDM support structure, and the UGS are removed and stored in designated locations. Fuel assemblies are moved between the core and the fuel transfer system using a refueling machine.

The spent fuel pool temporarily stores both new and spent fuel assembly during a refueling outage. The spent fuel assembly is transported by the fuel transfer system out of containment vessel horizontally through an underwater fuel transfer tube, into the spent fuel pool. The spent fuel pool is designed to store fuel assemblies for up to 10 years prior to the transporting to the land based fuel storage. Transporting new fuel assembly into the core is performed using the reverse process of the spent fuel handling, following initial receipt and inspection. Both the refueling pool and spent fuel pool are maintained by a dedicated chemistry control and a heat removal system. The time required to complete the refueling is estimated to be 10 days.

5.4 Reactor Protection

See Section 4 “Safety Concept”.

5.5 Secondary Side

As explained in Section 2.1, the primary coolant flows downwards through the helical tubes inside the SG. To maximize the heat transfer efficiency, the feedwater of SG secondary side flows into the SG block through two feedwater nozzles at the lower side of the SG shell and flows upwards to make the counter-flow against the primary coolant. The steam nozzles are also located at the lower side of the SG shell near the feedwater nozzles, which are intended to heat up the SG shell to minimize the mechanical stress on the SG

upper and lower tubesheets being induced by different thermal growth between the SG shell and the hot reactor coolant riser. The overheated steam flows out from the SG block through two steam nozzles. The minimum degree of overheat is 30ºC so there is little chance for the SG to be corroded.

5.6 Containment/Confinement

The reactor containment system is composed of two main structures, the CVs and the reactor compartment. The CVs are a steel cylindrical type vessels with 10-meter diameter and 24-meter height. The principal function of the CVs is to confine radioactive material release during both normal and accident conditions. The reactor compartment encloses the CVs and fuel handling system and protects them from external hazards.

BANDI employs a steel containment vessel design, which presents significant construction schedule improvements when compared to a conventional Post-Tensioned concrete design. The vessel is sized and designed to enable modular build, leading to further reductions in construction complexity and construction time.

Heat released from the RCS to the containment vessel is continuously removed to the water stored in the Containment Vessel Cooling Tank (CVCT) through metal wall during a postulated accident to reduce pressure and temperature of the containment vessel.

5.7 Electrical, I&C and Human Interface

The I&C system is composed of a fully digital system with data communication network and adopts a simple and compact structure suitable for BANDI as floating SMR plant.

BANDI can be prevented from unwanted reactor trip due to equipment failure or external disturbance by means of a Reactor Trip Prevention System (RTPS). To prevent unwanted trip when the plant is under the transient condition, the RTPS limits loading rates and power levels to maintain critical NSSS variables within their operating limits. In case of an accident, the operator is informed to recognize the accident situation in advance through the early warning system. Also, operator intervention is minimized by enhancing extended automatic control and mitigation functions against transients and disturbances.

Finally, the BANDI I&C design prevents the possibility of software CCF by implementing its own diversity design in the safety system. Therefore, diverse actuation system is not required, making I&C system more compact and simple.

5.8 Unique Technical Design Features (if any)

For small reactors, the control element (or rod) ejection accident presents critical safety concern since the reactivity worth of single control element is larger than that for large reactors. To eliminate this safety issue from the design basis, BANDI has the CRDM within the RPV. However, high temperature, pressure, radiation, and water-submerging conditions in the RPV are very challenging, under which the IV-CRDM must be proven for its functional and material integrity. Key element technologies for BANDI were developed and demonstrated with a full-scale test as shown in Figure 7.

Along with the basic design option, new technologies will be examined for their feasibility such as compact plate-shell SG, advanced nuclear fuels, reliable and more simple I&C systems, automatic load-following, and autonomous operation, etc.

Figure 7. In-vessel CRDM demonstration test facility.

6. Technology Readiness

SUMMARY FOR BOOKLET

The first phase of the conceptual design of BANDI was performed from 2016 to 2022. The second phase started in 2023 and will be performed until 2030. Iterative works of system design and performance analyse will continue to optimize the RCS and safety systems with their components. To prepare for marine-based applications, efforts will be made to seek ways to comply with the requirements and regulations of International Maritime Organization (IMO). Collaborations with marine shipbuilding industry will be further extended. Applications to the nuclear-renewable hybrid energy systems will also be investigated in the years to come.

The basic design concept of BANDI is rooted in KEPCO E&C's technologies and experiences, proven through its year-long services in conventional nuclear power business. This can minimize technical and licensing uncertainties and thus reduce the time to deployment. Critical nuclear safety functions of reactor shutdown, decay heat removal and radiation protection are enhanced by adopting inherent and passive safety design features.

6.1 Deployed Reactors
6.2 Reactors under Licensing Review
6.3 Reactors in the Design Stage

BANDI is at the second phase of conceptual design stage. The BANDI design utilizes over 45 years of operating experience in PWR technology. It aims to minimize technical and licensing uncertainties and thus reduce the time to deployment. The RCS consists of a RPV, one SG, two leak-tight canned motor RCPs, and a pressurizer integrated into the SG block upper head region. The BANDI reactor system is a "block-type" design that components of the primary system are directly nozzle-to-nozzle connected to each other without large pipes.

BANDI has a helical type OTSG which requires less space than conventional U-tube type SG and is easy to follow the load fluctuation on turbine. The pressurizer integrated into SG block upper head region provides a relatively much larger water and steam capacity than those of conventional PWRs that it can control the RCS volume by itself. This benefits reliable operation of BANDI.

The BANDI design adopts technology innovations developed in-house for five years from 2013, such as the control rod drive mechanism installed inside the reactor pressure vessel (IV-CRDM), Soluble Boron-Free(SBF) design and operation, and TM-ICI. The CRDM inside of RPV will eliminate the control rod (or element) ejection accident which can cause critical safety concerns for small reactors.

BANDI will be operating at soluble boron free (SBF) conditions. The benefits of no soluble boron are to simplify the design, operation and maintenance of nuclear reactor and Chemical and Volume Control System (CVCS), and to reduce the radioactive waste by removing of the boric acid process, and to prevent the boric acid induced corrosion.

The conceptual design of the BANDI NSSS has significantly been changed in 2023 and will be further optimized by 2024. The floating systems and BOP systems are now under conceptual design stage. The licensing review will begin in the late 2020's after completion of basic/standard design and construction of the first unit will start after 2030.

7. Safety Concepts

SUMMARY FOR BOOKLET

Key advanced design features of BANDI to improve safety and operability include:

- Block-type RCS arrangement to prevent LBLOCA
- Soluble boron-free (SBF) operation
- In-vessel Control Rod Drive Mechanism (IV-CRDM)
- In-core instrumentations mounted on the RPV head (Top-mounted ICI)
- Passive Emergency Core Cooling System (PECCS), Passive Residual Heat Removal System (PRHRS) and Passive Containment Vessel Cooling System (PCCS)
- Canned-motor RCPs
- Integrated pressurizer, etc.

The passive safety systems of BANDI consist of the PECCS, PRHRS, and PCCS. The PECCS performs gravity driven safety injection and safety depressurization system. The PRHRS performs decay heat removal by natural circulation and condensation of the steam. The PCCS is performed by condensation and heat transfer in the CV and external water tank, CVCT, which is surrounding the CV. The CVCT is designed to remove decay heat for at least a month with enough inventory of ultimate heat sink water.

7.1 Safety Philosophy and Implementation

BANDI has inherent passive safety features as shown in Figure 8. The passive safety systems consist of the PECCS, PRHRS, and PCCS, which rely on natural forces to enhance safety in case of a postulated accident.

PECCS

The PECCS provides an RCS inventory makeup for any loss of coolant events other than LBLOCA. In case of a SBLOCA, core inventory is made up by gravity with the reserved coolant inventory in the dome of the RV block. If the coolant level or pressure decreases or the CV pressure increases out of specified set points, the SDVs are automatically opened and soon pressure balance is reached between the RCS and CV. Steam and water discharged from the break points are cooled and condensed on the CV wall, and collected in the bottom and annulus between the RV and the CV. The CV heat is removed to the CVCT through the CV wall by conduction. The cooling water of ECCT in the CV dome is discharged to the CV space by gravity. When, the accumulated water level in the RV-CV annulus rises above the SRVs, which are automatically opened at a specified set point, the reactor core gets flooded and is then maintained in a long-term cooling mode by natural circulation.

PRHRS

The PRHRS provides core decay heat and RCS sensible heat removal when the normal cooling of RCS through SG and condenser is not available after reactor trip at any power level. The Steam from the SG condenses in the PRHRS heat exchanger, which is submerged inside the CVCT, and the condensate returns by gravity to the SG via the feedwater nozzles. It cools down the RCS to the safe shutdown condition and maintains it for at least a month without refilling the CVCT.

PCCS

The energy released to the containment atmosphere is continuously removed to the water stored in the CVCT, which surrounds the outer surface of the CV and is contact with the metal wall of the CV, through containment metal wall during the normal operation and the postulated accident. This passive containment cooling will decrease the Core Damage Frequency (CDF) as compared to the plant with active containment spray system and other containment cooling system. The CVCT has adequately large capacity enough to cool down the containment for at least a month without refilling. If the elevation of the CVCT falls below sea level, an infinite passive source of heat sink can be secured by seawater.

Figure 8. Safety systems of BANDI.

7.2 Transient/Accident Behaviour

To be updated in further design phase.

8. Fuel and Fuel Cycle

SUMMARY FOR BOOKLET

The BANDI reactor uses a conventional UO2 ceramic fuel enriched up to 4.95 % in 17x17 square array fuel assemblies. The basic core design is based on a single batch operation with a cycle length of 4~5 years. The new and spent fuels are transported from and to a land based fuel facility using a dedicated fuel transport ship. To optimize the fuel cycle cost, it is also possible to design a multi-batch core with a shorter cycle length depending on the owner requirement.

8.1 Fuel Cycle Options

Fuel

The nuclear fuel loaded in the BANDI reactor core is the well-proven UO2 ceramic fuel widely used in large commercial PWRs. The UO2 fuel pellets are enriched less than 5% and encapsulated in the fuel rods. The active core is 2.0 m in length, about a half of the commercial PWR fuel. The fuel rods are arranged in 17x17 square array in a fuel assembly. The reactor core is loaded with 52 fuel assemblies.

Fuel cycle options

The basic option for the BANDI core management is a single batch refueling cycle of 4-5 years. The main purpose of the extended cycle length is to minimize the refueling outage and thus to maximize the availability of the power plant.

However, if the plant operator wants to optimize the refueling cycle for fuel cost reduction, a multi-batch core management would also be possible. Then, due to a shorter cycle length, more frequent refueling would be needed compared to the single batch option. The option depends on the owner's choice.

New fuels are transported to the floating power plant using a dedicated fuel transport ship from a land-based fuel fabrication and storage facility. A conventional new fuel transport cask is used with a minor design modification for the shorter version of fuel.

Spent fuels are temporarily stored at the operating site (on-board or on-shore) for about 10 years before shipping to a dedicated spent fuel storage facility. Then, spent fuel is cooled down enough to be packed in dry spent fuel transport casks and shipped by dedicated fuel transport ships.

The back-end fuel cycle option for the spent fuel may be possible, but it depends on the plant owner's policy.

8.2 Resource Use Optimization
8.3 Unique Fuel/Fuel Cycle Design Features

9. Safeguard & Physical Security

SUMMARY FOR BOOKLET

9.1 Safeguards
9.2 Security
9.3 Unique Safeguards and/or Security Features

10. Project Delivery & Economics

SUMMARY FOR BOOKLET

10.1 Project Preparation and Negotiation
10.2 Construction and Commissioning
10.3 Operation and Maintenance