Status Report - ACP100 (China)

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1. Overview

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

Link to PRIS	--

- ☐ **New Concept**

Number of Units	--
Year	--

Reference Plant

Name of Site	LINGLONG-1 (Link to PRIS)
Net Power Output (MWe)	100
Gross Power Output (MWe)	125

1.1 Introduction

The ACP100 is an integrated PWR design developed by China National Nuclear Corporation (CNNC) to generate a gross electric power of 125 MW(e). The ACP100 is based on existing PWR technology adapting verified passive safety systems to cope with the consequences of accident events. In case of transients and postulated design basis accidents the natural convection cools down the reactor. The ACP100 integrated design of its reactor coolant system (RCS) enables the installation of the major primary circuit's components within the reactor pressure vessel (RPV).

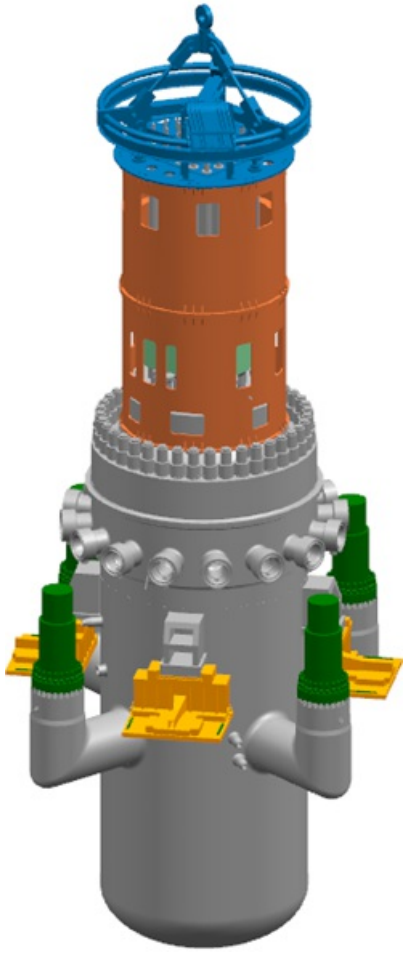


Figure 1. Representative picture of the ACP100 reactor.

1.2 Development Milestones

2016	Generic reactor safety review for ACP100 by IAEA finished
2017	CNNC signed an agreement with the Changjiang municipal government in Hainan Province to host the first of a kind (FOAK) ACP100 demonstration unit
2018	Preliminary safety assessment report (PSAR) finished
2019	PSAR submitted to National Nuclear Safety Authority, site preparation started
2020	Apply for authorize to Changjiang nuclear power site, Hainan, China
2021	FCD on Changjiang nuclear power site, Hainan, China
2026	Target commercial operation

1.3 Design organization or vendor company

1.4 Links to designer/vendor website

1.5 Design Description

1.6 Licensing Application Support Documents

1.7 Reactor Unit in PRIS

China	LINGLONG-1 (Hainan Changjiang SMR)	1 unit under construction

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)	Baseload	e.g. Baseload, Dispatchable, Off-grid/Remote, Mobile/Propulsion, Non-electric (specify)
Reference Location	On Coast	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	Integral	e.g. Loop-type (# loops), Direct-cycle, Semi-integral, Integral, Pool-type
Primary Circulation	Forced	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	57	e.g. #, n/a
Fuel Material Type	Oxide	e.g. Oxide, Nitride, Carbide, Metal, Molten Salt, (Other-specify)
Design Status	Under Construction	e.g. Conceptual, Detailed, Final (with secure suppliers)
Licensing Status	Under Construction (1 units)	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	~91	%, defined as Lifetime MWe-yrs delivered / (MWe capacity * Design Life), incl. outages
Major Planned Outages	24 months	# days every # months (specify purpose, including refuelling)
Operation / Maintenance Human Resources		# Staff in Operation / Maintenance Crew during Normal Operation
Reference Site Design	1 Unit	n Units/Modules
Capacity to Electric Grid	~125	MWe (net to grid)
Non-electric Capacity	385 MWth heat at 303ºC	e.g. MW(th) heat at x ºC, m3/day desalinated water, kg/day hydrogen, etc.
In-House Plant Consumption	25	MWe
Plant Footprint	200,000	m2 (rectangular building envelope)
Site Footprint	112,500	m2 (fenced area)
Emergency Planning Zone	0.5	km (radius)
Releases during Normal Operation		TBq/yr (Noble Gases / Tritium Gas / Liquids)
Load Following Range and Speed	100	x – 100%, % per minute
Seismic Design (SSE)	0.3	g (Safe-Shutdown Earthquake)
NSSS Operating Pressure (primary side)	15	MPa(abs), i.e. MPa(g)+0.1, at core outlet
NSSS Operating Pressure (secondary side)	4.6	MPa(abs), i.e. MPa(g)+0.1, at secondary side outlet
Primary Coolant Inventory (incl. pressurizer)	76.7	kg
Nominal Coolant Flow Rate (primary)	1997.8	kg/s
Nominal Coolant Flow Rate (secondary)	166.8	kg/s
Core Inlet Coolant Temperature	286.5	ºC
Core Outlet Coolant Temperature	319.5	ºC

Available Tempeature as Process Heat Source		ºC
NSSS Largest Component	RPV	e.g. RPV (empty), SG, Core Module (empty/fuelled), etc.
- NSSS Largest Component Length		mm
- NSSS Largest Component Diameter	5830	mm
- NSSS Largest Component Thickness		mm
- NSSS Largest Component Weight	303	tonne
Reactor Vessel Material	SA508	e.g. SS304, SS316, SA508, 800H, Hastelloy N
Steam Generator Design	Vertical once-through	e.g. Vertical/Horizontal, U-Tube/ Straight/Helical, cross/counter flow
Secondary Coolant Inventory		kg
Pressurizer Design	Vertical steam pressurized	e.g. separate vessel, integral, steam or gas pressurised, etc.
Pressurizer Volume	12.16/6.27	m3 / m3 (total / liquid)
Containment Type	Dry (double)	Dry (single/double), Dry/Wet Well, Inerted, etc.
Containment Volume		m3
Spent Fuel Pool Capacity and Total Volume	18	Years of full-power operation / m3
Non Electric Application		-
Core Delta Temperature		ºC
Fuel/Core		
Single Core Thermal Power	385	MW(th)
Refuelling Cycle	24 months	months or “continuous”
Fuel Material	UO2	e.g. UO2, MOX, UF4, UCO
Enrichment (avg./max.)	≤4.95%	%
Average Neutron Energy		eV
Fuel Cladding Material	Zr-4	e.g. Zr-4, SS, TRISO, E-110, none

Number of Fuel “Units”	57 Assembly	Specify as Assembly, Bundle, Plate, Sphere, or n/a
Weight of one Fuel Unit	402.8	kg
Total Fissile Loading (initial)	270.2	kg fissile material (specify isotopic and chemical composition)
% of fuel outside core during normal operation		Applicable to online refuelling and molten salt reactors
Fraction of fresh-fuel fissile material used up at discharge		%
Core Discharge Burnup		MWd/kgHM (heavy metal, eg U, Pu, Th)
Pin Burnup (max.)		MWd/kgHM
Breeding/Conversion Ratio		Fraction of fissile material bred in-situ over one fuel cycle or at equilibrium core
Reprocessing		e.g. None, Batch, Continuous (FP polishing/actinide removal), etc.
Main Reactivity Control	Control rod drive mechanism (CRDM); Soluble boron acid;	e.g. Rods, Boron Solution, Fuel Load, Temperature, Flow Rate, Reflectors
Solid Burnable Absorber	Gd2O3	e.g. Gd2O3
Core Volume (active)	5.667	m3 (used to calculate power density)
Fast Neutron Flux at Core Pressure Boundary		n/(cm²*s)
Max. Fast Neutron Flux		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	Active/Passive	- / - / -
- core injection	Active/Passive	- / - / -
- decay heat removal	Active/Passive	- /- / -

- containment isolation and cooling	Active/Passive	- / - / -
- emergency AC supply (e.g. diesels)	Active/Passive	- / - / -
DC Power Capacity (e.g. batteries)	72	Hours
Events in which Immediate Operator Action is required	72	e.g. any internal/external initiating events, none
Limiting (shortest) Subsequent Operator Action Time	0.5	Hours (that are assumed when following EOPs)
Severe Accident Core Provisions	no core melt	e.g. no core melt, IVMR, Core Catcher, Core Dump Tank, MCCI
Core Damage Frequency (CDF)	1.19E-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)	7.63E-9	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)		Months from first concrete to criticality
Design, Project Mgmt. and Procurement Effort		Person-years (PY) [DP&P]
Construction and Commissioning Effort		PY [C&C]
Material and Equipment Overnight Capital Cost		Million US$(2015) [M&E], if built in USA
Cost Breakdown	%[C&C]/%[M&E]	
- Site Development before first concrete		(e.g. 25/10) (30/40) (20/25) (20/10) (5/15) (----------) (to add up to 100/100)
- Nuclear Island (NSSS)		
- Conventional Island (Turbine and Cooling)		
- Balance of Plant (BOP)		
- Commissioning and First Fuel Loading		

Factory / On-Site split in [C&C] effort		%/% 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	67.94	MW/m3
Outer Diameter Of Fuel Rods		mm

4. Plant Layout, Site Environment and Grid Integration

SUMMARY FOR BOOKLET

4.1 Site Requirements during Construction

Plant layout arrangement

The ACP100 adopts compact single-unit plant layout, including nuclear island building (NI) and turbine generator building (CI). The fuel building, electrical building and the nuclear auxiliary building are arranged around the reactor building, allowing the NI building to work well with a smaller size. This layout can adjust itself well to various kinds of plant sites. The operation platform of the reactor, the operation platform of fuel and the transportation platform of the radioactive waste are arranged around the ground of the power plant, which simplify the transportation of the fuel, radioactive waste and big equipment in the NI, to lower the using frequency of NI hoists as well as the cost of construction.

The turbine generator building (CI) is arranged longitudinal to the main nuclear building. The head of steam turbine faces towards the nuclear building. The moisture separator re-heater (MSR) is arranged on the other side of operation layer of high-pressure cylinder. The plant is mainly equipped with turbine, generator, excitation device, MSR, condenser, condensate pump, low-pressure heater, deaerator, feed pump and other

auxiliary equipment.

The nuclear island foundation of the existing site is moderately weathered to slightly weathered rock. The bearing capacity is greater than 1.8 MPa. The elastic modulus is greater than 7 GPa. The shear wave velocity is greater than 1550 m/s.

The major equipment of the site under construction:

- Heaviest piece - the reactor pressure vessel: 303 t;
- The longest part - the ring crane beam: 29 m;
- The widest part - the reactor pressure vessel: 7.8m;
- The highest part - the rector pressure vessel: 7.8 m.

Buildings and structures (reactor, turbine and other buildings)

The ACP100 is designed with a single-reactor layout, and its nuclear island plants mainly include the reactor building (JR), the fuel building (JK), the electrical building (JL), and the auxiliary building (JH). The reactor building consists of three parts from outside to inside: the outer shielding building, the steel containment vessel, and the internal structures. The reactor building is surrounded by the fuel building, the electrical building, and the auxiliary building. The walls and panels of the fuel building, the electrical building, and the auxiliary building are connected to the outer shielding building of JR. The JR, JK, JL, and JH are interconnected to form an integral structure, sharing a flat raft foundation.

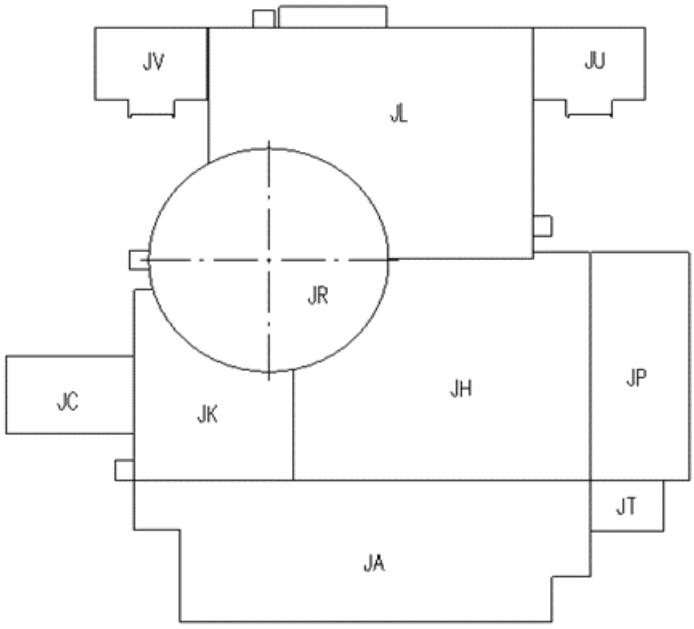


Figure 2. Overall layout plan of the nuclear island plant foundation.

The base elevation of the reactor building foundation can be determined based on the bottom flange elevation of the steel containment vessel. The minimum thickness of the foundation (the distance from the foundation bottom to the outer surface of the containment vessel bottom flange) is approximately 2 m. The base elevations of the other surrounding buildings are -11.7m, and the foundation thickness is approximately 2.2 m.

The outer shielding building includes the cylindrical part, the conical roof (shielding building dome), and the annular space between the building and steel containment vessel.

The distance between the inner side of the outer shielding building and the steel containment vessel shell is about 1.05 m. The inner diameter of the cylindrical shell of the outer shielding building is 32.1 m, and the wall thickness is 1 m.

The internal structures mainly consists of various equipment compartments on the periphery, the internal component storage pool, the refueling water pool, the internal refueling water tank, and the central reactor cavity. The base plate of the internal structure is directly cast inside the steel containment vessel. The bottom elevation of the reactor pit supporting the pressure vessel is -11.7 m, the bottom elevation of the internal refueling water tank is -6.56 m, the bottom elevation of the in-reactor structure storage pool is -4.86 m, and the bottom elevation of the refueling pool is -0.06 m. The main floor, equipment operation and transfer platform, is the 7.0 m .

The fuel building (JK) is approximately 22.6 m long and 29.0 m wide, with a top elevation of the base plate of -9.50 m and a roof top elevation of +26.30 m. There are four main layout layers in the building.

The electrical building (JL) is approximately 46.00 m long and 34.30 m wide, with a top elevation of the base plate of -9.5 m and a main roof top elevation of +20.2 m. There are a total of 7 layers in the building.

The auxiliary building (JH) is approximately 42.19 m long and 34.7 m wide, with a top elevation of the base plate of -9.5 m and a main roof top elevation of 17.7 m. There are a total of 6 layers in the building.

The auxiliary diesel generator building (JT) is 13.8 m long and 5.3 m wide, with a roof structure elevation of 5.0 m.

The fire pump room (JP) is 34.7 m long and 14.0 m wide, with an underground base plate top elevation of -9.9 m, a buried depth of 11.750 m, a roof structure elevation of 9.7 m, and a partial elevation of 14.0 m.

The standby diesel generator buildings JU/JV are located on the east and west sides of the electrical building (JL), with one standby diesel engine arranged in each building. The standby diesel generator buildings (JU/JV) are 23.1 m long and 12.65 m wide, with a base plate top elevation of -9.4 m (partially -8.8 m) and a roof structure elevation of 17.3 m (partially 20.8 m).

Axis dimensions of turbine building is approximately 60 m long and 61.4 m wide. The turbine building is reinforced concrete structure, mainly include turbine hall, deaerator bay, chemical equipment and lubricating oil storage and delivery system.

The turbine hall is approximately 29 m wide, with a top elevation of the base plate of -6.0 m and a main roof top elevation of +25.77 m. There are a total of 3 layers in the building.

The deaerator bay is approximately 13 m wide , with a top elevation of the base plate of -6.0 m and a main roof top elevation of +25.77 m. There are a total of 6 layers in the building.

The chemical equipment is approximately 11 m wide , with a top elevation of the base plate of +0.0 m and a main roof top elevation of +6.0 m. There is a total of 1 layers in the building.

The lubricating oil storage and delivery system is approximately 8.4 m wide , with a top elevation of the base plate of +0.0 m and a main roof top elevation of +5.0 m. There is a total of 1 layers in the building.

Containment layout and structure

The reactor building consists of a double-shell containment and internal structure, the internal containment

is a steel shell. It protects the systems inside the building against external impacts. Under abnormal or accident conditions, it limits the radiological consequences to acceptable values at the site boundary.

Spent fuel facilities

Fuel building is required for spent fuel examination, storage and preparing of delivery off the site.

4.2 Site Considerations during Operation

Water usage needs for all plant systems

The main uses of freshwater include production water, personal domestic water, firewater, dust fall at the construction site and car washing, etc. during construction, as well as production water, domestic water, firewater, street flushing, car washing and greening water during operation.

Maximum acceptable ambient air temperature, humidity, and heat sink temperature for full-power operation

The once-through seawater cooling is adopted in service water system, the design reference temperature is 31.6℃, the maximum design temperature is 34℃, the maximum acceptable seawater temperature is 36℃.

Cooling options / requirements; effect of heat sink temperature

Generally there are two options of cooling systems, which is once-through cooling system and closed-circuit cooling system. The once-through cooling system is suitable for coastal plant sites, and the closed-circuit cooling system is suitable for plant sites far from the sea or inland. The heat sink temperature will affect the power generation capacity of the power plant.

Emergency planning and response

The emergency planning and response arrangement is incorporated in the whole site emergency organization system. In the on-site emergency planning, the emergency classification, the emergency planning zone, the emergency relative facilities, the emergency evacuation routes, etc are all thoroughly considered according to the design of ACP100, to guarantee a better response under emergency conditions.

4.3 Grid Integration

This power plant is a unit with a power generation capacity of 125 MW. The output voltage of the generator is 13.8 kV. The frequency is 50 Hz. It can be connected to the local power grid after boosting through the main transformer.

The auxiliary power consumption rate of the power plant is about 10%.

The power plant requires two external power sources, one main power source and one auxiliary power source.

The two external power sources are composed of two independent power grid systems, which are used to reduce the possibility of faults in the external power sources.If the main power supply outside the power plant fails, it should automatically switch to the auxiliary power supply outside the plant. After the main power supply outside the power plant is restored, it can be manually switched back to the main power supply outside the power plant. Each of the two external power sources should have sufficient capacity to enable all plant equipment that needs to be put into use to quickly switch from one power source to another.

5. Technical NSSS/Power Conversion System Designn

SUMMARY FOR BOOKLET

5.1 Primary Circuit

The integrated nuclear steam supply system (NSSS) design consists of the reactor core, and sixteen once-through steam generators (OTSG), mounted in an RPV. The four canned motor pumps are installed at nozzles of the RPV. The heat, which nuclear fission in the reactor core produces, is transferred to coolant in the primary circuit through OTSGs to fulfil thermal conduction and convection. A pressurizer is connected to RPV via a surge pipe to provide the overpressure prevent.

Reactor Pressure Vessel and Internals

The RPV and equipment layout are designed to enable the natural circulation between reactor core and steam generators. The RPV is protected by safety relief valves against over-pressurization in the case of strong difference between core power and the heat removed from the RPV. The internals not only support and fasten the core but also form the flow path of coolant inside RPV.

Steam Generator

There are 16 OTSGs, which are mounted within the RPV. All the 16 OTSGs are fitted in the annulus between the reactor vessel and hold-down barrel. The bottoms of OTSGs are limited their position by the hole on barrel supporting hub, the heads are welded to the reactor vessel steam cavity.

Primary pumps

A reactor coolant pump is directly connected to nozzles on RPV. The reactor coolant pump casing (nozzles) and stator shell provide a barrier to the release of reactor coolant and other radioactive materials to the containment atmosphere.

The reactor coolant pumps are high-inertia, high-reliability, low-maintenance, seal-less pumps of either canned motor design that circulate the reactor coolant through OTSGs in the reactor vessel.

Pressurizer

The pressurizer of ACP100 is located outside of the reactor vessel. The pressurizer is a vertical, cylindrical vessel with hemispherical top and bottom heads.

Decay Heat Removal System

The PDHRS prevents core meltdown in the case of design basis accident (DBA) and beyond DBA, such as station black out, complete loss of feed water, small-break LOCA (i.e., to prevent the change of beyond DBA to severe phase). The PDHRS of ACP100 consists of one emergency cooler and associated valves, piping, and instrumentation. The emergency cooler is located in the in-containment refuelling water storage tank, which provides the heat sink for the emergency cooler. The decay heat is removed from the core by natural

circulation. The PDHRS provides core cooling for 7 days without operator intervention or long term with IRWST makeup water collected by gravity force from the steam condensed in containment.

Passive Core Cooling System

The passive core cooling system is designed to provide adequate core cooling in the event of design basis events. The passive core cooling system uses four different sources of passive injection during loss of coolant accidents.

Accumulators provide a very high flow for a limited duration of several minutes.

The core makeup tanks provide a relatively high flow for a longer duration.

The in-containment refueling water storage tank provides a lower flow, but for a much longer time.

The containment is the final long-term source of water. It becomes available following the injection of the other three sources and flood up of containment.

Chemical and Volume Control System

The chemical and volume control system provides controlling of chemistry, purity, and inventory for the reactor coolant system. Reliability is achieved by the use of redundant equipment (pumps, filters, and demineralizers).

The chemical and volume control system consists of regenerative and letdown heat exchangers, demineralizers and filters, charging pumps, tanks, and associated valves, piping, and instrumentation.

The chemical and volume control system provides containment isolation of chemical and volume control system lines penetrating containment, termination of inadvertent reactor coolant system boron dilution, isolation of makeup on a steam generator or pressurizer high level signal, and preservation of the reactor coolant system pressure boundary, including isolation of normal chemical and volume control system letdown from the reactor coolant system.

Emergency Core Cooling System

The emergency core cooling system (ECCS) consists of two coolant storage tanks (CST), two safety injection tanks (SIT), an in-containment refueling water storage tank (IRWST) and associated injection lines. The ACP100 has a safety related direct current (DC) power source to support accident mitigation for up to 72 hours, along with auxiliary power units to recharge the battery system for up to seven days. After LOCA accidents, the steam in containment is condensed continuously at containment internal face thus the heat is conducted to containment, which is cooled by PAS, thus ensuring the containment integrity.

Instrumentation and Control System

The Instrumentation and Control (I&C) system designed for ACP100 is based on defense in depth concept, compliance with the single failure criterion and diversity. The diversity in the design of I&C system is achieved through: (1) different hardware and software platforms for 1E and N1E I&C, (2) reactor protection system (RPS) with functional diversity, and (3) diverse protection systems to cope with the common mode failure of the RPS. I&C systems of the NSSS include reactor nuclear instrumentation system, RPS, diverse actuation system, reactor control system, rod control and rod position monitoring system, reactor in–core instrumentation system, loose parts and vibration monitoring system and other process control systems.

5.2 Reactor Core and Fuel

The 57 fuel assemblies (FAs) of ACP100 core with total length of 2.15 m core have a squared 17x17 configuration. The fuel U-235 enrichment is about 1.9–4.95%. The reactor will be able to operate 24 months at balance fuel cycle.

The reactor core is the heart of the reactor design, providing the fuel for generation of nuclear heat for transfer to pressurised water flowing through the core and onward heat transfer to the secondary systems so that electrical power can be generated.

UO2 pellets are contained in tubes made from zirconium alloys, which give good neutron economy, structural stability and corrosion resistance in the PWR environment.

The core contains 57 fuel assemblies and has an active fuelled length of 2.15 m. The poison used is distributed Gd2O3 (containing natural gadolinium) .

The advanced yet proven nature of the fuel selected means that there is a mature global supply chain available, minimizing risks associated with the expensive and time consuming nature of developing new fuel technologies. The plant has the capability to take advantage of future developments in cladding technology upon maturity, where deemed beneficial.

The core is cooled and moderated by light water at a pressure of 15.0 MPa in the reactor coolant system. The coolant contains boron as a neutron poison. The concentration of boron is varied as required to control relatively slow reactivity changes including the effects of fuel burnup. In addition, Gd2O3 homogeneously mixed in UO2 pellet is employed as burnable absorber to control the reactivity of the core in all cycles.

The 264 fuel rods are mechanically joined in a square array (17×17) to form a fuel assembly. The fuel rods are supported at intervals along their length by grid assemblies which maintain the lateral spacing between the rods throughout the design life of the assembly. The grid assemblies consist of interlocked straps. The straps contain spring fingers and dimples for fuel rod support. The fuel rods consist of slightly enriched sintered UO2 pellets contained in cladding tubes, which is plugged and seal welded at the ends to encapsulate the fuel. All fuel rods are pressurized with helium during fabrication to reduce stresses and strains and to increase fatigue life.

The central position in the assembly is reserved for use by the in-core instrumentation, while the remaining 24 positions in the array are equipped with guide thimbles joined to the grids and the top and bottom nozzles. Depending upon the position of the assembly in the core, the guide thimbles are used as core locations for rod cluster control assemblies, and neutron source assemblies. Otherwise, the guide thimbles are fitted with plugging devices to limit bypass flow.

5.3 Fuel Handling

The In-Refueling Water Storage Tank (IRWST) is a passive water tank, resting on the internal structure base slab. During refueling operations, it provides water for refueling cavity, internals storage compartment and refueling transfer canal to complete the refueling operation. Under the condition of LOCA and the steam pipe rupture, it provides water for emergency reactor core cooling. In the severe accidents, water in it floods the internal structure under the balanced water level due to gravity. During the operation of reactor automatic depressurization system, it absorbs the sprayed steam from the RCS. During the operation of the passive residual heat removal cooler, it works as the heat sink of the passive residual heat removal system.

The reactor pool is used during refueling operation or inspection of reactor internals. The reactor pool

consists of two compartments which can be separated by bulkhead: reactor cavity and internals storage compartment adjacent to the reactor.

Brief description

The fuel handling and storage system (RFH) is designed to:

- Enable loading and unloading of fuel assemblies into and from the reactor during shutdown;
- Store new fuel before it is loaded into the reactor;
- Store spent fuel;
- Load spent fuel assemblies into casks for transportation.

The various components, including fuel handling equipment, fuel storage equipment and fuel handling tools, required to ensure proper operation of the RFH system are located in reactor building and fuel building.

Fuel movement from fresh to spent fuel bay

Fresh Fuel: New fuel is transported to the fuel in & out room, then to the fuel assembly acceptance room of the fuel building. The new fuel is stored at new fuel storage room or at the spent fuel storage pool after the new fuel visual inspection.

Spent Fuel: The spent fuel shipping cask is transported to the cask prepare pit then to the loading pit of the fuel building and ready for reception of the spent fuel assembly. Moving the spent fuel assembly from the spent fuel pool to the spent fuel shipping cask. After loading, moving the cask out for transportation off the site.

5.4 Reactor Protection

The reactivity is controlled by means of control rods, solid burnable poison and soluble boron dissolved in the primary coolant. There are 20 control rods, with a magnetic force type control rod driving mechanism. The concentration of soluble boron in the reactor coolant system is controlled.

The safety systems of ACP100 consist of shutdown system, passive decay heat remove system, passive emergency core cooling system, passive containment air cooling system. These systems could maintain the integrity of the reactor core and the containment throughout the plant life time.

5.5 Secondary Side

The feed water flow control system function is to supply feed water to the steam generators and to control the feed water flow to maintain the feed water accord with the turbine load.

The feed water flow control system is not a safety system. Nevertheless, isolation feed water function during accident conditions, system instrumentation channels, which provide information on feed water flow rate to the reactor protection system and used for post-accident monitoring, have a safety-related function.

Turbine generator description

Rated power of steam turbine generator set is 127.52MW. The unit is a full speed (3000 r/min), single shaft, two casings with two exhausts, reheat, and condensing nuclear turbine. The steam turbine consists of one High Pressure (HP) and one Low Pressure (LP) casing.

Feed water systems

The function of main feed water flow control system (TFM) is to control the flow of feed water that enters the steam generator in order to keep water level in steam generator secondary side at a reference level programmed in relation to the turbine generator load.

Auxiliary systems

Steam and Power Conversion System is designed to convert the thermal energy produced in the reactor into electrical energy. It consists of Steam / Water Systems, Turbine and Major Auxiliaries Systems, Generator and Auxiliary System, Condenser System, Feedwater Heater System, Circulating Cooling Water System, Conventional Island Closed Cycle Cooling Water System and so on.

Main steam is supplied from steam generators to drive the turbine. And heat energy of the steam is turned into the mechanical energy by the turbine, finally transformed into electric power by the generator.

Main Steam System (CI part)

The main steam system (TSM) routes the steam produced by the steam generators to a manifold from where the steam to the following equipments and systems are provided:

- The high pressure cylinder
- The turbine bypass system-C
- The turbine gland seal system
- The auxiliary steam system

Turbine bypass system

The turbine bypass system (TSC) is used to bypass steam directly to condenser during startup, reactor cool down, turbine trip, load reduction etc.

Condensate Extraction System

The condensate extraction system (TFE) is in the system which between the turbine and the low pressure feed water heater system, a major component of the turbine thermodynamic system. The main function of the condensate extraction system is as follows:

- Establish and maintain condenser vacuum for turbine together with condenser vacuum system and circulating water system
- Condenser the steam into water in condenser
- Extract the condensate from condenser hot well and send it to the deaerator through the low pressure heaters
- Receive drains from drain tanks
- Provide de-superheating water to LP cylinder spray water system
- Provide de-superheating water to turbine bypass system.

Low Pressure Feedwater Heater System

The function of low pressure feed water heater system (TFL) is to heat condensate by using turbine extraction steam to improve thermal efficiency of the unit.

Main Feedwater Deaerator System

The basic function of feed water deaerator system (TFD) is removal of oxygen and other non-condensable

gas in feed water, in order to minimize the corrosion in steam generator, turbine and auxiliary equipment and pipeline in thermal system.

The function of deaerator are as follows:

- To provide a continuous supply of heated and deaerated water of specified conditions to the feed water pumps and start-up pumps
- To maintain net positive suction head requirement on the feedwater pumps.
- To maintain a storage capacity to meet any transient mismatch between steam generator requirements and available condensate supply
- To vent incondensable gases to the main condenser and atmosphere
- To receive MSR shell drains

Main Feedwater Pump System

The main feed water pump system (TFP) pump the feed water deaerated from deaerator to steam generators through HP heaters.

Auxiliary Steam System

The function of Auxiliary steam system (WSD) is to distribute the auxiliary steam which is produced by auxiliary boiler (during shutdown and startup) or main steam (during normal operation) to each user.

The WSD provide steam to following users and equipment:

- Deaerator pegging and heating steam
- Turbine gland seal system
- Hot water production and distribution system
- NI users

Condenser Vacuum System

The condenser vacuum system (TTV) removes air and non-condensable gases from the condenser to establish and maintain required vacuum at startup and during operation. The system also provides condenser vacuum breaking so as to provide a turbine faster deceleration in case of tripping.

Circulating Water System

The purpose of the Circulating Water System (WCW) is to supply cooling water to the turbine generator condenser water boxes and the Auxiliary Cooling Water system. This system is not safety classified since it is not associated directly or indirectly with any nuclear safety function.

The circulating water is supplied by circulating water pumps to the turbine generator condenser water boxes and the Auxiliary Cooling Water system through water intake, sluice gates, bar screens, drum screens. Tunnel or channel is used to supply water from river to pump station.

The circulating water is discharged to river through circulating water discharge pipe, water discharge surge tank, and water discharge tunnel or channel.

Condensate Polishing System

The function of condensate polishing system is demineralizing the condensate from main condenser,

removing the contamination of steam and water, and protecting the steamer.

Conventional Island Closed Cycle Cooling Water System

The function of conventional island closed circulating cooling water system (WCI) is to remove the heat produced by operating equipment in conventional island and BOP. And ensure safe operation of these devices.

5.6 Containment/Confinement

The ACP100 containment houses the RCS, the passive safety systems and the auxiliary systems. ACP100 adopts small steel containment cooled by air with no need of drive signal.

ACP100 nuclear power plant reactor building consists of three parts which are the shield building, the steel containment and the internal structure. The steel containment is a free-standing, cylindrical steel vessel with ellipsoidal upper and lower heads. The steel containment vessel is an integral part of the containment system; it serves both to limit releases in the event of an accident and to provide the safety-related ultimate heat sink. The internal structure of the reactor building is located in the steel containment which is surrounded by the shielding building that is exposed to ambient conditions. The steel containment and the shield building work together as a part of passive cooling flow of PAS system.

The wall thickness in most of the cylinder is 36.5 mm. The wall thickness of the lowest course of the cylindrical shell is increased to 39 mm to provide margin in the event of corrosion in the embedment transition region. The thickness in most of ellipsoidal bottom and top head is 32 mm with a major diameter of 30 m and a height of 8.7 m, the thickness for the upper part (the height is no less than 2.7 m) of the bottom head is increased to 34.5 mm to provide margin in the event of corrosion.

The containment vessel includes the shell, hoop stiffeners and crane girder, equipment hatches, emergency airlocks, fuel transfer channel penetration and other electrical and mechanical penetrations.

The steel containment has the following design parameters:

- internal design pressure: 0.36MPa (relative pressure)
- external design pressure: 0.02MPa (relative pressure)
- design temperature: 140℃

5.7 Electrical, I&C and Human Interface

The ACP100 utilizes the Distributed Control system (DCS), which consists of safety-class and non-safety-class system. The safety-class DCS implements reactor trip and engineered safety features actuation based on 4 independent divisions (Div A/B/C/D). Each division consists of Protection Instrumentation Pre-processing System (PIPS), Adapting&Logic Unit (ALU), Transfer Unit (TU), Priority Logic Module (PLM), Safety Visual Display Unit (SVDU) and Primary/Secondary Display Safety Panel(PDSP/SDSP). The safety-class DCS integrated based on NASPIC platform of China, and the simplified architecture is as below. The safety-class signals from Process instrumentations and the Reactor Neutron Instrumentation (RNI) are sent to the safety-class DCS. The functionality of the Reactor Protection System is carried out under these 4 divisions to initiate the Reactor Trip Breaker (RTB), Squib Valve Controller (SVC) and other ESFs. The Operators in Main Control Room (MCR) utilize the SVDU to monitor the reactor safety status, and utilize the PDSP/SDSP to carry out manual safety operations.

Data Sheets:

Type	Full rational speed, single axle, two casing two exhaust, mid-reheated, condensing type
Number of Casings	2
Number of Exhausts	2
Rated output (Maximum. Guaranteed)	127.52MW
Rated Speed	3000r/min
Frequency	50 Hz
Rated voltage	24 kV

Safety related electrical systems

Class 1E DC and AC uninterruptible power supply (UPS) systems provide reliable power to safety-related plant instrumentation, control, monitoring, and critical functional equipment required for safe plant shutdown. In the event of loss of all off-site and/or on-site AC power, the battery pack is capable of providing continuous power to the corresponding DC and AC UPS loads.

Class 1E DC and AC uninterruptible power supply (UPS) system is divided into four independent sequences A, B, C, D, sequence A and D are respectively composed of a group of batteries, a group of switch cabinets, two battery chargers, an inverter connected to the switch cabinet and a backup bypass voltage regulating transformer connected to the switch cabinet, and the battery discharge time is 24 hours. Sequence B and C are respectively composed of two groups of batteries, two groups of switch cabinets, four battery chargers, two inverters connected to the switch cabinet and a standby bypass voltage regulating transformer connected to the switch cabinet, the discharge time of the first group of batteries is 24 hours, and the discharge time of the second group of batteries is 72 hours. The battery charger is connected to the switchgear. The input power for the Class 1E battery charger is drawn from a low-voltage system with a backup diesel generator as a backup power source.

In order to provide power after the design benchmark event, the voltage regulating transformer power supply of the second group of 220V AC uninterruptible power supply systems in sequences B and C can be switched to the auxiliary diesel generator set of the power plant.

Control room layout

In ACP100 Main Control Room, there are four NC digital Operating Working Positions (OWP) which are the main control means for operators. Safety dedicated panels are used to control the plant for safety functions. Sixteen large display panels are located in front of the operators to provide the plant overview information. DAS panel is provided for the condition of reactor protection system common failure.

5.8 Unique Technical Design Features (if any)

6. Technology Readiness

SUMMARY FOR BOOKLET

The ACP100 preliminary safety assessment report (PSAR) is approved by National Nuclear Safety Authority and detailed engineering design is in progress. Changjiang nuclear power site, Hainan,

China, was chosen to build the first of a kind (FOAK) ACP100 demonstration project. FCD in July, 2021.Construction period of FOAK is 55 months, target commercial operation is in 2026.

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

7. Safety Concepts

SUMMARY FOR BOOKLET

7.1 Safety Philosophy and Implementation

The ACP100 satisfies the basic safety functions that a nuclear power plant should have: reactivity control, residual heat removal, and radioactive release containment. The concept of defense in depth is applied in the design., providing a series of multi-level defenses (inherent characteristics, equipment and procedures). Due to the design characteristics of the ACP100, such as small radioactive source term, small residual heat in the core, high inherent safety, the strengthened accident prevention, the defense in depth levels can be focused on the first three levels and at most the fourth level, thereby realizing limited or even no need for external intervention measures in technology.

The ACP100 has multiple inherent safety characteristics including the integrated primary coolant system eliminating large break LOCAs; long characteristic times in transients or accidents due to large coolant inventory and the use of passive safety systems; negative reactivity effects and coefficients, etc.

The ACP100 adopts passive safety systems, including the passive emergency core cooling system, the passive decay heat removal system, the reactor automatic depressurization system, and the passive containment air cooling system. The safety system is simplified to reduce their failures. the safety of the reactor during accidents is achieved through natural forces, reducing the dependence on external water sources, power sources and personnel intervention. There is no need for human intervention for a long time after accidents. The integrated reactor design minimizes the probability and impact of design basis accident. The emergency planning zone can be limited to the site area.

Passive Decay Heat Removal System

The PDHRS prevents core meltdown in the case of design basis accident (DBA) and DEC-A, such as station black out, complete loss of feed water, small-break LOCA. The PDHRS of ACP100 consists of one emergency cooler and associated valves, piping, and instrumentation. The emergency cooler is located in the in-containment refueling water storage tank, which provides the heat sink for the emergency cooler. The decay heat is removed from the core by natural circulation. The PDHRS provides core cooling for long term days without operator intervention.

Passive Emergency Core Cooling System

The emergency core cooling system (ECCS) consists of two coolant storage tanks (CST), two safety

injection tanks (SIT), an in-containment refueling water storage tank (IRWST) and associated injection lines. The ACP100 has a safety related direct current (DC) power source to support accident mitigation for up to72 hours. After LOCA accidents, the steam in containment is condensed continuously at containment internal face thus the heat is conducted to containment, which is cooled by passive containment air cooling system, thus ensuring the containment integrity.

Reactor Automatic Depressurization System

The reactor automatic depressurization system (RDP) is mainly composed by pressure relief valves, isolation valves and associated pipes, instrumentation, etc. RDP utilizes a three-level depressurization approach. Each level has 2 trains. Every depressurization line connects an isolation valve and pressure relief valve in series. The 1st level and 2nd level depressurization lines are connected in parallel as a set, whose common inlet main lines are separately connected to the nozzles of 2 safety valves at the top of the pressurizer and as well the steam space of the pressurizer. The common outlet line of either level goes through the sprayers (spargers) into the in containment refueling water storage tank, and vacuum protection valves are placed on the common outlet lines.

RDP's 3rd depressurization line has further 2 levels as 3A and 3B, either of which contains2 trains. 3A and 3B are connected in parallel as a set, and the inlet and outlet are connected to the pressurizer surge line and the reactor pressure vessel RHR lines, so that the pressure can be released directly to the containment.

Passive Containment Air Cooling System

The ACP100 containment houses the RCS, the passive safety systems and the auxiliary systems. ACP100 adopts a small steel containment cooled by air with no need of drive signal. The inner steel containment vessel is under pressure and used as a heat transfer surface, the outer concrete containment structure organizes an air flow channel. The inner surface of the steel shell is heated by steam condensation. Heat is transferred to the outer surface of the steel shell. The outer surface is cooled by natural air circulation.

Severe accident prevention and mitigation measures

Severe accident prevention and mitigation are achieved through passive reactor cavity flooding preventing RPV melt, passive hydrogen recombination system preventing containment hydrogen explosion and maintaining the containment integrity after severe accidents, automatic pressure relief system and RPV off-gas system to remove non-condensable gas gathered at RPV head after accidents.

7.2 Transient/Accident Behaviour

To cope with design basis accidents, passive safety systems are adopted. The primary side passive decay heat removal system is used to continuously remove the residual heat from the core in the SBO accident. The passive emergency core cooling system is used to ensure the continuous cooling of the core in the small or medium break LOCA accidents. The reactor automatic depressurization system is used to actively relieve pressure to ensure the timely injection of the ECCS system. The containment air cooing system is used to automatically export the heat released into the containment after accidents. These passive safety systems ensure the safety of the reactor under accidents through natural forces, without the need for safety related emergency AC power supply and there is no need for human intervention for a long time after accidents.

To cope with design extended conditions without core melting (DEC-A), in addition to the passive safety system, the defense in depth function is also realized by using of non-safety related systems. The diversity

protection system is applied to achieve emergency shutdown and trigger protection actions, the normal residual heat removal system is used to perform the low-pressure safety injection function, and the full-pressure accident isolation valve is set on the main steam pipeline in the containment to prevent the bypass of radioactive releases outside the containment. Through the combination of passive and active means, as well as the joint action of the safety system and non-safety system, the safety of the reactor under the DEC-A is ensured.

To cope with severe accidents (DEC-B) that lead to core melting, special measure for the prevention and mitigation of severe accidents are implemented. Mainly, the risk of hydrogen combustion and explosion in the containment is controlled by the hydrogen recombiners, the in-vessel retention (IVR) technology is used to keep the core melt in the reactor pressure vessel (RPV), and the high pressure melt ejection is prevented by opening the valves of the 3rd stage RDP system.

8. Fuel and Fuel Cycle

SUMMARY FOR BOOKLET

8.1 Fuel Cycle Options

Spent fuel processing is similar to other nuclear power plants. It is temporarily stored in spent fuel pools. Waste management approach and disposal plan is similar to other nuclear power plants.

Spent Fuel Cooling Safety Approach/ System

The In-Refueling Water Storage Tank (IRWST) is a passive water tank, resting on the internal structure base slab. During refueling operations, it provides water for refueling cavity, internals storage compartment and refueling transfer canal to complete the refueling operation. Under the condition of LOCA and the steam pipe rupture, it provides water for emergency reactor core cooling. In the severe accidents, water in it floods the internal structure under the balanced water level due to gravity. During the operation of reactor automatic depressurization system, it absorbs the sprayed steam from the RCS. During the operation of the passive residual heat removal cooler, it works as the heat sink of the passive residual heat removal system.

The reactor pool is used during refueling operation or inspection of reactor internals. The reactor pool consists of two compartments which can be separated by bulkhead: reactor cavity and internals storage compartment adjacent to the reactor.

The fuel assembly is composed of a fuel assembly skeleton, a top nozzle assembly and 264 fuel rods arranged in a 17×17 square array. The fuel assembly skeleton comprises 24 guide thimbles, one instrumentation tube, 11spacer grids (8 Structure grids and 3 Intermediate mixing grids) and a bottom nozzle. The instrumentation tube, located at the assembly centre, is used to insert in-core neutron detector. The guide thimbles are joined to the top and bottom nozzles of the fuel assembly and provide the supporting structure for the fuel grids.

The fuel cycle is 24 months.

Failed fuel detection

The on-line and off-line sipping test systems are used to detect failed fuel assembly.

The on-line sipping test system, which is secured on the refueling machine, is used to detect leakage of the cladding of the fuel assembly during normal performance of the core unloading operations.

The off-line sipping test system, which is secured in the spent fuel pool, is used to test the leak tightness of the fuel assembly after irradiation.

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

Physical protection

The protection objective of the physical protection system is to ensure the safety of the nuclear material in the nuclear power plant and the critical and important equipment that will melt the core and cause a nuclear leakage accident if damaged.

The physical protection system of ACP100 project organically combines personnel protection and technical defense. Civil personnel protection consists of guards and armed forces. Technical defense provides effective detection and delay through technical means such as physical barriers at all levels, intrusion alarm systems, video surveillance systems, access control systems, and security communication systems. By setting up physical barriers at all levels, intrusion alarm equipment, video review equipment and means of communication, and controlling the entry and exit of people and vehicles in different areas, it becomes feasible to monitor various illegal intrusions, make timely, fast and accurate responses to the possible intrusion of hostile individuals or hostile gangs, and provide a safe and reliable environment for the safe operation of nuclear power plants.

The physical protection system of ACP100 project also meets the requirements of being compatible with the safe operation of nuclear power plants, nuclear accident emergency, fire protection, and radiation protection systems.

Insider actions

The ACP100 project has established employee management system at all stages. The system will regularly determine the trustworthiness of personnel exposed to nuclear and other radioactivity materials, related facilities and related activities, and sensitive information and sensitive information systems through questionnaires, reception days of the general manager, daily conversations, etc. to reduce the risks posed by insider activity.

For employed personnel, licenses of corresponding grades shall be issued according to their work contents. The ACP100 project will conduct 1-2 training on safety and security knowledge for staff and other workforce every year to achieve the purpose of consciously observing on-site safety and security regulations.

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