Introduction of CAP1400

--An Advanced Large Passive NPP for the World

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Deputy Director of GT Department of SNERDI

Oct. 2015

国家核电 SNPTC

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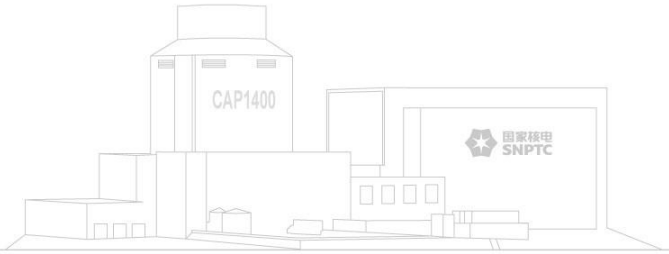

1. *General Pictures of CAP1400*
2. *Design Features*
3. *Verification and Validation*
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5. *Summary*

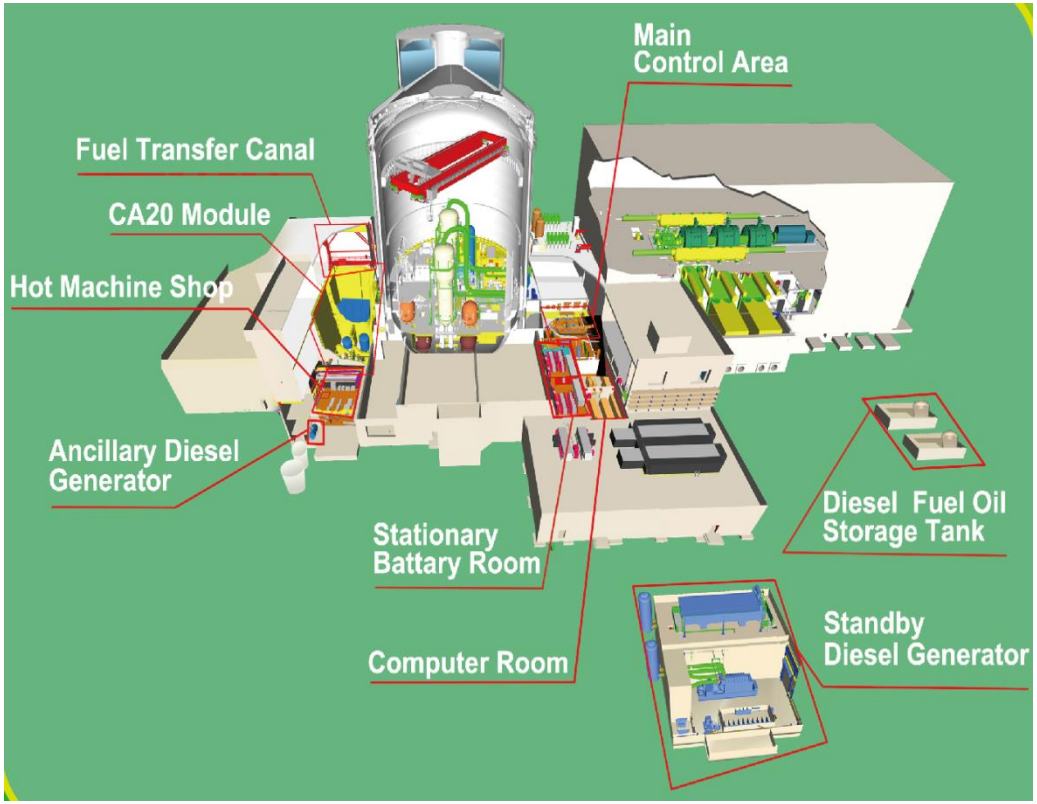
1. General Pictures of CAP1400

General Parameters

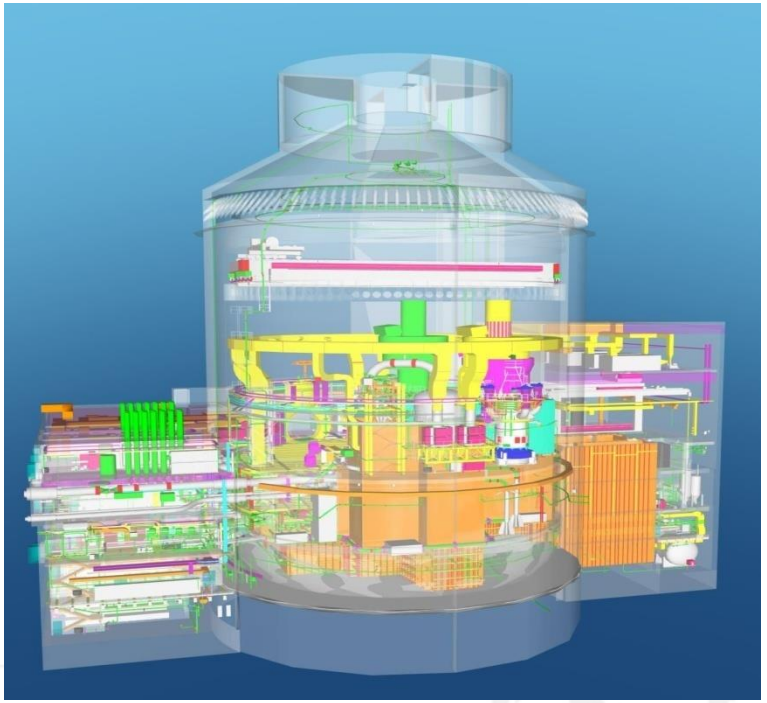
Parameters	CAP1400
Core thermal power, MWt	4040
Electric power, MWe	~1500
RCS average temp, ℃	304
RCS pressure, MPa(a)	15.5
Fuel assemblies	193
Fuel assembly type	RFA or Innovated design
Average linear power, W/cm	181
SG type	SNP140
SG outlet pressure, MPa (a)	6
Steam flow per loop, kg/s	1122
Design flow per pump, m^3/h	21642
DNBR margin	>15%

1. General Pictures of CAP1400

☐ General Layout



CAP1400	0.17 m²/kW
GII+	~0.21 m²/kW



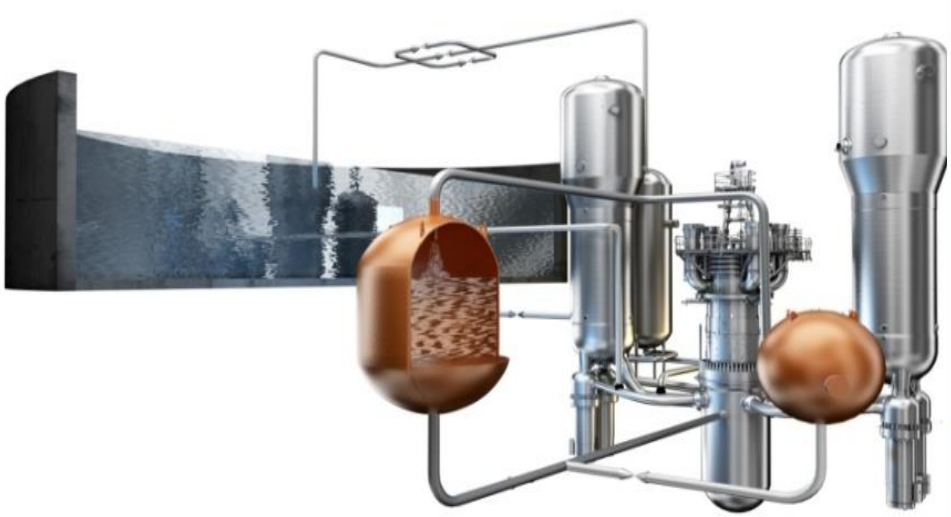
Only 5 main buildings in a CAP1400 plant, reduce the number of buildings and safety system equipment to minimize the site area--land saving

1. General Pictures of CAP1400

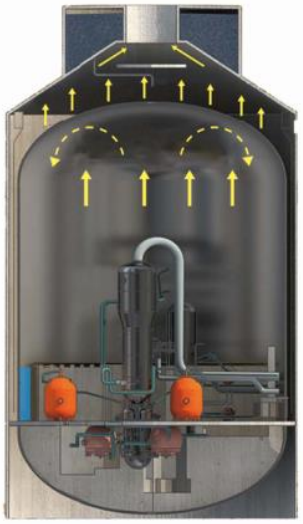
☐ Overall Performance of CAP1400

❑ Safety

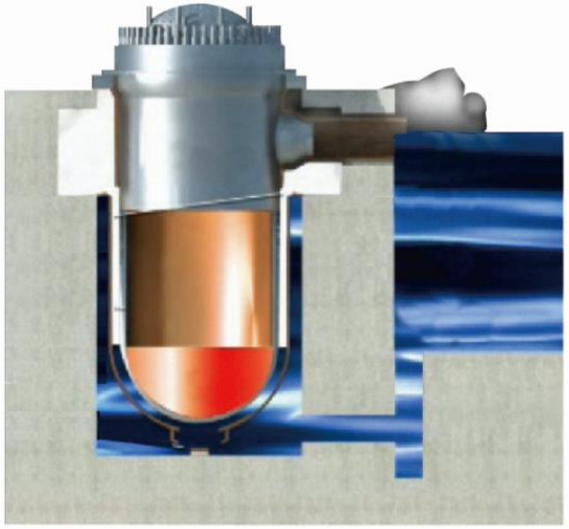
- **Passive SF & comprehensive SA prevention and mitigation**
- **Low safety risk:** CDF (Core Damage Freq.) : 4.02E-7/RY ; LRF (Large Release Freq.) : 5.21E-8/RY
- **Enhanced margin for DBE:** DNBR Margin > 15%; CV Pressure Margin > 10%; SSE (Safety Shutdown Earthquake), 0.3 g
- **Sufficient margin against extreme external events:** HCLPF for all safety-class SSCs ≥0.5g, plus "Dry Site" principal.



PXS



PCS



IVR

1. General Pictures of CAP1400

☐ Overall Performance of CAP1400

❑ Economy

1 Self design with IPR

~1500MWe(gross)

~Systematic optimization for efficiency

2 Localization

Key equipment and material localized

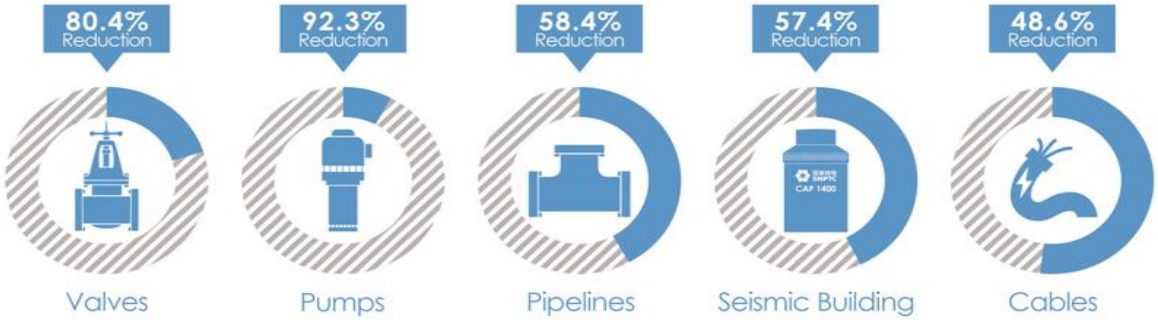
Economy

3 Benign competition

Monopoly and vicious competition avoided

Shared profit

4 Simplification and short construction period



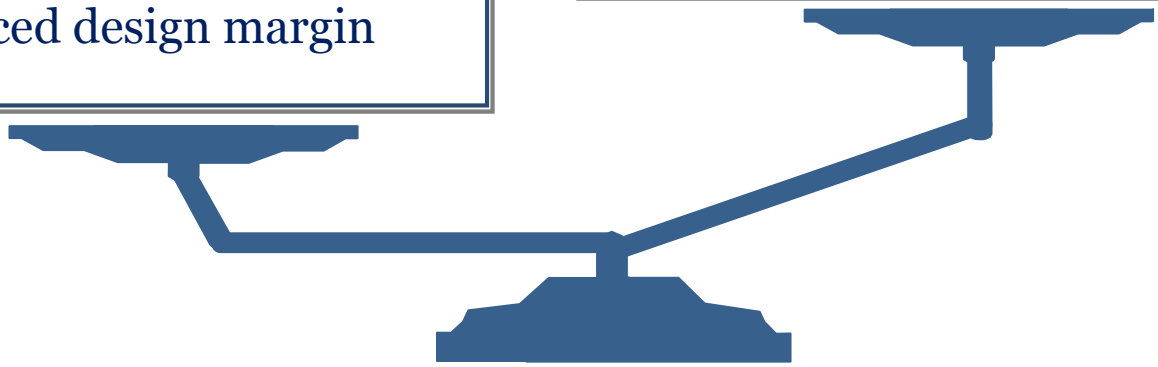
1. General Pictures of CAP1400

☐ Overall Performance of CAP1400

❑ Advancement

- Simplification (Reduced weld for primary equipment and operational waste)
- MOX fuel capability
- RVI redesigned, the neutron shield pad no longer needed
- Enhanced design margin

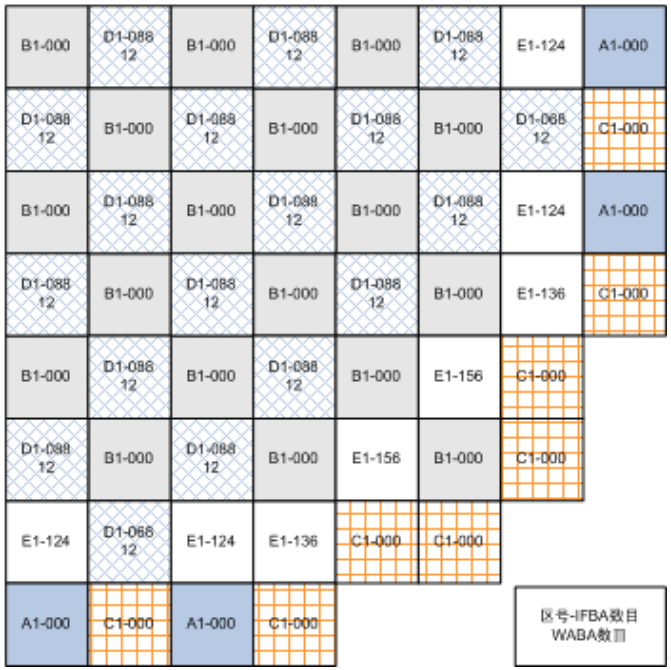
- Design reliability assurance program implemented
- Utilize the latest safety design standards, As High As Reasonable Achievable
- Meet the most strict discharge standard, As Low As Reasonable Achievable
- Integration of human factors balanced PSA and D-RAP

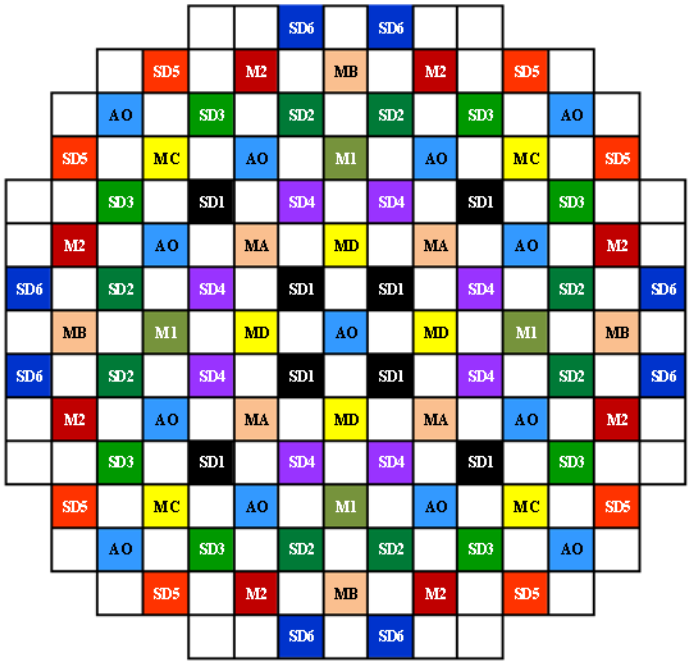


2. Design Features

Fuel assembly & Core Design

- 193 fuel assemblies (advanced 14 feet fuel assemblies), 18 month refuel cycle, with the capability of 50% MOX fuel loading.
- High burnup (Average discharge burnup beyond 50000 MWD/tU), and low-leakage core pattern minimizes the fast neutron leakage.
- MSHIM control strategy, capability of load-follow without adjustment of boron concentration.



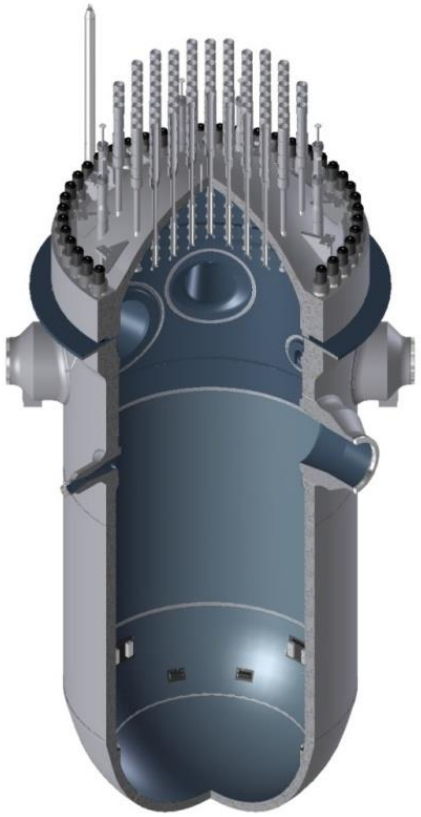


2. Design Features

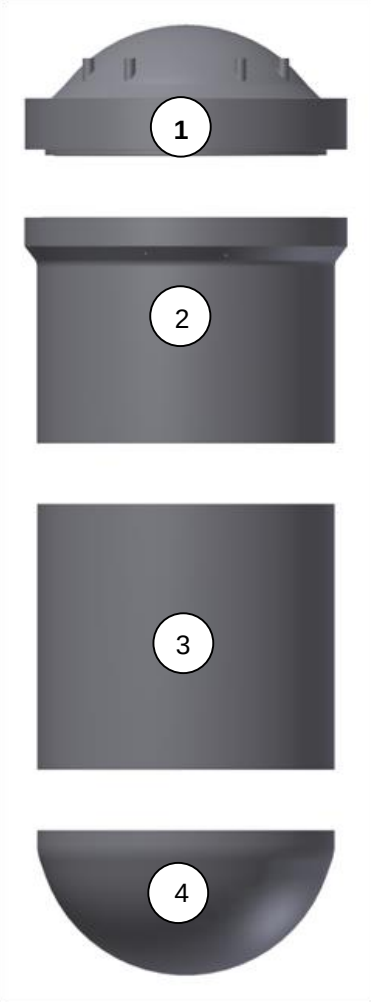
Reactor Pressure Vessel(RPV) Design

- RPV with 4 inlet and 2 outlet nozzles, with 4.89m O.D. and 12.6m height,
- The core region is located as low as possible in RPV and the shape of lower plenum is more flat to make benefit for LLOCA and IVR,
- The top and bottom heads are integrated forging to further reduce the number of weld joints, to reduce the cost time of in-service inspection.

Parameters	Value
Height	12635mm
Weight	449t
Vessel O.D.	4892mm
Vessel I.D.	4430mm
No. and I.D. of Inlet Nozzles	4/650mm
No. and I.D. of outlet Nozzles	2/900mm



2. Design Features



(1) Top head

(2)Upper shell

(3) Cylinder

(4) Bottom head

RPV manufacture

2. Design Features

Reactor Vessel Internal(RVI) Design

No need of neutron shield panels

To avoid excessive radiation exposure to RV, reduce the risk of appearance of loose components in reactor.

No penetration

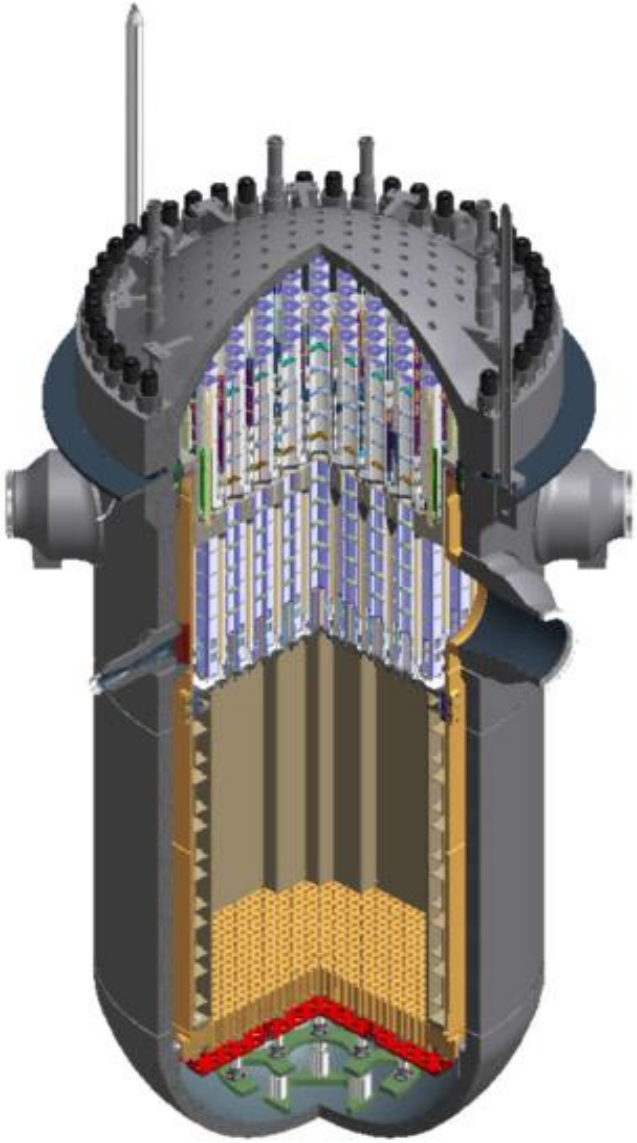
All the core instruments are penetrated though top head.

Optimized RVI design

To improve the flow characteristic and IVR margin.

An all-welded structure, core shroud,

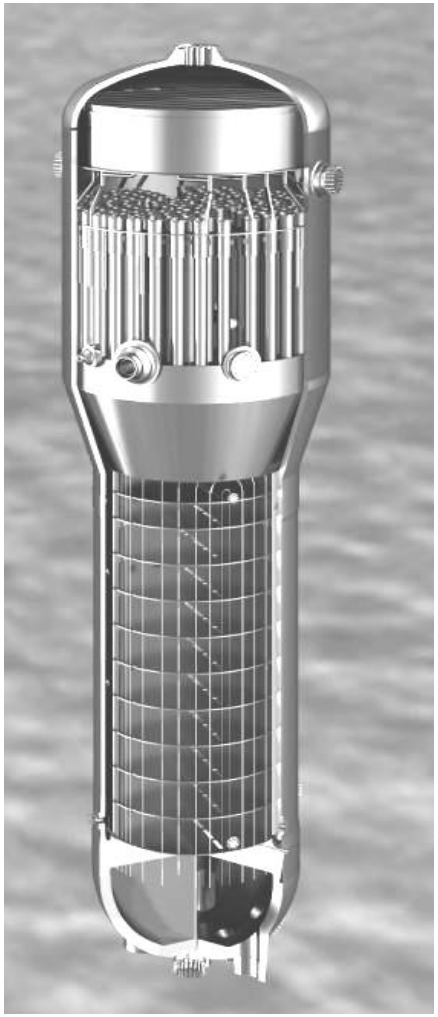
used to instead of the baffle-former assembly, to avoid the use of bolts, which are susceptible to irradiation -assisted-stress corrosion cracking (IASCC), found in many operating plants.



2. Design Features

Steam Generators, SG

- Tube plugging margin is **10%**
- Large heat transfer area **- 14,666m²**
- Self-designed and improved
- to get **high quality**
- Outlet steam performance.

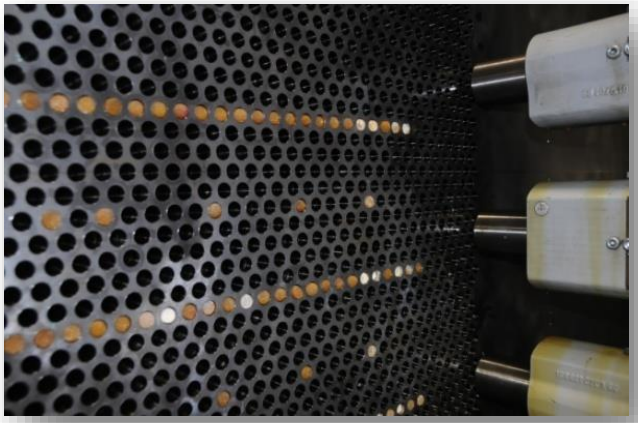


Design Parameters	Value
Number of tubes	12,606
Heat transfer area	14,666m²
Tube O.D.	17.48mm
Overall height	24m
Overall weight	~807t
Upper shell I.D.	6,120mm
Lower shell I.D.	4,655mm

2. Design Features

(1) Elliptic Head

(2)Cylinder



(3) Tube sheet

(4) Channel head

SG manufacture

2. Design Features

Reactor Coolant Pumps, RCP

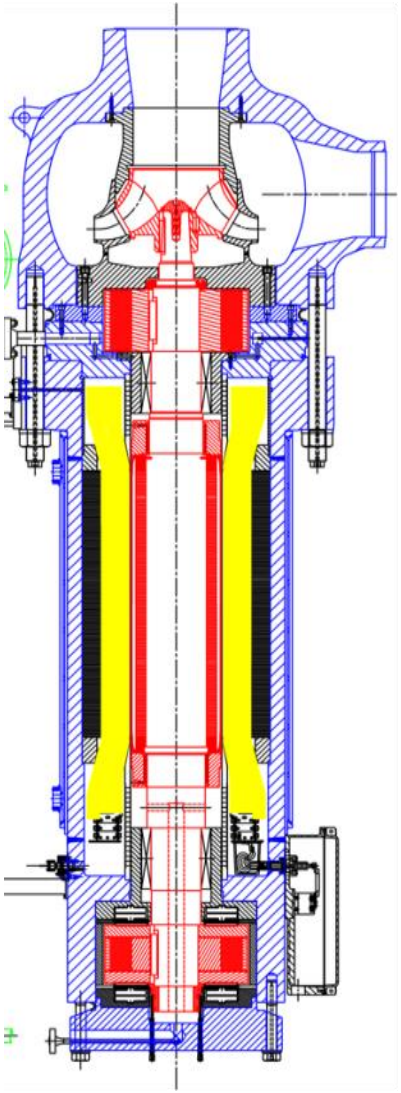
- Either **canned motor pump** or **wet winding pump** is applicable.
- Seals are not required to restrict leakage.

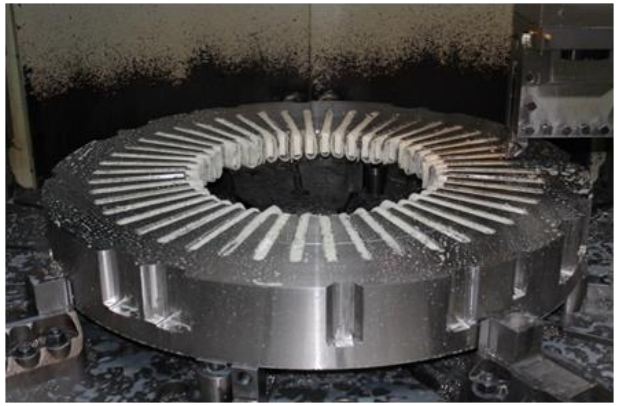
Eliminates

The RCP seal **LOCA**

Parameters	Value
Operation temp	284.3℃
Design flow	21,642m³/h
Design head	111m
Motor frequency	50Hz

2. Design Features

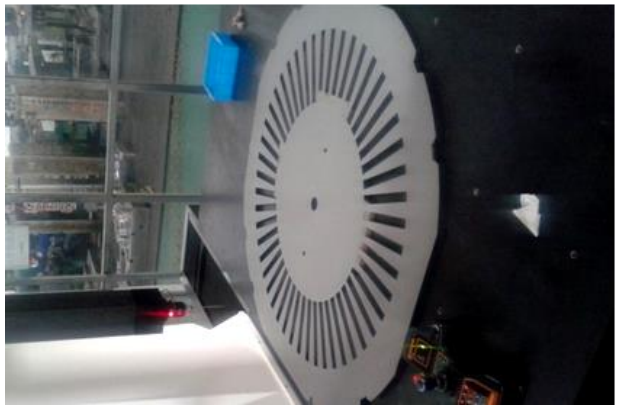




(1)Finger plate

(2)Stator Winding Mockup

(3)Pump Shell



(4)Punching

Pump manufacture

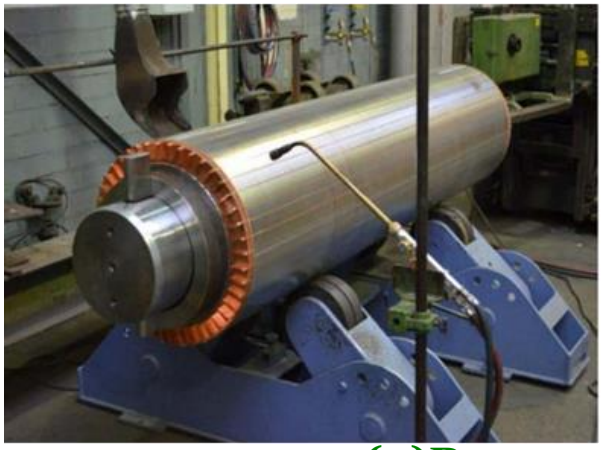
RCP-CANNED PUMP-SBN/HEC

2. Design Features

(1)Test loop

(2)Prototype

(3)Stator



(4)Rotator

RCP-RUV PUMP-SEC/KSB

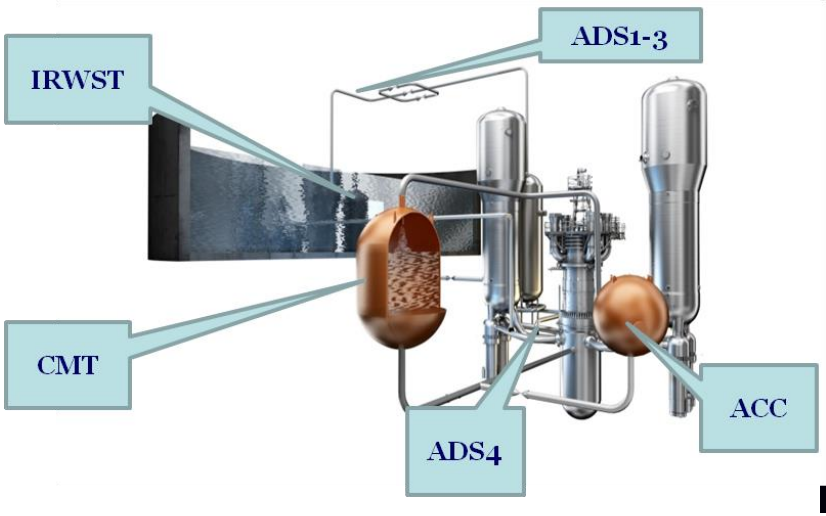
Pump manufacture

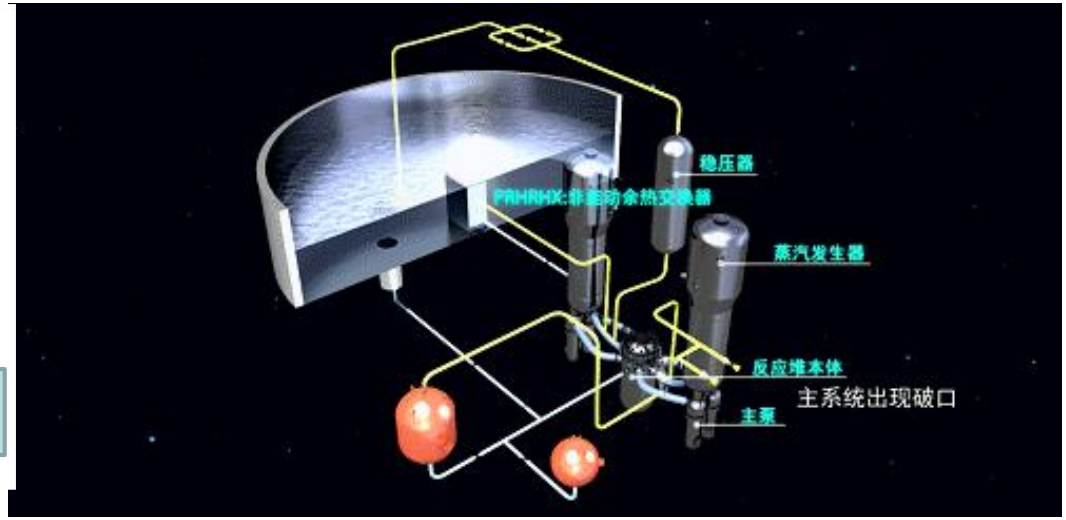
2. Design Features

Passive Core Cooling System (PXS) Design

CAP1400 Design Parameter
CMT Volume: 85m³, ACC Volume: 78.6m³
Water Volume66.4m³
IRWST Mini. Water Volume: 2,780m³

Proven technology with verified capacity Maintain reactor core safety continuously.



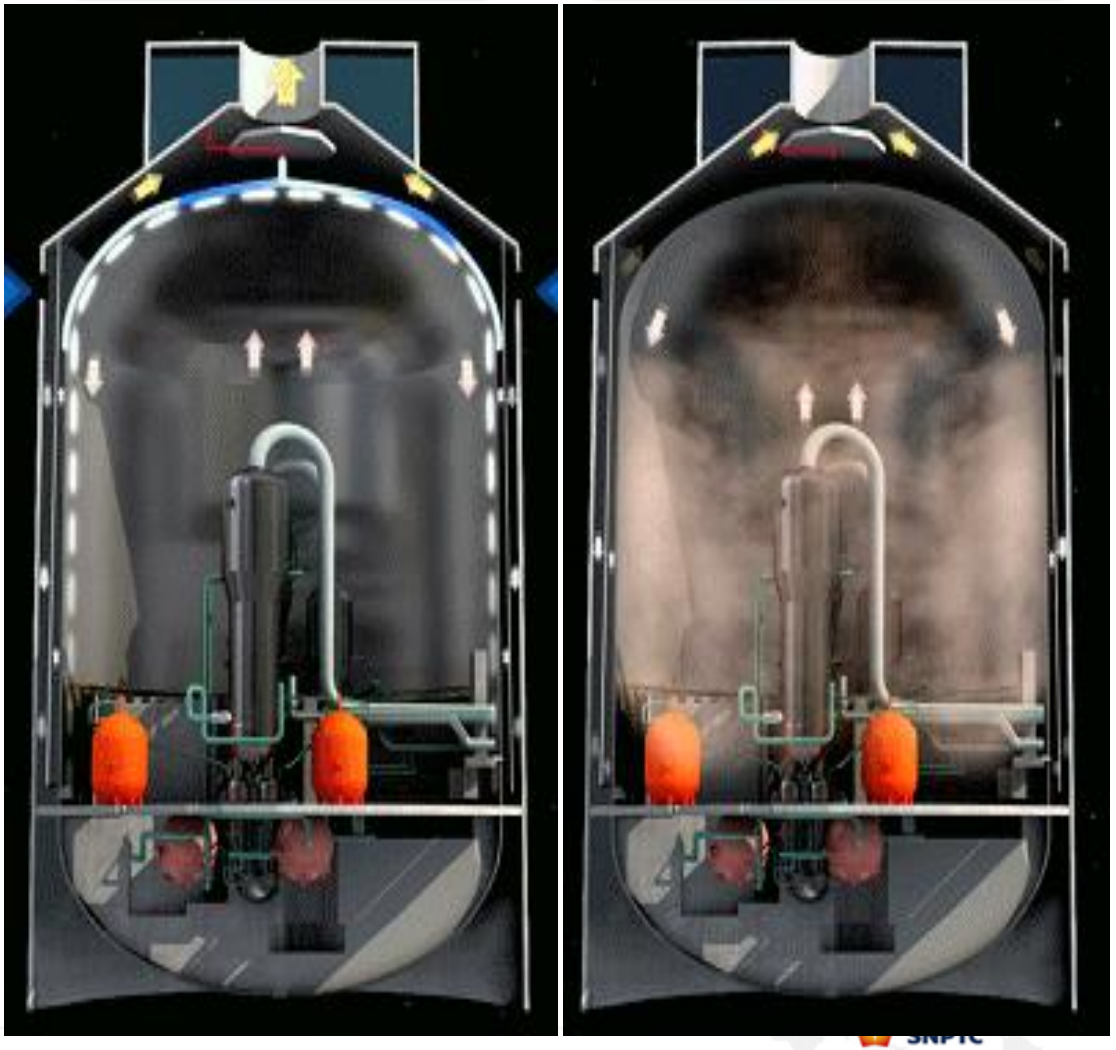


2. Design Features

Passive Containment Cooling System (PCS) Design

Functions of the PCS are to:

- Remove the heat from the containment by water spraying on the containment surface and natural air circulation.
- Provide 72 hr water supply from PCCWST and additional 4days water from PCCAWST(Seismic type II).
- Have possible backup mobile water pump and alternative water source for long-term cooling in some BDBA.



2. Design Features

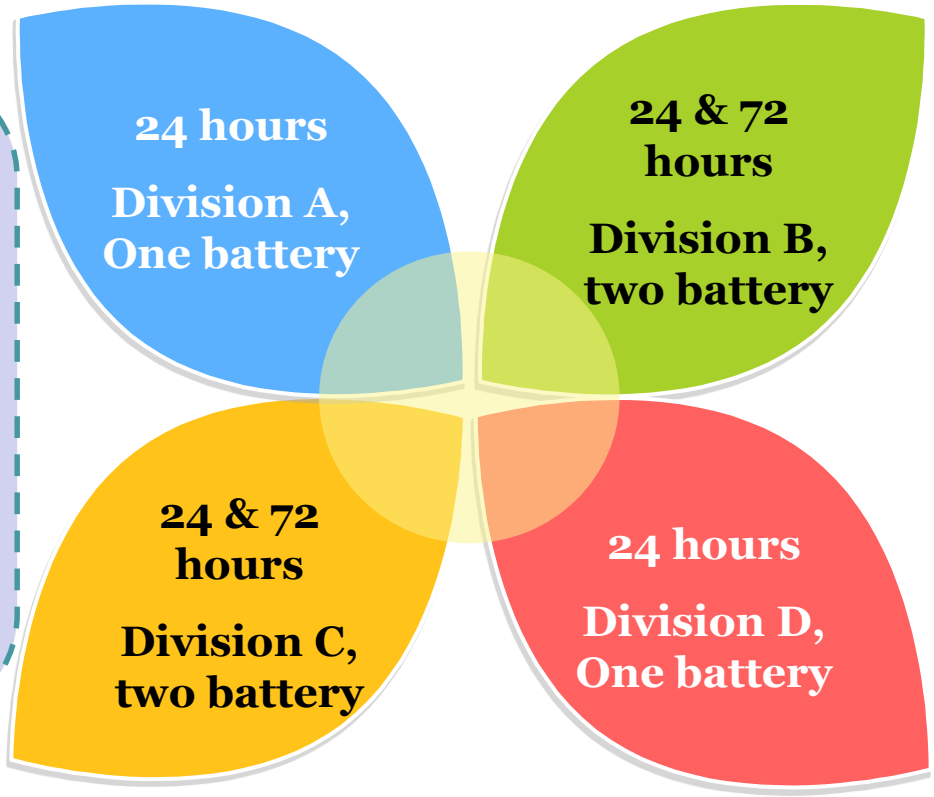
Electrical Design

- Four independent, Class 1E 250V dc divisions, A, B, C, and D.

Four independent, Class 1E 250 V dc divisions.

Each division has a 24 hour battery bank.

Division B and C also has a 72 hour battery bank.

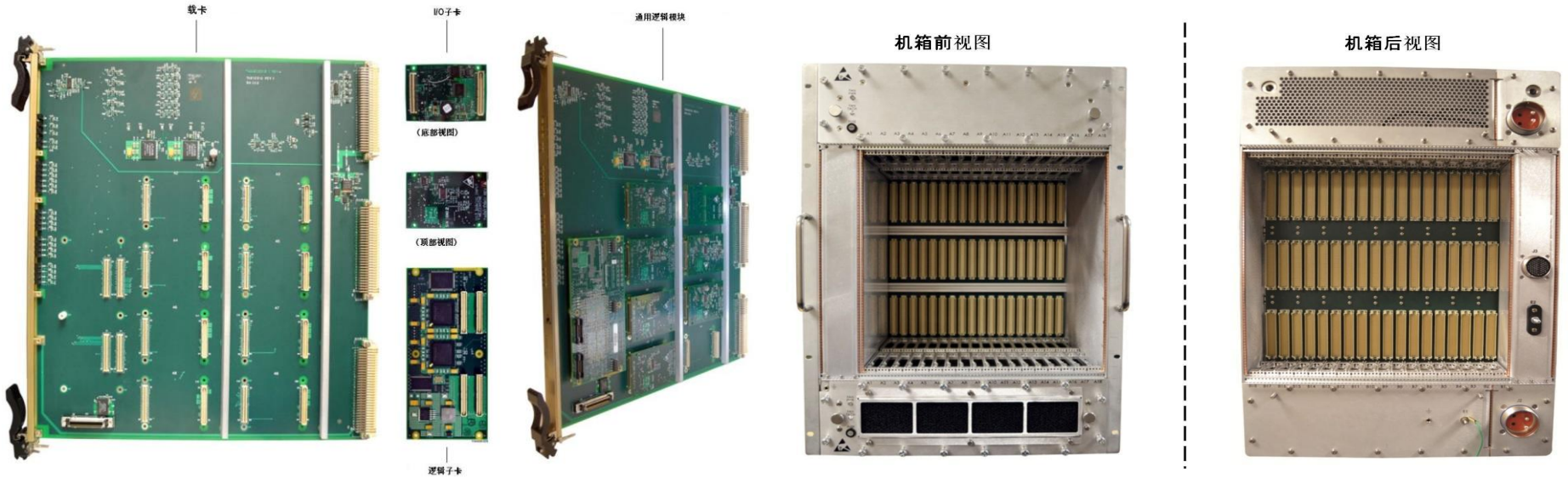


2. Design Features

☐ I&C Hardware

I&C system platform NuPAC for 1E, and NuCON for Non 1E

- ❑ Both NuPAC and NuCON are digital system used for NI and CI monitoring.
- ❑ protection and control functions, including turbine control and diagnosis.



Reactor protection system--NuPAC

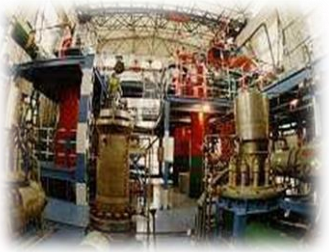
3. Verification &Validation

Systematic Verification Tests

- All tests before FCD were finished, supporting the design, safety review, and software V&V.
- Totally 887 cases performed.

Tests for passive safety systems	Tests for key equipment
• PXS performance test • PCS performance test • IVR test	• SG hot-stage performance test • Core hydro-simulation test • Reactor internal flow-induced vibration test

Facility for hydro-simulation



Facility for SG steam-water separation test

ACME complex

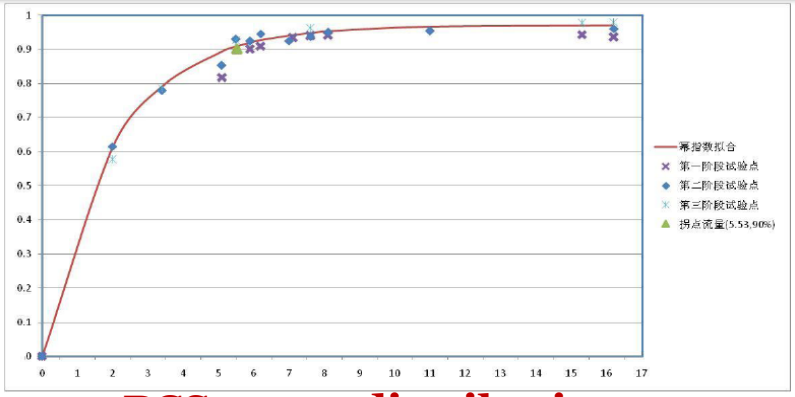
CERT facility

IVR test facility

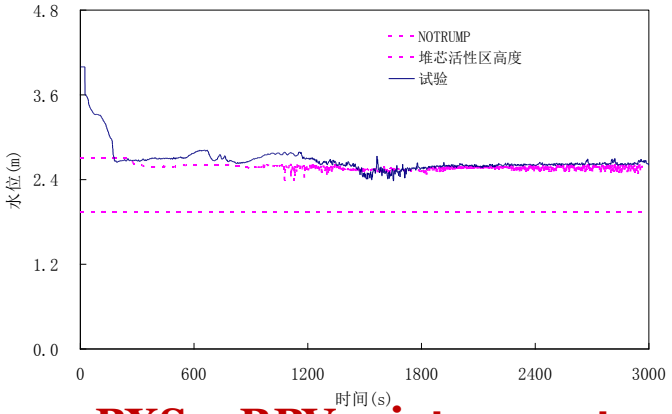
Facility for FIV test

3. Verification &Validation

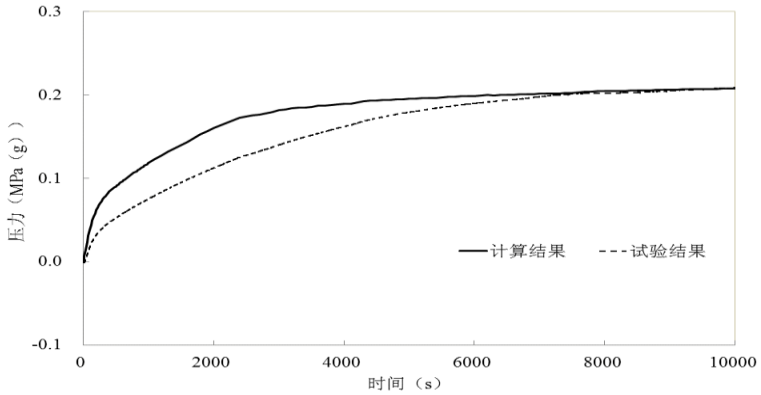
Key verification tests result shows the feasibility of CAP1400



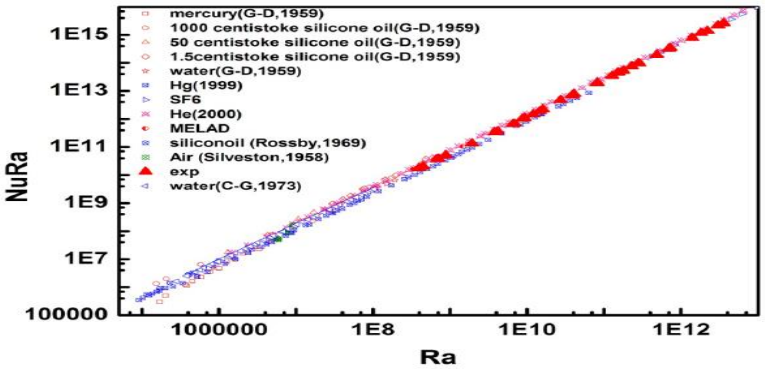
PCS water distribution



PXS – RPV mixture water level(CAP03 case)



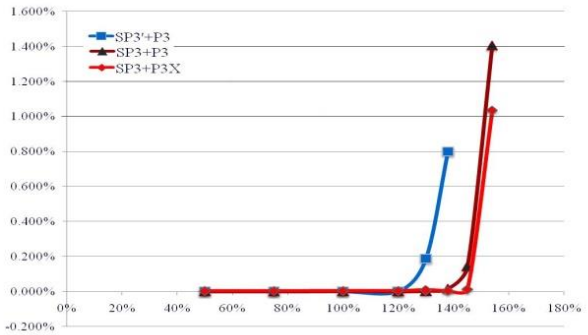
PCS heat removal (LOCA)



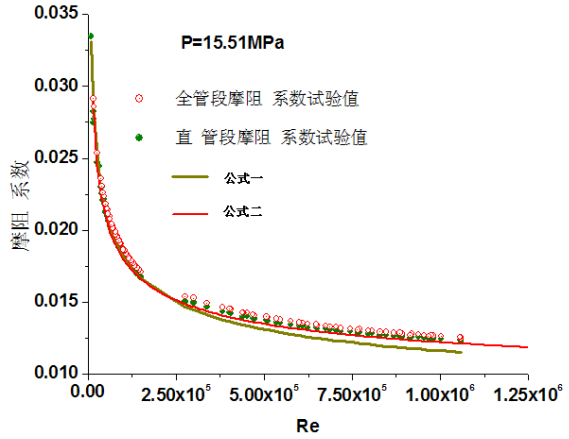
IVR- metal heat transfer

3. Verification &Validation

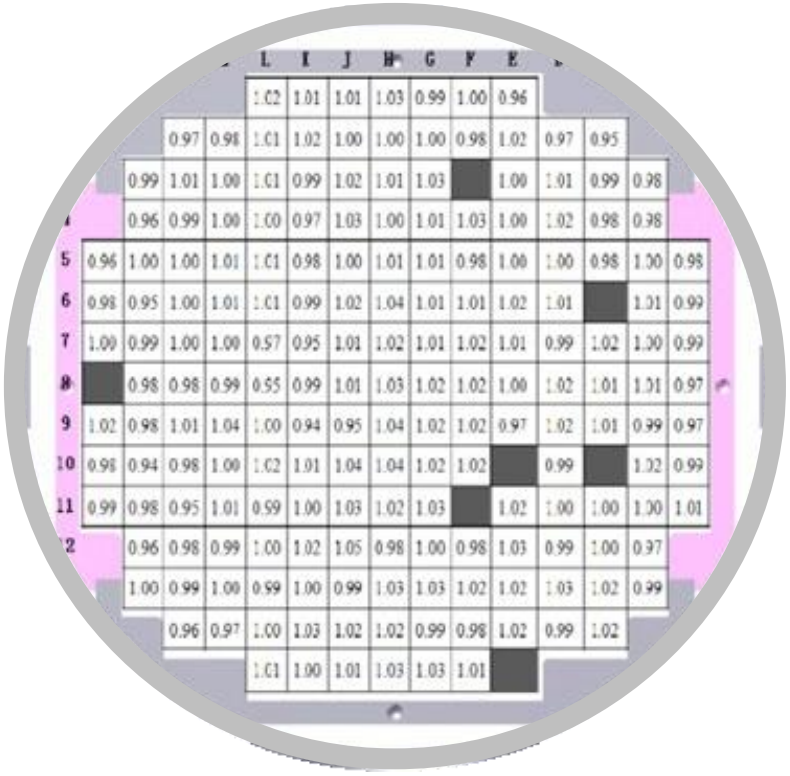
Key verification tests result shows the feasibility of CAP1400



SG separator system



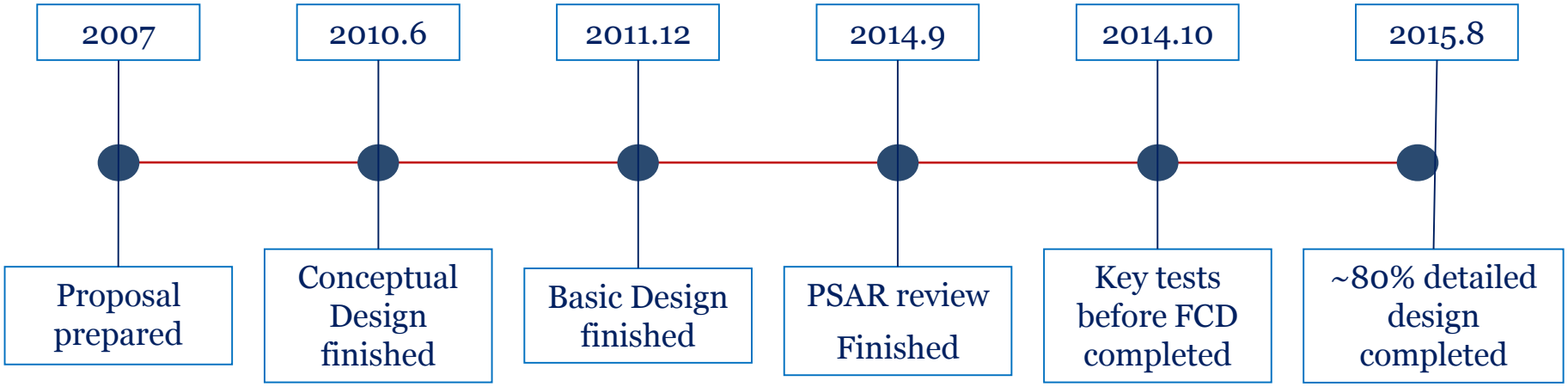
SG tube frictional resistance

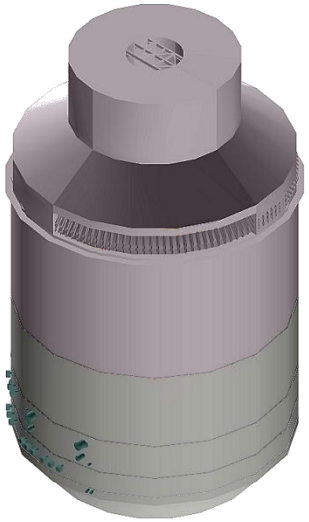


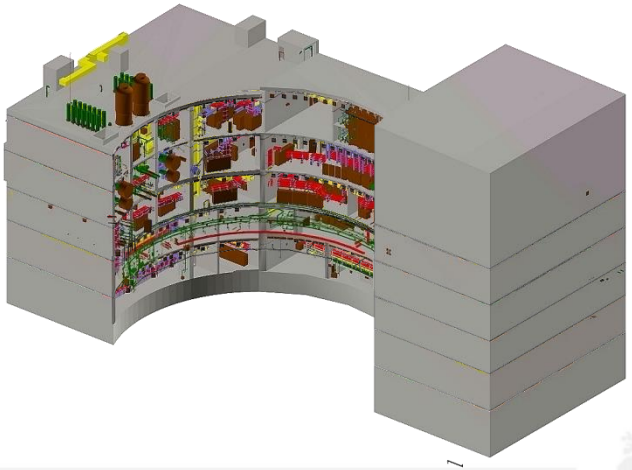
Flow distribution of core inlet

4. Progress of 1st CAP1400

Key Milestone







4. Progress of 1st CAP1400

Licensing Status

The Site Safety Evaluation Report and the Environmental Impact Evaluation Report

2013.03
Preliminary work approved

2013.06
The two evaluation report* accepted

2014.07
Feasibility study report accepted

2013.04~2014.09
Licensing Review

Scope and depth are Unprecedented
- 5 aspects review.
- Over 5000 questions replied
- The review requirements reflected in the detailed design.

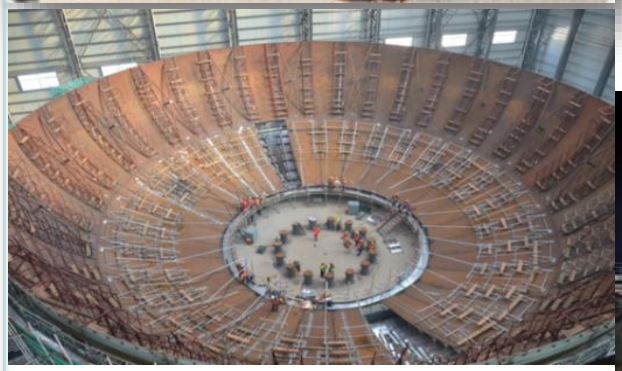
After the review, NNSA believed the CAP1400 could meet the latest China and IAEA nuclear safety standards.

CAP1400 PSAR passed through the safety review

4. Progress of 1st CAP1400

First CAP1400 site

- Located at Shi Dao Wan, Shandong Province.
- 2×CAP1400 units
- Nuclear Island sits on rock basement.
- Dry site design, large margin against external flooding.



CAP1400 Site Preparation is ready
Proceeding sites are under preparation
in Fujian, Guangdong, Zhejiang etc

国家核电 SNPTC

4. Progress of 1st CAP1400

Equipment Procurement

undertaken, long lead equipment contracts signed.

Equipment	Vendor	Expected Delivery Time	Equipment	Vendor	Expected Delivery Time	Equipment	Vendor	Expected Delivery Time
SG	东方重机 DCE-HM	SG1: 2016-6-30 SG2: 2016-8-30	CMT	中国二重CNEG	2015-7-30	RCP-Canned	沈鼓/哈电 SBN/HEC	2016-12-31
SG	上核设备	SG1: 2016-4-30 SG2: 2016-6-30	Polar Crane	大连华锐 太原重工	2016-1-28	RCP-RUV	SEC-KSB	2016-12-31
RV	中国一重 CFHI	2016-3-31	Main piping	中国二重 吉林中意	2015-12-31 2016-1-31	CV Steel Containment	国核设备 SNPEM	2014-11-30
ACC	海陆重工 HLHI	2015-9-30	Squib valve	大连大高 中核苏阀	2017-6-30	CVS makeup pump	福斯(西班牙)	2016-2-20
ACC	哈电重装 HEC-HE	2015-9-30	I&C system	国核自仪 SNPAS	2016-6-30 2016-12-30	RNS pump	江苏海狮 Sea-lion	2015-12-1
Internals	一机床	2016-7-28 2017-1-31	Simulator	国核自仪 SNPAS	2016-4-30	Diesel Generator	陕柴 SXD	2016-3-29 2016-9-29
CRDM	一机床	First batch: 2015-8-15, Sec. batch: 2016-6-30 First batch: 2016-6-15, Sec. batch: 2016-12-30	Refueling Machine	NA	2015-12-31 2015-12-31	IHP	国核设备 SNPEM	2015-11-30
Pressurizer	东方重机 DCE-HM	2015-10-20	RNS HX	上海电气电站设备	2015-6-30	Equipment Hatch	国核设备 SNPEM	2015-6-30
Pressurizer	上核设备	2016-2-25	RNS HX	东方重机 DCE-HM	2015-12-31	Personal Hatch	国核设备 SNPEM	2015-6-30
CMT	中国一重 CFHI	2015-7-30	PRHR HX	哈电重装 HEC-HE	2016-3-30	RCP VFD	待定 TBD	2016-3-30

5. Summary

- CAP1400 has better safety, economic and neighborhood advantage, which makes CAP1400 one of the prioritized options for domestic & oversea utility.
- CAP1400 demonstration project goes well. Licensing application, long lead equipments manufacture and site preparation are ready for FCD this year.
- CAP1400 will better meet future requirement of nuclear power build, and contribute to the world's energy power development as far as possible.
- China is willing to share the success in the implementation of the nuclear power development in a controllable, safe and healthy manner to enhance your national capability of localization for the clean and affordable energy finally to benefit the world.

国家核电
SNPTC
Safe Nuclear Energy
Better Natural Life

Thanks for your attention!