Technical Meeting on the Safety of High Temperature Gas Cooled Reactors in the Light of the Fukushima Daiichi Accident

HTR Progress in China

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Outline

- *1 China Nuclear Power Plants*
- *2 HTGR development in China*
- *3 HTR-PM design*
- *4 Project Status*

  - *HTR-10: 10MW high temperature test reactor*
  - *HTR-PM: High temperature gas cooled reactor—pebble-bed module*

1 China Nuclear Power Plants

- ***China re-start new construction of NPPs in later 2012, after Fukushima accident***
  - ***Tianwan 3#,4#: VVER1000***
  - ***Fuqing 4#: CNP 1000***
  - ***Yangjiang 4#,5#,6#: CPR 1000***
  - ***Shidao bay: HTR-PM***

1 China Nuclear Power Plants

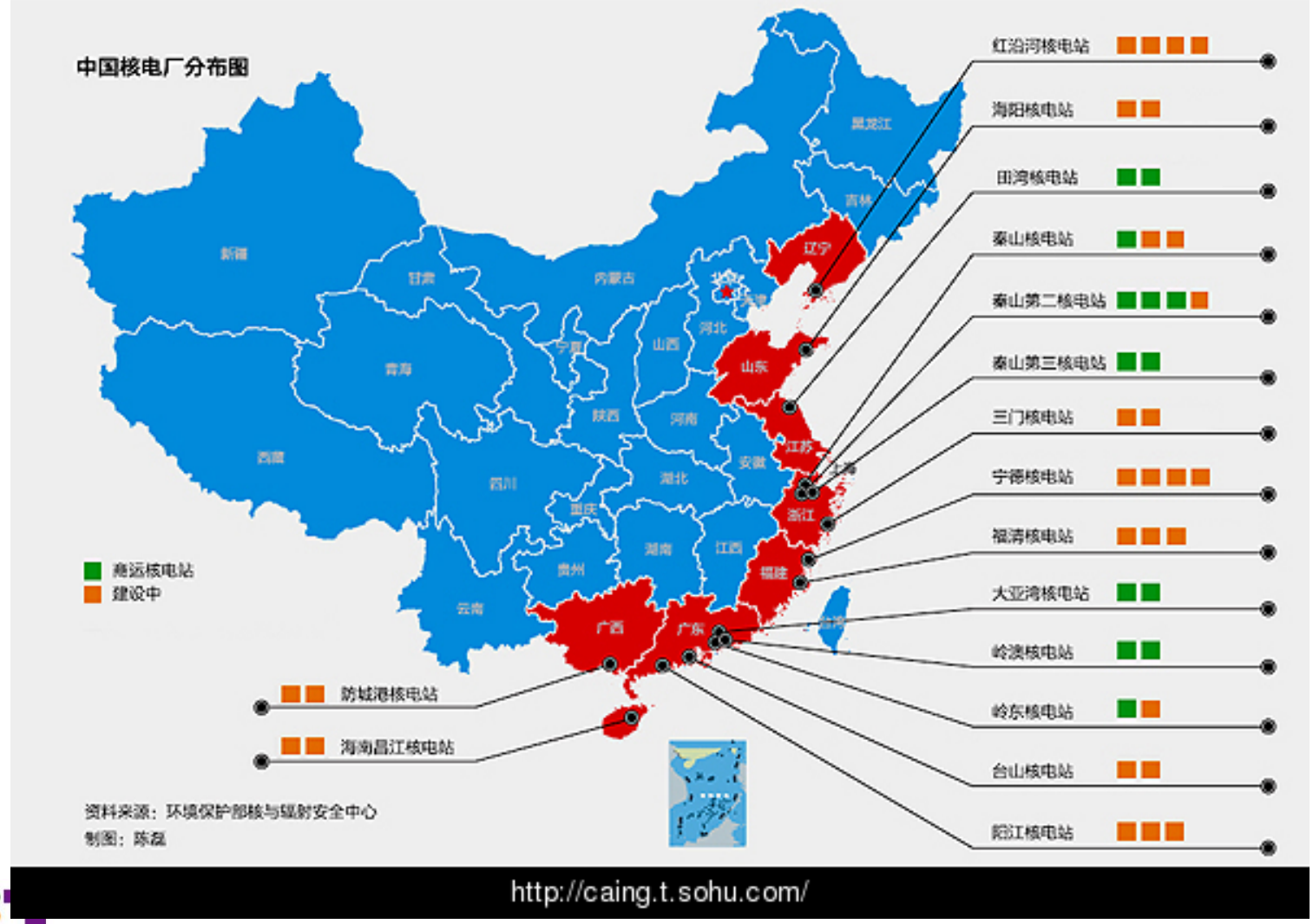
- **Statistics data for all Chinese NPPs:**
  - **Operating NPPs:**
    - **17 units**
    - **14.7GWe**
  - **Under construction:**
    - **30 units**
    - **32.5GWe**

1 China Nuclear Power Plants

在建机组 Units under Construction	厂址 Site	机组 Unit	型号 Type
2代+机组23台 23GII+ units	红沿河	2~4#	CPR1000
	宁德	2~4#	CPR1000
	福清	1~4#	M310+
	阳江	2~6#	CPR1000
	方家山	1~2#	M310+
	昌江	1~2#	CNP600
	防城港	1~2#	CPR1000
	田湾	3~4#	VVER-1000/428
三代机组6台 6GIII units	三门	1~2#	AP1000
	海阳	1~2#	AP1000
	台山	1~2#	EPR
1台四代原型堆 1Prototype Reactor of GIV	石岛湾	1#	HTGR

后续项目 Following up Projects	型号 Type
三门3~4# 海阳3~4# 陆丰1~2# 徐大堡1~2#	AP /CAP 1000
CAP 1400 示范项目 (山东荣成)	CAP 1400

Map for current NPPs in coast region



Map for future NPPs

2 HTGR development in China

- HTGR Roles in China
- Development history in China

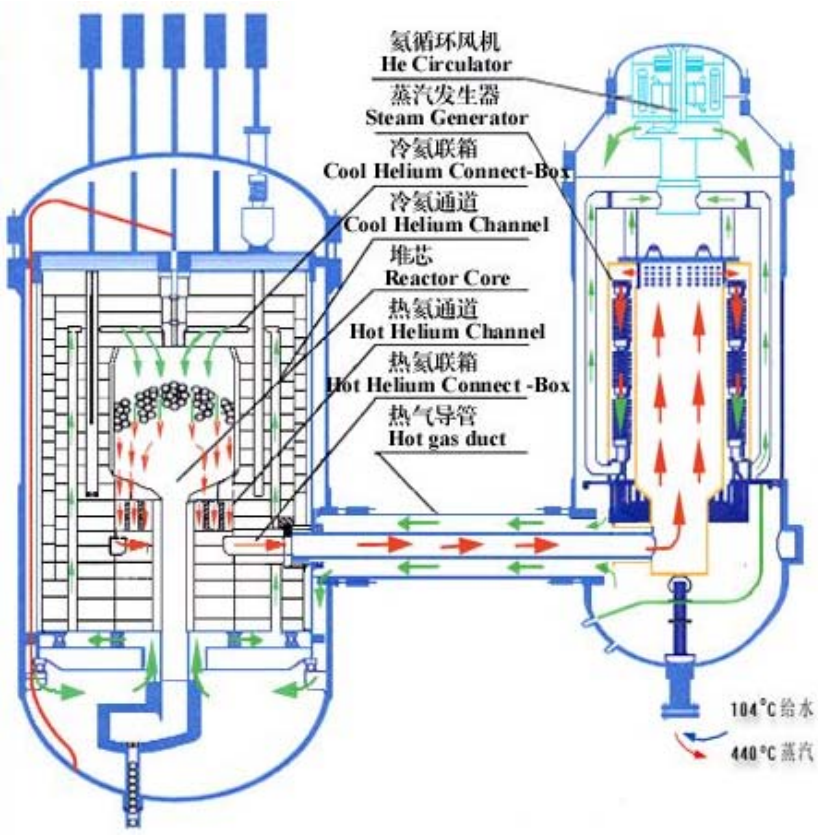
HTGR Roles in China

- **Roles of HTGR in China**
  - **Supplementary for electricity generation to PWR**
  - **Suitable for process heat application**
  - **Suitable for international market**
    - **SMR is more flexible for developing countries**

Development history in China

- *1970s：Technology research*
- *1986：National Hi-Tech program (863 program), start the design of HTGR*
  - *Adopted the pebble bed HTR*
- *1995：start the construction of HTR-10*
- *2000：criticality of HTR-10*
- *2001：start the commercial HTGR project*
- *2012: start the construction of HTR-PM*

HTR-10 project



HTR-10 main milestones

- *March 14,1992: Project approval by Government*
- *Dec 1992-Dec 1994: PSAR*
- *Dec 15,1998-Nov.17,2000: FSAR*
- *July 16,1995-Dec. 2000: Construction*
- *Dec.1,2000: Physical critical*
- *Jan 7, 2003: Electricity output to grid*
- *Jan 29, 2003: Full power operation*

- *Oct.15,2003: safety demonstration experiments and long-term operation*
  - *CR withdrawal without Control Rod Drop, helium blower trip without Control Rod Drop, flap close failure without Control Rod Drop*
  - *Many experiments followed, more will be planned*

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HTR-10 main parameters

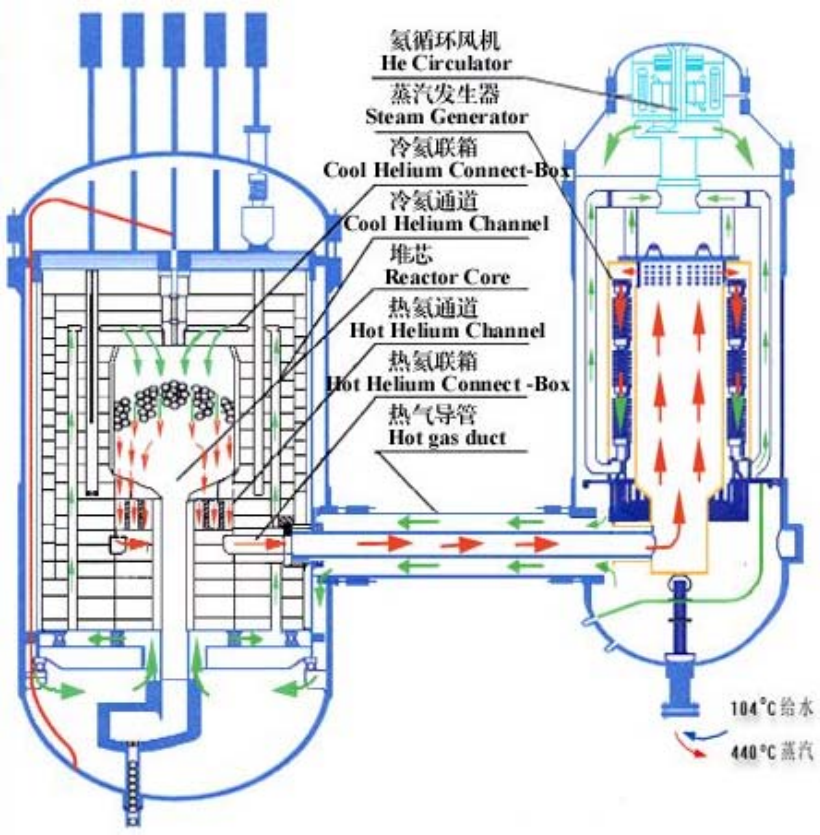
Thermal power	***MW***	***10***
Reactor core diameter	***cm***	***180***
Average core height	***cm***	***197***
Primary helium pressure	*MPa*	*3.0*
Average helium temperature at reactor inlet/outlet	***^{o}C***	***250/700***
Helium mass flow rate at full power	*kg/s*	*4.3*
Average core power density	*MW/m^3*	*2*
Number of control rods in side reflector		*10*
Number of absorber ball units in side reflector		*7*
Nuclear fuel		*UO_2*
Heavy metal loading per fuel element	***g***	***5***
Enrichment of fresh fuel element	***%***	***17***
Number of fuel elements in core		***27,000***
Fuel loading mode		*multi-pass*
Max. fuel temperature at normal operation	*^{o}C*	*919*
Average discharge burn-up	***GWd/tHM***	***80***

HTR-10 main parameters

Height of RPV	***m***	***11***
Inner diameter of RPV	***m***	***4.2***
Helium blower pressure raise	*kPa*	*60*
Number of SG units/tubes		*30*
Heat transfer area of SG	*m^2*	*55*
Feed water temperature	*^oC*	*104*
Steam pressure	*MPa*	*3.5*
Steam temperature	***^oC***	***435***
Steam flow rate	*t/h*	*12.5*
Electric power	***MW***	***2.5***

HTR-10 core layout

- *Pebble bed*
- *Helium cooled, graphite moderated*
- *Modular High-Temperature Gas-Cooled reactor*
  - *Inherent safety*
  - *Melt-free*
- *Steam cycle*
- *Side by side of RPV & SG*



HTR-10 project highlights

- ***Sphere TRISO fuel technology***
- ***Demonstration on inherent safety characteristics of Modular High-Temperature Gas-cooled Reactor***
- ***Digitalized Instrumentation and Control system***
- ***Test bed for future development***

HTR-10 main achievements

- ***The sign for China to master the Modular HTGR technology***
- ***The platform to demonstrate and verify the HTGR technology***
  - ***visible inherent safety that can be demonstrated to public***
  - ***Only pebble bed HTGR that is operating***
- ***Technical basis for HTR-PM (prototype)***

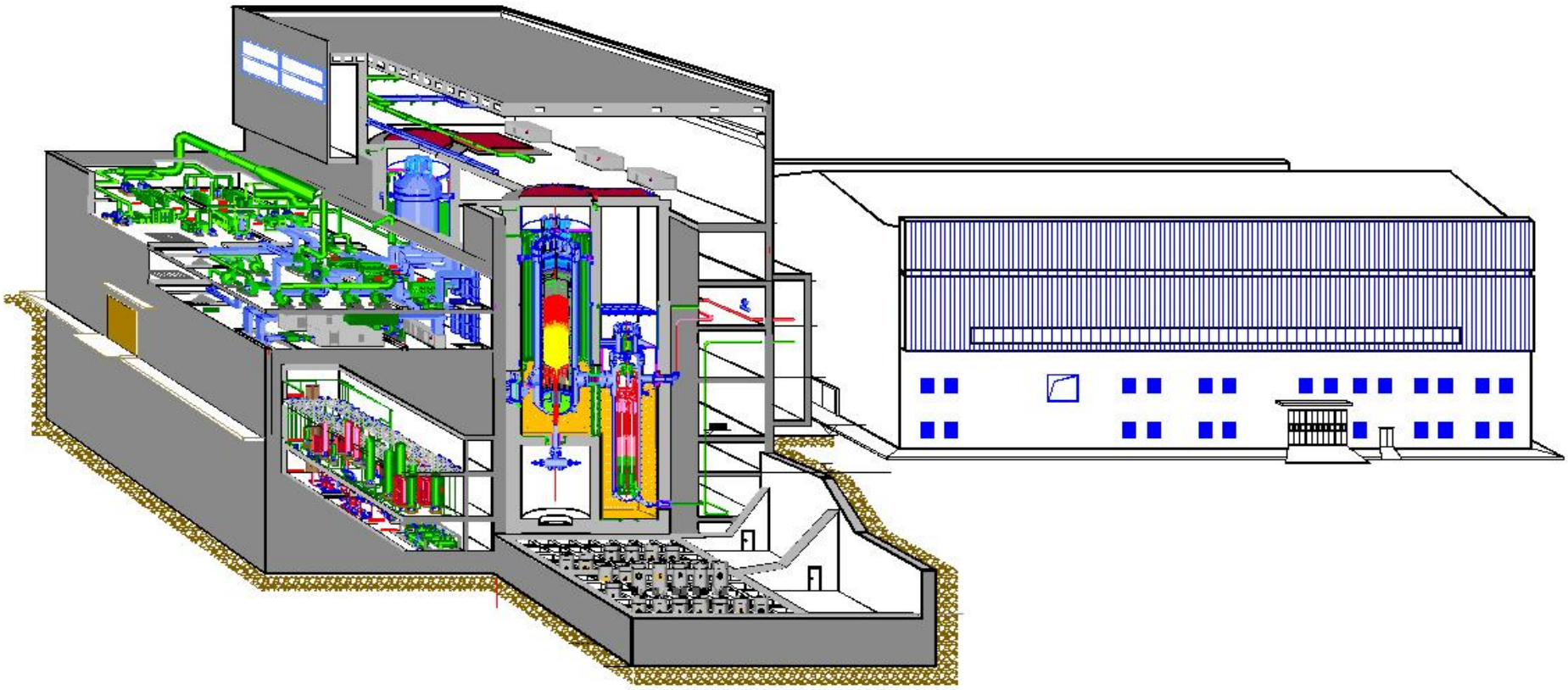
3 HTR-PM design

- HTR-PM demonstration plant
  - 2001: feasibility study
    - Choose mature steam cycle from steam cycle, direct gas cycle, indirect gas cycle
  - 2004: standard design
    - 2006: fixed the main parameters: 2×250MWth, 2 reactors with 1 turbine
  - 2006: approved as national key technology project
  - 2009: finished preliminary design and PSAR
  - 2012: FCD

Site for HTR-PM

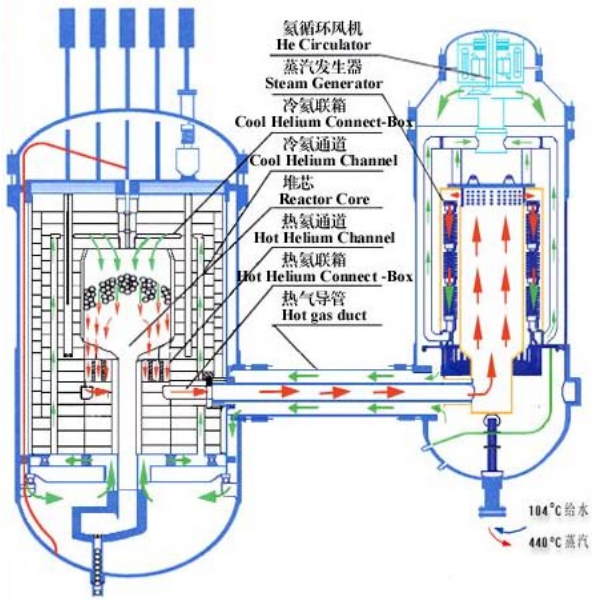
Plant overview

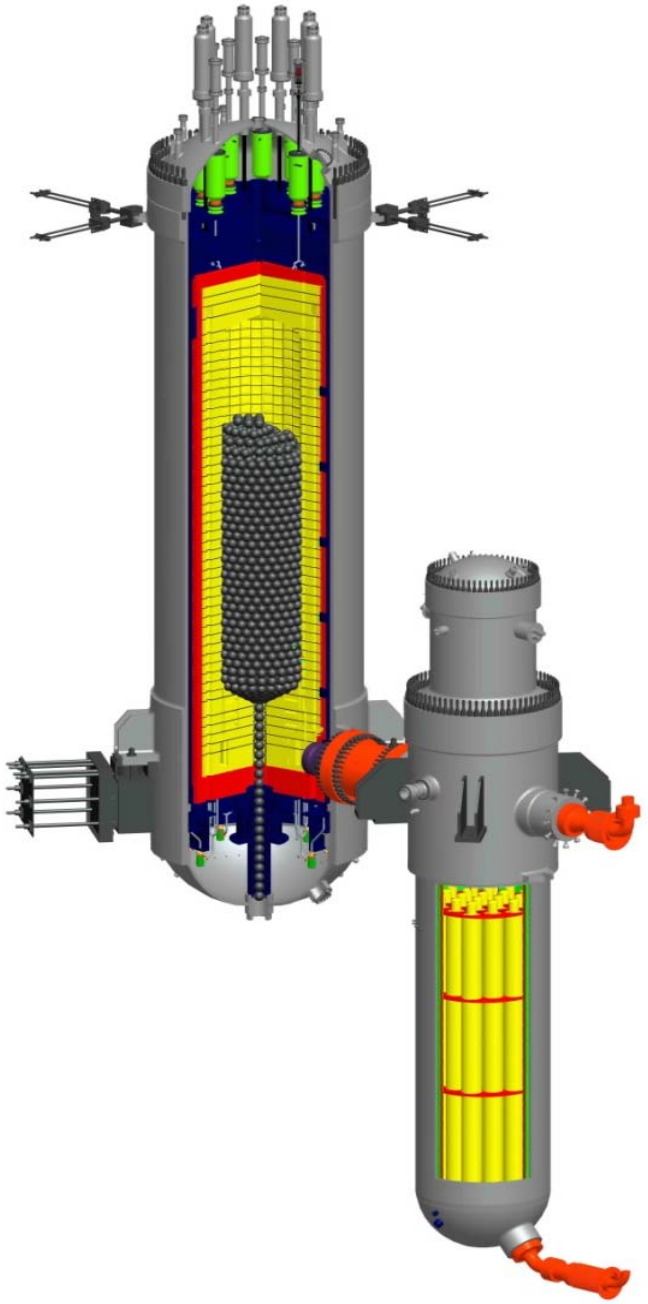
Nuclear island & conventional island

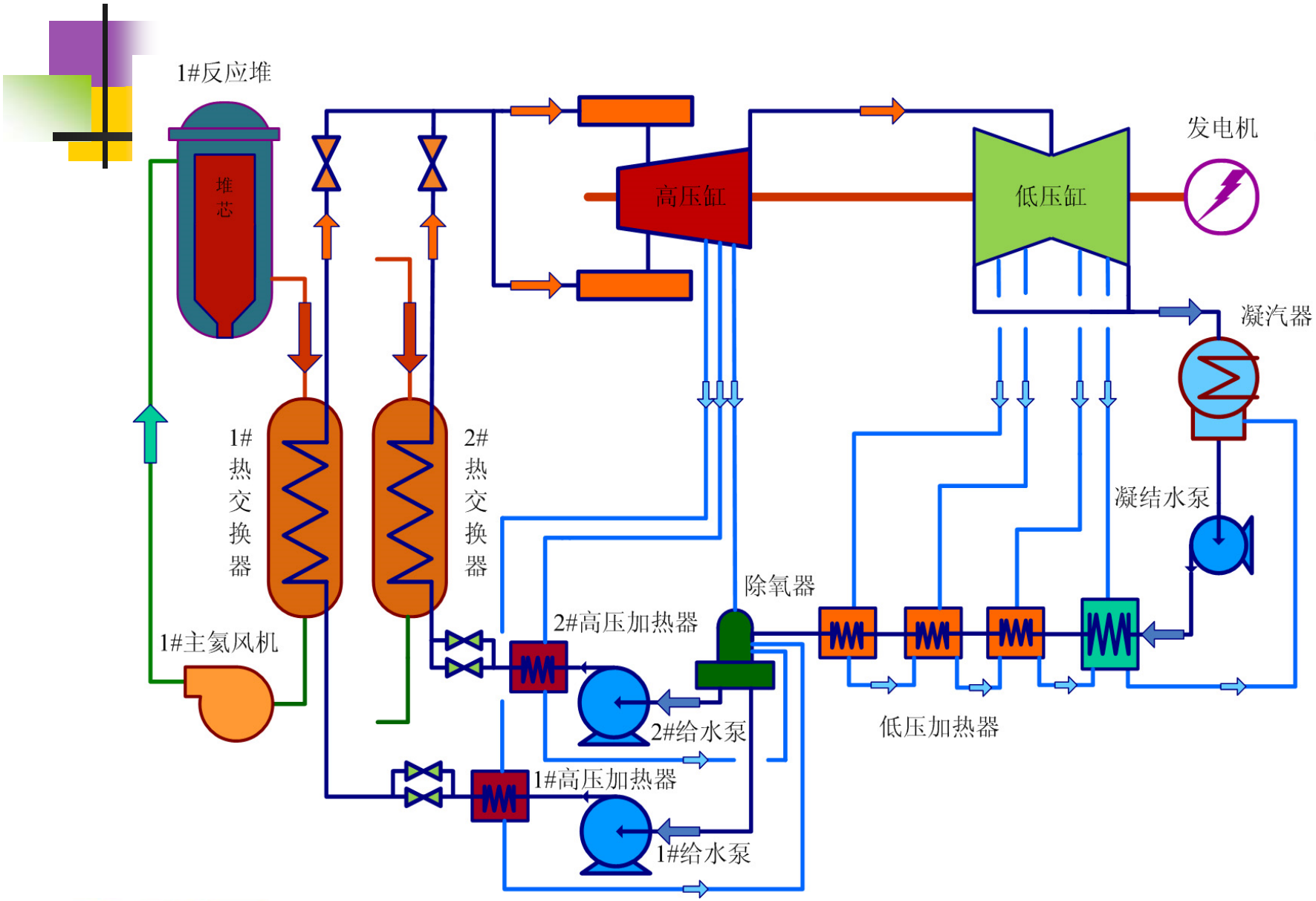


Reactor Layout

- *Similar layout as HTR-10*
  - *Single zone, pebble bed*
  - *Side by side arrangement*
  - *Super heat steam*
  - *Modular(Inherent safety)*
- *Larger size*







Thermal loop

Main design parameters

Reactor module numbers	2
Thermal power/module	250MW
Lifetime	40a
Core diameter/height	3.0/11m
Primary system pressure	7.0 MPa
Helium inlet/outlet temperature	250/750℃
Helium mass flow	96 kg/s
Fresh steam temperature/pressure	566℃/13.2 MPa
Electric power	210 MW

HTR-PM design features

- ***Single zone, pebble bed***
- ***Super heat steam turbine***
  - ***Like conventional turbine in fossil plant***
- ***1 turbine with 2 reactors***
  - ***More reactor are possible in future***
- ***Modular concept：Inherent safety***
  - ***Simplified safety system***
- ***Standard design***
  - ***Duplicable for future***

4 HTR-PM project status

- National key technology project
  - Design
  - Manufacturing
  - Licensing
  - Construction
  - Experiment
  - Fuel fabrication
  - Operation

Design

- ***2001-2003**: HTR-PM concept studies were conducted. The steam turbine was selected.*
- ***2004-2006**: HTR-PM standard design was conducted from May, 2004 to May, 2006. A preliminary decision was made in August of 2004 to design a reactor of 458 MWt thermal power output with reheated steam cycle and annular core. (dynamic annual core and solid annual core)*
- ***2006.09**: A decision to change from 1×458 MWt to 2×250 MWt was made, maintain the plant output on 200 MWe.*

Design

- *2008: Finished the basic design.*
  - *submit PSAR*
  - *Start the procurement of key component*
- *2009: Assessment of PSAR is finished*
  - *Start the engineering design*
- *2012: start FCD*
  - *-2017: connect to Grid*

4 HTR-PM project status

- ***Progress for construction and experiment***
  - ***See photos***

Conclusion remarks

- ***China need nuclear power***
  - ***LWR is the main stream***
  - ***HTGR will be supplementary for electricity generation, and can be used for co-generation and process heat application***
- ***China started the research on HTGR since 1970s, started the construction of HTR-10 in 1995***
- ***China adopts the pebble bed HTGR***

Conclusion remarks

- ***HTR-PM will be the first commercial modular HTGR power plant in the world, based on the success of HTR-10***
  - ***The project covers the research, design, manufacturing, construction, experiment, fuel fabrication, licensing, operation***
  - ***One unit of HTR-PM have two reactor modules***
  - ***The project is supported by central government***

Conclusion remarks

- ***Following HTR-PM, commercial deployment of HTR-PM based on batch construction is foreseeing, and unit with more modules and bigger power size is under investigation***
- ***We hope more countries will be interested in HTGR***
- ***International cooperation on HTGR is necessary and inevitable***
  - ***GIF, IAEA, bilateral, …***
  - ***Academic, technical, business, …***

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- ***You are welcomed to HTR-PM site during HTR-2014 conference***
  - ***2014.10.27-31***
  - ***Weihai, China***

Organized by

Institute of Nuclear and New Energy Technology (INET), Tsinghua University

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Technical Sessions

- Trk1 National Research Programs and Industrial Projects
- Trk2 Industrial Applications and Markets
- Trk3 Fuel and Waste
- Trk4 Materials and Components
- Trk5 Reactor Physics Analysis
- Trk6 Thermal-hydraulics and Coupled Code Analyses
- Trk7 Development, Design and Engineering
- Trk8 Safety and Licensing

Important dates

Abstract due:	March 15,	2014
Draft papers due:	May 30,	2014
Final papers due:	September 3,	2014

Abstract Instruction

Describe new and significant work
Use 200 -300 words in English
Electronic submission in PDF or MS Word

Website

http://www.htr2014.cn/

Technical tour

Visit to HTR-PM site will be arranged during HTR2014

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One task for this meeting

- ***A plenary speech related to this CRP is arranged in HTR-2014***
  - ***A speaker is supposed to be nominated in this meeting***