Overview and Progress of High Temperature Reactor Pebble-bed Module Demonstration Project (HTR-PM)

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Abstract

The High Temperature Reactor Pebble-bed Module Demonstration Project (hereinafter referred as HTR-PM Demonstration Project) is a commercialization nuclear power project with safety features of the fourth generation nuclear energy systems. Located in Shidao Bay, Rongcheng, Shandong, P. R. China, HTR-PM Demonstration Project is built with Chinese independent design and research, possessing the characteristic of inherent safety, simple systems, high power generation efficiency, extensive scope of applications and so on. Since the kick-off construction in December 2012, HTR-PM Demonstration Project has made smooth progress in civil works and installation, significant progress has been made in technology research and development, engineering design, equipment manufacturing, nuclear fuel supply, commissioning and operation preparation and other domains. This paper gives a brief overview on technical features and current progress of the HTR-PM Demonstration Project.

【Key Words】 HTR-PM Demonstration Project; project overview; current progress

1. Introduction

HTR-PM is engineered with inherent safety. Its safety objective is that no significant off-site radiation effects will be caused by any serious accidents which could be envisioned in reality. In the case of a loss of coolant accident, the maximum temperature of the fuel element won't exceed the design limit for fuel damage even no emergency cooling measures have been taken.

The prototype reactor of HTR-PM Demonstration Project is the 10 MW high-temperature gas-cooled test reactor (HTR-10) of the Institute of Nuclear and New Energy Technology, Tsinghua University (INET). HTR-10 is one of the scientific and technology projects listed in the "863 Program".. Upon completion of construction, the first criticality was reached successfully in December 2000. It was connected to the grid and finished the 72–hour operation at full power in January 2003. With the approval by the National Nuclear Safety Administration, 3 tests, i.e. loss of external power supply, shutdown of main helium fan and AWTS were carried out in April and September 2004 successfully, verifying the inherent safety of HTR.

Figure 1. 10 MW high-temperature gas-cooled test reactor

2. Technical features and significance of HTR-PM Demonstration Project

HTR-PM Demonstration Project is composed of two reactors, with power of 250MWt each and two steam generators, which jointly supply superheated steam of high parameter for one turbine generator, with electric power of 200MWe.

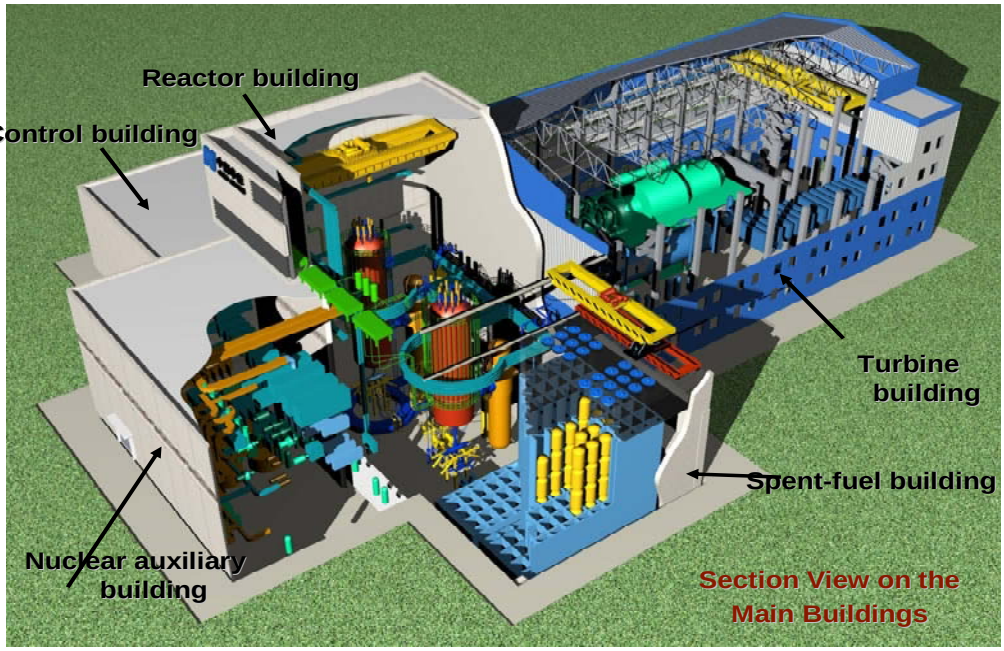
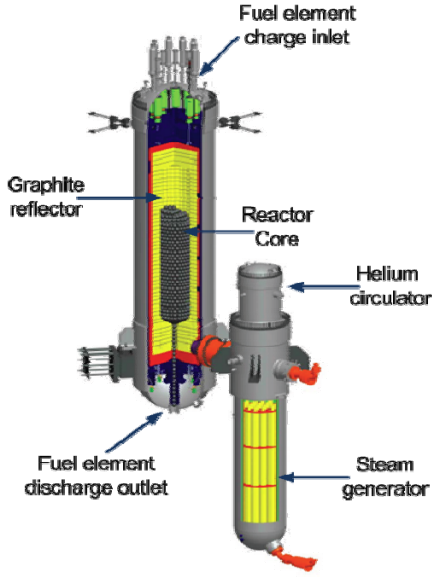


Figure 2. Schematic diagram of HTR-PM Demonstration Project system and main buildings

The two reactors of HTR-PM Demonstration Project have independent primary loops and share auxiliary facilities, such as fuel handling system and helium purification system. The two reactors have the same structural design, adopting a single zone pebble bed core and two independent reactor shutdown systems, i.e.the control rod and absorption ball shutdown systems. Shutdown through fall of balls by gravity enhances the reliability of the shutdown system. Meanwhile HTR-PM can contain all fission products inside the SiC layer of the TRISO coated fuel below 1600℃. The operation mode of continuous handling and multiple cycles makes the power distribution of reactors and the burnup of discharged fuel more uniform. HTR-PM adopts passive residual heat removal system, transmitting the residual heat of core scattered to the cabin wall by natural circulation and natural convection to the

ultimate heat sink-the atmosphere.



Thermal power	**500 MW**
Electric power	**212 MWe**
Number of reactors	**2**
Core diameter	**3 meters**
Core height	**11 meters**
Helium pressure	**7Mpa**
Core outlet temperature	**750ºC**
Core inlet temperature	**250ºC**
Main steam temperature	**566ºC**
Steam pressure	**13.25Mpa**

Figure 3. HTR-PM's nuclear steam supply module and technical parameters

HTR-PM possesses the characteristic of inherent safety, simple systems, high power generation efficiency, extensive scope of applications and potential economic competitiveness. As one of the six candidate nuclear energy systems of generation four in the international nuclear energy sector, it is a new type of nuclear reactor that can satisfy the future demand in the energy market. HTR-PM is a new generation of advanced reactors with Chinese design and independent intellectual property rights and is one of the sixteen major projects listed in the National Guideline on Medium and Long-Term Program for Science and Technology Development. The construction of the HTR-PM Demonstration Project is of great significance to the Chinese nuclear technology advancement and the exploration of the future world nuclear power market.

HTR-PM will have the widespread commercial value and the prospects for development, in the area of Electric Power Generation, heat and power cogeneration, hydrogen production.

3.Overview of HTR-PM Demonstration Project

Located in Ningjin town, Shidao district, Rongcheng city, Shandong province, the HTR-PM Demonstration Project site is 68 kilometers to the south of Weihai city, 120 kilometers to the southeast of Yantai city, 185 kilometers to the northeast of Qingdao city. With unique natural conditions, it is one of the few excellent coastal sites which are argumented and qualifed for building large-scale nuclear power base. It has been listed in the new sites to be protected in the *National Nuclear Power Long-Term and Medium Term Development Plan (2011-2020).*.

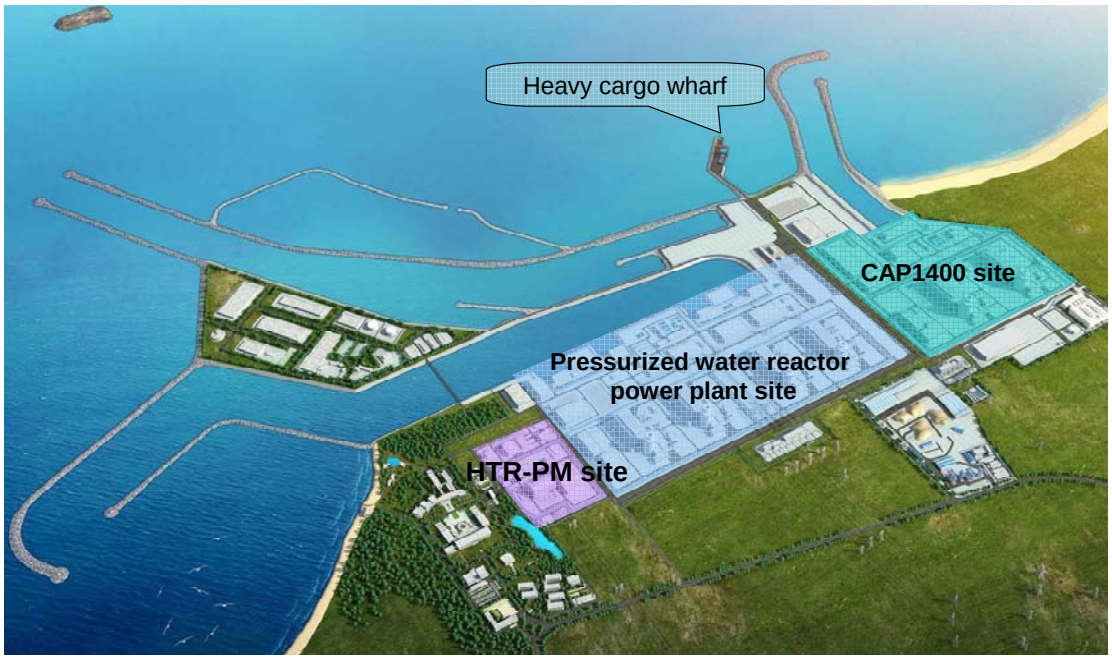


Figure 4. Shidao Bay nuclear power site planning

In March 2004, China Huaneng Group launched the preliminary work on 200MW HTR-PM project joinly with China Nuclear Engineering Group Co. and Tsinghua University. In February 2006, HTR-PM Demonstration Project was listed as one of the sixteen major projects included in the National Guideline on Medium and Long-Term Program for Science and Technology Development In February 2008, the State Council executive meeting approved the overall implementation plan of HTR-PM Demonstration Project. In September 2009, Ministry of Environmental Protection (National Nuclear Safety Administration) organized an expert meeting with participation of some members of the nuclear safety and environmental experts committee, proposing to issue the construction permit. On March 1, 2011, the State Council executive meeting approved the feasibility report of HTR-PM Demonstration Project. However, due to the Fukushima nuclear power plant accident in Japan on March 11, 2011, the project was postponed. On December 3, 2012, the National Development and Reform Commission approved the feasibility report of HTR-PM Demonstration Project and National Nuclear Safety Administration issued the construction permit on December 5. On December 9, 2012, the first concrete for the Nuclear Island foundation plate was poured, marking the official start of the construction of the HTR-PM Demonstration Project, which is the first of its kind in the world with inherent safety of the generation four nuclear energy system.

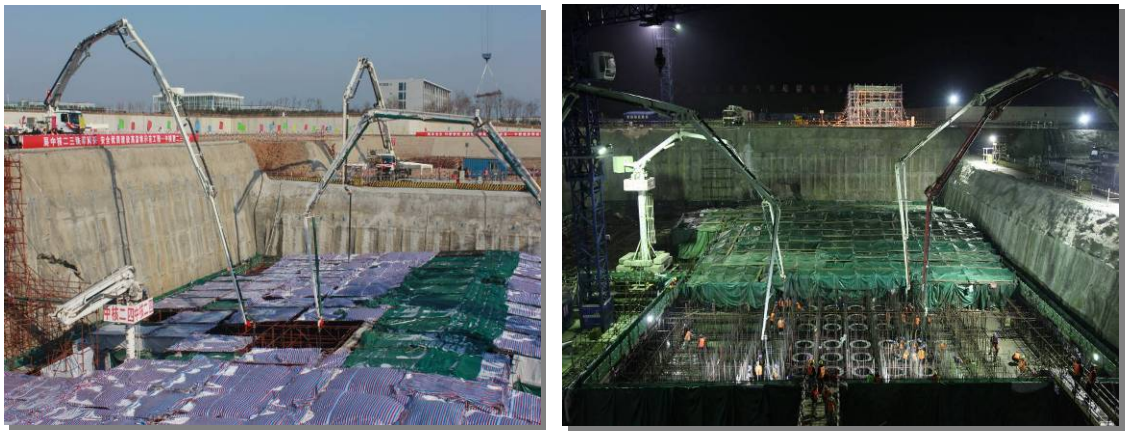


Figure 5. NI FCD (December 9, 2012)

As the owner, Huaneng Shandong Shidao Bay Nuclear Power Co., Ltd. (hereinafter referred to as HSNPC) is fully responsible for the construction of HTR-PM Demonstration Project. The nuclear island part is to be constructed by Chinergy Co., Ltd. under EPC contract and the design of the whole plant is also under the responsibilities of Chinergy Co., Ltd.. HSNPC is in charge of the construction of conventional island and BOP part. Institute of Nuclear and New Energy Technology, Tsinghua University (INET), China Nuclear Industry 24 Construction Co., Ltd. and China Nuclear Industry 23 Construction Co., Ltd. are the sub-contractors for nuclear island design, civil works and installation respectively. Other major organizations involved include State Nuclear Electric Power Planning Design & Research Institute.

During the construction period of the project, the owner takes overall responsibilities, with EPC mode adopted for the nuclear island and its BOP works, the owner is in charge of the construction management of conventional island and its BOP works, and the owner will take a lead in joint commissioning works.

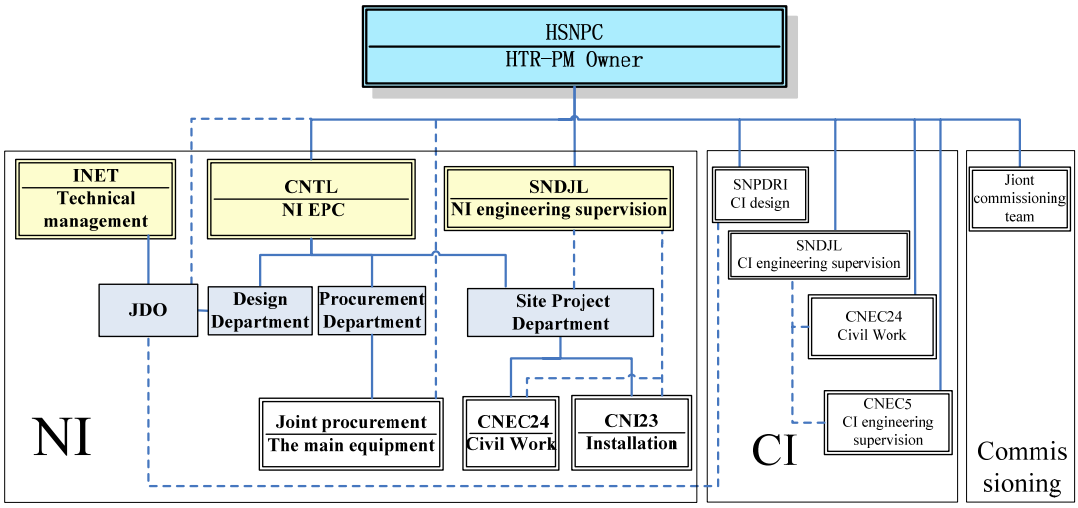


Figure 6. HTR-PM project management mode

The construction period of HTR-PM Demonstration Project is 59 months, with 43 months for civil works and installation and 16 months for commissioning. With first concrete in December, 2012, it is planned to be put into operation at the end of 2017.

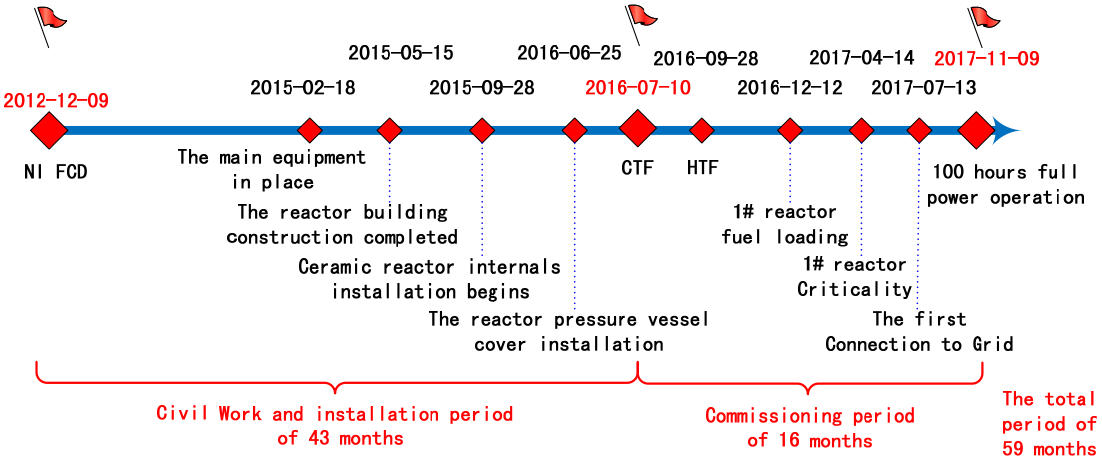


Figure 7. The HTR-PM schedule

HTR-PM Demonstration Project is the first nuclear power project in construction in which China Huaneng Group holds controlling interest. HSNPC has established safety, quality management system, experience feedback system based on the construction and management experience of other domestic nuclear projects and construction and management experiences of CHNG thermal power stations. Since the kick-off of HTR-PM Demonstration Project, no safety incidents or accidents, casualties, or quality accidents have happened owing to good safety and quality management. Based on the practices in other domestic nuclear power projects, HTR-PM has established a six-level schedule system for the overall schedule of 59-month construction period. Annual target plans, monthly plans and specific plans are prepared and periodic high-level coordinations accelerate the accomplishment of works as planned.

4. Progress of HTR-PM Demonstration Project

4-1.Civil works and installation construction

The civil works and installation construction of HTR-PM Demonstration Project have been advancing steadily and safely with quality under control, with overall progress satisfying the level 2 schedule.

The civil works of the main buildings in nuclear island has been completed as follows:

- The two-layer concreting of the nuclear island foundation was finished on March 17, 2013;
- The concreting of -11.05 m floor slab of the nuclear island buildings was finished on August 8, 2013;
- The concreting of -5 m floor slab of the nuclear island buildings was finished on October 21, 2013;
- The concreting of 0 m floor slab of the reactor building was finished on March 28, 2014;
- The concreting of 7.45 m floor slab of the reactor building was finished on August 12, 2014;
- The first concrete of CI was September 7, 2014.

The installation works in the reactor building has been completed as follows.

- Module A of the cooling water system (CWS) for the compartment wall of the steam generator cabin from -15.5 m to -8 m was lifted on April 14, 2013;
- Module B of the cooling water system (CWS) for the compartment wall of the steam generator cabin from -8 m to - 0 m was lifted on August 12, 2013;
- Module A of the cooling water system (CWS) for the compartment wall of the reactor cabin from -5m to 0m was lifted on November 21, 2013;
- Module C of the cooling water system (CWS) for the compartment wall of the steam generator

cabin from 0m to 5m was lifted on December 31 2013;

- Module D of the cooling water system (CWS) for the compartment wall of the steam generator cabin from 5m to 13.3m was lifted on June 18, 2014;
- Module B of the cooling water system (CWS) for the compartment wall of the reactor cabin from 5m to 13.0m was lifted on June 18, 2014;
- Module C of the cooling water system (CWS) for the compartment wall of the reactor cabin from 13.0m to 21.0m was lifted on September 10, 2014.

As of September 2014, 15152 tons of steels have been binded; 73785 m^3 concrete have been poured and 7 pre-introduction equipment, 14 modules of cooling water system (CWS) for the compartment wall have been installed.

Currently the civil works from 7.5m to 14m of the nuclear island buildings is in progress and the prefabrication and installation work of cooling water system (CWS) for the compartment wall above 21 m are under way.

Nuclear island foundation finished

Module B of CWS for reactor cabin

The construction of 7.55 m floor slab

CI FCD (September 7, 2014)

Figure 8. HTR-PM construction progress

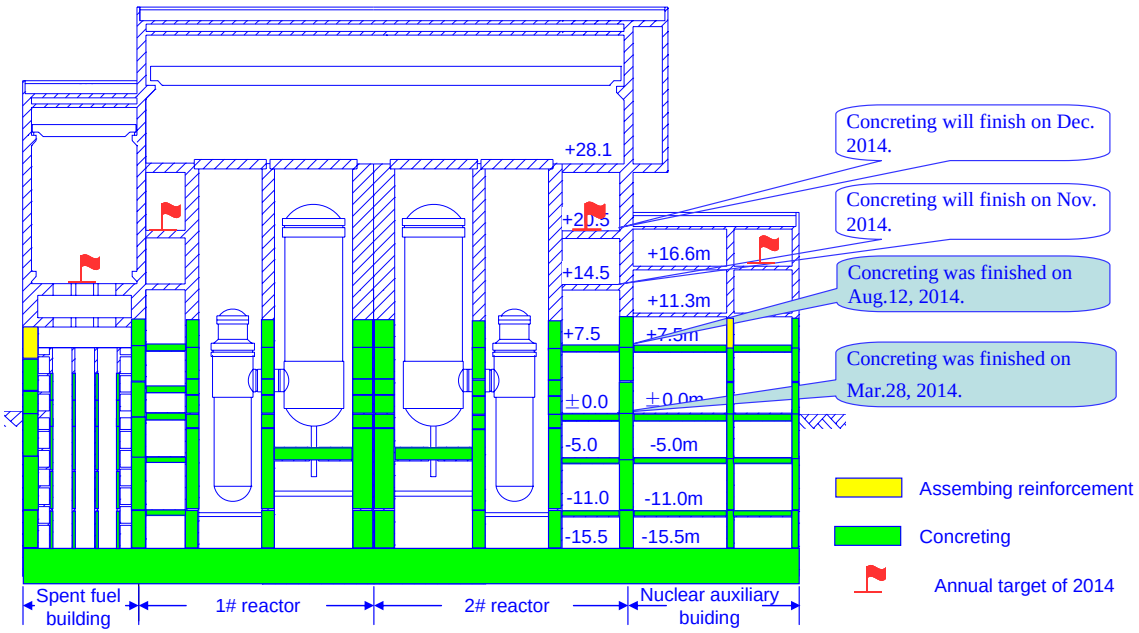


Figure 9. The schematic for HTR-PM civil works

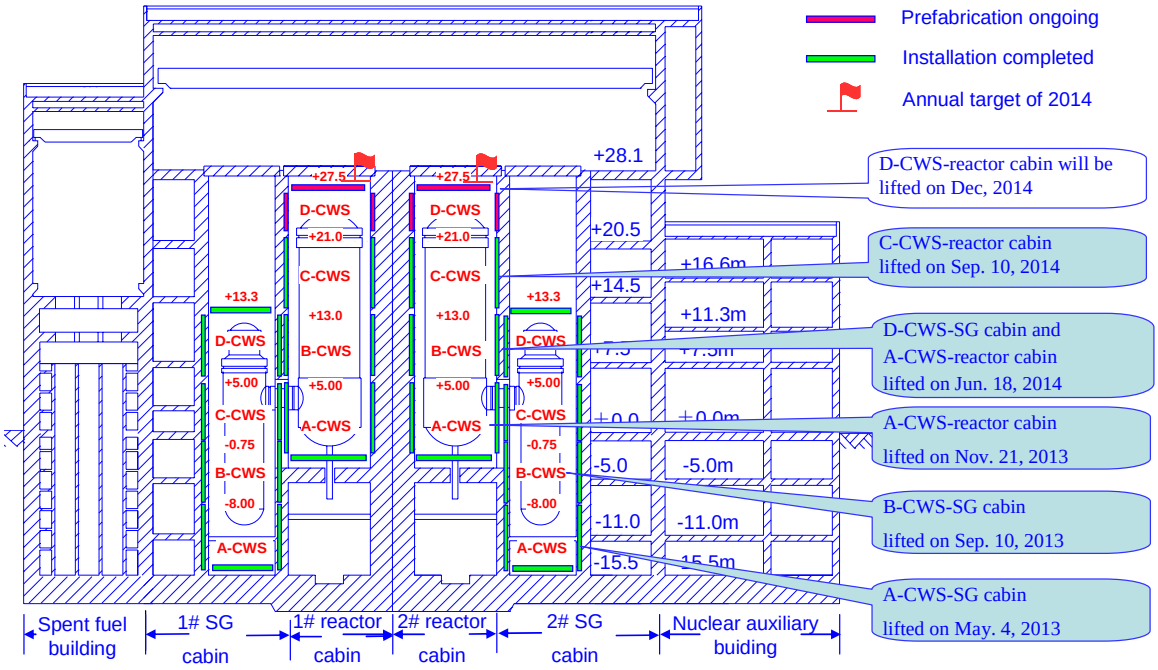


Figure 10. The schematic for HTR-PM cooling water system

4.2 Engineering Design

The preparation of construction drawings for nuclear island and conventional island are under way as planned and civil works construction drawings for level +14.5m of nuclear island have been submitted to HSNPC. By the end of 2014, over 90% of the civil works drawings will be submitted, satisfying the requirements of continuous construction and equipment procurement.

At present, 375 technical specifications, 93.5% of the total amount, have been published for the equipment in nuclear island and its BOP, and 112 technical specifications, 91.06% of the total amount, have been issued for the equipment in conventional island and its BOP.

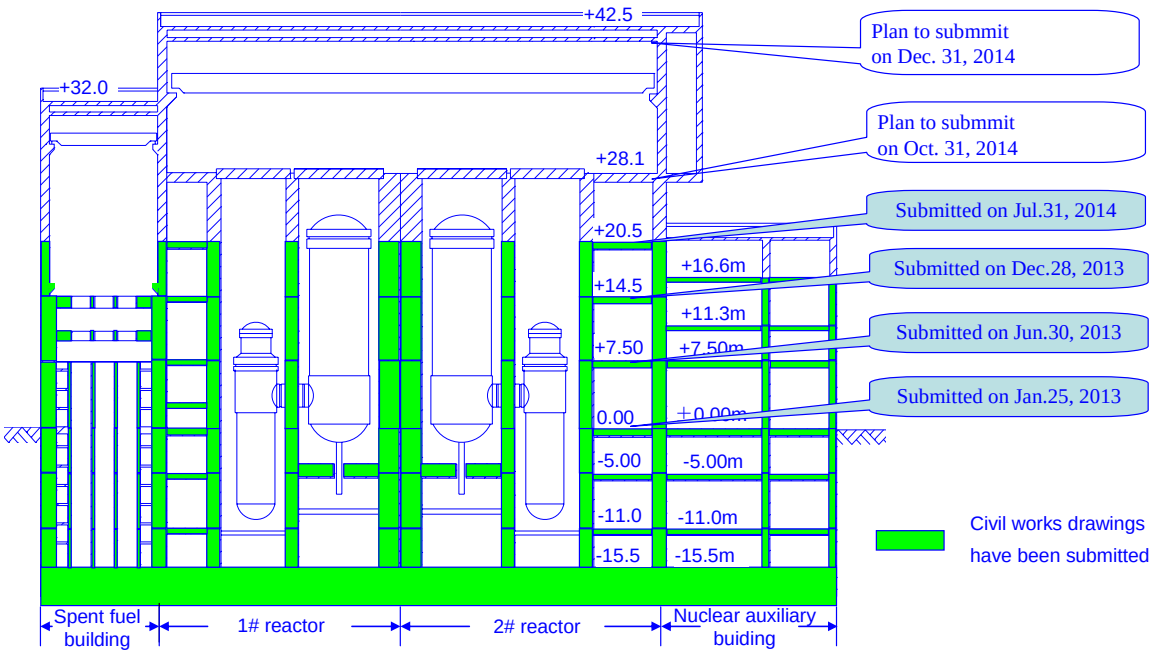


Figure 11. The schematic for HTR-PM engineering design

4.3 Equipment Procurement and Manufacturing

The manufacturing and scientific R&D contracts for major components in nuclear island and conventional island have been signed. Inivitation for bidding and contract signign for the main systems and important components have been finished, including 53 (151 in total) contracts for nuclear island and 43 (58 in total)contacts for conventional island. Great achievements have been made on major components in nuclear island after overcoming various kinds of difficulties.

Machining, assembling and welding of RPV in progress as scheduled..

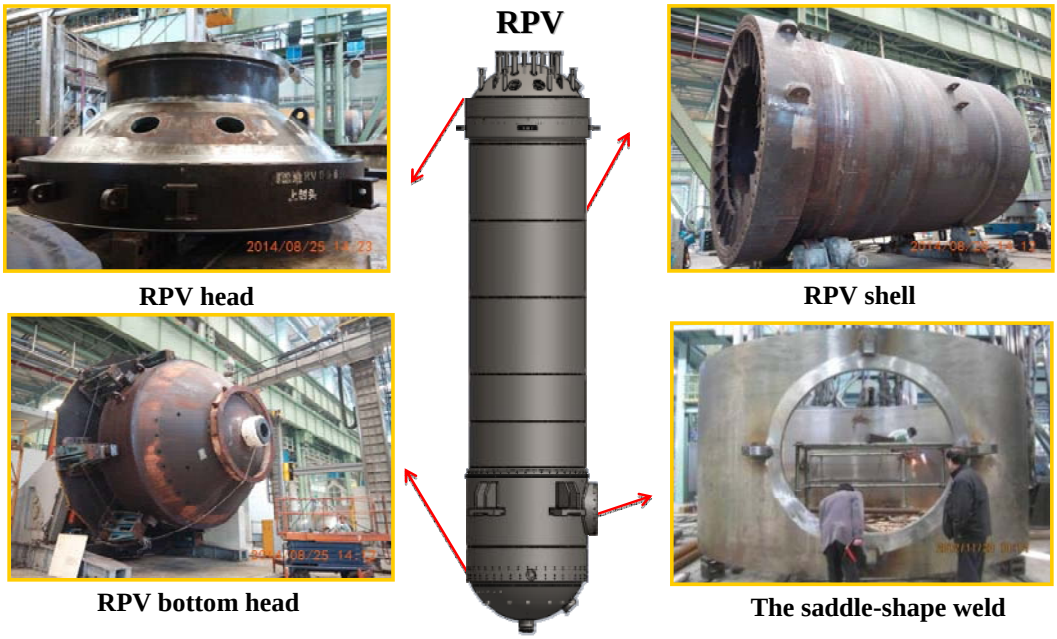


Figure 12. The RPV manufacturing progress

All parts of Metal reactor internal's shell have been rolled. Metal reactor internal enters the stage of

machining, assembling and welding

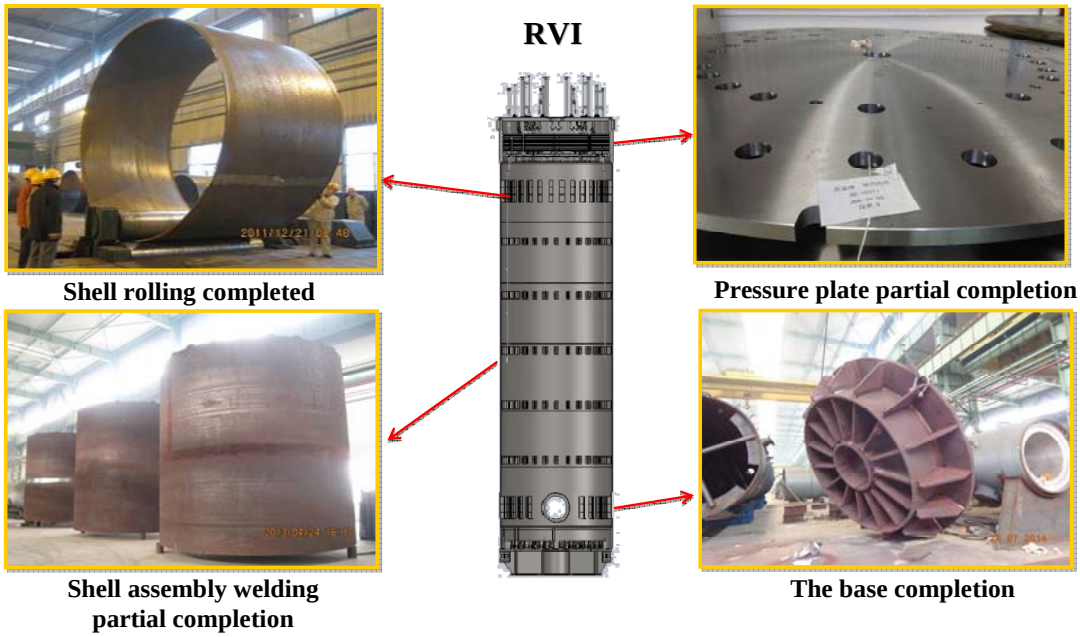
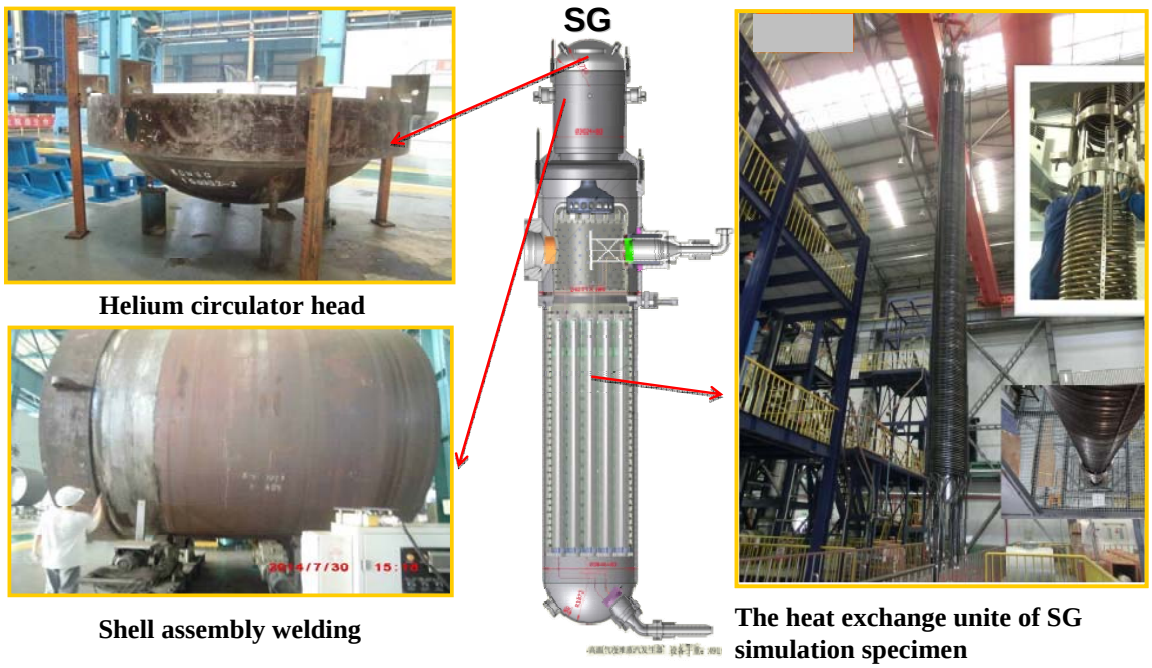


Figure 13. The RVI manufacturing progress

A heat exchange unite of SG simulation specimen has been assembled with 5 layers.



. Figure 14. The SG manufacturing and R&D progress

The model machine of helium circulator has been validated by 100 hours high temperature endurance test. The DCS system has finished with preliminary design and entered into detailed design stage . The protection system sample is under prototype testing. The complete supply chain of nuclear fuel has been fully implemented. Procurement contract for enriched uranium has been signed. Technical negotiations on fuel element processing have also been reached.

4.4 Commissioning and Operation Preparation

The production and operation organization for HTR-PM Demonstration Project has been established. The operations, maintenance, technical support, commissioning management departments have been working according to the plan in respective fields. Production and operation management system have been basically established and production outline of demonstration project, sub-outlines of sub-areas and management programs have been compiled. Great achievements have been made in operating personnel training. Up to now, 21 persons have been issued with senior operator's license for HTR-10 and 52 with operator's license.

5. Challenges and countermeasures

HTR-PM Demonstration Project is built with a reactor first of its kind in the world. It's a project involving the industry, academy and research cooperation. Some design and equipment manufacturing technology has not yet been mature. Design changes have led to difficulties in construction on site and equipment manufacturing, imposing pressure to the project schedule and investment control, challenging the management of the project. With the development of design research, equipment manufacturing research and construction preparation, various kinds of problems and difficulties have gradually appeared and have been addressed: Design changes and field changes are minimized by standard design process and rigorous review. High level coordination and increased investment help resolving the problems in equipment manufacturing technology and schedule. The two approaches jointly promote the progress of the HTR-PM Demonstration Project.

6. Conclusion

As a new generation of nuclear power plant independently designed and constructed by China, HTR-PM Demonstration Project involves simultaneous works in scientific research, design and verification. Without any reference from matured power station for engineering design, equipment manufacturing, construction and installation, and commissioning and operation, the project has been facing a lot of new technical and management challanges. The HTR-PM Demonstration Project team led by China Huaneng Group has explored the management and operation mechanism for HTR-PM Demonstration Project and established a technological innovation system of government promoting, enterprise leading, R&D heading, market operating, win-win cooperation of industry, academy, research and application, which promotes the work in various fields orderly, making sure that the HTR-PM Demonstration Project will be completed and put into operation successfully and promoting the competitiveness of the Chinese generation four advanced nuclear energy technology in the world.