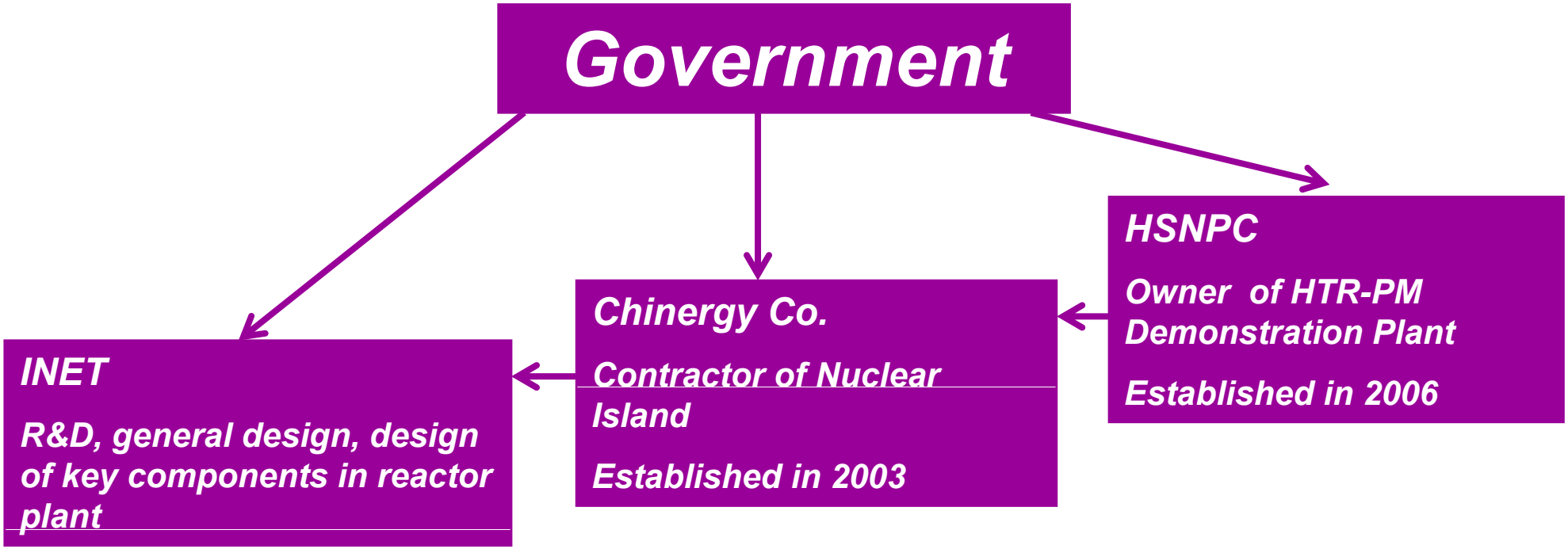
IAEA TWG-GCR-22

HTR-PM Project Status and Test Program

SUN Yuliang
Deputy Director, INET/ Tsinghua University

March 28 – April 1, 2011

Project organization



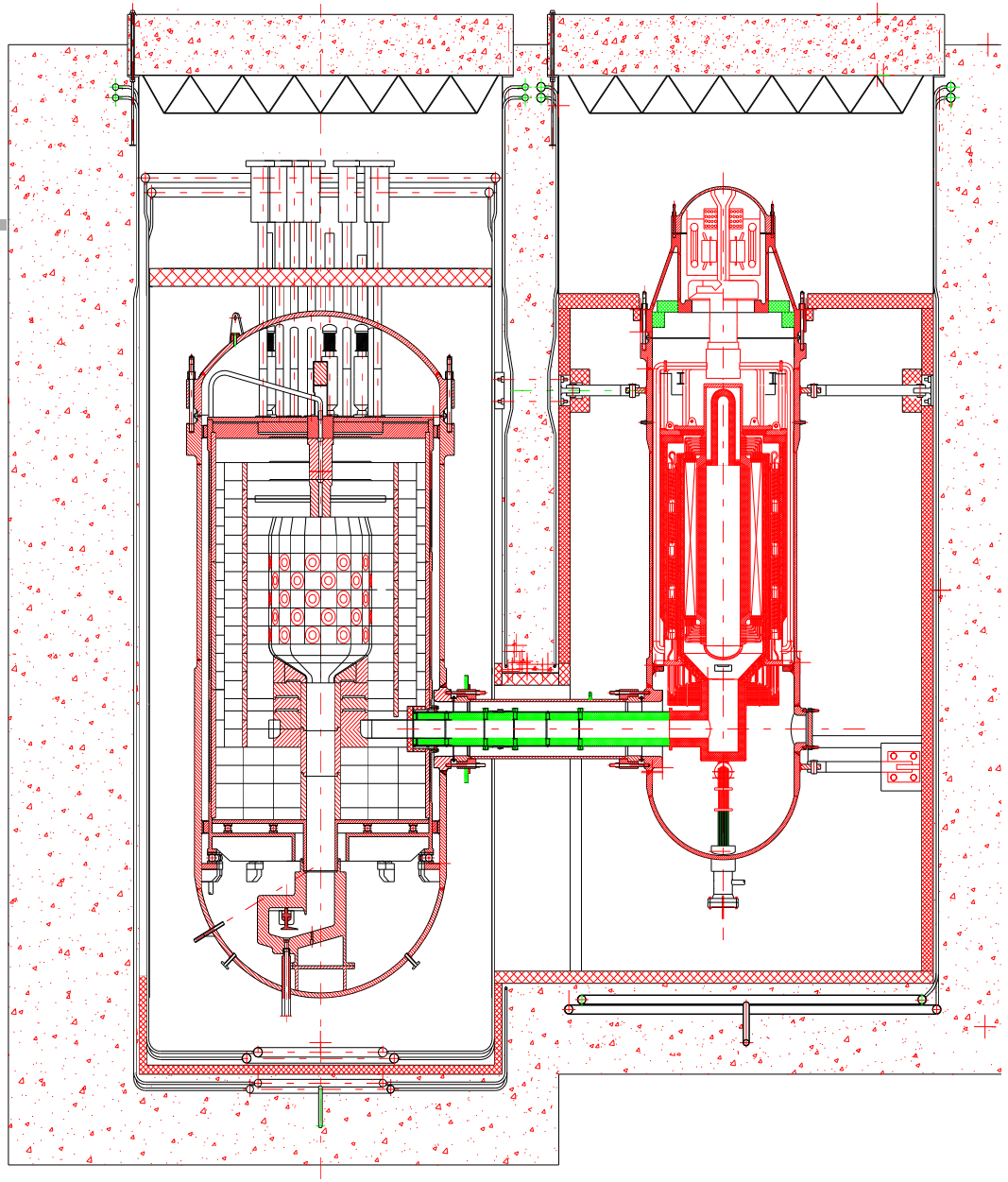
Technical development strategy

- **Basis**: HTR-10 as prototype, referenced HTR-Module, AVR, THTR, etc..
- **Key technology research**：scaling up and commercial operation;
- **Engineering tests**：verification of key system and components before installed in the reactors;
- **Manufacturing**：first of its kind;
- **Licensing**：step-by-step;
- **Fuel**: based on HTR-10 fuel fabrication and copy.

Contents

- *Design*
- *Manufacturing*
- *Licensing*
- *Construction*
- *Test*
- *Fuel*
- *Costs*

Reactor Power, MWth	10
Pressure, MPa	3
Reactor Inlet Temperature, ℃	250
Reactor Outlet Temperature, ℃	700
Fuel Elements Number	27000



HTR-10 as a prototype

INET

HTR-PM technical progress

***2001-2003**: HTR-PM concept studies were conducted with the support from the State Power Corporation by INET and East China Power Design Institute (ECPDI). **The steam turbine was selected**.*

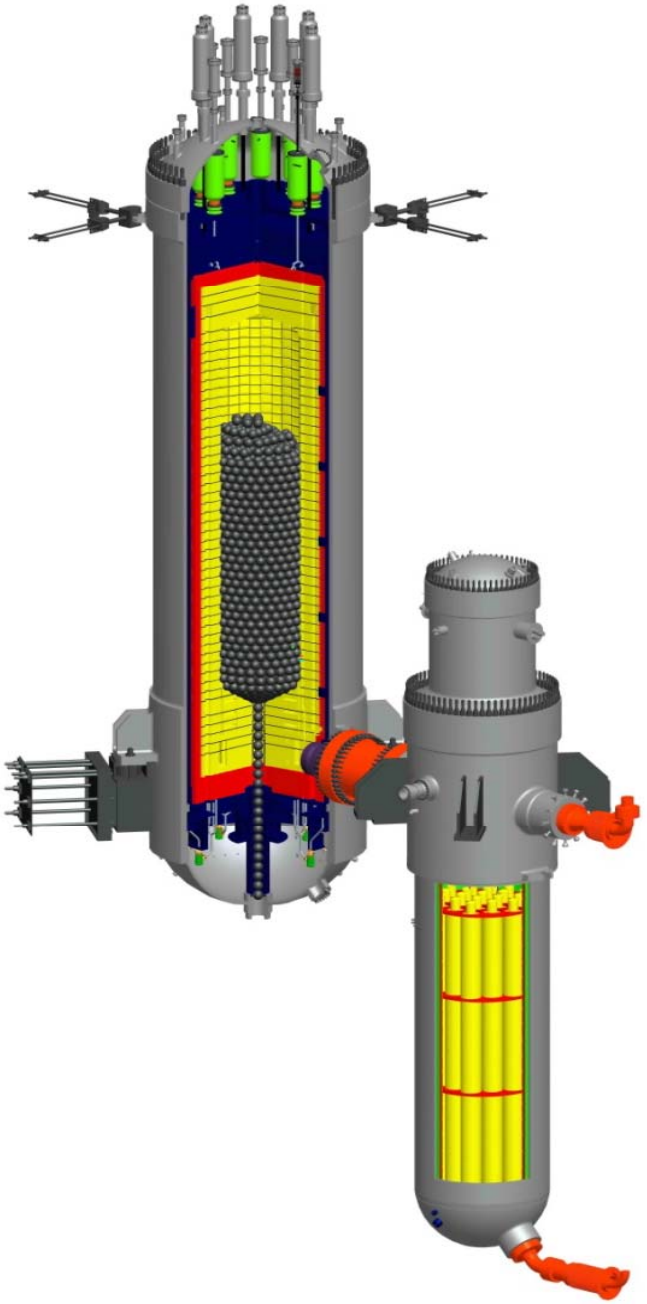
***2004-2006**: HTR-PM standard design was conducted from May, 2004 to May, 2006. A preliminary decision was made in August of 2004 to design a reactor of 458 MWt thermal power output with reheated steam cycle and annular core. (dynamic annual core and solid annual core)*

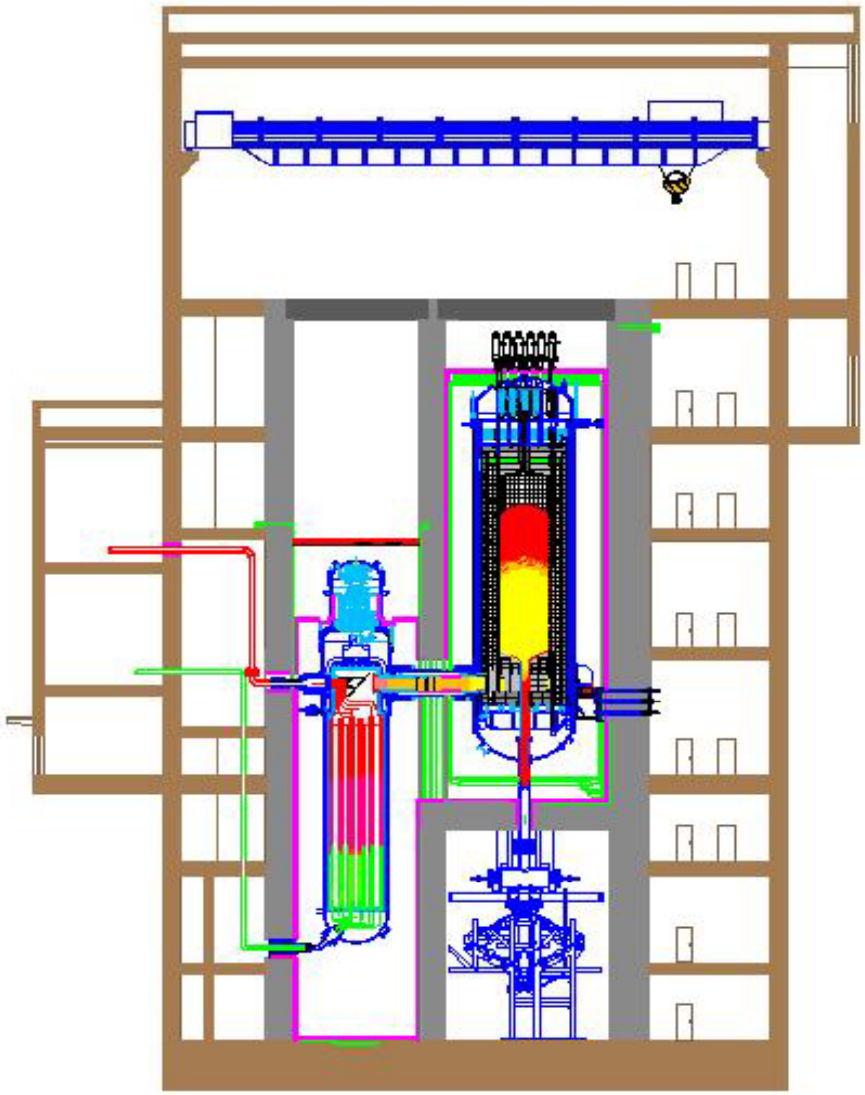
***2006.09**: **We made a decision to change** from 1×458 MWt **to** 2×250 MWt, maintain the plant output on 200 MWe.*

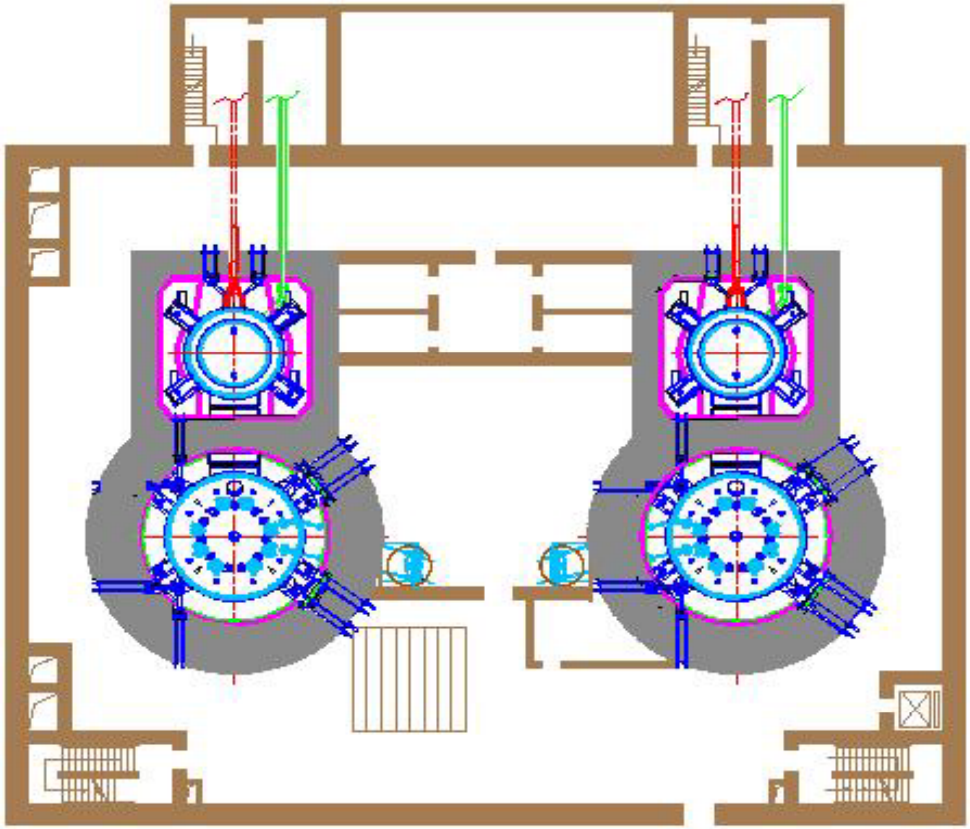
HTR-PM Designs Parameters

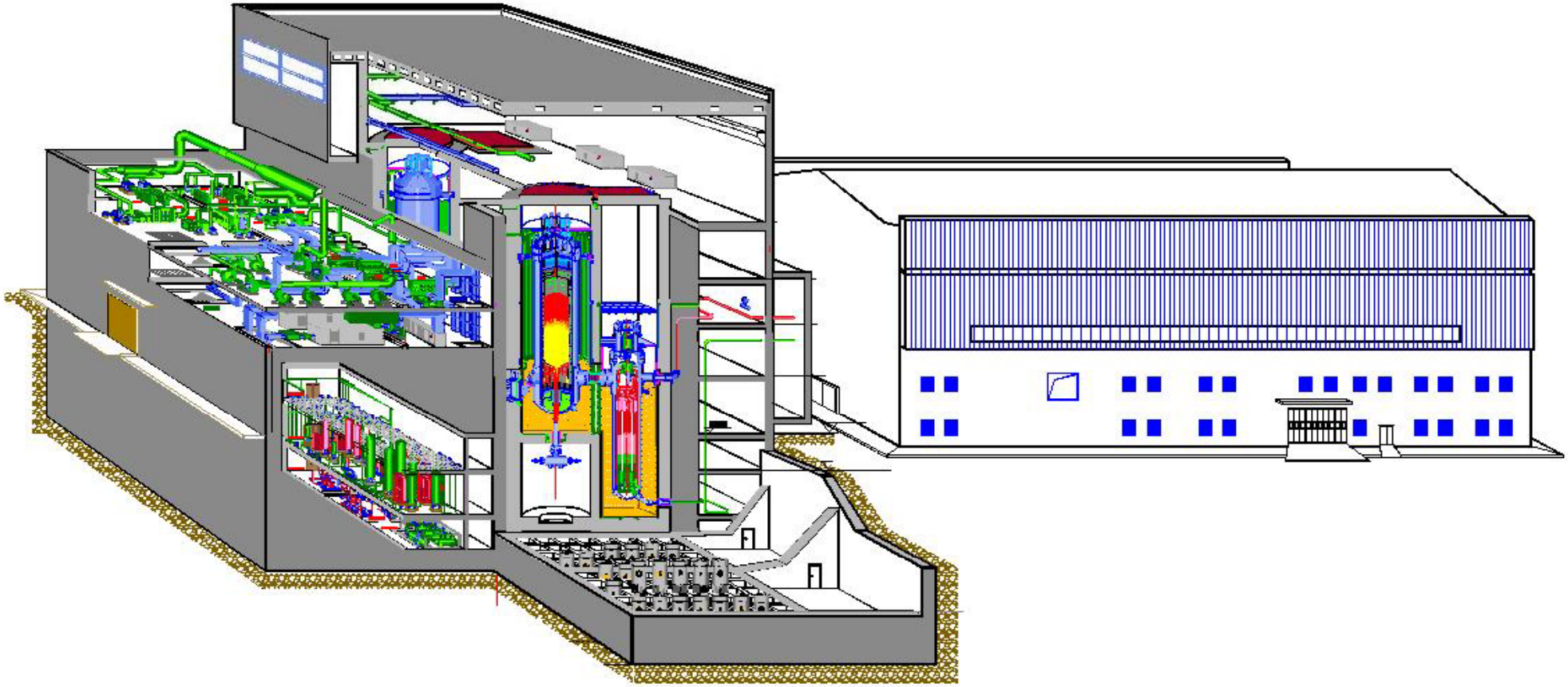
Plant electrical power, MWe	211
Core thermal power, MW	250
Number of NSSS Modules	2
Core diameter, m	3
Core height, m	11
Primary helium pressure, MPa	7
Core outlet temperature, ℃	750
Core inlet temperature, ℃	250
Fuel enrichment, %	8.9
Steam pressure, MPa	13.25
Steam temperature, ℃	567

HTR-PM：final technical solution in 2006









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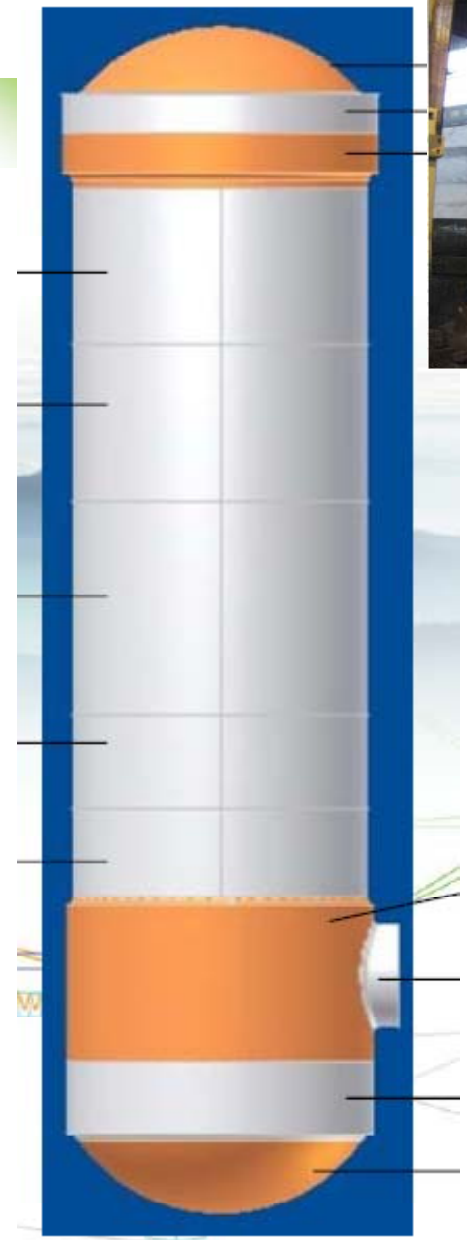
Manufacturing

- ***Key components***
  - ***RPVs***
  - ***Steam generators***
  - ***Graphite reactor internals***
  - ***Carbon reactor internals***
  - ***Metallic reactor internals***
  - ***Helium blowers***

  92% of components in price has been ordered
- ***Uranium contract has been signed***

INET

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RPV fabrication, 1

RPV fabrication, 2

RPV fabrication, 3

Fabrication of steam generator

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Licensing basis

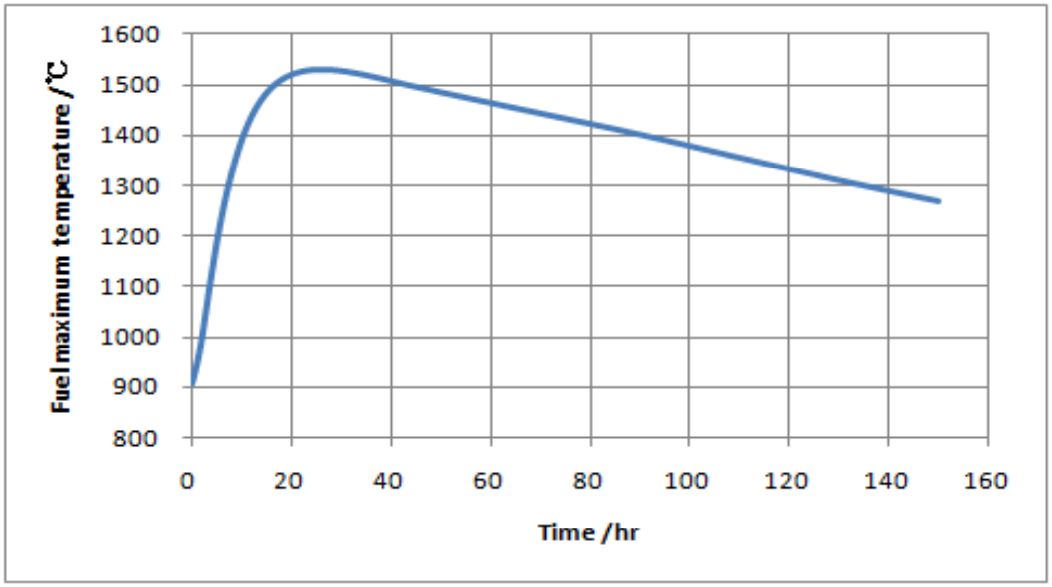
- ***HTR-10's licensing experience** of PSAR, FSAR, commissioning and Testing*
- ***HTR design criterion**, design criterion of key systems were documented and reviewed by the licensing authority after HTR-10*
- ***Important licensing criterion**, codes, standards, safety goal, key issues foreseeing in the licensing were documented, reviewed and accepted by the licensing authority before the formal start of licensing*
- ***Licensing experience**, Chinese licensing authority licensed French 1000 MWe PWR, VVER, SFR, HTR, CANDU, AP1000, EPR. Currently more than 26 units are under construction in China. The licensing authority understands well the different safety features of PWRs and HTRs and is able to give a balanced evaluation. For example, the time span during the accident is considered to be an important issue of the defense in depth.*

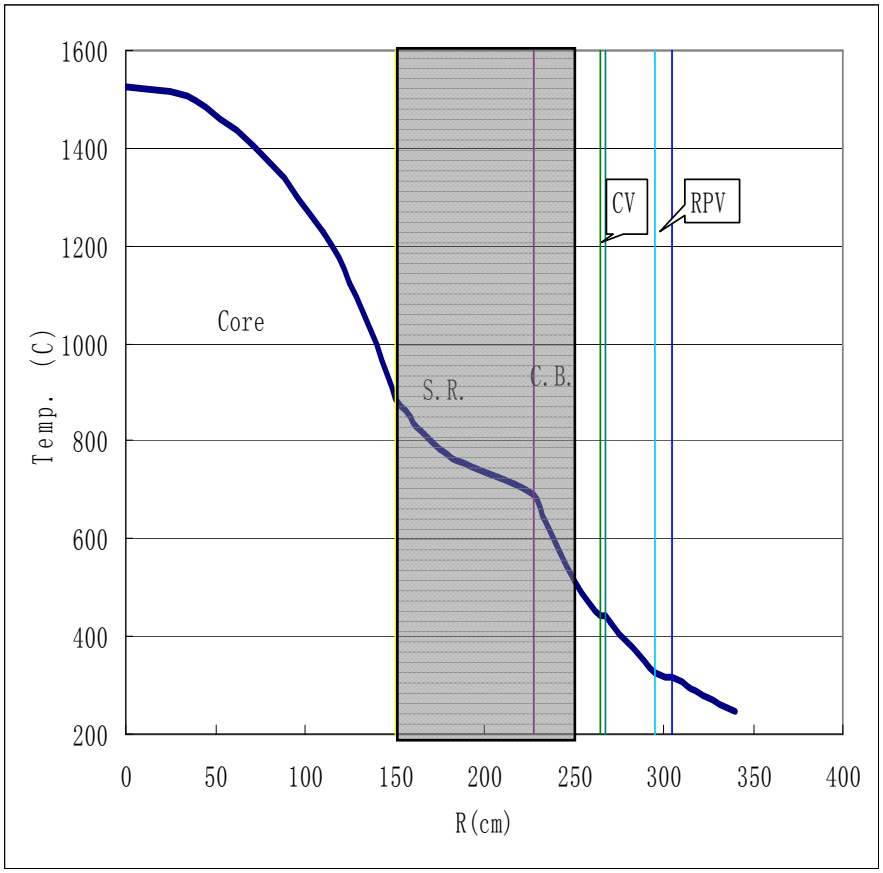
Licensing procedures

- *Submit of PSAR*
- *Technical briefing*
- *Review conference（2 times）*
- *Key issues discussion and PSA review*
- *Key issues discussion（5 times）*
- *Key issues concluding discussion*
- *Safety advisory committee*
- *More than 2000 questions and answers in documents*
- *16 issues needs more testing and should be solved before FSAR (Final Safety Analysis Report)*

There are also several other licensing like environment protection, ocean, emergency planning.

Safety: Fuel temperature afetr LOCA





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Site infrastructure

HTR-PM construction, 1

HTR-PM construction, 2

HTR-PM construction, 3

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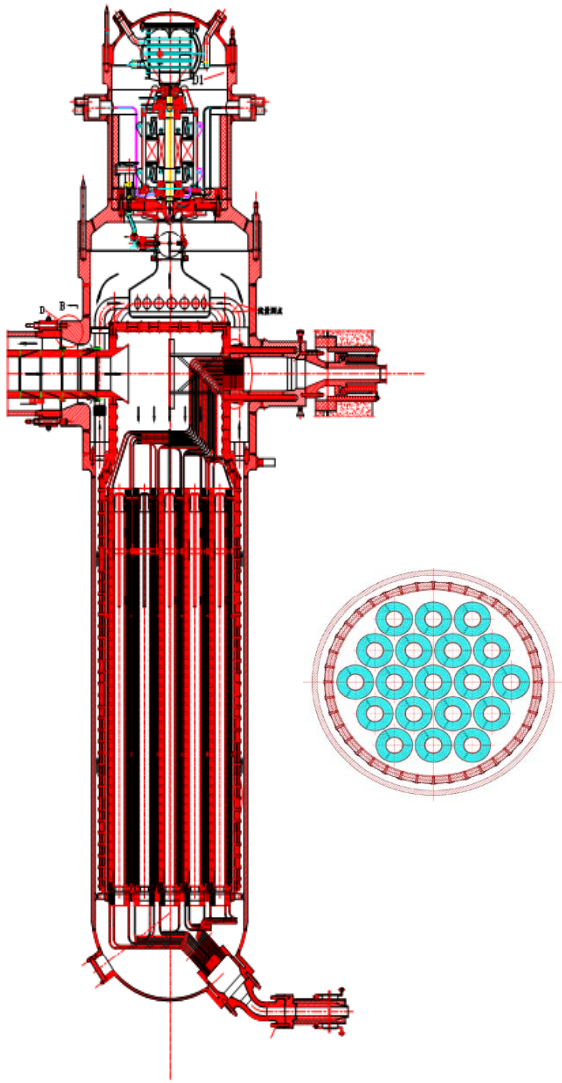
List of the key approved projects

- P1, Verification of helical once-through steam generator
- P2, Verification of fuel handling technology and the key component
- P3, Verification of small absorber ball shutdown system
- P4, Verification of digitalized protection system
- P5, Key components and technology of spherical fuel element fabrication
- P6, Verification of the control rod driven mechanism
- P7, Verification and research on helium purification and helium sealing

- P8, Experimental verification for some technical problems of the demonstration project using the HTR-10
- P9, Irradiation test of spherical fuel elements
- P10, Research and verification of important safety topics
- P11, Research on the dynamic response and structural integrality of graphite internals
- P12, Research on HTGR physics and thermal hydraulics and system simulation
- P13, Research on HTGR fission products behavior
- P14, Key technology on hydrogen production by HTGR

P1, Verification of helical once-through steam generator

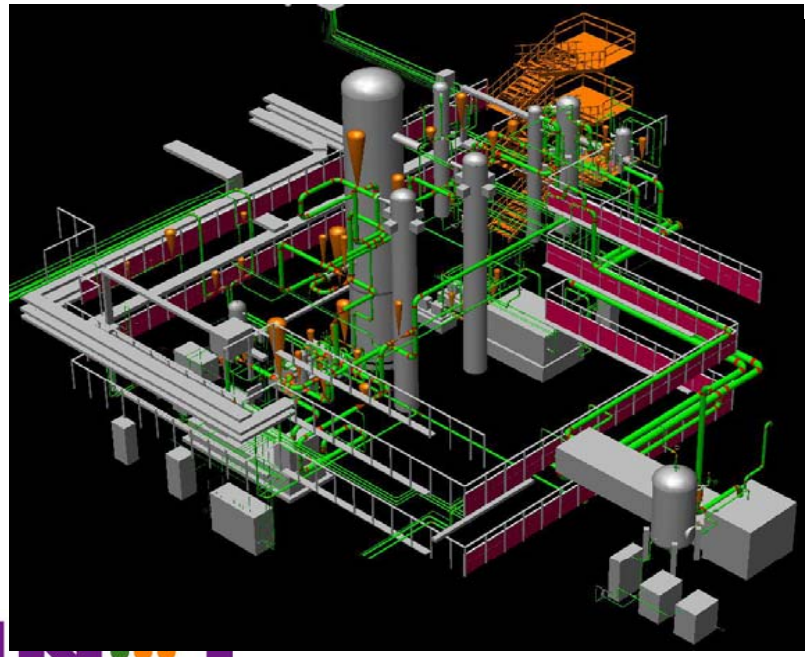


- *Experimentally verify the design of the once-through SG, ensure its design specification*
- *Sub-projects：*
  - *1）Research on the thermal-hydraulic characteristics of the once-through SG*
  - *2）Experiment on shell-side helium flow distribution*
  - *3）Development of the analysis software for the once-through SG*
  - *4）Reliability and insulation performance of the thermal insulation structures*
  - *5）Research on the key manufacture technology for the modular once-through SG*
  - *6）In-service inspection and integrality monitoring of the heat transfer tubes*
  - *7）Engineering experiment on the once-through SG*

Helium Test Loop

Parameters of the facility

- ***Thermal power of steam generator：10MW***
- ***Temperature：750 ℃***
- ***Pressure：7 MPa***
- ***Working fluid：Helium***



Experiments to be carried out：

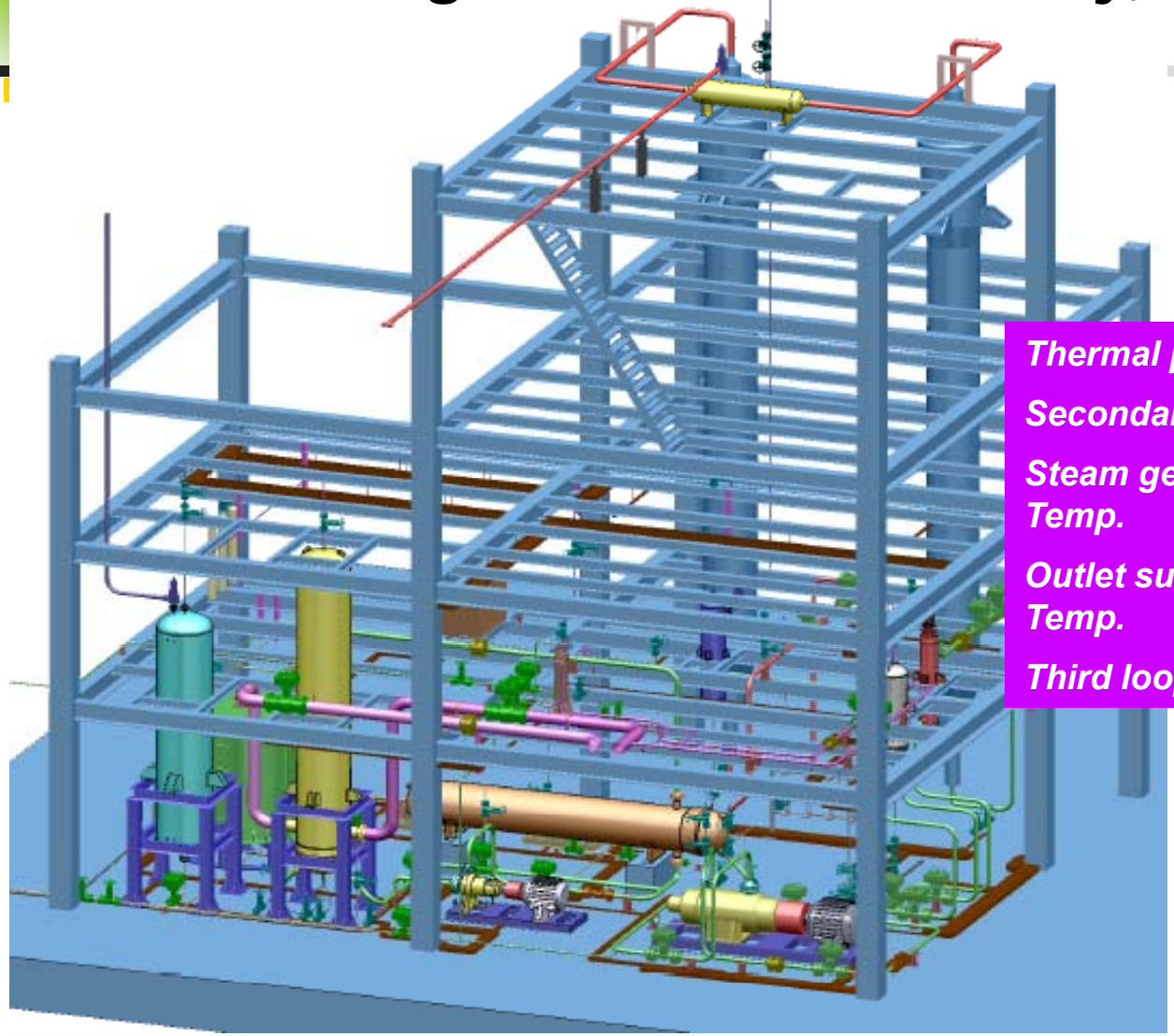
- ***Steam generator 1/19 test, steam 13.25MPa, 567 ℃***
- ***Fuel handling system***
- ***Small absorber sphere second shut down system***
- ***Helium purification system***

Fabrication of the electric helium heater

Transport of the electric helium heater

Installation of electric heater, 115 ton

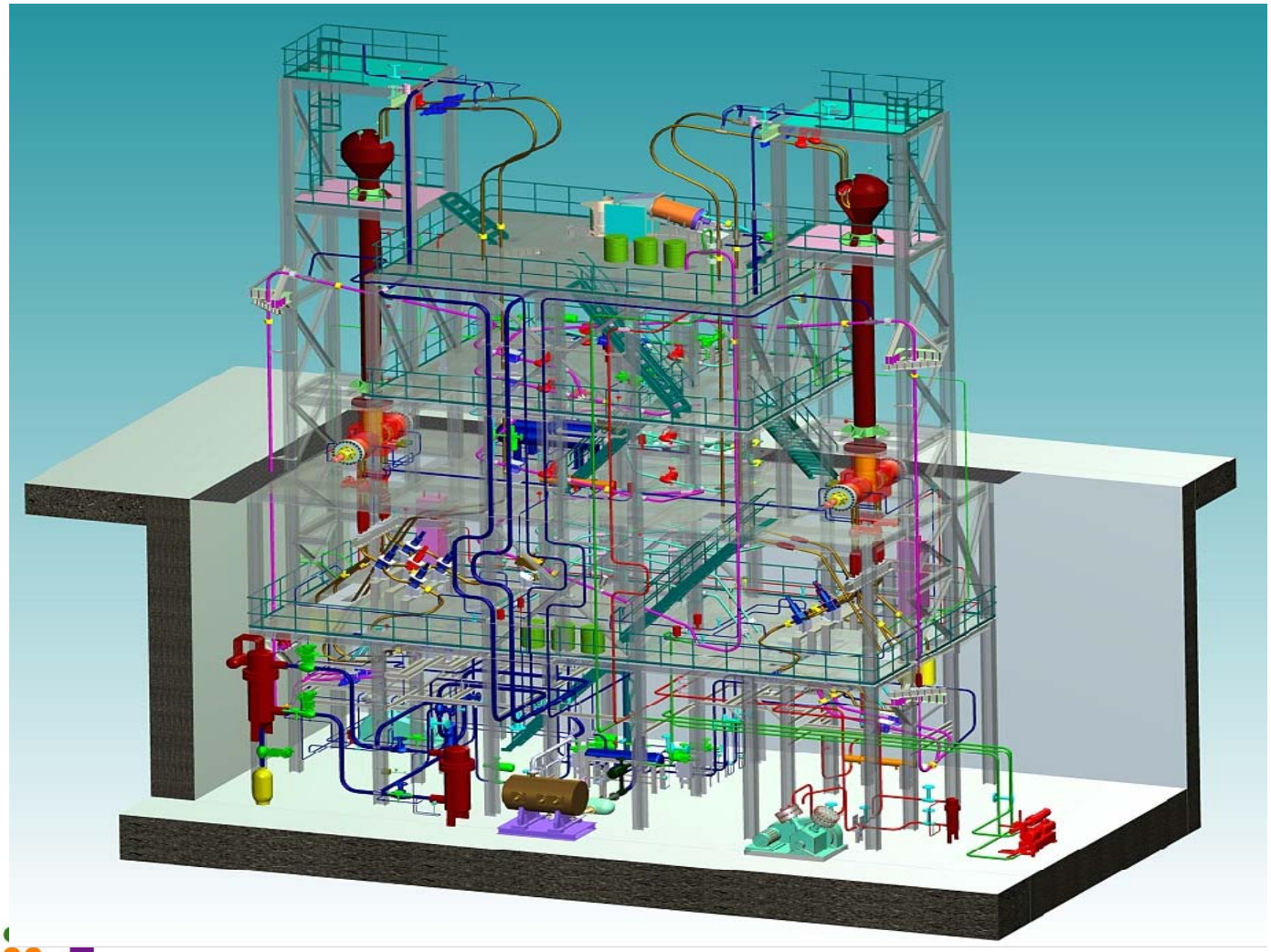
Steam generator test facility, in P1



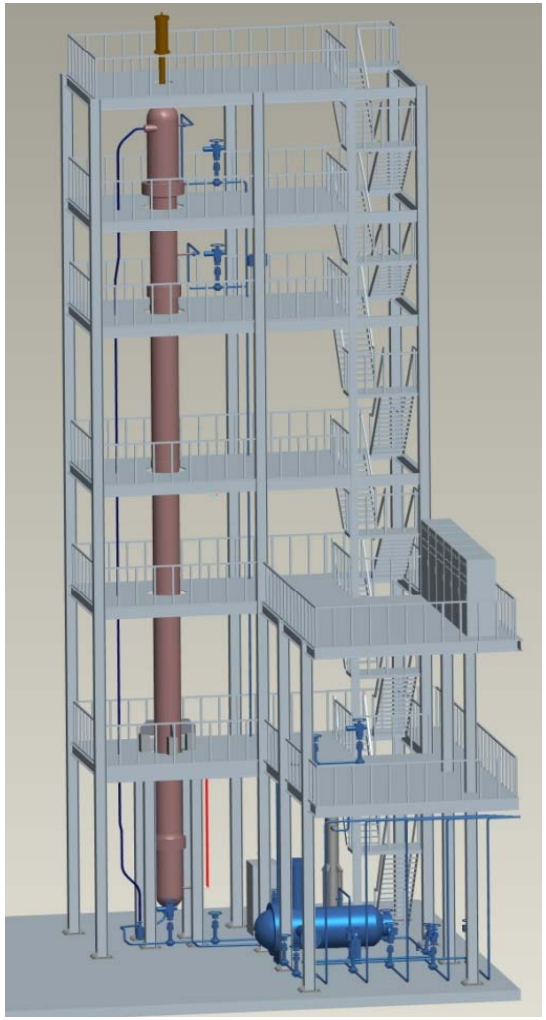
Thermal power	10MW
Secondary loop pressure	13.25 MPa
Steam generator inlet water Temp.	205℃
Outlet superheated steam Temp.	570℃
Third loop pressure	3MPa

Some tests finished for Fuel Handling System, in P2

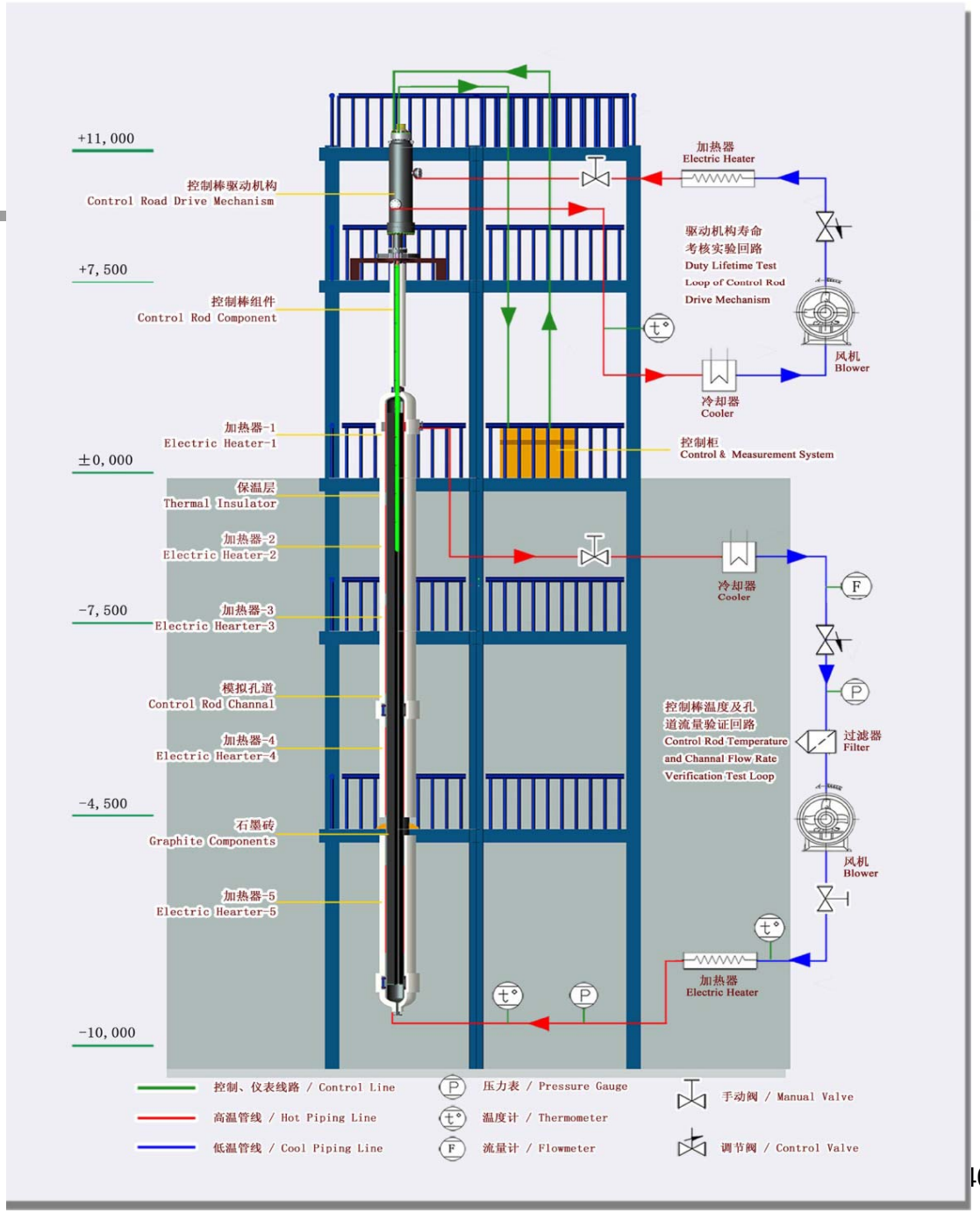
Full-scope Test Facility of Fuel Handling System, in P2



Full-scale engineering test rig of the absorber sphere shutdown system, in P3



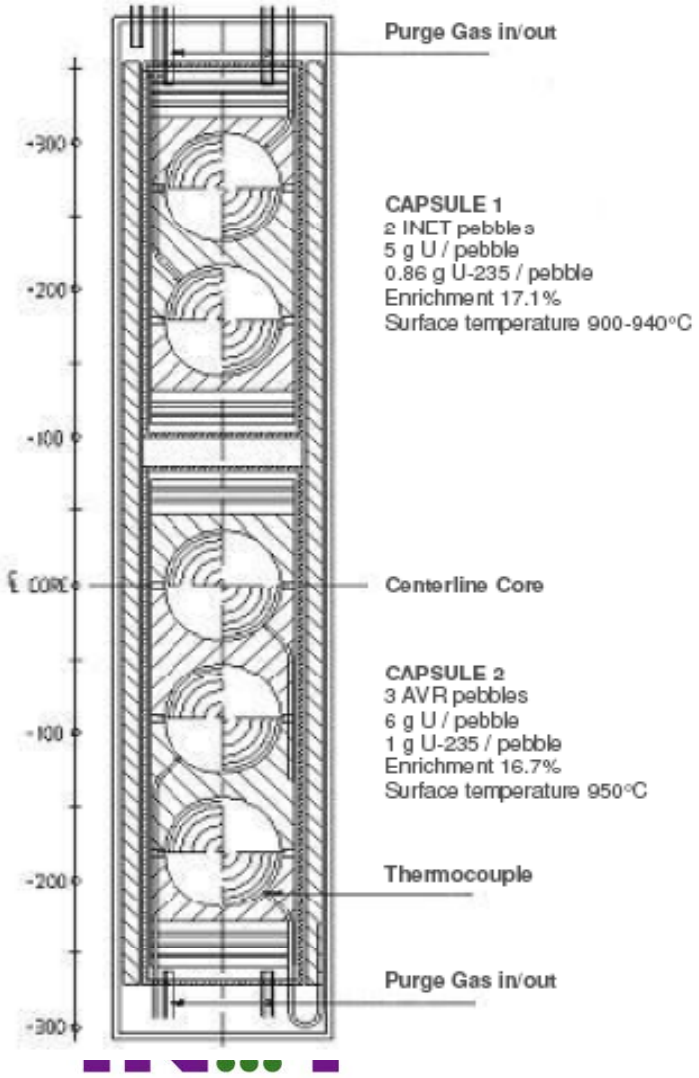
Test Facility of Control Rod Drive Mechanism, in P6



HTR-10 operation, in P8

- ***HTR-10 is under maintenance:***
  - ***Renew of the 10 years old digitized control systems;***
  - ***Improvement of helium purification system;***
  - ***In-service inspection of RPV;***
  - ***Add more measurement, including fission products, temperature in the cavity cooling system;***
  - ***Replace some components in turbine plant;***
- ***HTR-10 will operate again by the end of this year and will further operate in the next years to obtain more experience for HTR-PM project;***
- ***It is planning to conduct temperature measurement in the core and possibly high temperature operation.***

P9, Irradiation test of the spherical fuel elements



- *Obtain irradiation data of the HTR-PM fuel element samples, establish calculation model for the fuel elements*
- *Sub-projects*
  - *1）Irradiation test of the HTR-PM fuel elements*
  - *2）Post-irradiation examination of the spherical fuel elements*
  - *3）Research on the calculating model of the fuel elements*

- ***P10, Research and verification of important safety topics***

  Experimental research on the effective heat conductivity of pebble bed, experimental and theoretical research on graphite corrosion caused by water and air, experimental research on deposition and distribution rules of the graphite dust

P11, Research on dynamic response and structural integrality of the graphite internals

Through the theoretical analysis and model experiment, study the dynamic response of the graphite core structures under seismic condition and evaluate its integrality definitely

- ***P12, Research on HTR-PM physics and thermal hydraulics and system simulation,***

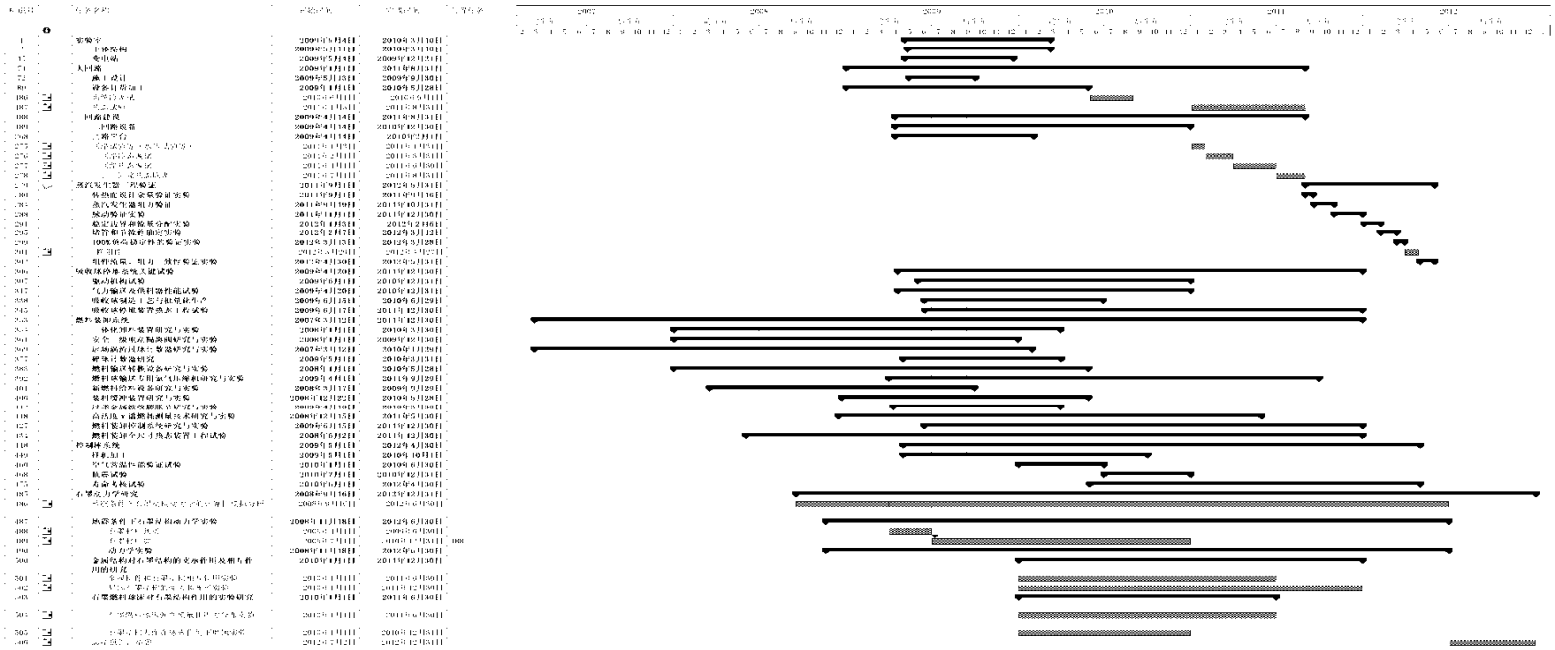
  Experiment on hot gas mixing in mixture chamber

- ***P13, Research on the HTGR fission products behavior***

  Sampling of primary loop helium, measurement of the activity of gaseous fission product in helium in HTR-10, Measurement of the adsorption and deposition of solid fission products

Schedule

Detailed schedule for experiments closely relating to the demonstration plant



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Fuel fabrication

- *Technology of 5g U/fuel to 7g U/fuel has been demonstrated, √*
- *INET demo production facility has been finished, √*
- *Licensing of the manufacturing of irradiated fuels, is in the final stages*
- *Irradiation test, issued, prepared, and start soon*
- *Engineering and licensing of a new plant is finished, start the construction soon*

Fuel fabrication

Contents

- *Design*
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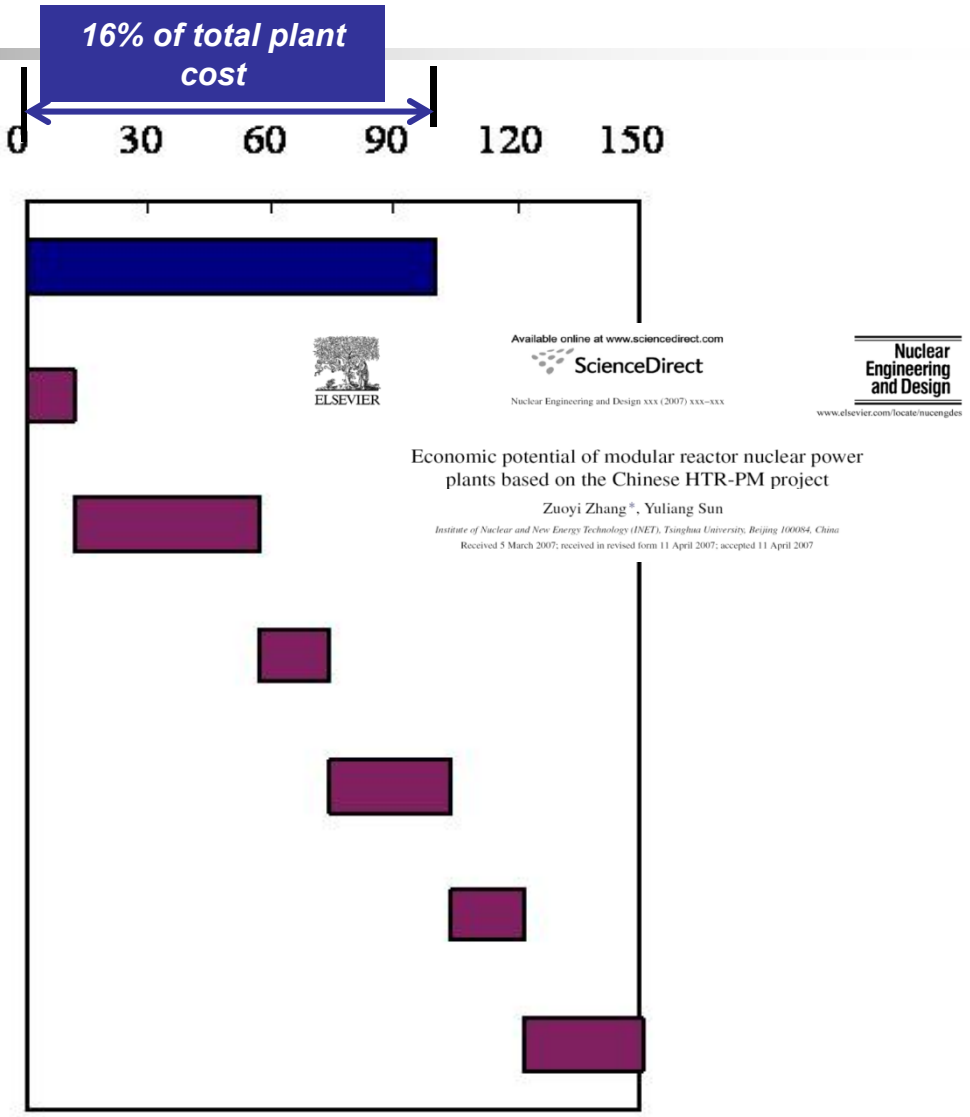
Costs of the demonstration plant

- *The cost issue is one of the focus in the project.*
- *More than 90% (in costs) of the equipments has been ordered through bidding process. There is a detailed costs databank for HTR-PM and also the PWR projects currently under construction in China.*
- *The conclusion which was accepted is: given that the government provides 30% of the capital cost and 100% of the R&D cost, the HTR-PM demonstration plant will achieve the capital cost (USD/kWe) and generation costs (cents/kWhr) similar to the current 2nd generation 1000 MWe PWR in the Chinese market.*

HTR-PM economic potential published in the paper of 2007 has been further proven



The way to cost effective HTR-PM plants, as conclusions of the paper in 2007

- *adopt multiple NSSS modules and one turbine generator for one plant to achieve large capacity;*
- *reduce the costs of RPVs and reactor internals through mass production;*
- *share auxiliary systems as much as possible in one plant;*
- *reduce the workload of design and engineering management;*
- *shorten construction schedule.*

The Next Step

A 600 MWe Multi-Module HTR-PM Super-critical Steam Turbine Plant, (6×250 MWt HTR-PM module+ 1×660 MWe steam turbine)

- ***standardize the reactor module,***
- ***is inherently safe and competitive,***
- ***and usable for co-generation.***

The schedule

- *A0: Authorized to proceed*
  - *Key components ordered*
- *A1: FCD, First Concrete Deployment,*
  - *PSAR reviewed and construction licensing approved*
  - *Most of detailed engineering finished*
  - *FCD approved*
- *A2: RPV shipped to the site, A1+16m*
  - *RPV fabrication finished*
  - *Verification tests finished: steam generator*
  - *Other components nearly finished: Steam generator, reactor internals, connecting vessel, helium blower, etc..*
- *A3: Fuel loading*
  - *FSAR approved*
  - *Fuel available*
- *A4: Connecting to the grid*

Conclusion

- *The HTR-PM project is on the track as planned.*
- *However challenges still exist: 1st of its kind components, verification tests, fuel, risk management……*
- *We are looking forward to more world efforts on the first HTR-PM demonstration project.*