Chinese HTR Program: HTR-10 results & Work Progress on HTR-PM

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May 15, 2007

ICAPP 2007, NICE

PRESENTED
by

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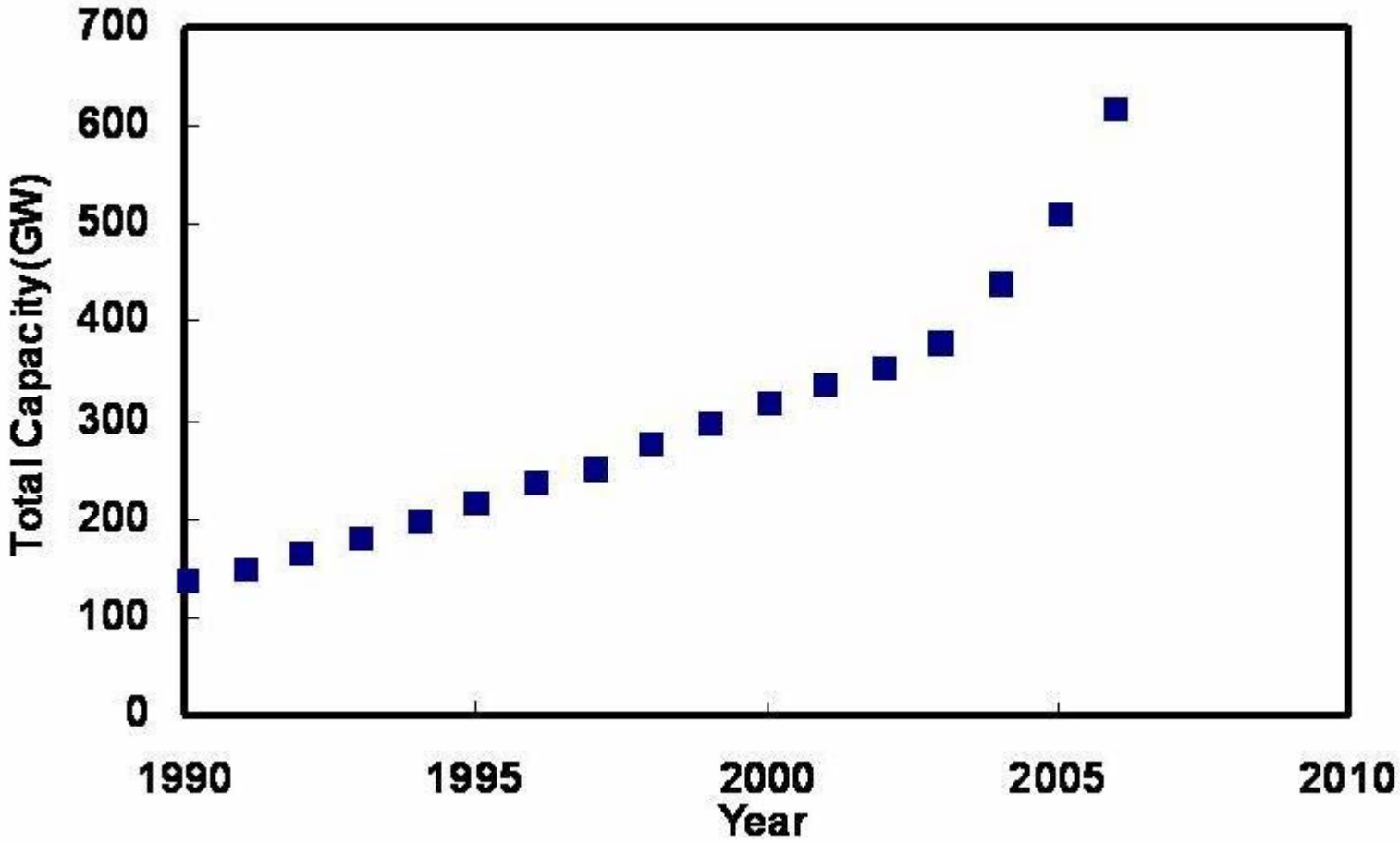
  University of Stuttgart/Germany

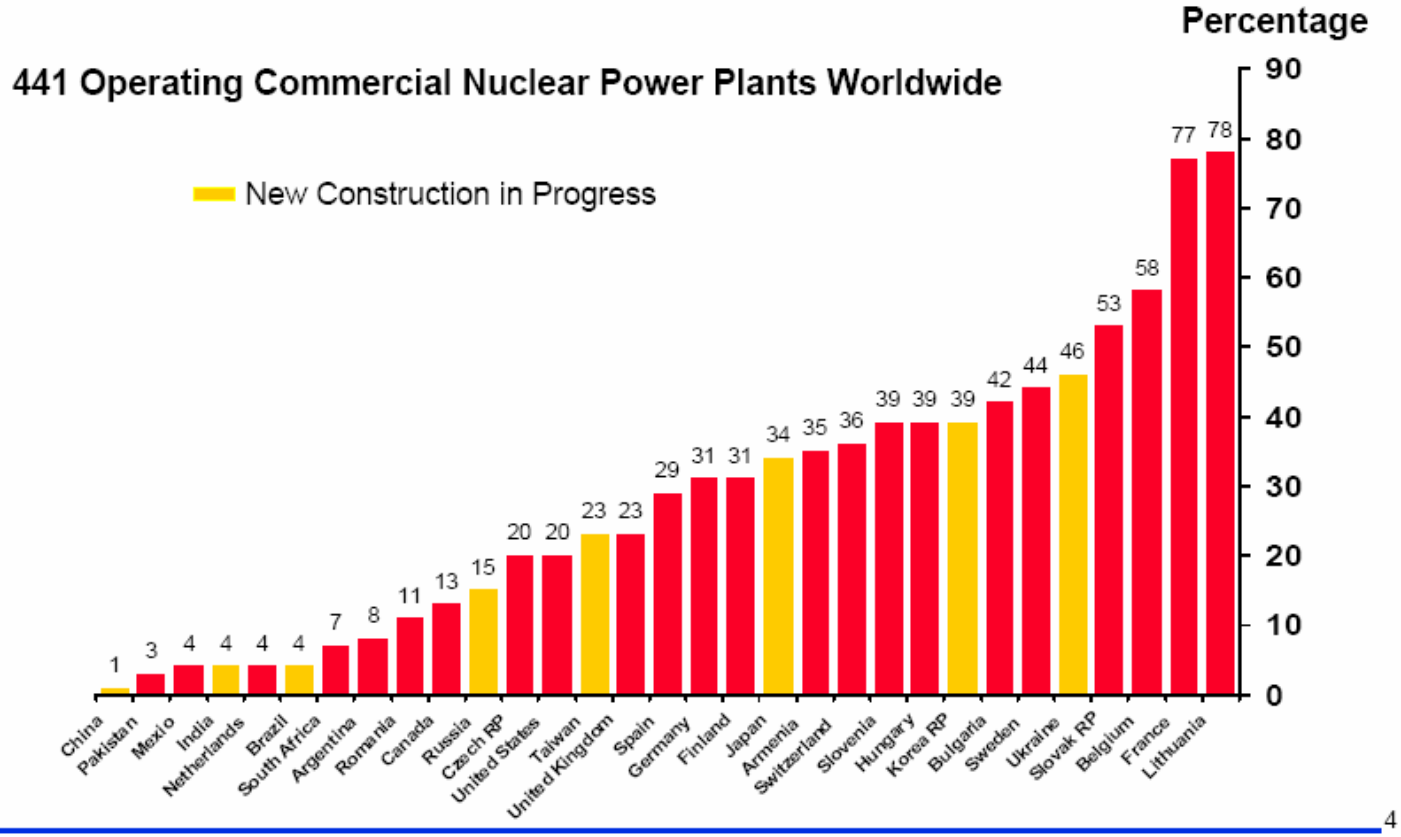
- *PRINCIPAL EDITOR*

  NUCLEAR ENGINEERING AND DESIGN

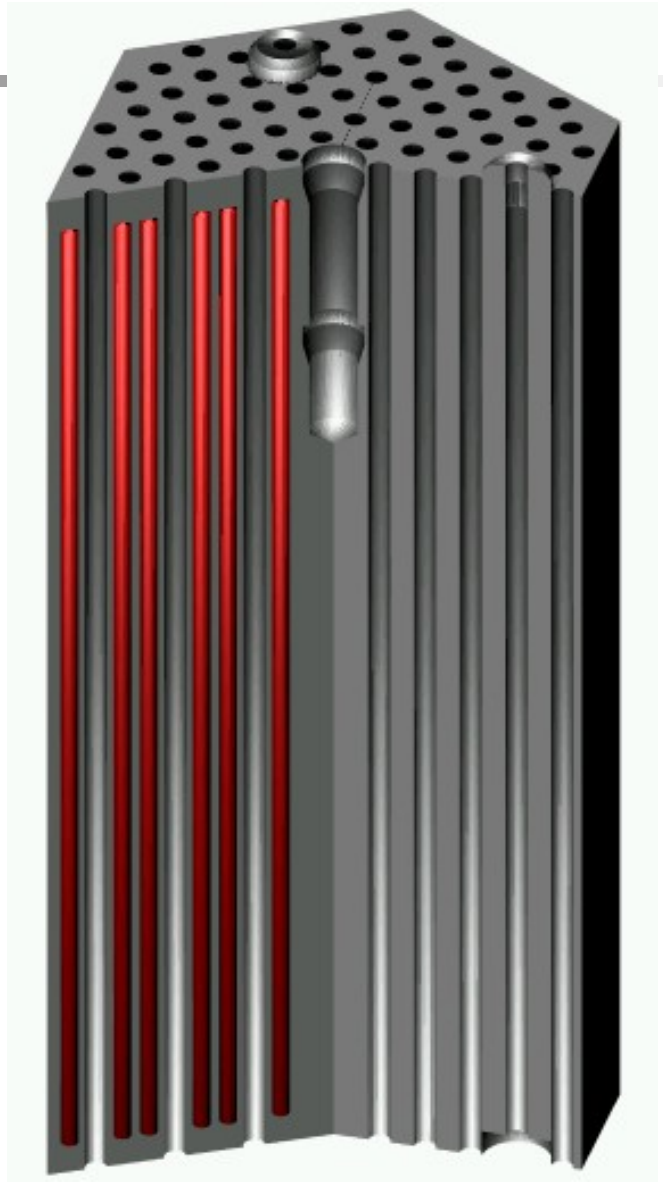
Installed capacity in China



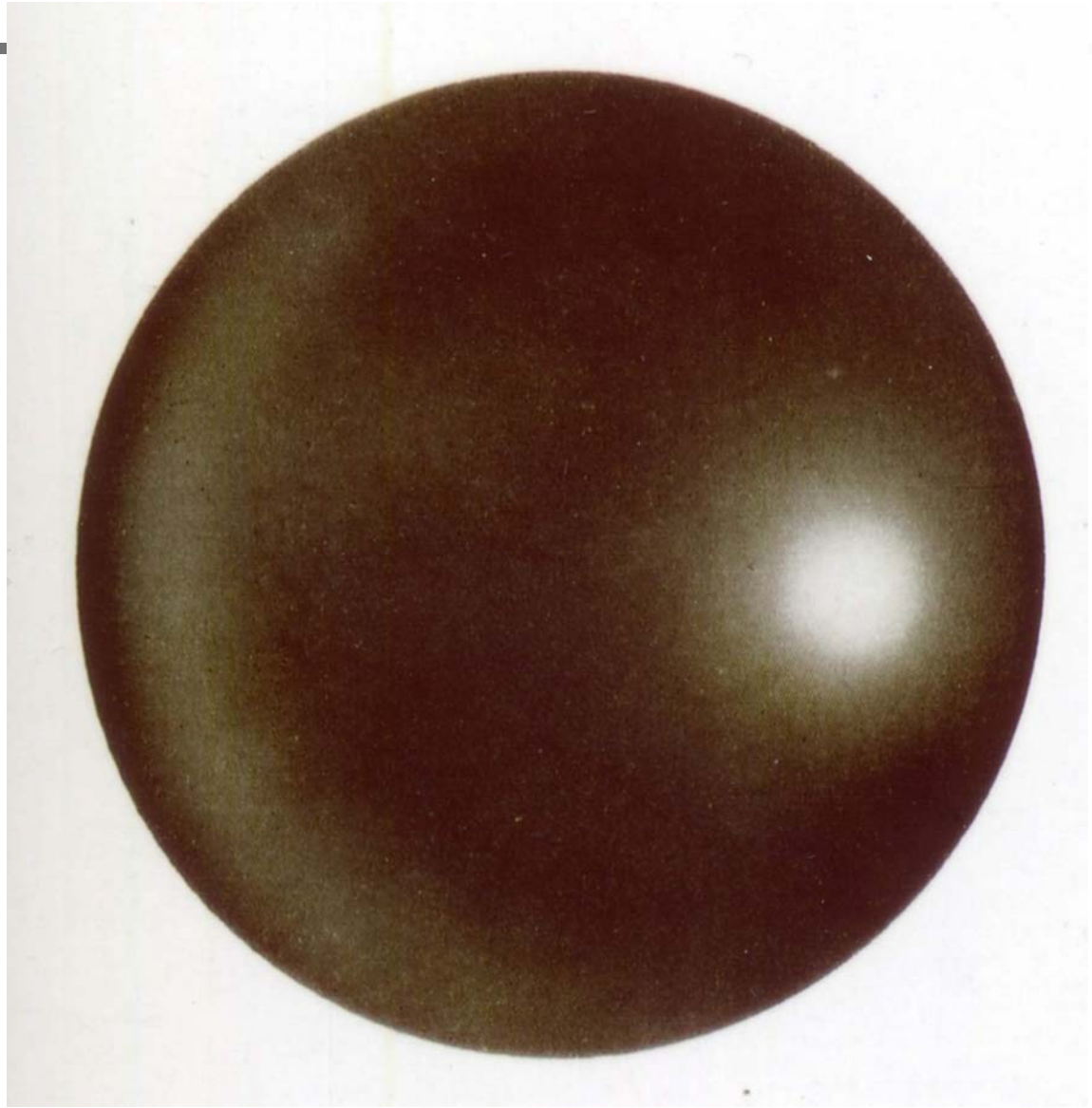
Nuclear Plays A Major Role in Global Electricity Generation



BLOCK



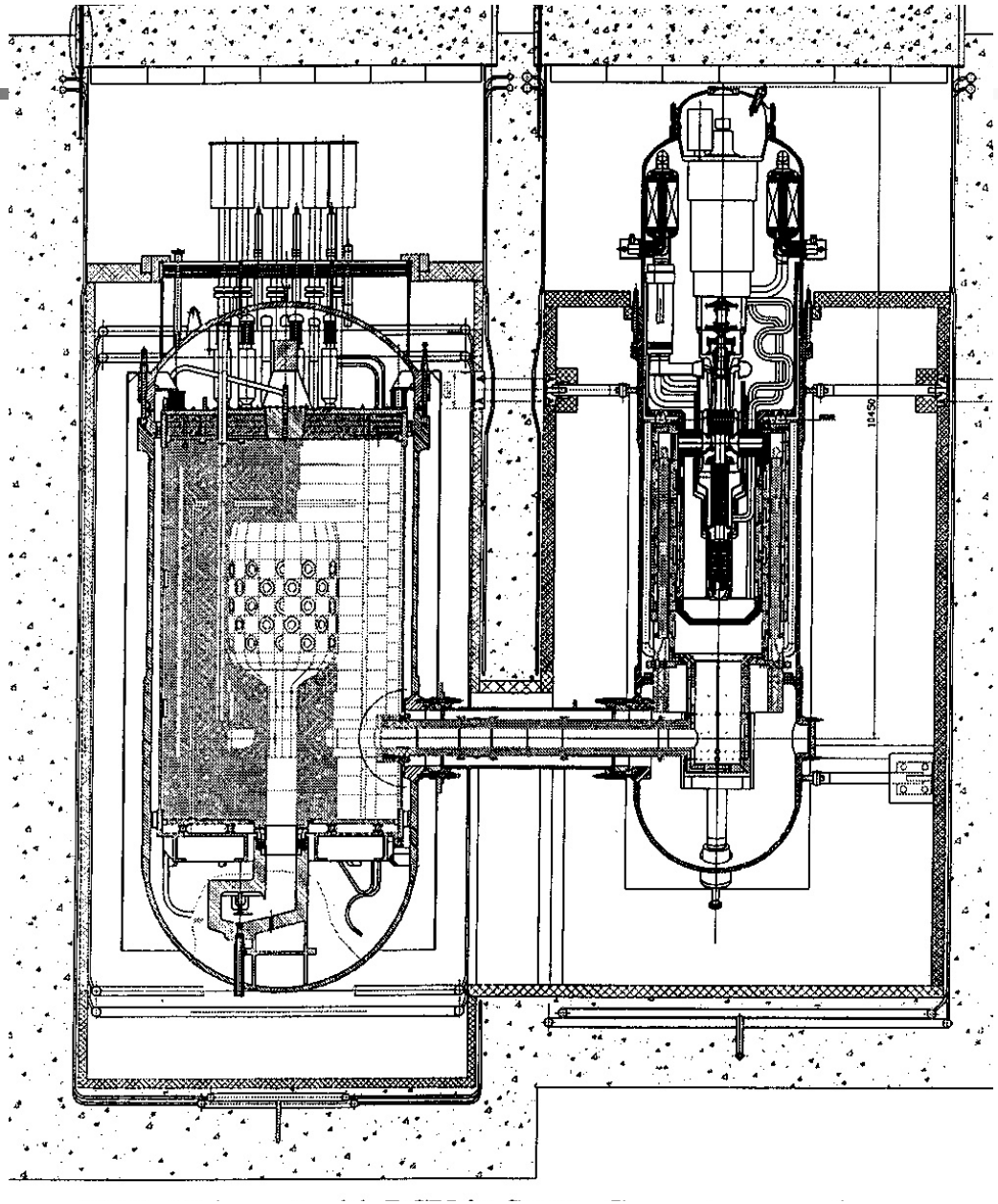
PEBBLE



INET

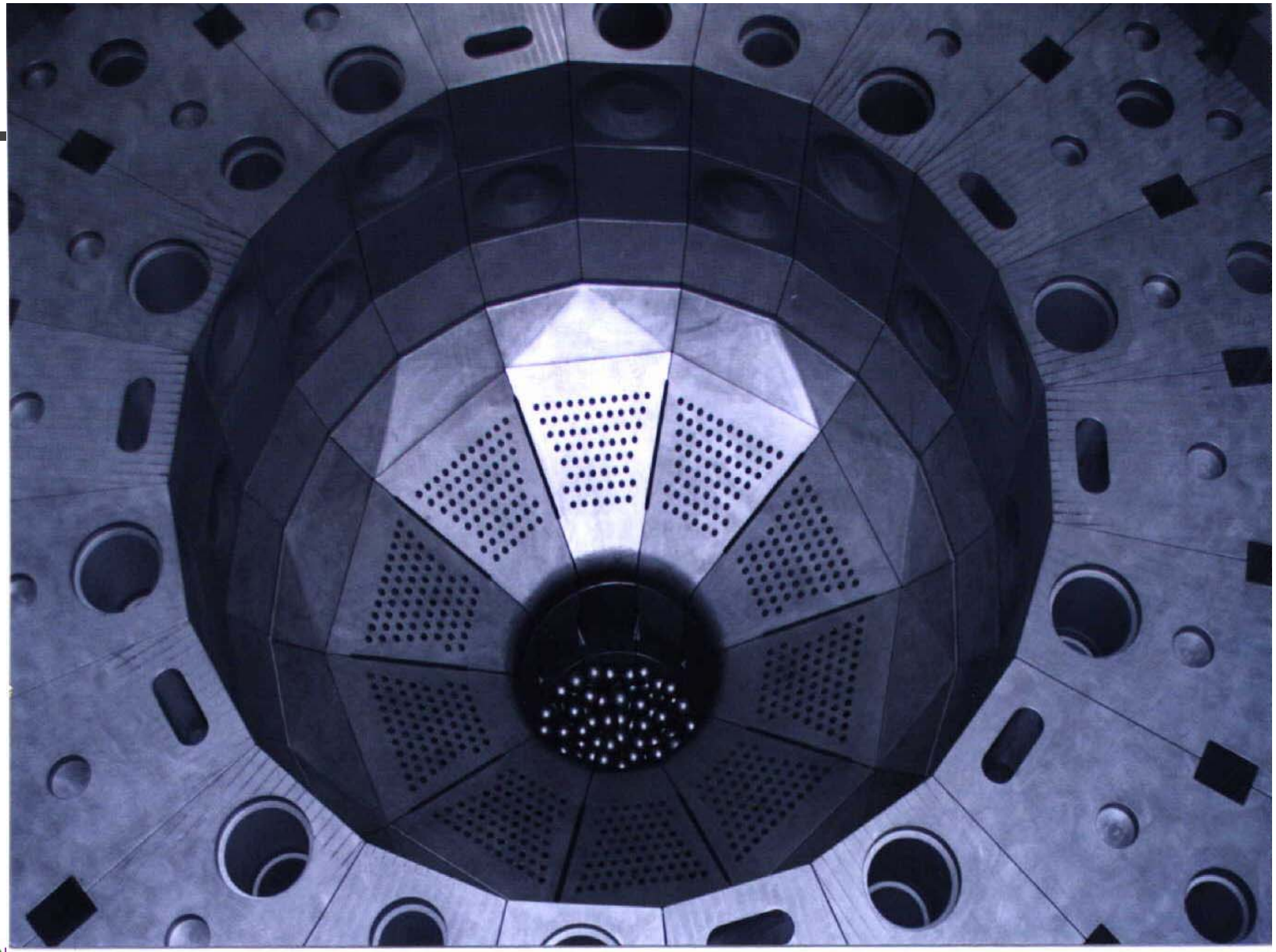
HTR-10

Cross Section



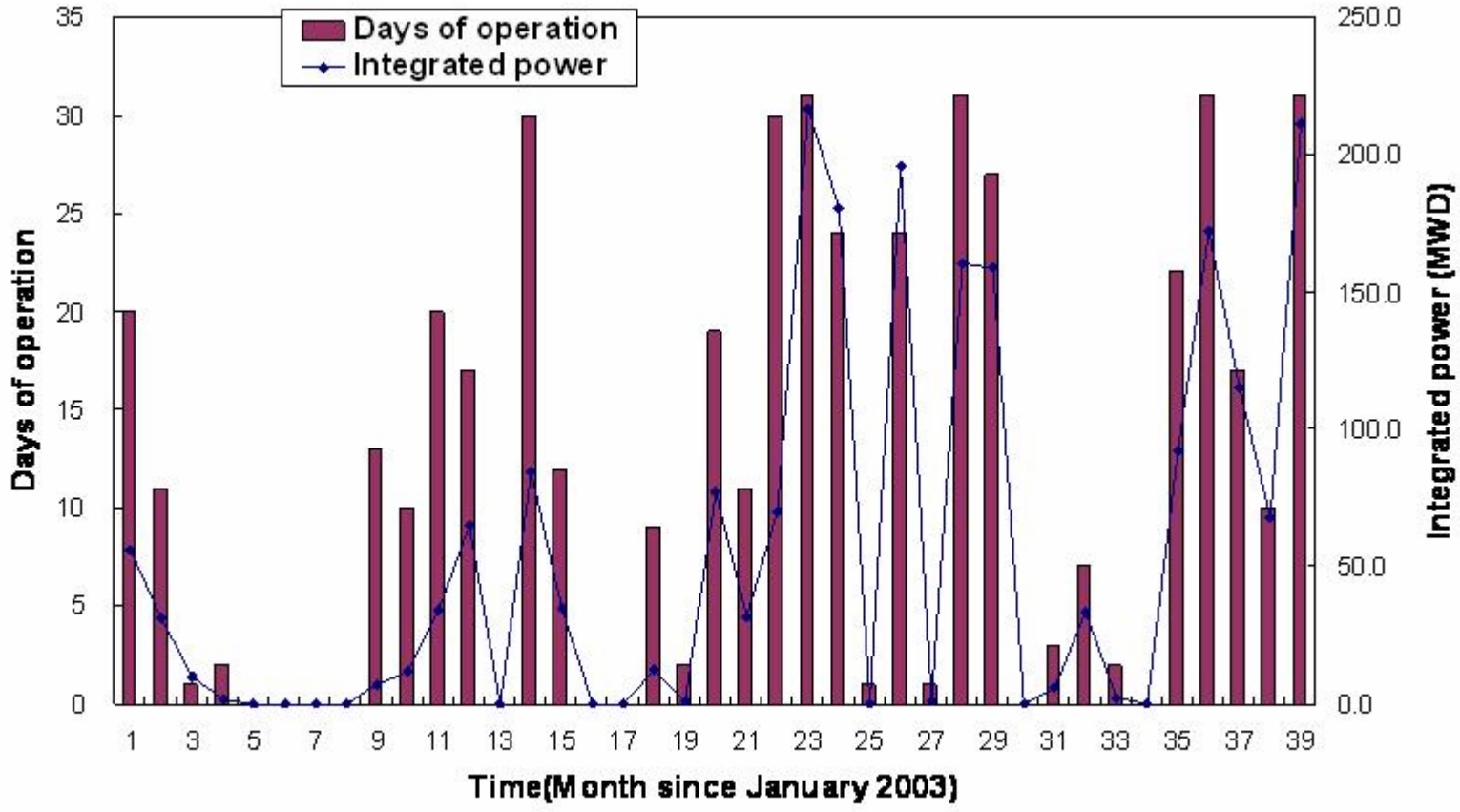
HTR-10

CORE



REACTOR BUILDING OF CHINA‘S HTR-10

Operation record of HTR-10 until April of 2006



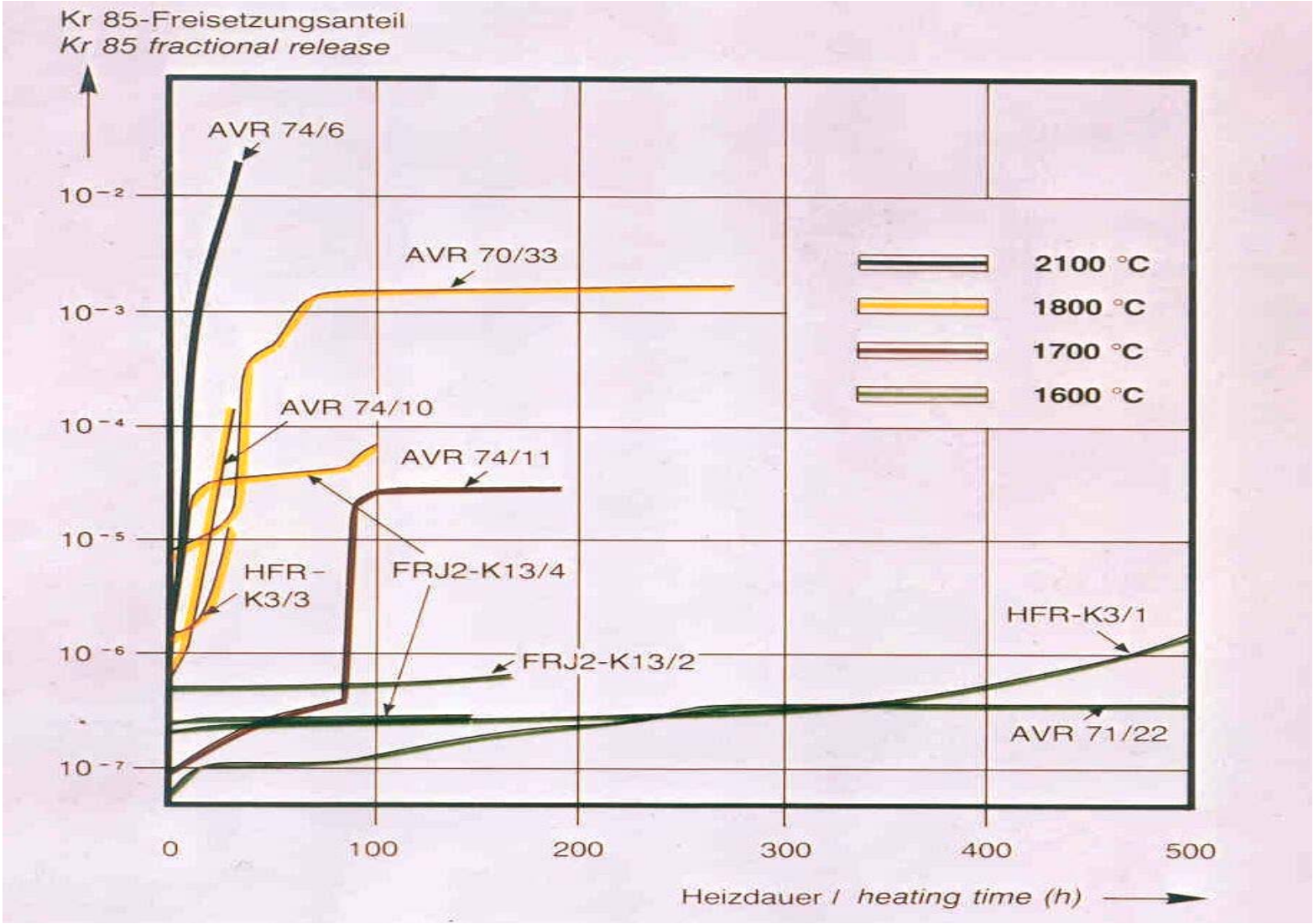
Pebble-bed Fuel Elements

60 mm diameter

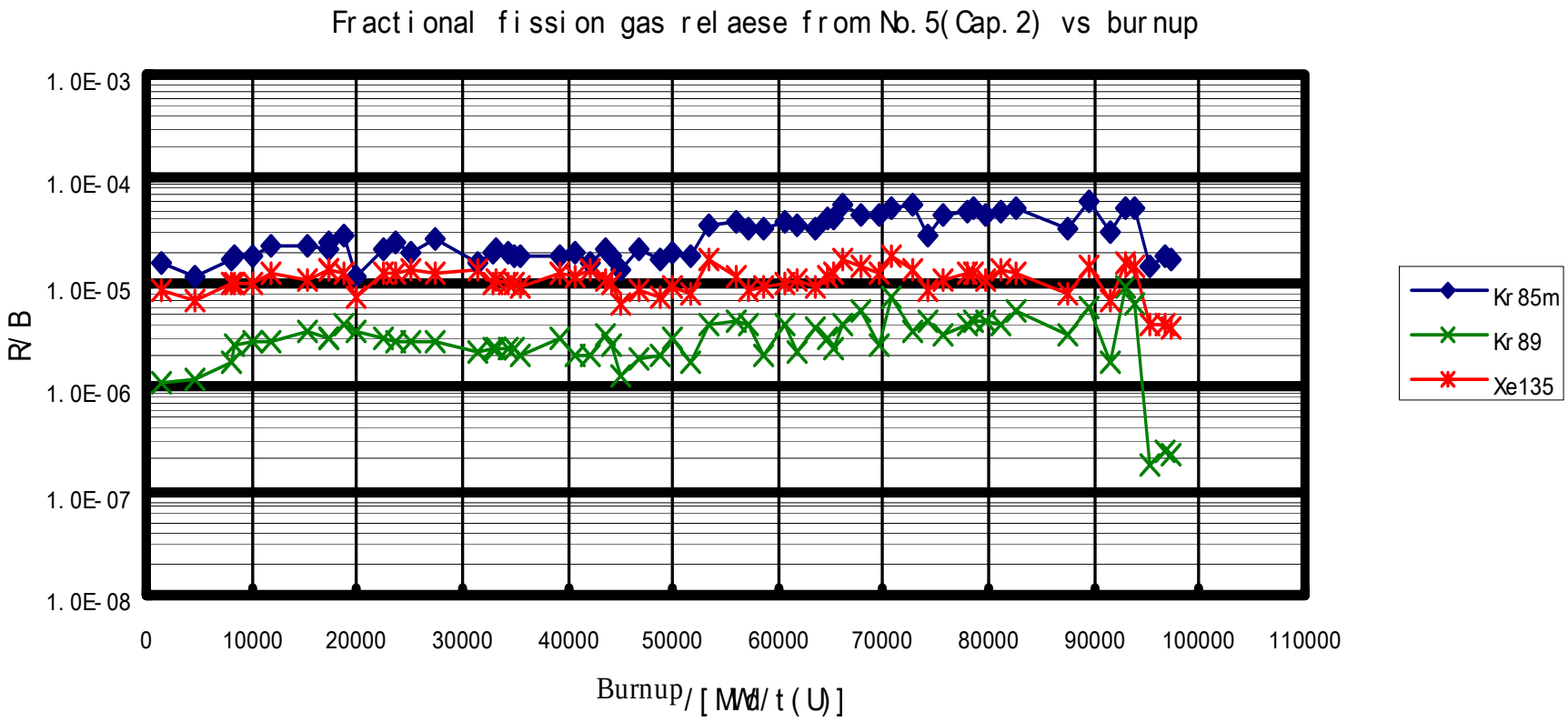
TRISO

1 mm

FRACTIONAL FISSION PRODUCT RELEASE Of COATED PARTICLES VS. TIME AND TEMPERATURE



R/B of Chinese Irradiation tests



The

"CHERNOBYL-EXPERIMENT"

of the

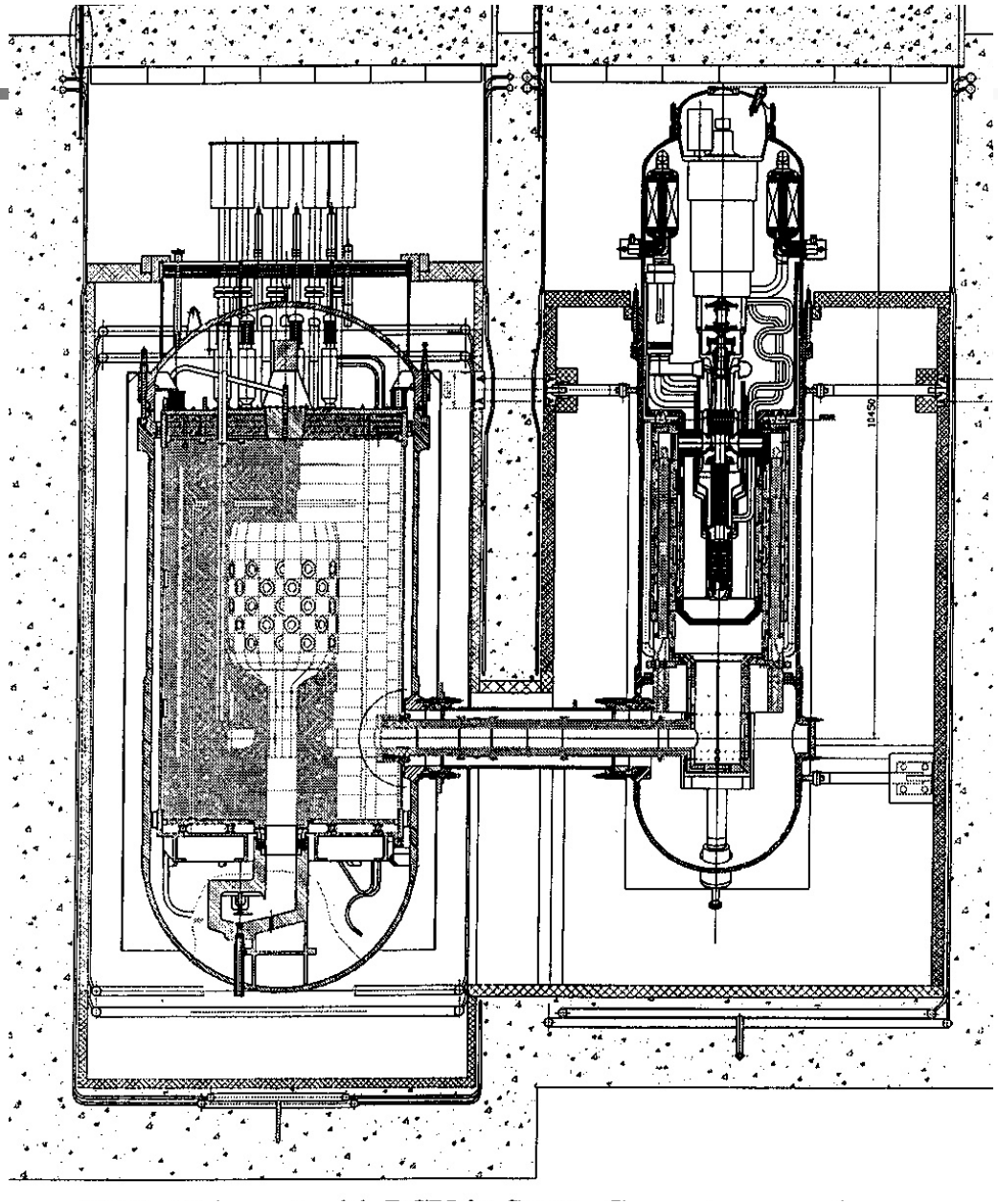
HTR-10

Outside Chernobyl Reactor after Accident

INET

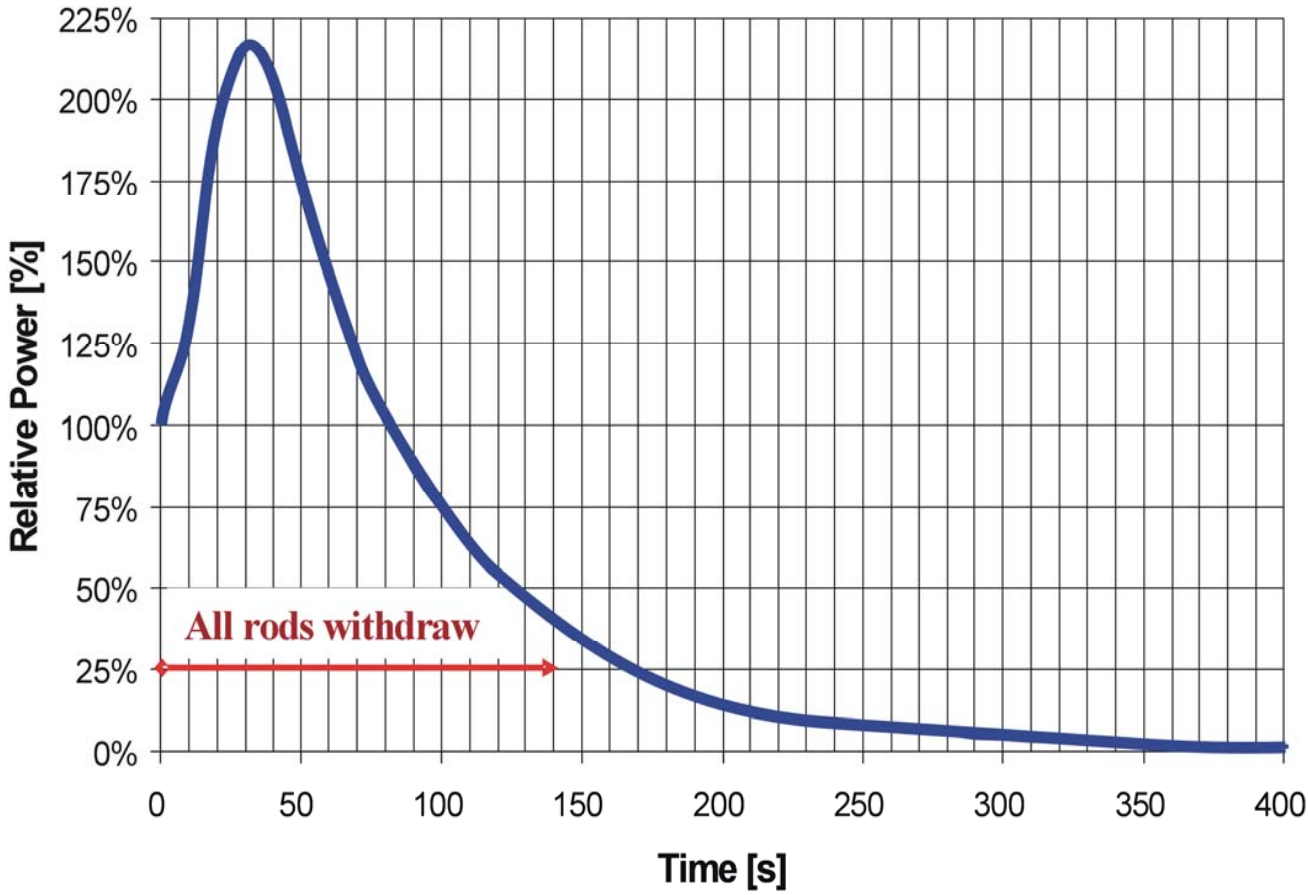
HTR-10

Cross Section

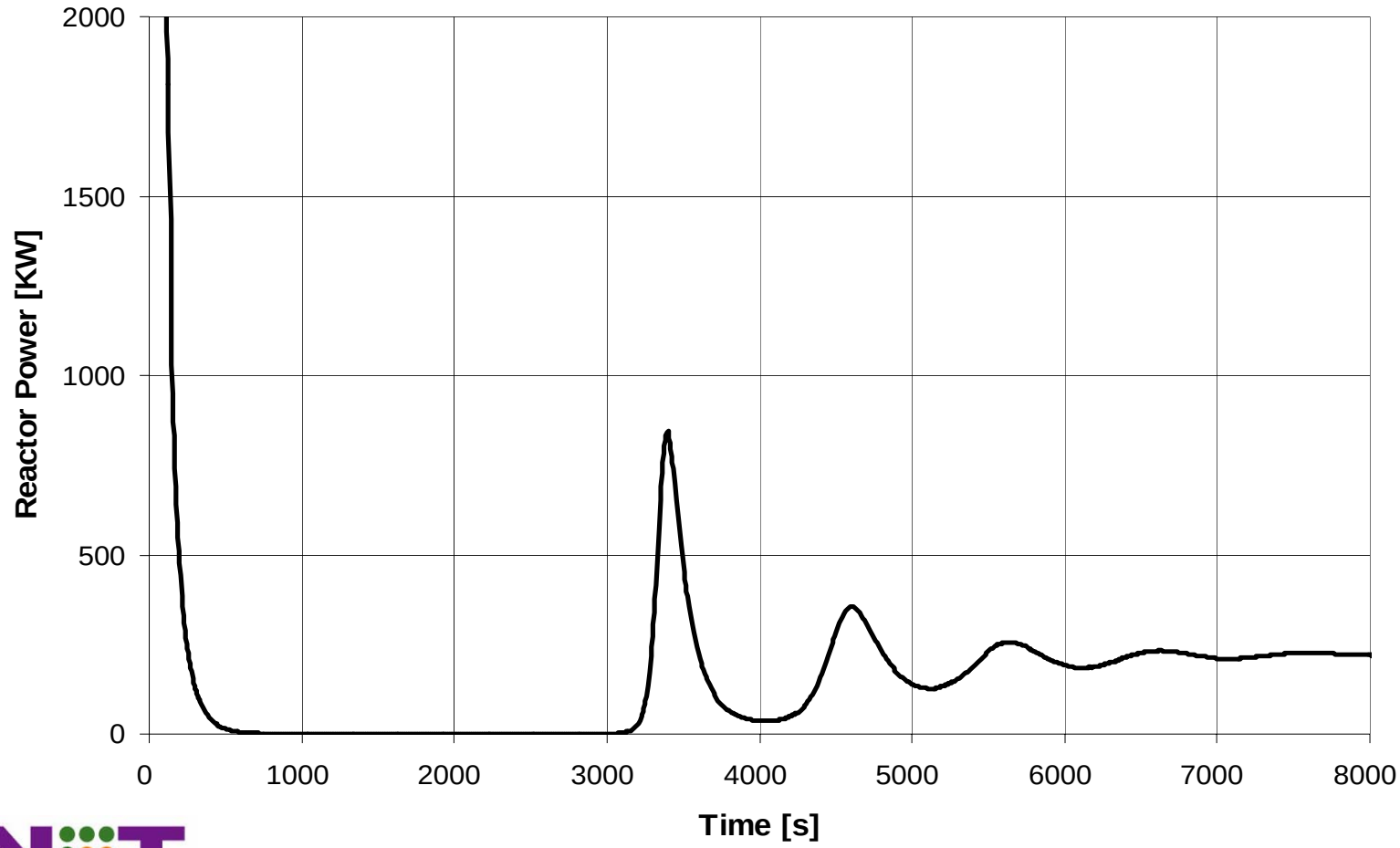


HTR-10: Reactor SCRAM without rods

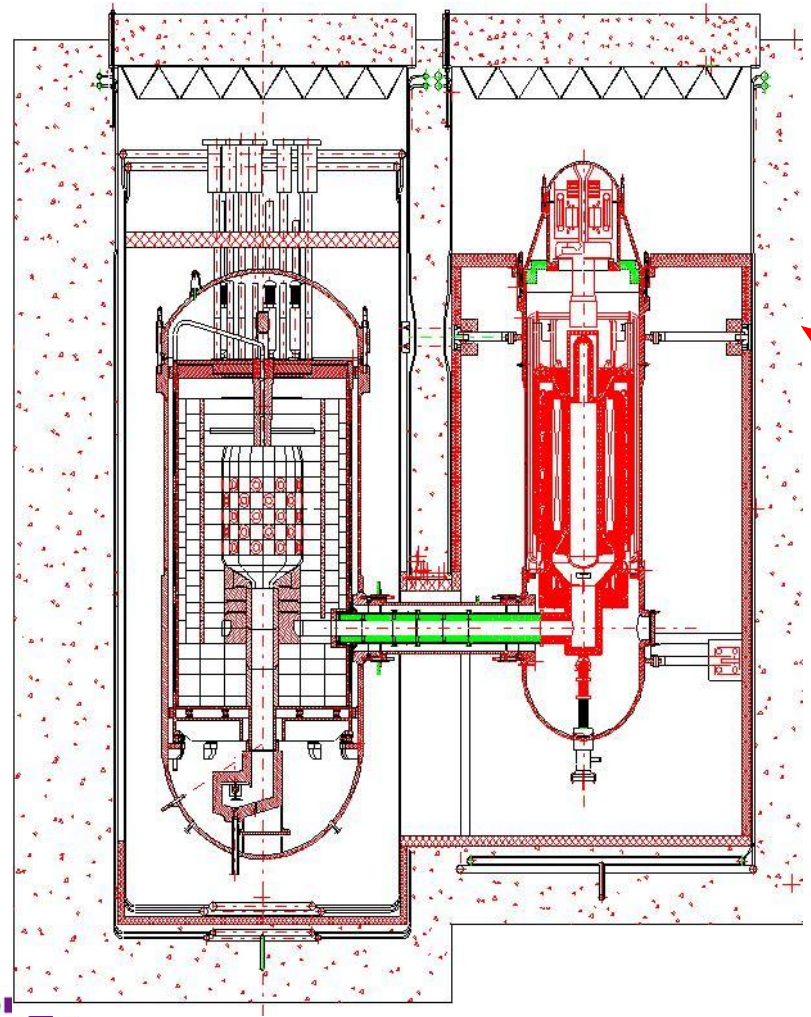
EXPERIMENT in 2004

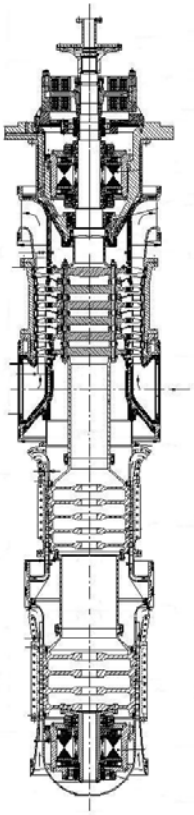


Recriticality of the HTR-10 EXPERIMENT



HTR-10GT: Gas Turbine for HTR-10





Helium Turbine-Compressor

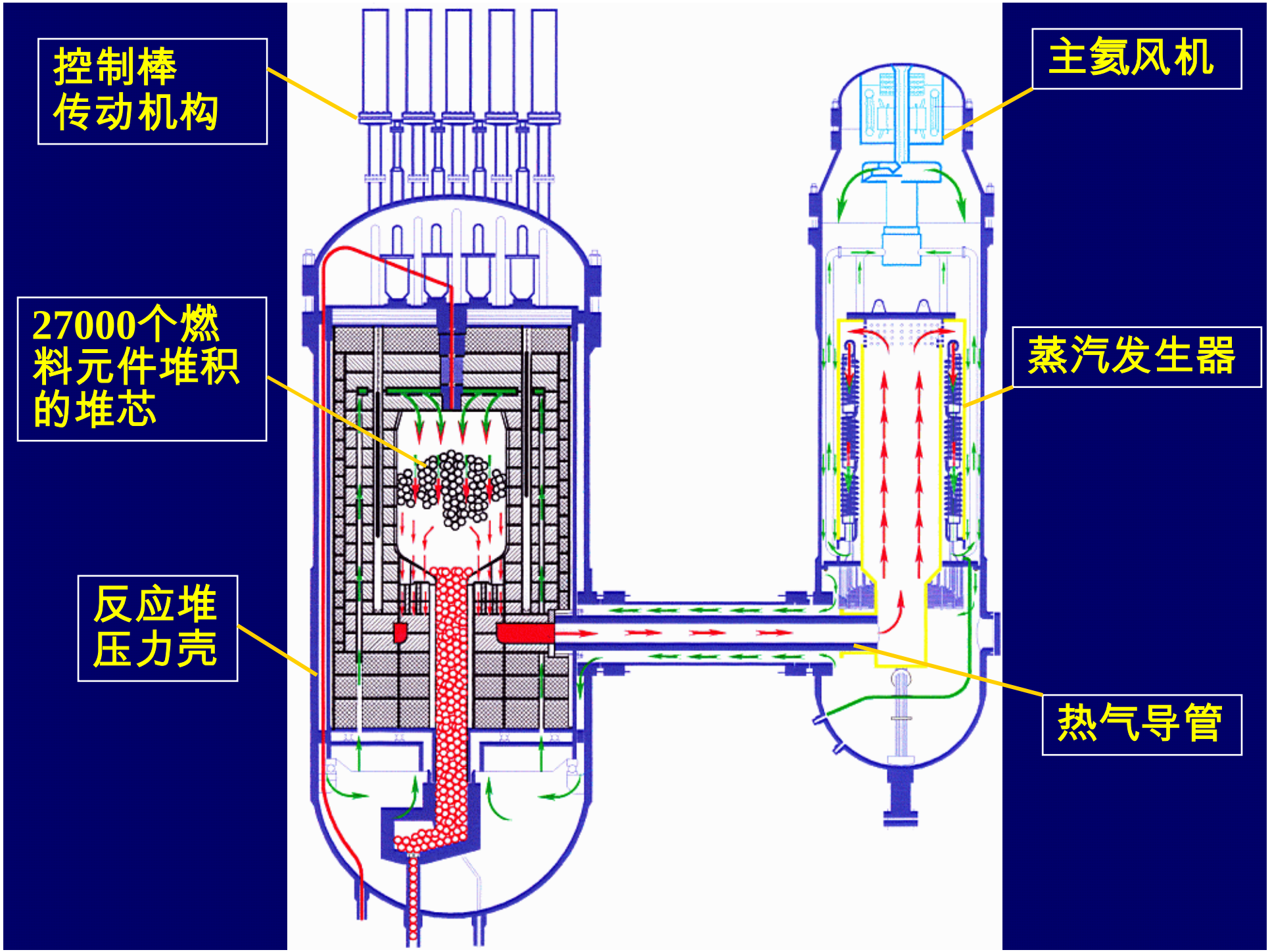
Helium compressor test

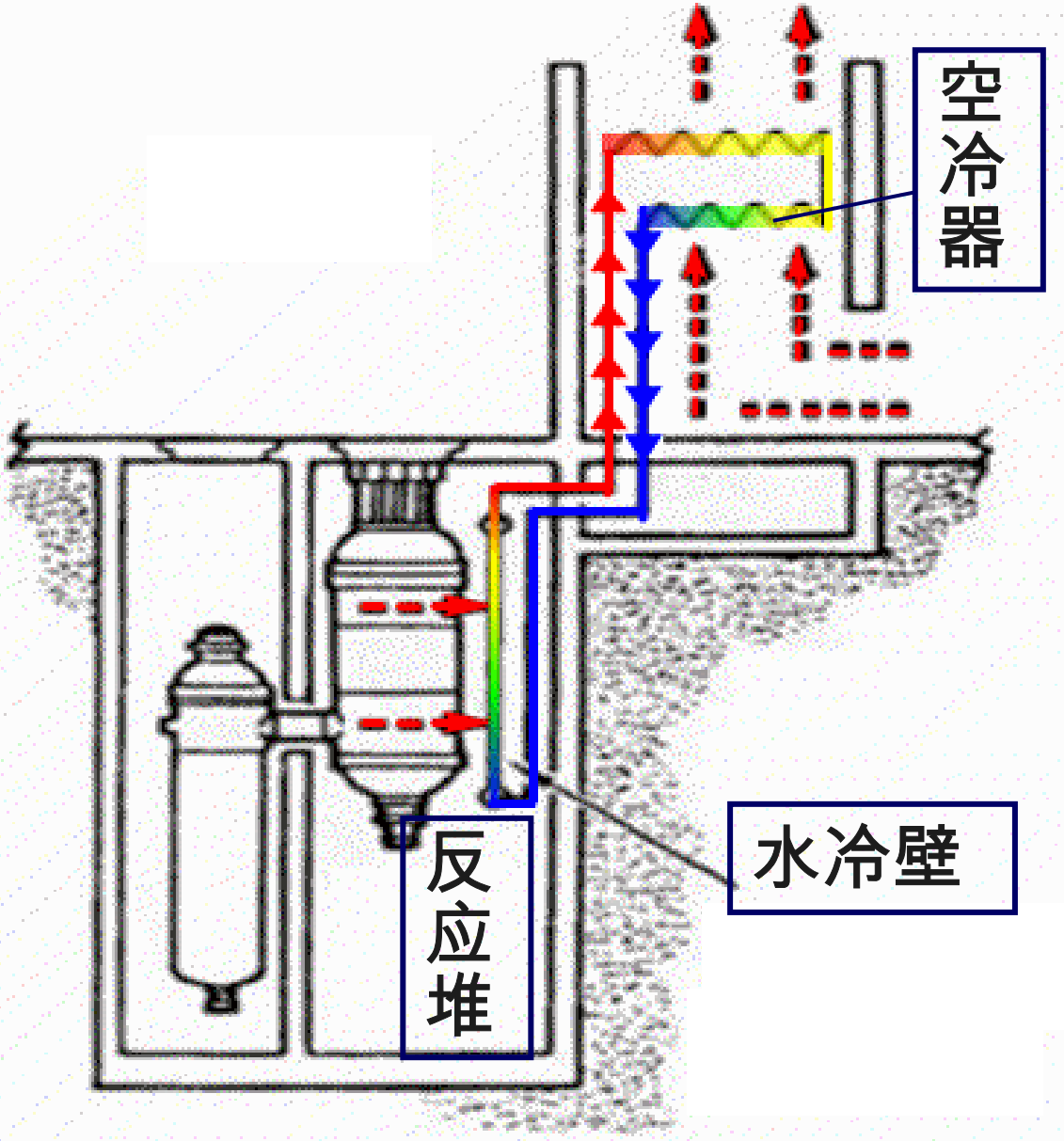
HTR-PM project

- ***A project to build a demonstration plant, High Temperature Reactor- Pebble-bed Module (HTR-PM), was proposed after the completion of HTR-10.***
- ***The role of high temperature gas-cooled reactor:***
  - ***a supplement to Light Water Reactors (LWR) of electricity generation;***
  - ***an energy source for process heat to produce hydrogen in the long run to relieve the demands on petroleum;***
  - ***an opportunity to develop advanced nuclear technology.***

Objectives

- ***Safety: The inherent safety of HTR technology should be maintained.***
- ***Economy: HTR-PM is expected to demonstrate the economic potential of the Nth-of-its-kind modular high temperature reactors.***
- ***Lower technological risks: Based on the prototype reactor of HTR-10, HTR-PM will adopt to the greatest extent of the international cooperation.***


控制棒
传动机构
27000个燃
料元件堆积
的堆芯
反应堆
压力壳
主氦风机
蒸汽发生器
热气导管



非能动余热排出系统

10 MW High Temperature Gas Cooled Reactor

国家重大科技专项

大型先进压水堆及高温气冷堆核电站示范工程

中国核工业集团公司

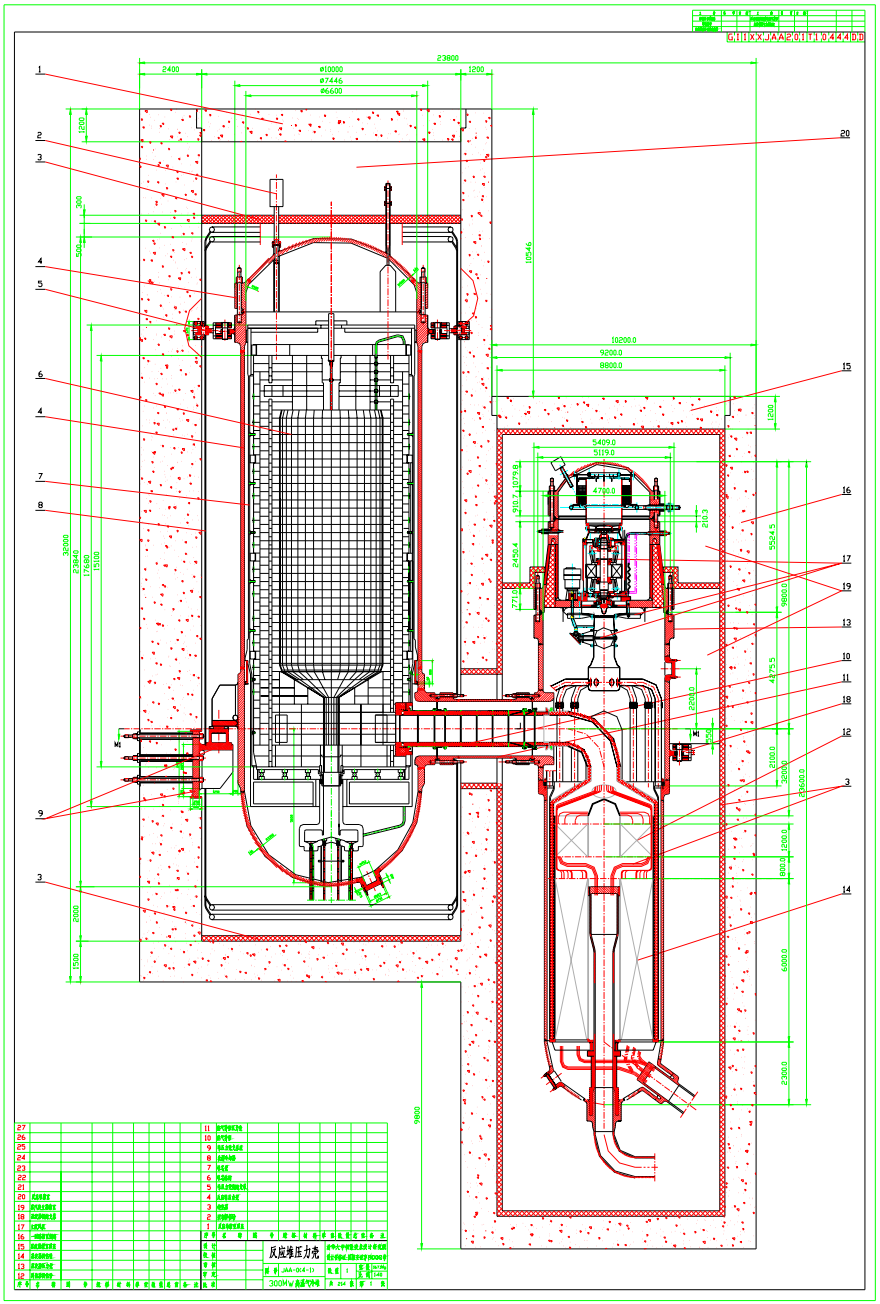
清　华　大　学

One of the Top 16 Government Projects

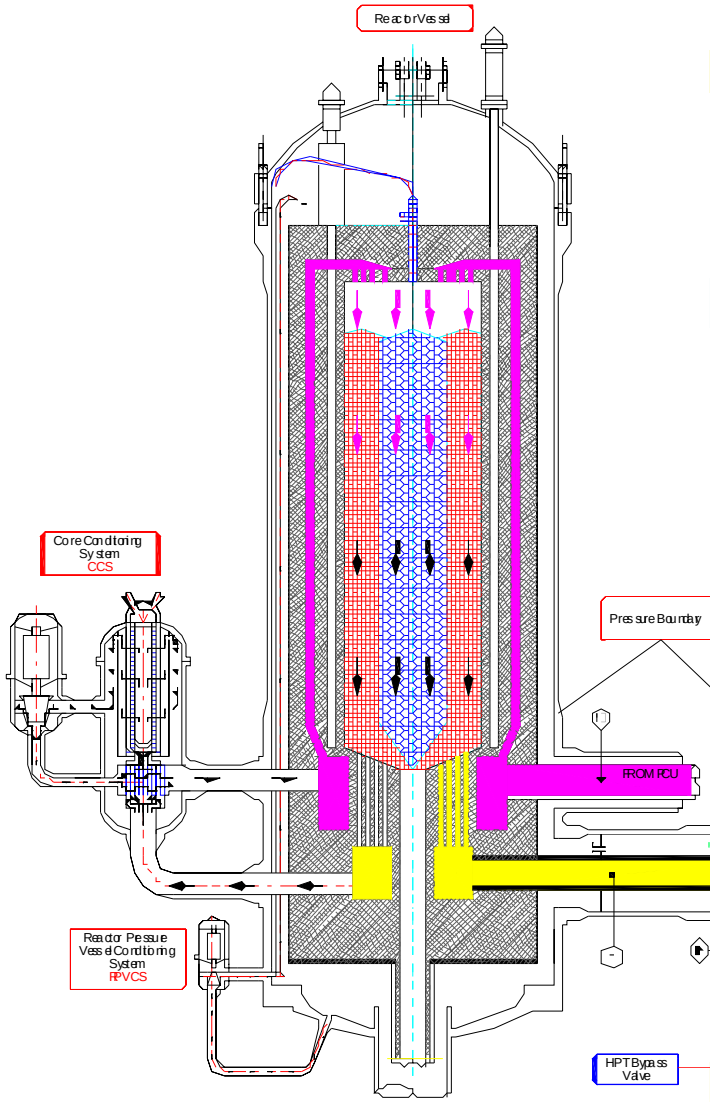
(2006-2020)

INET

early design of a modular HTR-PM



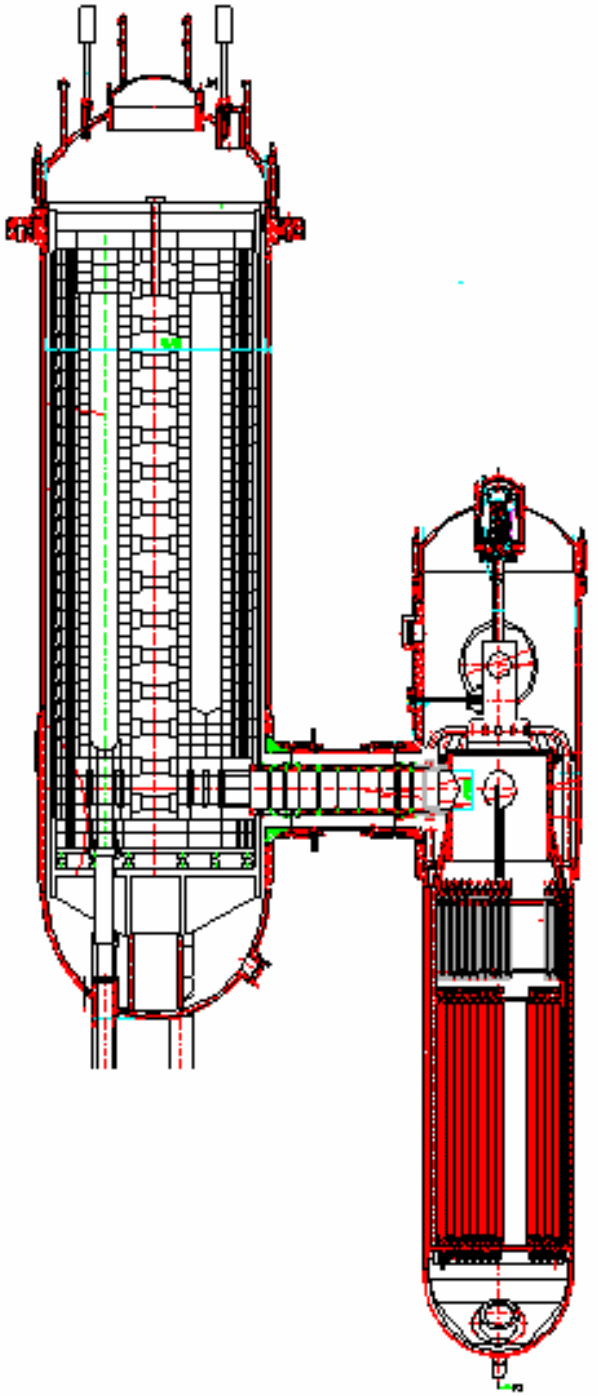
Movable Center Column (Example: PBMR)



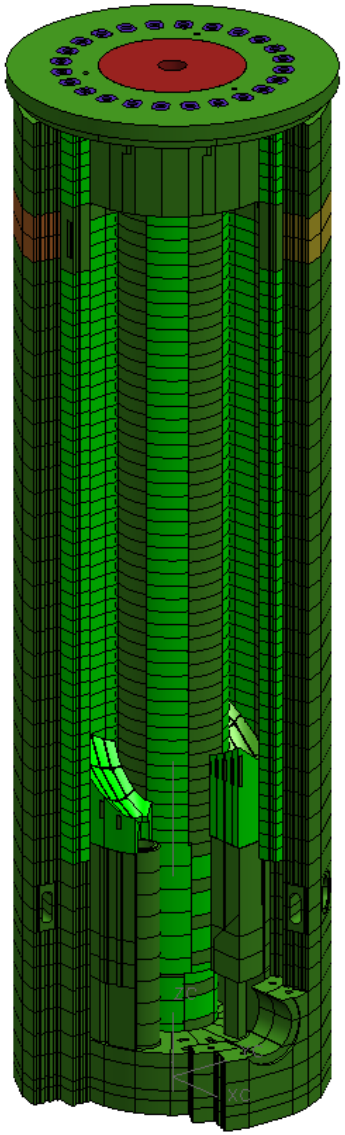
HTR-PM DESIGN VARIANT:

CENTRAL COLUMN;

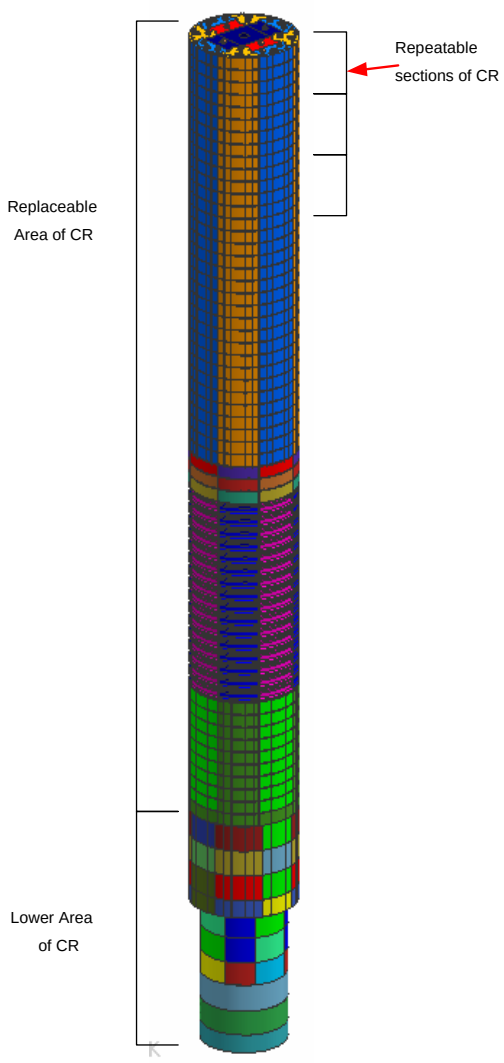
458 MW_{th}

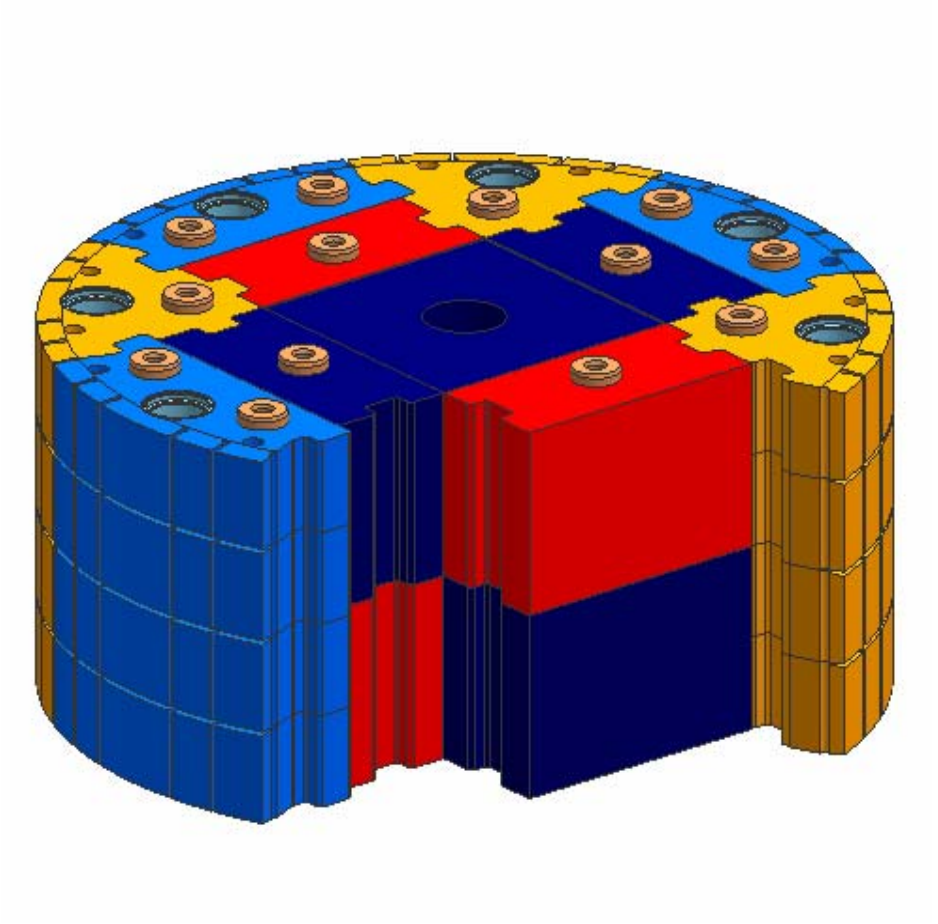


PBMR: modular HTR of 400 MW_{th} with solid center column

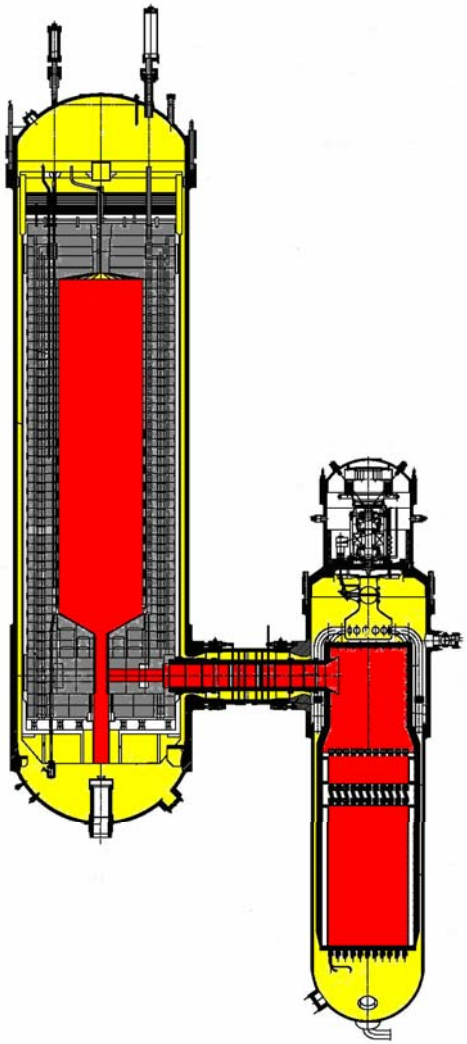


Centre Reflector Construction (PBMR)

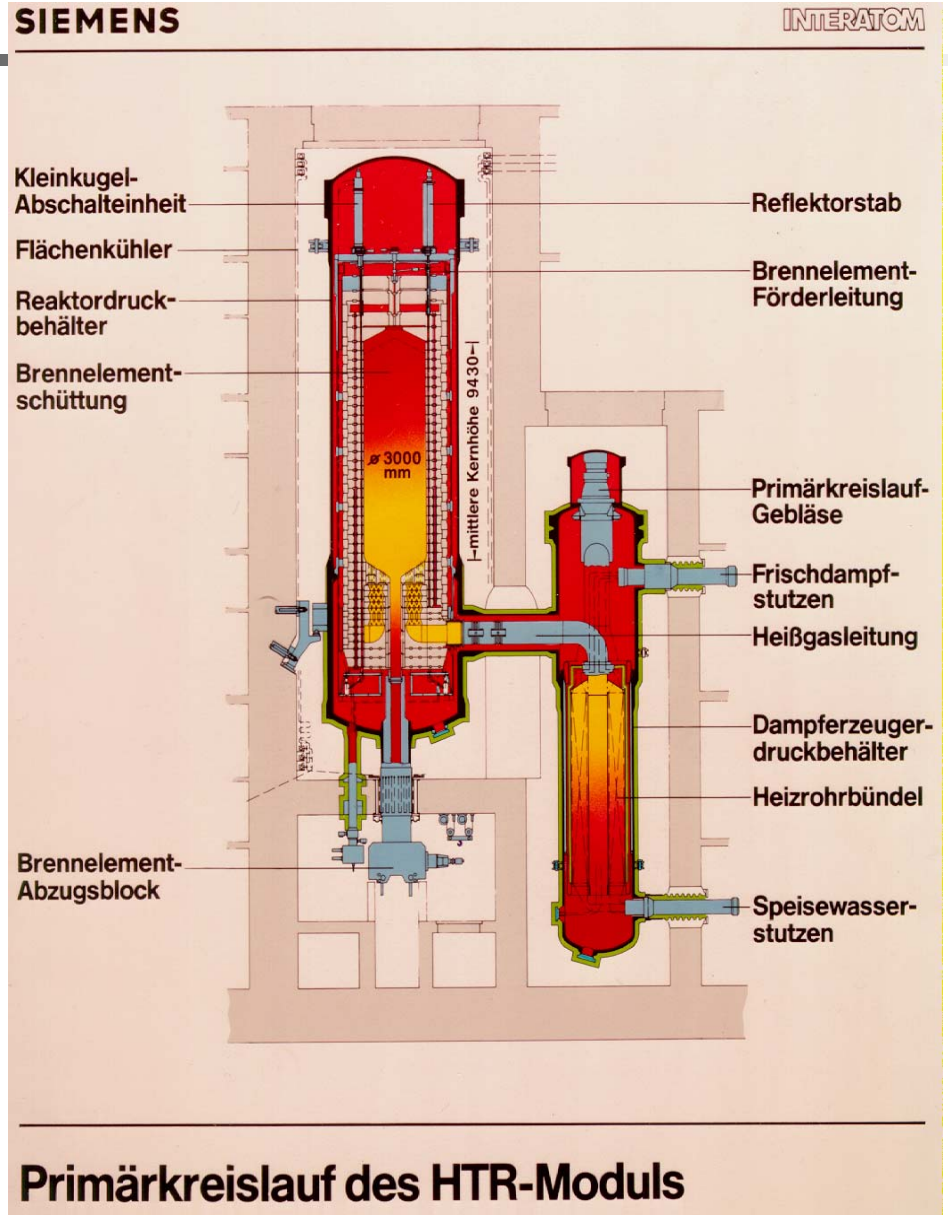




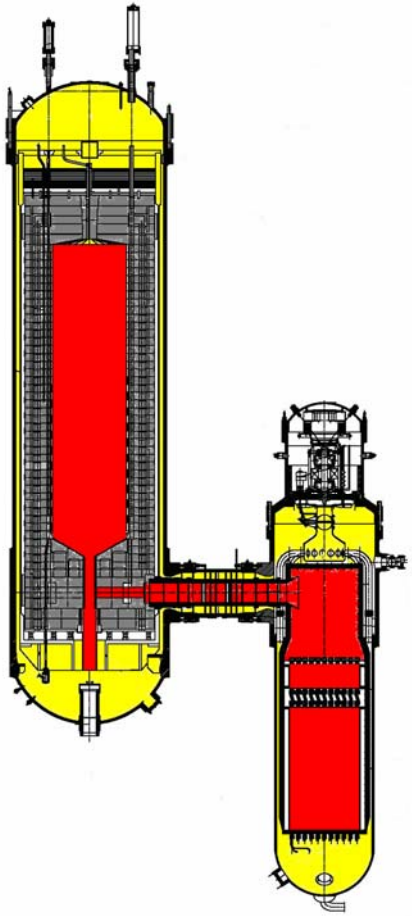
HTR-PM 250



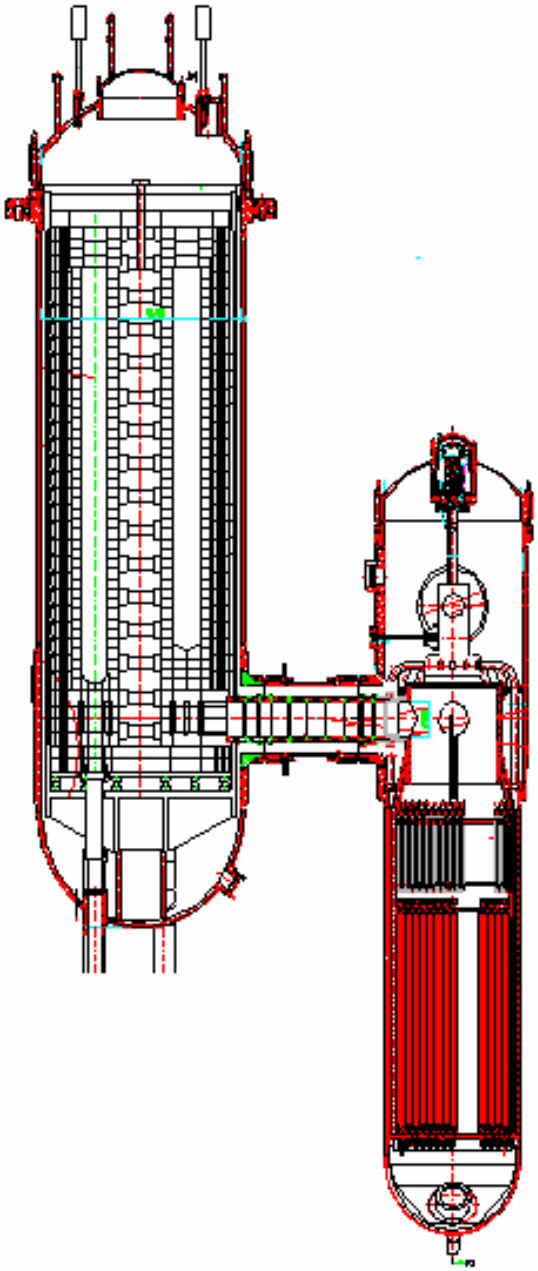
HTR-MODULE (CORE + STEAM GENERATOR)

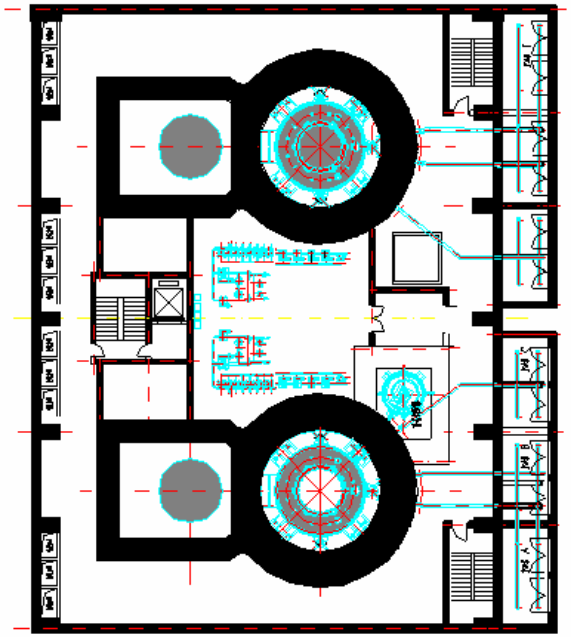


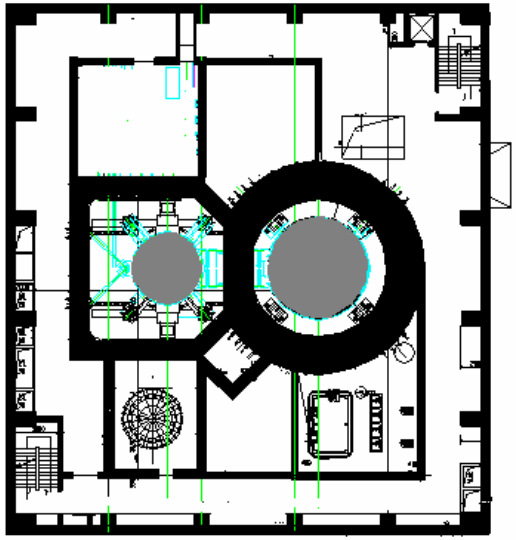
2 Modules - one zone



1 Module - two zone



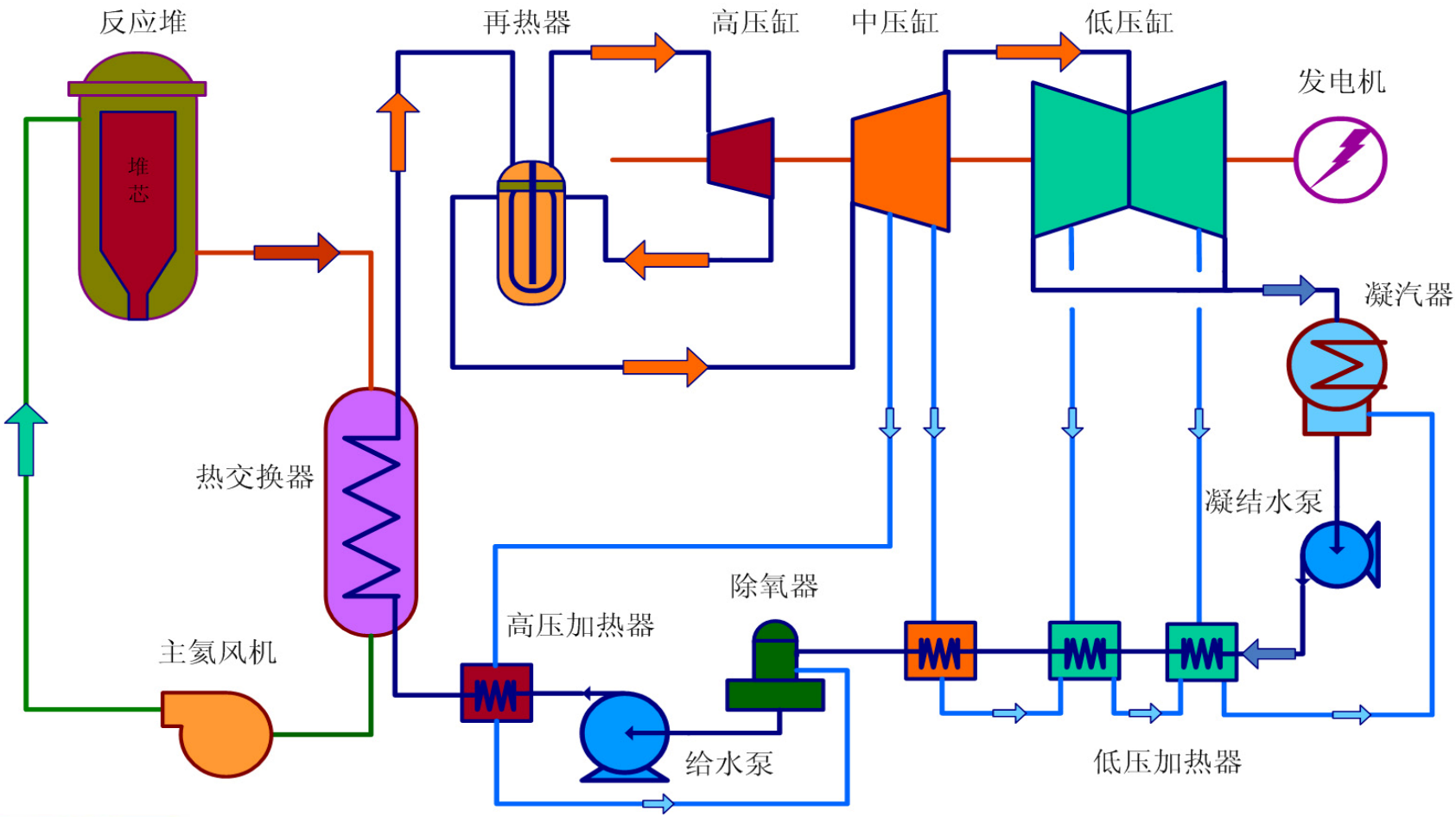




2 Modules - one zone

1 Module - two zone

堆外再热方案


反应堆
堆芯
再热器
高压缸
中压缸
低压缸
发电机
凝汽器
热交换器
凝结水泵
除氧器
高压加热器
主氦风机
给水泵
低压加热器

HTR-PM technical progress

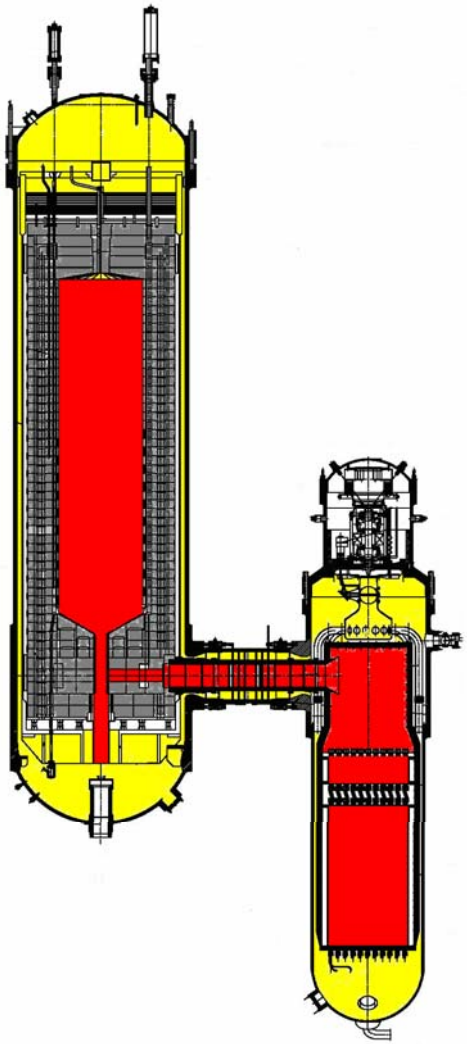
***2001-2003**: HTR-PM concept studies were conducted with the support from the State Power Corporation by INET and East China Power Design Institute (ECPDI). The steam turbine was selected.*

***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)*

***2006.08-2006.10**: We made a decision to change from 1×458 MWt to 2×250 MWt, maintain the plant output on 200 MWe.*

HTR-PM500

(2 x 250)



Reasons to change the design

- **Technical uncertainties for the annual core:**
  - **Dynamic annual core: reactivity control, helium outlet temperature, fuel flow demonstration, etc..**
  - **Solid annual core: graphite replacement, pressure drop, fuel flow at the bottom, etc..**
- **Cost analysis indicates the difference between specific capital costs of 1×458 MWt and 2×250 MWt are limited.**
- **It is estimated that the specific costs of a ready-to-build 2×250 MWth modular plant will be only 5% higher than the specific costs of one 458 MWth plant. When considering the technical uncertainties of the latter, a 2×250 MWth modular plant seems to be more attractive.**

Parameters of the two designs

	458 MW	2×250MW
NSSS Modules	1	2
Core thermal power, MW	458	500
Plant electrical power, MWe	190	200
Diameter of core inner reflector, M	2.2	0
Diameter of core outer reflector, M	4	3
Core height, M	11	11
Primary helium pressure, Mpa	9	7
Core outlet temperature, ℃	750	750
Core inlet temperature, ℃	250	250
Fuel enrichment, %	9.5	8.9

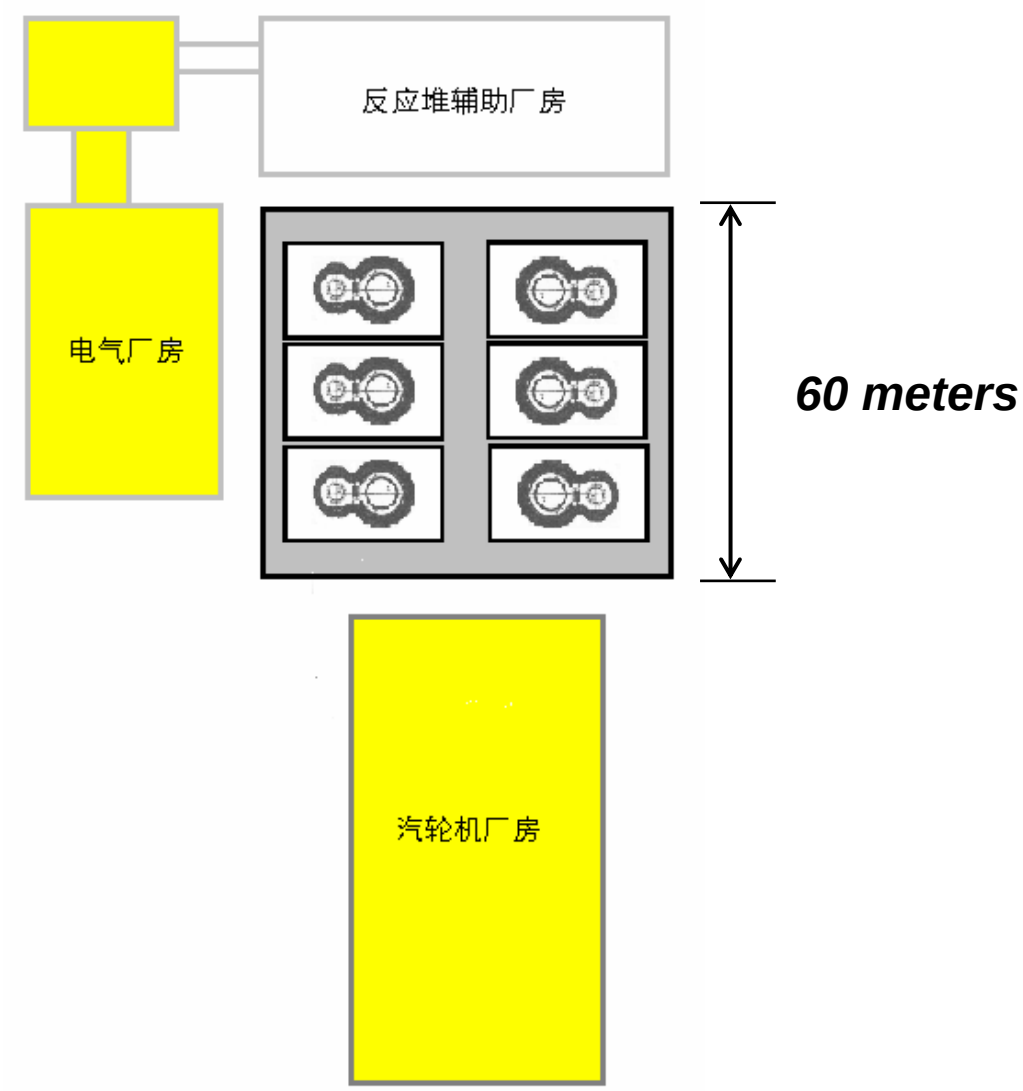
Cost comparison of the two designs

	458MW	2×250MW
RPV weight	1	2×0.57
Graphite weight	1	2×0.60
Metallic reactor internals weight	1	2×0.86
Blower power	1	2×0.57
Control rods	24	2×10
Small absorption sphere systems	8	2×20
Fuel discharging systems	3	2
Volume of the reactor plant building	1	0.96
Reactor protection systems	1	2
Main control room	1	1
Helium purification systems	2×100 %	2×100 %
Fresh fuel and spent fuel systems	1×100 %	1×100 %
Emergency electrical systems	2×100 %	2×100 %

Cost estimate of the two designs

It is estimated that the specific costs of a ready-to-build 2×250 MWth modular plant will be only 5% higher than the specific costs of one 458 MWth plant. When considering the technical uncertainties of the latter, a 2×250 MWth modular plant seems to be more attractive.

Multiple NSSS Modules HTR-PM Plant



Reference

+Model
NED 4805 1–10

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Economic potential of modular reactor nuclear power plants based on the Chinese HTR-PM project

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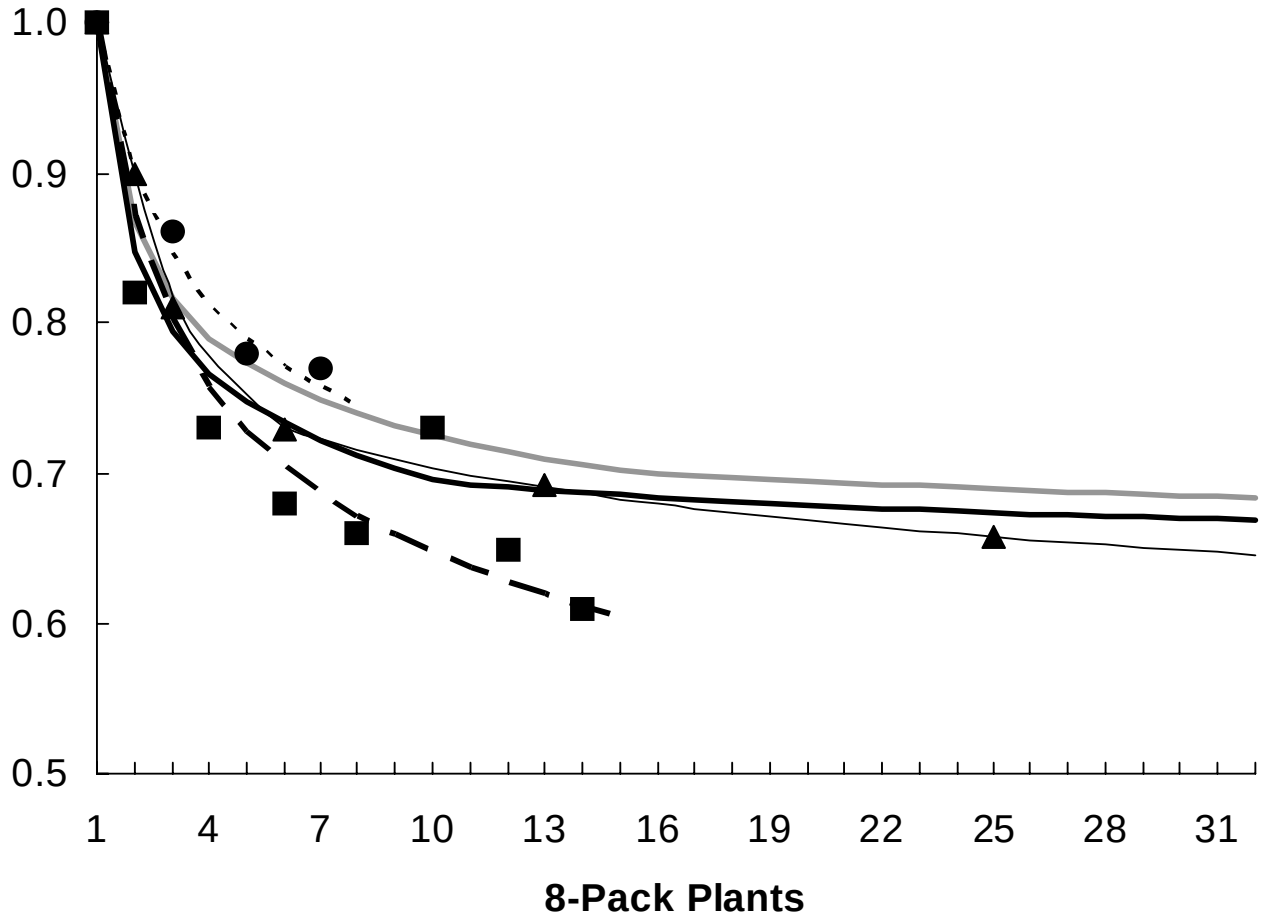
Received 5 March 2007; received in revised form 11 April 2007; accepted 11 April 2007

Abstract

INET

COST LEARNING CURVE for the HTR-PM 500



COST COMPARISON: PWR/HTR-PM (1000 MW_{el})

Reactor plant equipments

Turbine plant equipments

BOP

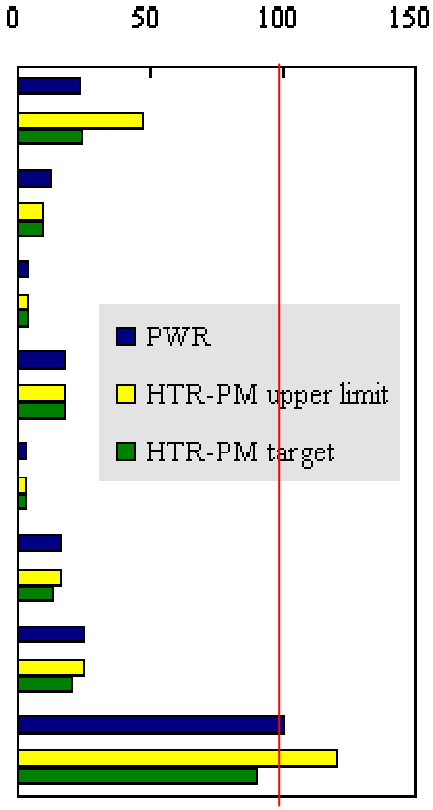
Buildings and structures, construction and commissioning

First load fuel

Engineering and design, project management, owner's cost

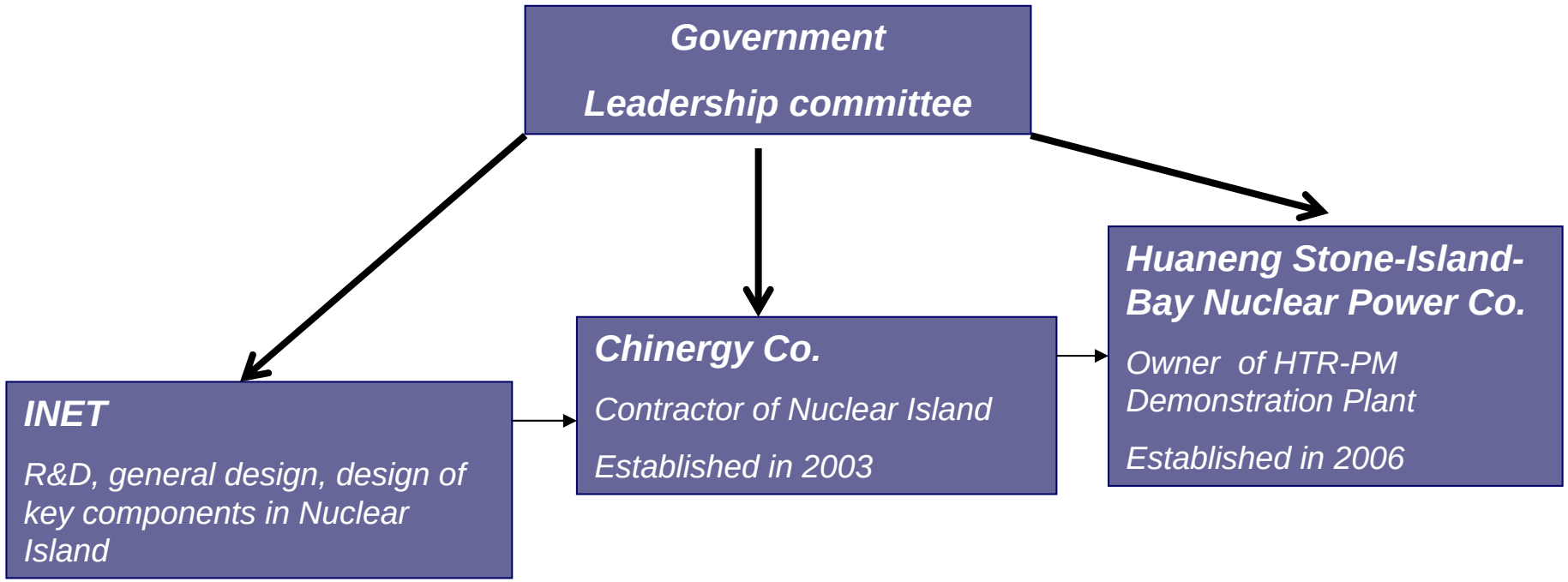
Financial cost, tax, insurances, contingencies

Sum of total plant costs



Signing-ceremony of the contract: December 25, 2006

Project organization



Site Preparation

Schedule

- *2007: preliminary design of HTR-PM, submit of PSAR, site work, …;*
- *2008-2009: CP from NNSA, pouring first concrete;*
- *2013: finish the project.*

R&D program

1, Key technology (before 2009):

Key technology in reactor physics: safety goal, accident analysis, PSA, afterheat removal, water and air ingress, fission product, simulator;

Key technology in main components: Fuel handling, Steam generator, Control rods, Second shutdown system, Helium purification;

Fuel: 5g to 7g, production line;

2, Component demonstration test (before 2012):

Helium test facility, Fuel handling system, Steam generator, Control rods,

Second shutdown system, Helium purification;

HTR-10 operation;

Afterheat removal, water and air ingress, fission product;

3, Future development (before 2020):

VHTR, hydrogen, gas turbine and super-critical power cycle, spent fuel.

Fuel

- ***Modifying INET production line to a pilot production line;***
- ***Producing fuel for first core and irradiation using INET pilot line;***
- ***Copying several pilot lines to produce refueling fuel for demonstration plant;***
- ***Future production base.***

HTR-10 experience feedback

- ***Experience feedback to the HTR-PM design***
- ***Test of the technology to be used in HTR-PM: like magnetic bearing helium blower***
- ***HTR-10GT: gas turbine (one shaft, magnetic bearing, indirect cycle)***

Step by step approach

1) 2 reactor modules + 1 steam turbine: focus is on the the reactor technology from 10 MW to 250 MW;

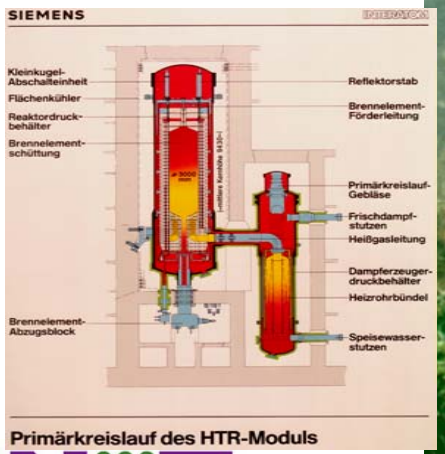
2) 6-10 reactor modules + 1 steam turbine (600-1000 MWe): achieve the economy goal preliminary;

3) Super critical steam turbine, helium gas turbine, hydrogen production: achieve the economy advantages.

10MW High Temperature Reactor

INET, Tsinghua University, 2000

HTR-MODULE (CORE + STEAM GENERATOR)



示范电站厂址

谢 谢 ！

INNOT