Hotlab-NPIC

Activities and status of PIE for nuclear fuel in NPIC

Feng Mingquan
Li Guoyun

Reactor Operation & Application Sub-institute
Nuclear Power Institute of China (NPIC)

May. 2011

Contents

Introduction

❖ Purpose of Irradiation Tests:

Qualification of design and manufacture technology for new fuel assembly;

Demonstration of the properties (such as deformation, corrosion, swelling etc.) for fuel and materials during operation conditions until design life time;

Permission for get from National Nuclear Safety Authority.

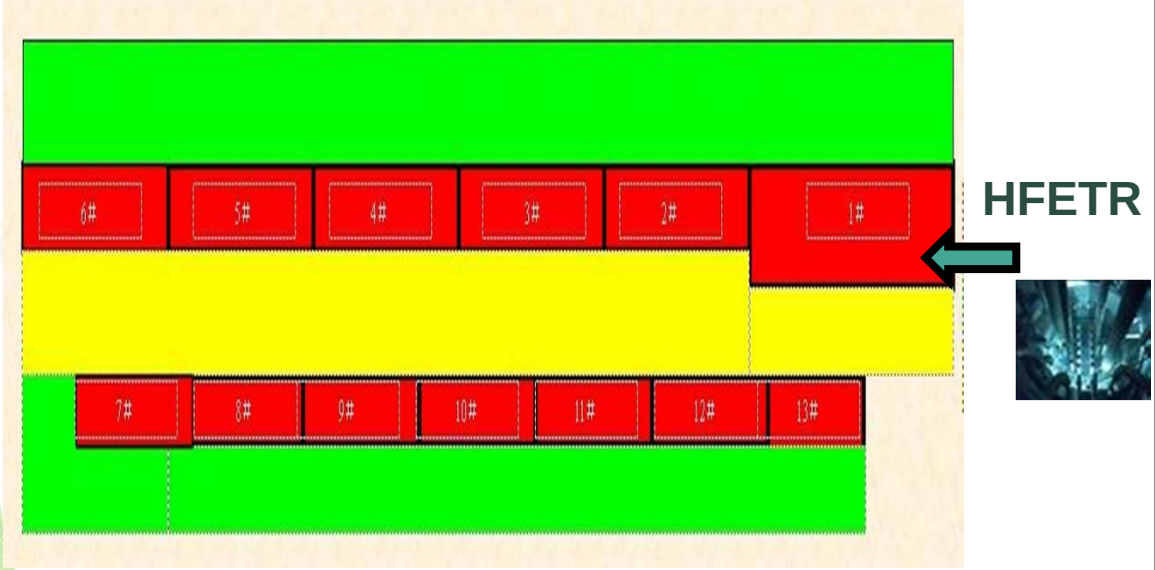
Introduction

- NPIC Hot Laboratory has been operated since 1980,and used to PIE on fuels and materials mainly irradiated in HFETR.
- 20 hot cells and 15 semi-hot cells as three lines located in HFETR main building (total construction area around 5000m^2).

Introduction

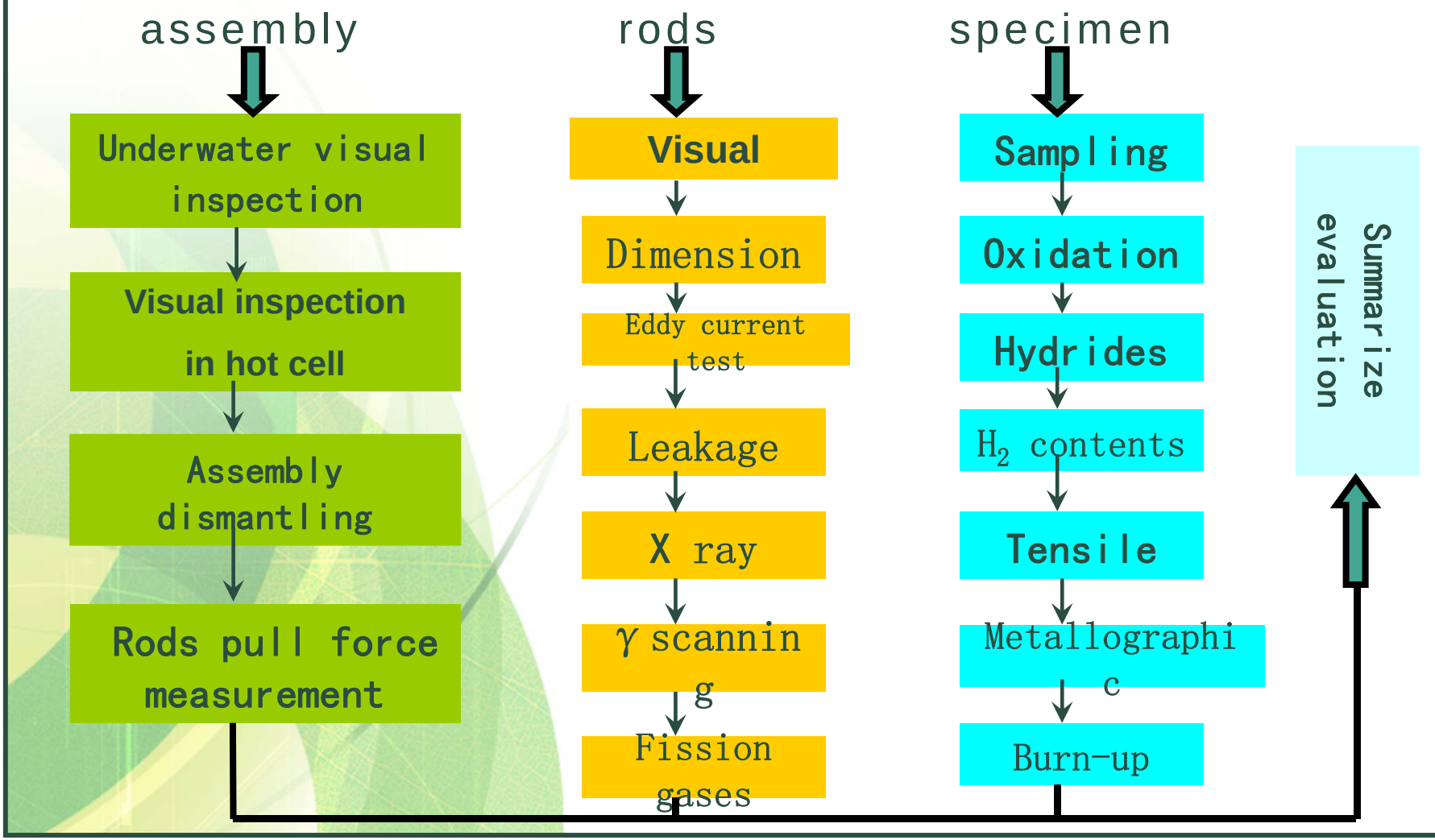
- The dismantling and cutting hot cell connects with HFETR spent fuel pool through 8 meters deep underwater transportation channel.

Irradiated fuel and specimen can be transported to the north or south line hot cells on the **second floor** and semi-hot cells on the **first floor** through transfer hall on the three floor.



hot cells on the 2nd floor

Post Irradiation Examination



North Line Hot Cells for PIE:

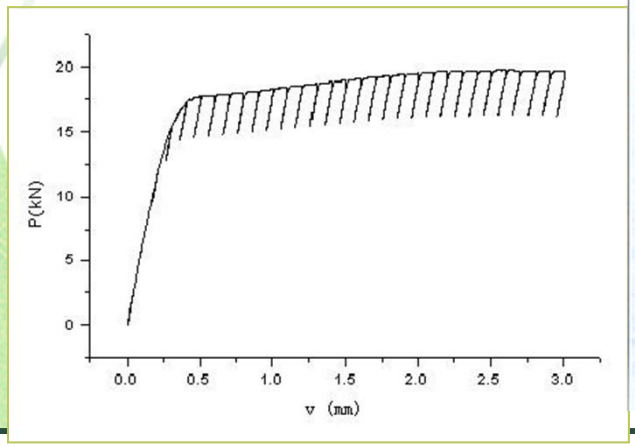
- Dismantle and cut
- Non-destructive test:
- Visual
- Dimension
- Eddy current
- Leakage
- γ Scanning
- Fission gases
- Density

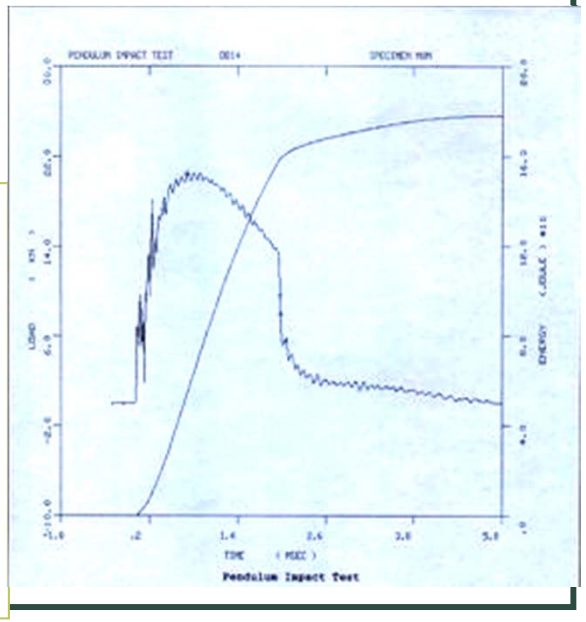
South Line Hot Cells for PIE:

- **Sampling (grinding, polish etc.)**
- **Metallographic**
- **Blister test**

Materials Test line Hot Cells for PIE

- Burst
- Tensile
- Charpy-V(RPV)
- Toughness (RPV)





Semi-Hot Cells for PIE

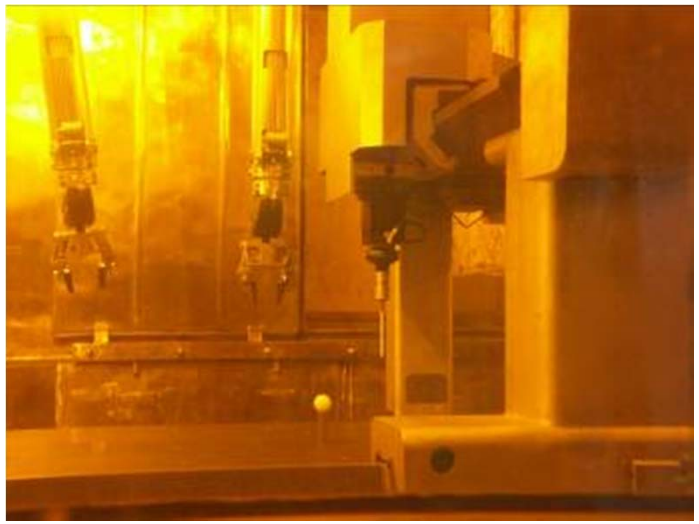
- Radiochemistry analysis
- Water condition control and analysis
- Crude depositing composition analysis
- H_2 contents measurement
- SEM analysis
- Burn-up determination
- X-ray radiography

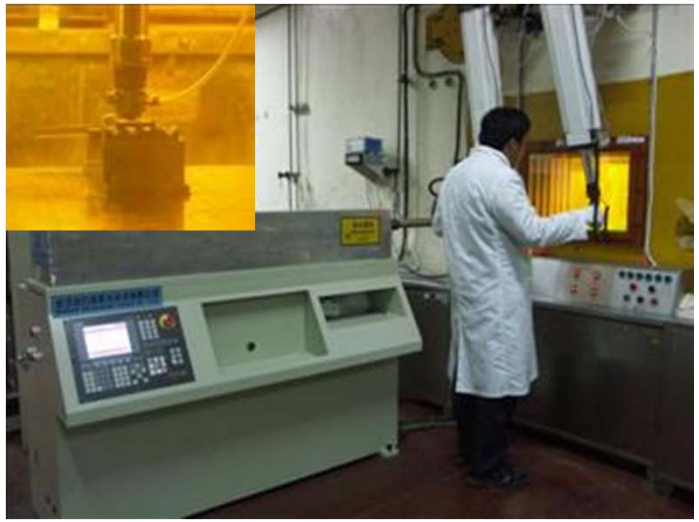
Pool Side Inspection in HFETR

- Underwater visual inspection
- Disassembly for irradiated sub-assembly
- Rod extraction
- Kr-85 leakage detection
- Dimension measurement
- Eddy current test

Renew of PIE Facilities

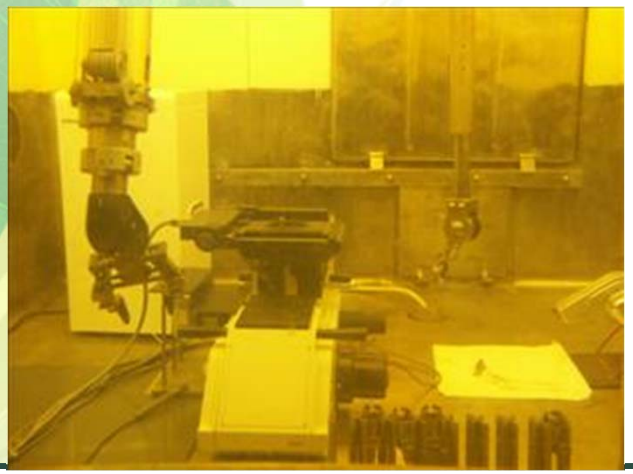
- Anti-irradiation macro camera system（Rees R93/R981）;
- 3 dimensional measurement computer system;
- Laser cutting system;
- Deferential scanning calorimeter (NETSCH DSC404C)

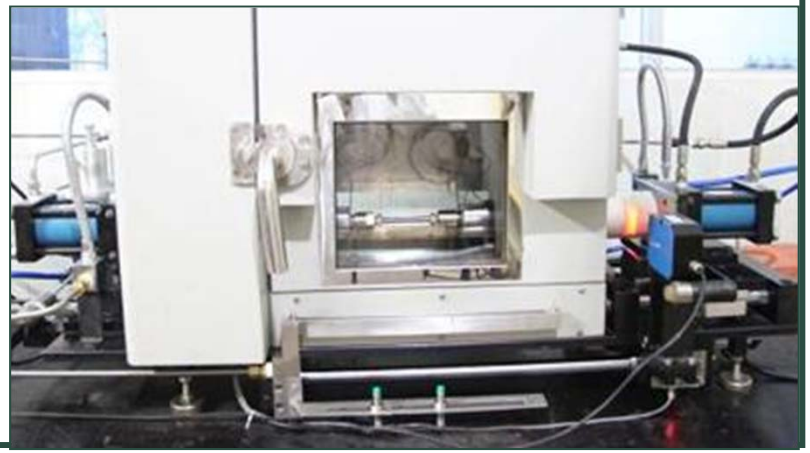




Renew of PIE Facilities

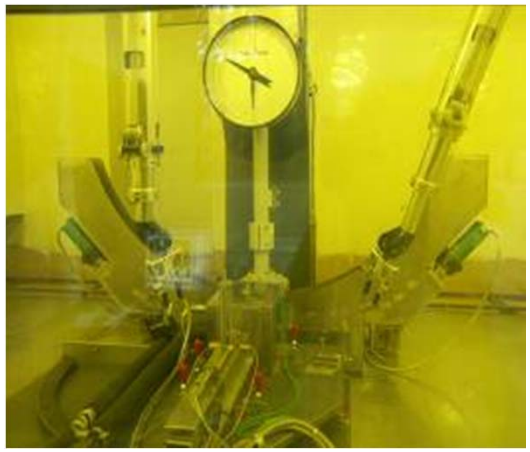
- Blister test system for dispersion fuel tubes ;
- Burst test for high temperature;
- Auto grinding polisher;
- Digital metallographic microscope（LeikaMEF4A）

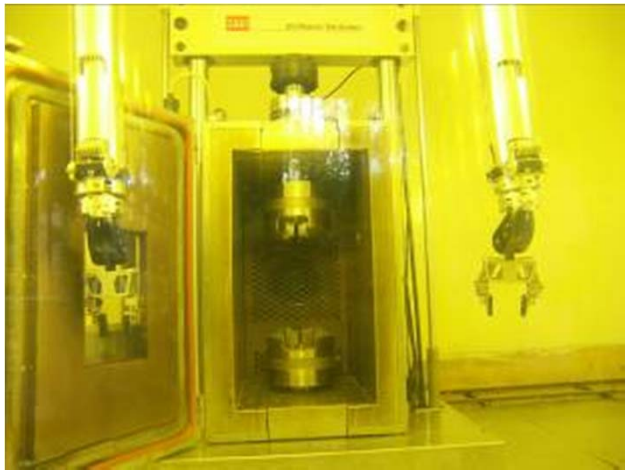




Renew of Facilities for Irradiated Materials:

- Instrumented Charpy-V impact machine with auto specimen feeding system（ ZwickRKP450）
- Instrumented drop-weight test machine （Dynutup8250）
- MTS810.10 universal material test machine





Present status of Hot Laboratory

- SEM
- Mass spectrometer;
- Ion chromatography;
- High performance liquid chromatography;

Finished Irradiation Tests and PIE for Fuel in HFETR as follow:

- Coated UO_2 particles fuel for HTGR
- U-Al alloy tubular fuel element (High Enrichment) for HFETR
- U_3Si_2-Al dispersion tubular fuel element (Low Enrichment) for HFETR
- U_3Si_2-Al dispersion tubular fuel element (another Al cladding) for HFETR
- U_3Si_2-Al dispersion mini-plate fuel for Research Reactor
- 4×4 sub-assembly (UO_2 –Zr-4)for typical PWR
- another sub-assemblies for PWR (different purpose)

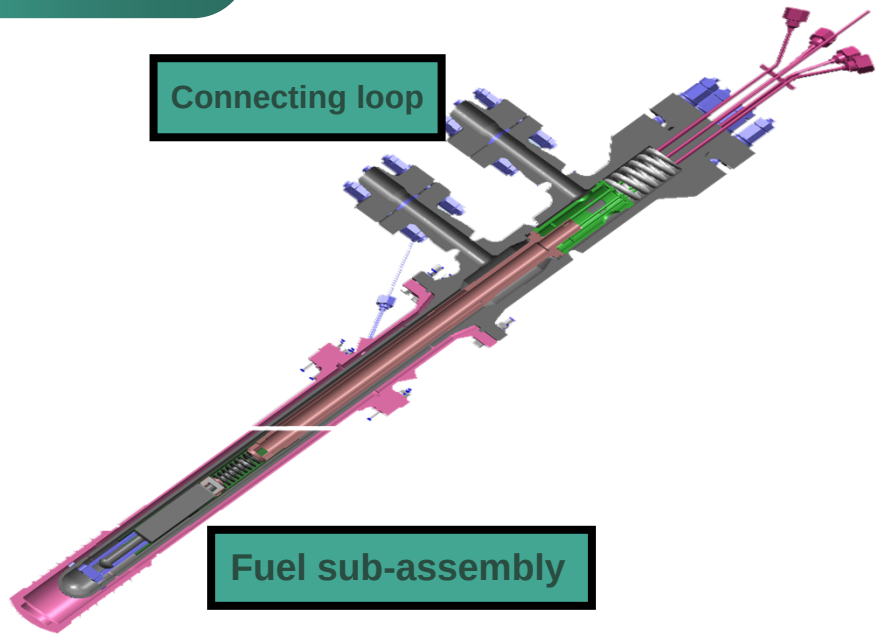
Structure of Irradiation device

- ✓ max. pressure：17.5MPa
- ✓ Max. temperature ： 420℃
- ✓Total length： ~10m
- ✓ Three tubes structure：

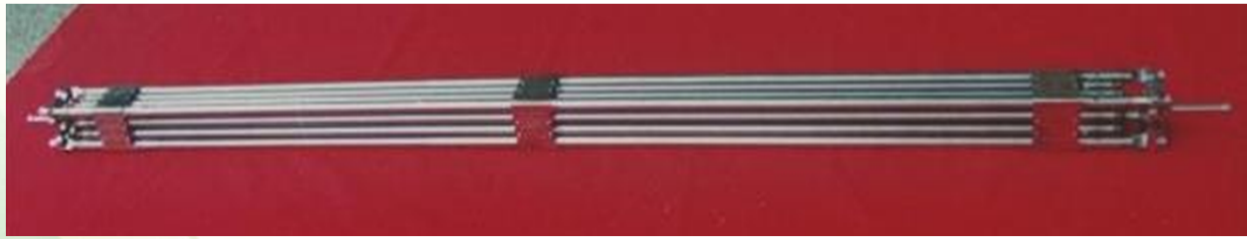
Out : isolation heat tube

Middle :pressure tube

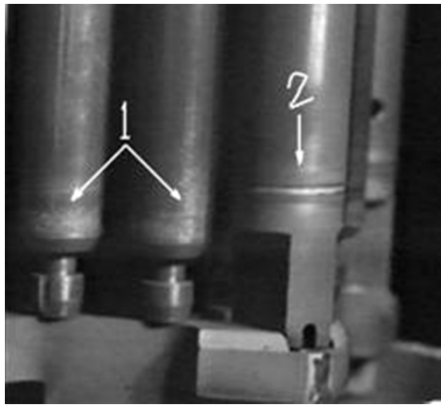
Inner: flow distributing tube



4×4 test sub-assembly

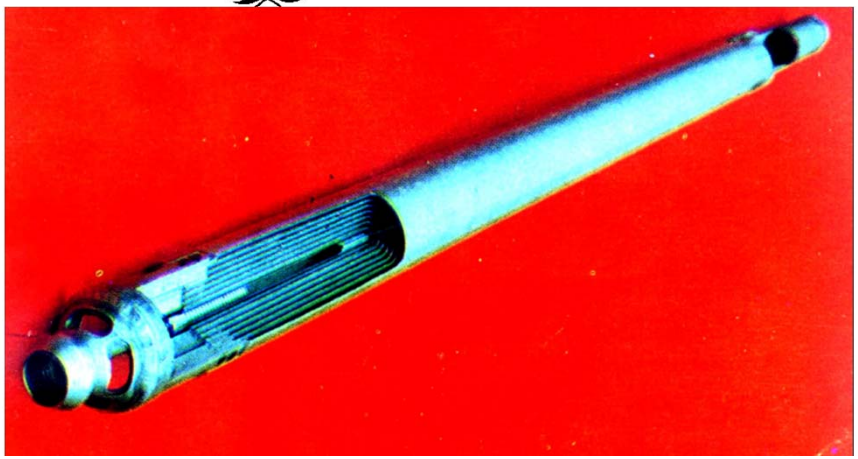


Pre-irradiation



Post-irradiation （42000MWd/tU）

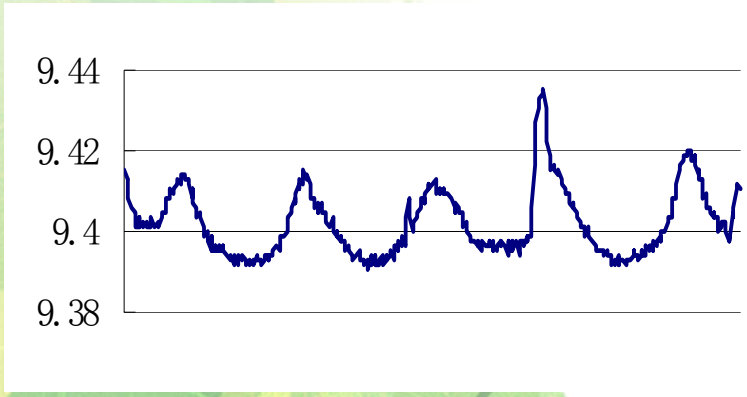
LEU tubular assembly for HFETR



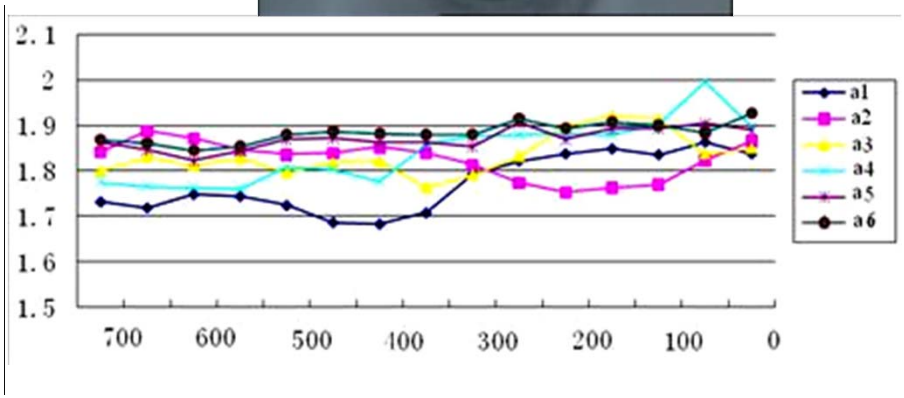
Fuel Assembly Model

Post-irradiation （burn-up 55 % atom ）

Dimensional measurement

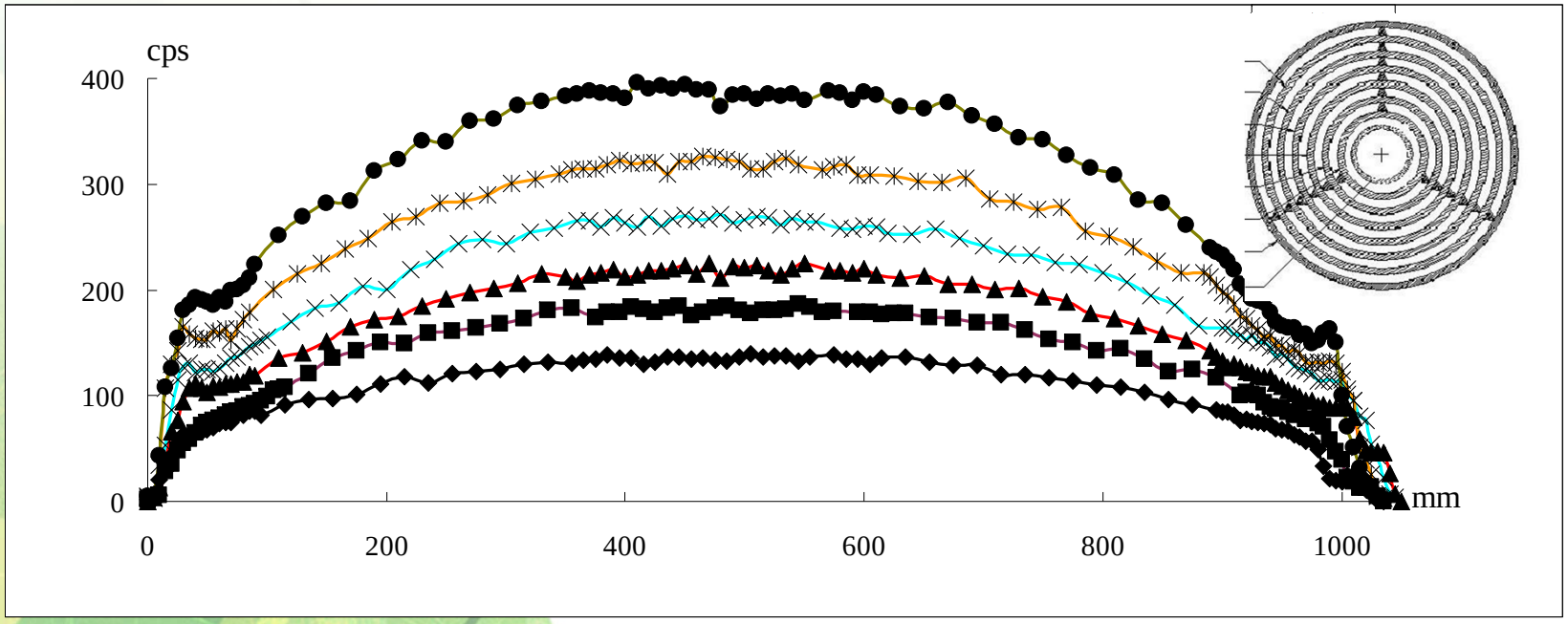


Diameter variation of fuel rod (PWR)



Coolant channel variation between fuel tubes (HFETR)

Gamma scanning



Relative distribution of Cs- 137 for fuel tubes (HFETR)

Some Experiences of Irradiation Test for Fuel

Blistering test

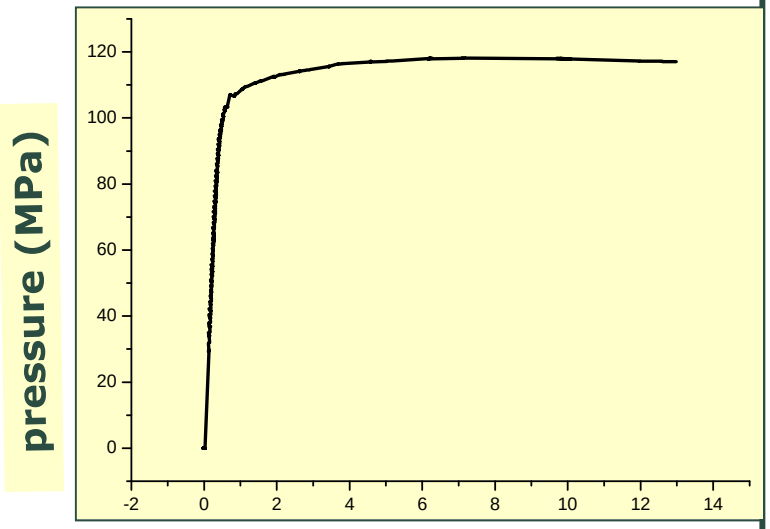
（for LEU dispersion fuel tubes）

threshold temperature： 525℃

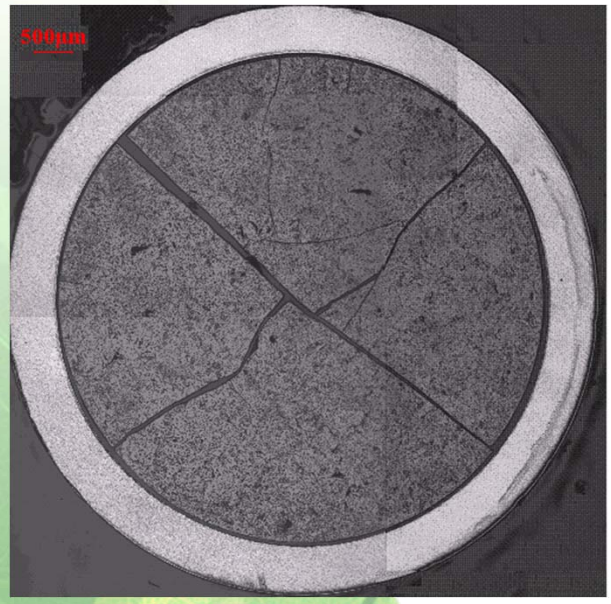
Burst test

（for cladding tube of PWR ）

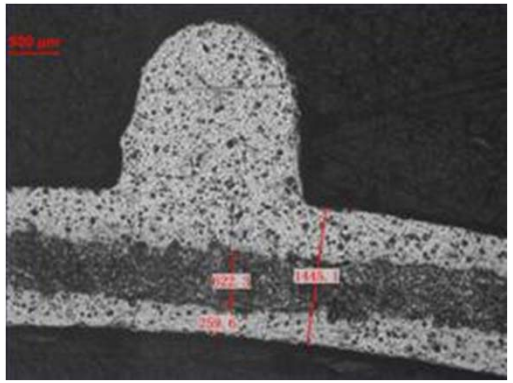
（350℃，0~160MPa ）

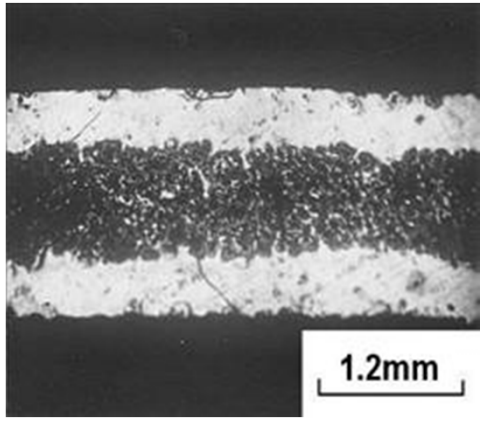


Macro examination



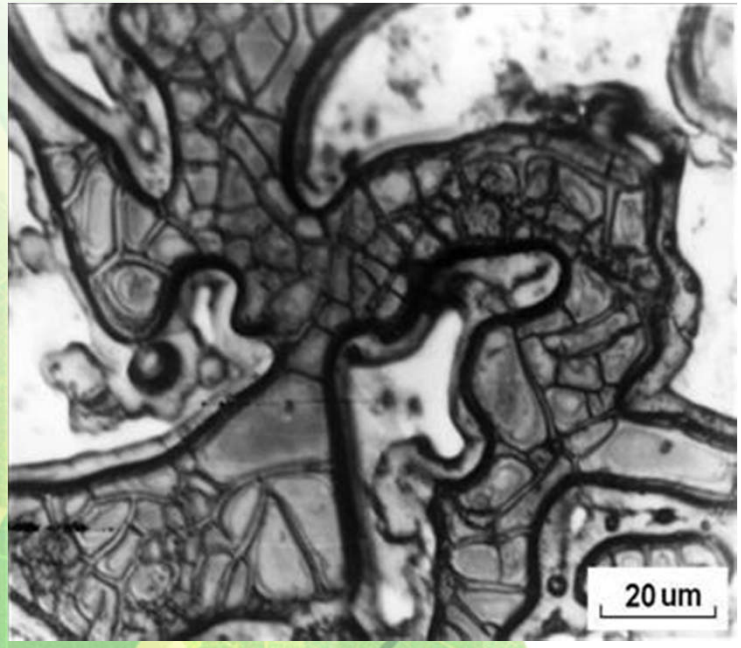
A PWR fuel rod

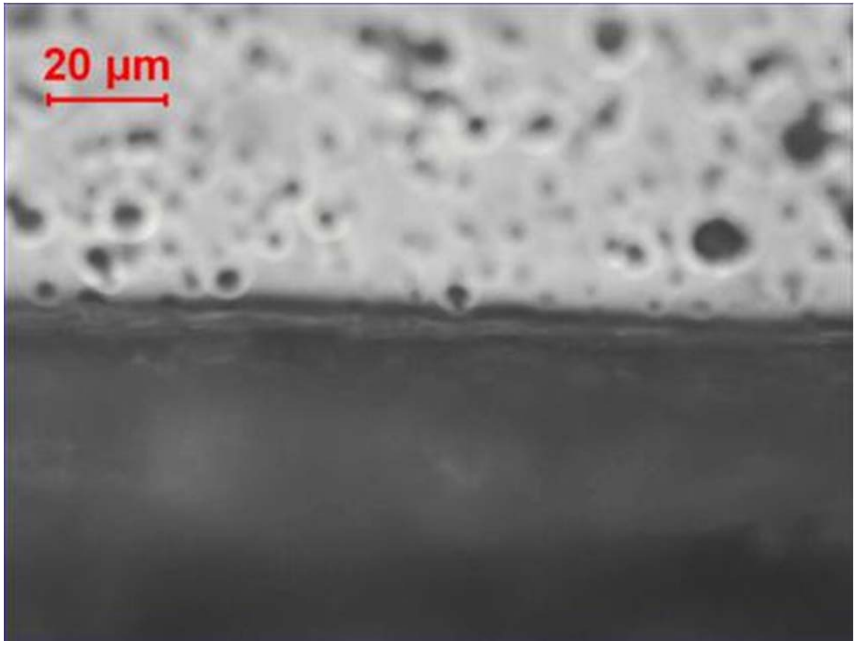




irradiated fuel meat(U_3Si_2)

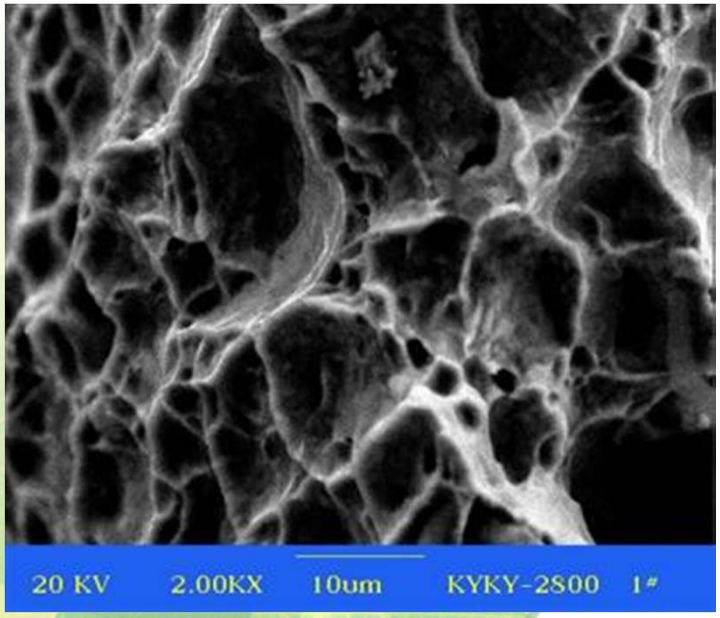
Microanalysis



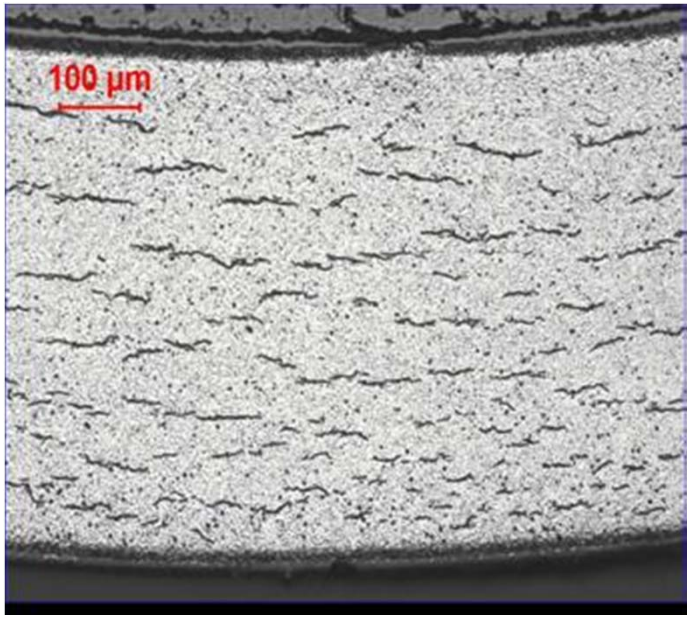


Microstructures of irradiated fuel meat(U_3Si_2)

Microanalysis of cladding tube



fracture topography

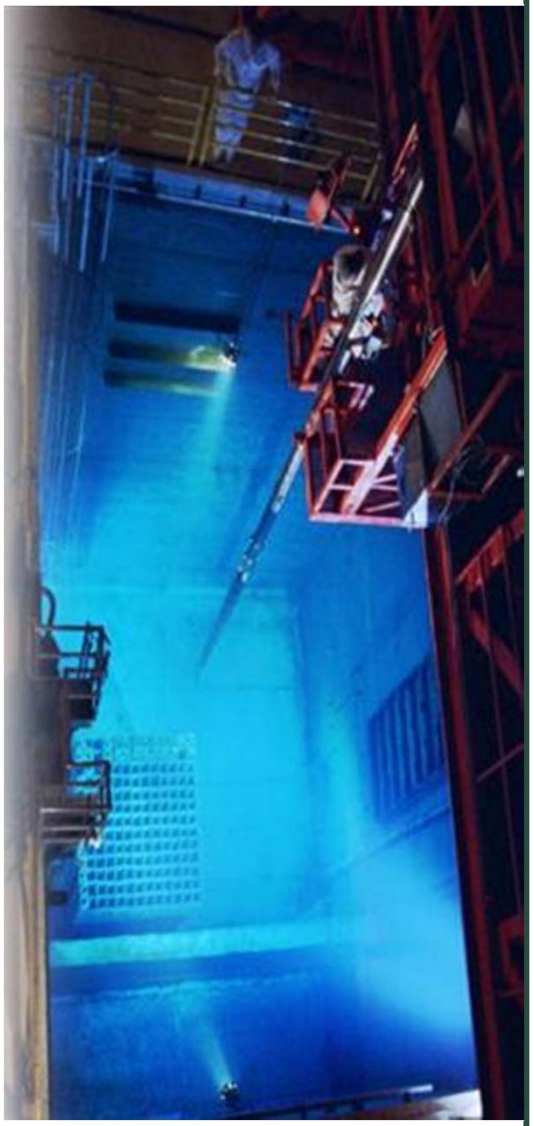


Hydrides distribution

Pool Side Inspection in NPP

- Visual inspection of fuel assembly。
- Dimensional measurement of fuel assembly
- Ultrasonic testing （UT）of FA for failure rods detection
- Oxide layer thickness measurement of fuel rods
- Disassembling & reconstitution of FA
- Eddy current test of fuel rods

planning in 2011~2013



Renew of Devices and Instruments

- ICP-AES mass spectrometer
- New SEM
- Reconstitution of Charpy-V specimens
- 2 cast iron cells to be reconstructed

Under construction in 2010~2012

CONCLUSIONS

NPIC Hot Laboratory plays a very important role for PIE of fuel in China.

With reconstruction of some hot cells and renew of instruments & facilities, more PIE works would be performed in NPIC Hot Laboratory in next decade.

Thank you
for your attention !