中核集团秦山核电有限公司
CNNC Qinshan Nuclear Power Co.,Ltd.

Pool-Side Inspection of Post-Irradiation Fuel Assembly in QINSHAN NPP

2011.5

Slovakia

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1. Introduction

- There are 13 nuclear power units in operation now. Another two units will put into operation soon.
- There are 24 units under construction with Construction Permit (CP) issued by national nuclear safety administration (NNSA).
- 8 units are waiting for CP. Their PSARs are being reviewed by NNSA.

NAME	TYPE	POWER	NUMBER	STATUS	Fuel Management	PLAN
Qinshan NPP	Chinese design M310	310MWe 1000MWe	1 2	In operation Under construction	Yearly	
Daya Bay NPP	French CPR	984MWe	2	In operation	18-month	
Qinshan phase II	Chinese design CNP650	650 MWe 650MWe	2 2	In operation Unit 1 in operation Unit 2 will be in operation soon	Yearly Yearly	Application for 18-month fuel cycle
Qinshan phase III	CANDU-6	700 MWe	2	In operation	N/A	
LingAo NPP	French CPR CNP1000	990MWe	2 2	In operation Unit 1 in operation Unit 2 will be in operation soon	¼ AFM, 12m Yearly	Application for 18-month fuel cycle
Tianwan NPP	WWER-1000 M310	1060MWe 1000MWe	2 2	In operation PSAR stage, suspended	Yearly Yearly	18-month
Hongyanhe NPP	CPR1000	1080MWe	4	Under construction	Yearly	
Ningde NPP	CPR1000	1080MWe	4	Under construction	Yearly	
Fuqing NPP	M310 M310 Modified M310	1000MWe 1000MWe 1100MWe	2 2 2	Under construction PSAR stage, suspended PSAR stage, suspended	Yearly Yearly 18-month	
Yangjiang NPP	CPR1000	1080MWe	2 2	Under construction PSAR stage, suspended	Yearly Yearly	
Shanmen NPP	AP1000	1250MWe	2	Under construction		AFM
Haiyang NPP	AP1000	1250MWe	2	Under construction		AFM
Taishan NPP	EPR	1750MWe	2	Under construction		AFM
Shidaowan NPP	HTR-PM	200MWe	1	Waiting for NEA permission, suspended	N/A	
Changjiang NPP	CNP650	650MWe	2	Under construction	Yearly	
Fangchenggang NPP	CPR1000	1080MWe	2	Under construction	Yearly	

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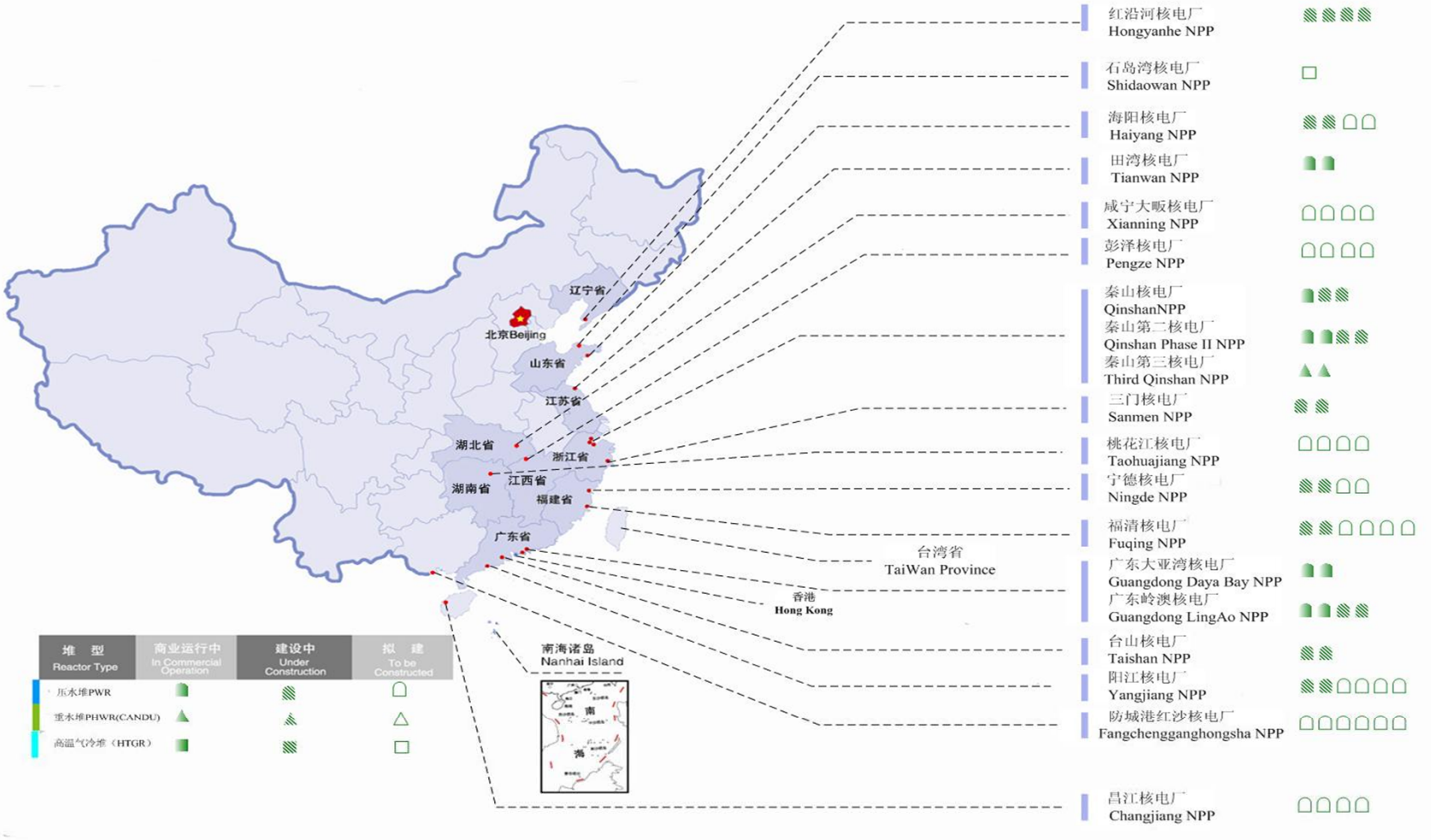

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Current situation

- But since the accident of Fukushima nuclear power plant due to earthquake and tsunami in Japan, the situation of nuclear power development changed obviously.
- A series of comprehensive safe inspections and reviews are required in all nuclear power plants.
- In the near future maybe some significant modifications will be forced to implement such as movable diesel generator, passive containment hydrogen recombining system, etc.

Current situation

- To the nuclear power plants under construction, evaluate and review its safety standard based on the most advanced standard.
- Adjust and improve the nuclear power development programming, and suspend to issue any Construction Permit until the new programming is unveiled.
- It is obvious that China is reconsidering the development plan of NPP.

Qinshan NPP

- Qinshan NPP (QNPP)is the second generation nuclear power plant with capacity of 310 Mwe, which came into operation in 1991.
- The current cycle is C13 and design life is 30 years.
- QNPP is the first nuclear plant designed and constructed by ourselves in china mainland.

Fuel assembly

- The design institute of QNPP is Shanghai Nuclear Engineering Research & Design Institute.
- The fuel assembly (FA) of QNPP is supplied by China Jianzhong Nuclear Fuel Co., Ltd (CJNF).

Main parameters

- Enrichment: 3.4%
- Arrangement:
  15×15 square matrix
- Neutron flux thimble: 1
- Guide thimble: 20
- Fuel rods: 204
- Length : 3500mm
- Section: 199.3×199.3mm
- Weight : 465Kg

Modifications on FAs

- There are two main modifications after cycle 7, the bottom filter and pellet chamfers were added.
- Now all of the spent FAs store in the pool in FX and will start transportation to the reprocess factory in the near future.

2. Pool-side Inspection

- Pool-side inspection(PSI) in QNPP include
- Sipping Inspection
- Visual Test
- Dimension Measurement
  - verticality, twist, variation of rod spacer, irradiative growth, etc.
- Disassembly Inspection
  - ET and oxidation film thickness for rods.

Application of PSI

- PSI of the post-irradiative FAs is used to evaluate the integrity and reliability of reloaded FAs during outage;
- Determinate the FAs when fuel damage happened and locate the position of failure rods before repair if necessary.

Process

- Based on daily operational monitoring on Fuel Reliability Index and Iodine Equivalent Value, there will be a preliminary judgment of fuel integrity.
- If no FA failure happens, inspection of VT and dimension measurement will be arranged at a specified ratio of fuel assembles aim to evaluate the reliability and integrity of reloaded FAs during reloading outage.

Process

- But if judgment goes to the contrary, sipping inspection for all FAs need to reload will be arranged in order to find out the damaged FAs.
- If success, there will be a comprehensive inspection include VT, dimension measurement inspection, and disassembly inspection by ET before repair it by taking the place of failure rods with intact ones, if necessary and possible.

Failure History

Cycle	FAs failure history
C1~C3	No FA failure happened.
C4	9 FAs breakage, 2FAs have grid spacers deformation, and 6 FAs have mix wing damage.
C5~C6	1 FA damage
C7~C12	No FA failure happened.

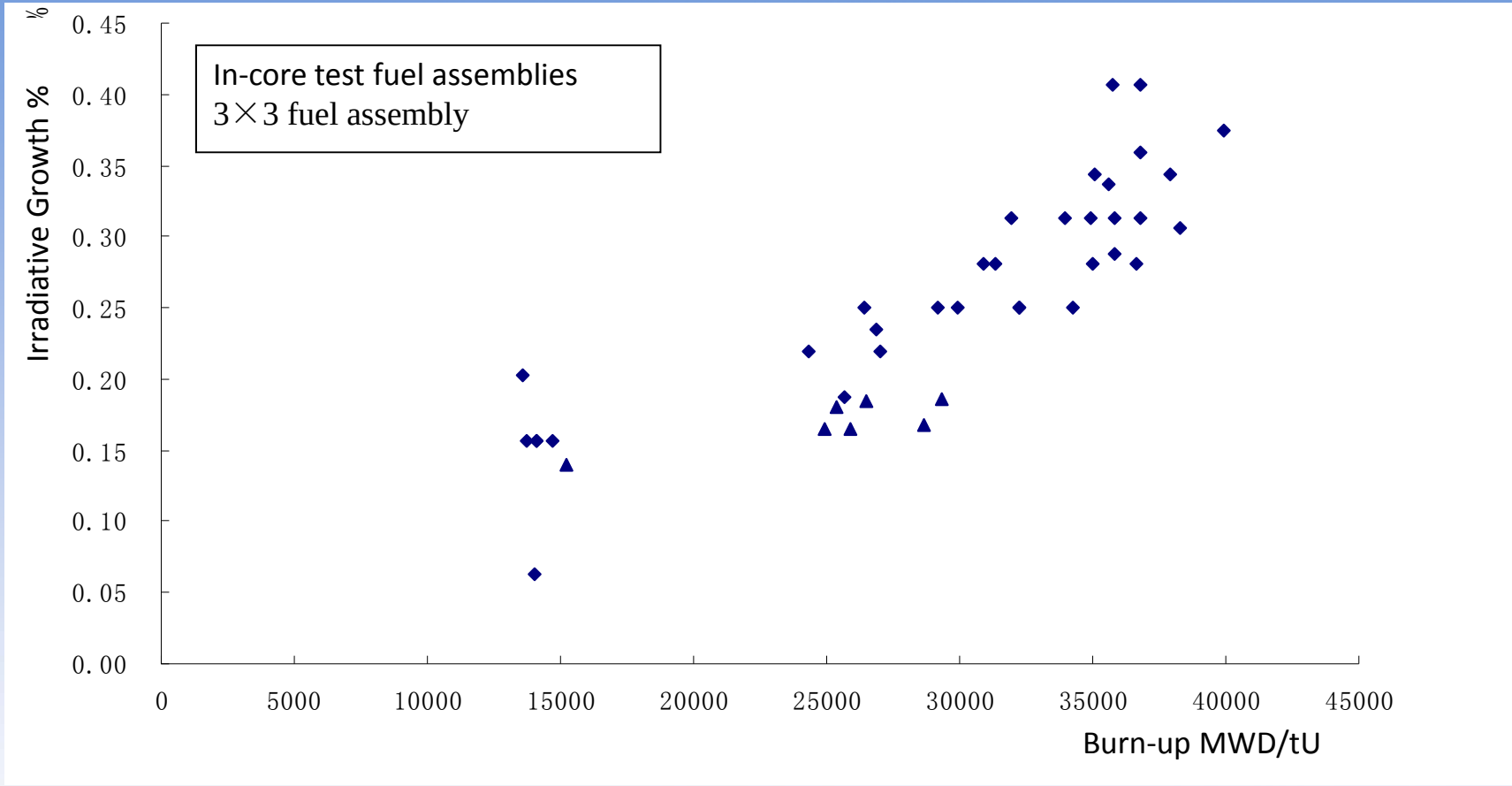
In-core Burn-up Increment Test

- As fuel management is developing, the burn-up of FA is requested to increase properly in order to prolong the cycle life.
- The PSI in QNPP gave a way to verify the fuel property after burn-up increment test in core.
- Restricted by the level at that time on design, technology and verification test, the burn-up limit of Qinshan NPP FAs was only 30000MWd/tU initially, and large margin was reserved.

Results

- Guaranteed reactor safety, many tests were performed to increase the burn-up gradually.
- After more than 7 cycles efforts, the test was complete successfully till the ending of cycle 11.
- After this fuel management improvement, average burn-up of FAs is nearly to 32000～33000MWd/tU，burn-up limit of FAs achieve to 40000MWd/tU，and 44000MWd/tU for rods.

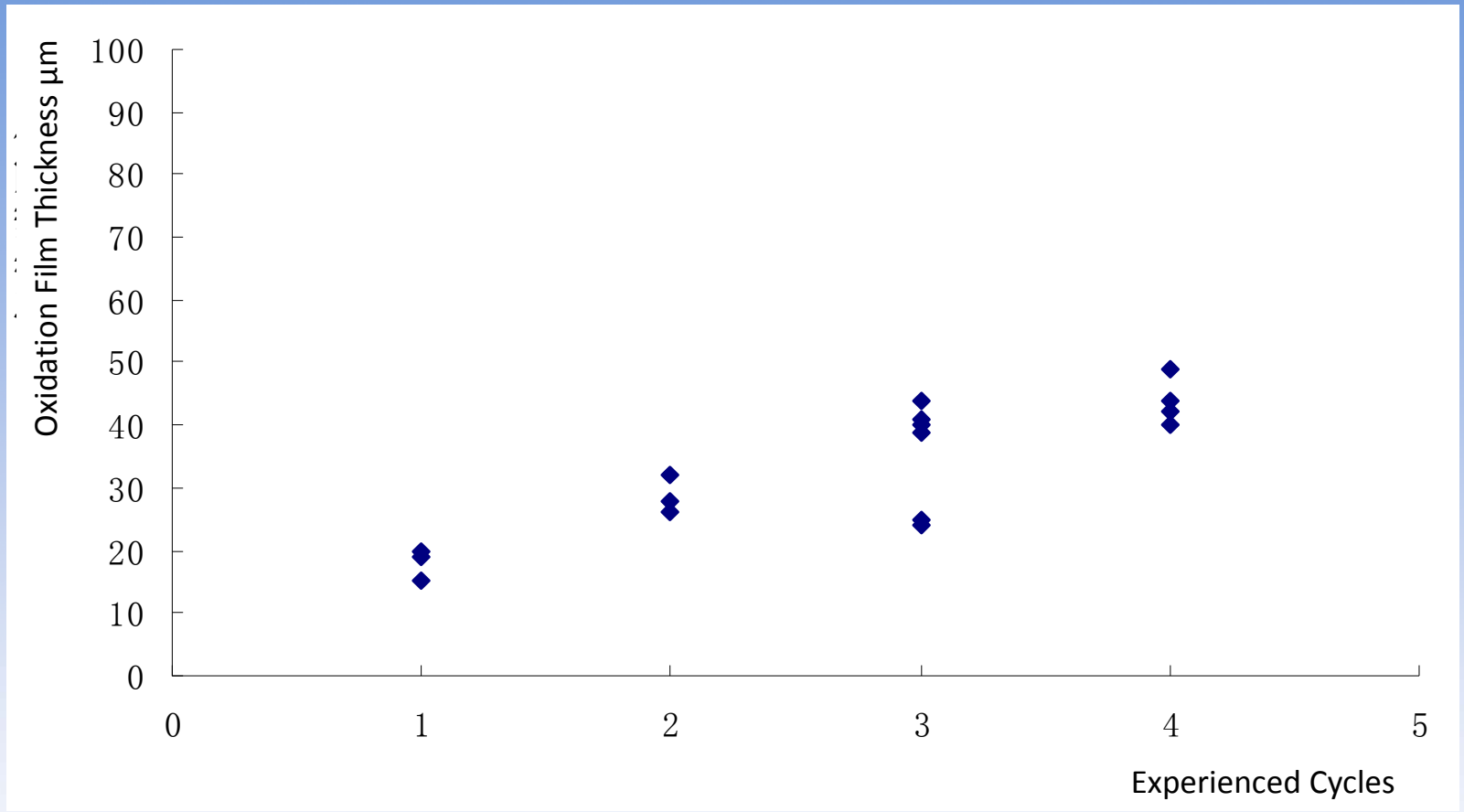
Irradiative Growth



Irradiative Growth

- No irradiative growth of FAs is occurring.
- Nevertheless irradiative growth of fuel rod is observed.
- The distribution of irradiative growth value versus burn-up is shown as follows.
- The relevant results of 3×3 FAs during the design verification test are also shown.

Thickness of Oxidation Film



Thickness of Oxidation Film

- Max-thickness of oxidation film is 49μm much lower than the requirement of regulation and guideline that corrosion thickness at the end of life should less than 10% (0.7mm) of cladding wall.
- That means the anti-corrosion performance of fuel cladding is sufficient in the range of burn-up test, and the fuel rod is safe.

Other Needed Tests

- ET inspection on fuel rod:
  - no inner and outer wall defects,
  - No holes, ring ridges.
  - no PCI,
  - abrasion,
  - hydrogen brittleness.
- Other needed verifications are all satisfied:
  - Rod drop test, etc.;
  - Computer codes calculations;

Final Conclusion

- The high performance of FAs of Qinshan NPP can be guaranteed within the burn-up test range, and are capable to satisfy the operation safety after 4 cycles, and 40000 MWd/tU burn-up.

3. Hot Cell Inspection

- China Institute of Atomic Energy undertakes a nuclear energy science and technology research subject, *post-irradiative inspection of Fuel assemblies of PWRs*.
- By means of the hot cell inspection on the FA rods of QNPP, CIAE will obtain the data such as structures, performance, rationality and dependability of domestic FAs, and evaluate the in-core behaviors, meanwhile accumulate the behavior data.

Selected Rods

Operation Cycles	Enrichment	Burn-up (MWD/tU)	Unload Date	Position of Rod
4	3.4%	39922.18	2006-6-25	A-15 K-08 N-04
3	3.4%	36006.96	2006-6-25	A-15 K-08 N-04
4	3.0%	33956.02	2002-4-14	K-08 N-04

Inspection Items

- The non-destructive will include:
  - VT,
  - ET,
  - Dimensions measurement,
  - Gamma spectrometry,
- the destructive inspection will involve:
  - release rate of fission gas,
  - axial tension test of cladding,
  - analysis of macro and micro structure of UO2 pellets,
  - micro-structure analysis and SEM to tension samples

Inspection Items

- Others inspection:
  - Determination of absolute burn-up of fuel rods by precise analysis of the concentration of Cs137 and Nd148,
  - In-core behavior analysis and performance evaluation of fuel rods by compare the results of hot-cell examination with computer code calculation.

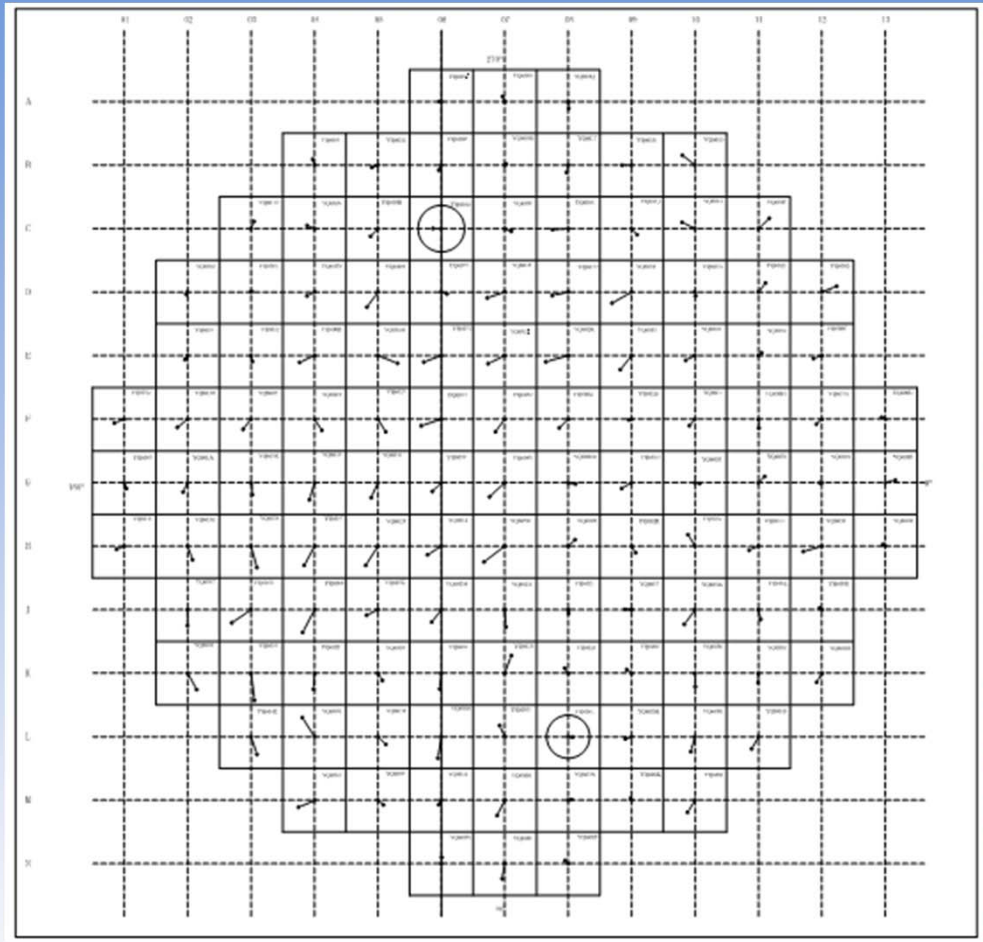
4. Other Methods

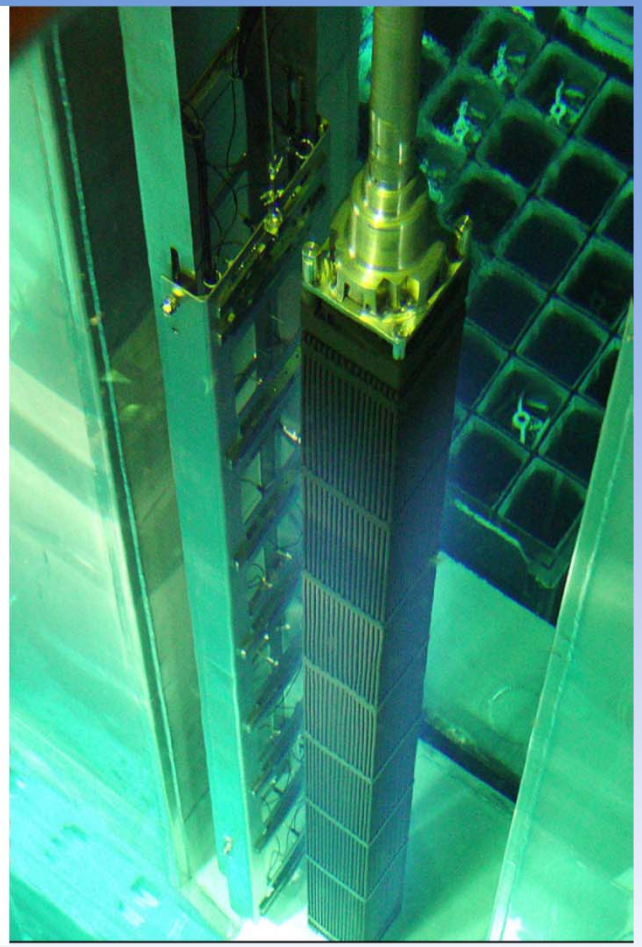
- Since 2003, QNPP Phase 2 and Research Institute of Nuclear Power Operation researched and developed cooperatively the ultrasonic measurement system of deformation of post-irradiative FAs.
- This system has already turned into running and do help greatly during reloading outage.

Advantage

- This system has its advantage in technical:
  - less measurement time (less than 5mins/assembly),
  - higher accuracy (less than 0.3mm of system errors),
- any bending and twist of fuel assemblies can be detected precisely and rapidly.
- The measurement of results can be the guide to fuel loading in order to mitigate the difficulty due to deformation of post-irradiative FAs.

Pattern and Picture





5. Summary

1. pool-side inspection in QNPP is an efficient way to evaluate the reliability and integrity of fuel assemblies;

2. The results of pool-side support the conclusion that the integrity of fuel assemblies can be guaranteed during in-core test of burn-up increments in QNPP, and then improve the fuel management level and the economy of plant;

3. Specialization, integration and high technology of pool-side inspection increase the work efficiency, save the human resource cost significantly, shorten the time of outage, and then also improve the economy of plants finally.

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Thanks!

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