FAC Management and operation experience feedback in China NPP

IAEA Technical Meeting/Workshop on
"Erosion-Corrosion Including Flow Accelerated Corrosion and Environmentally Assisted Cracking issues in NPP"

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Research institute of nuclear power operation

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Brief Overview of china nuclear power development and RINPC

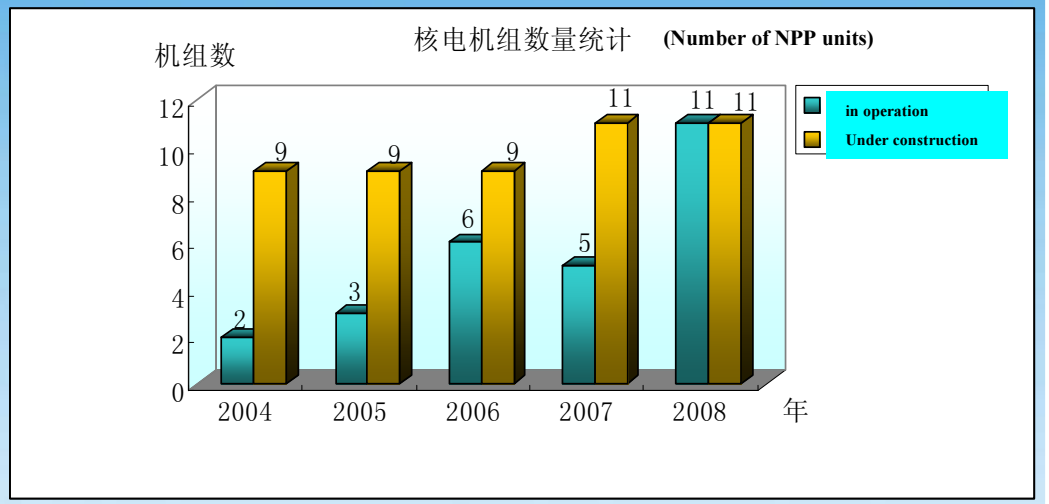
Current Status (till the end of 2008):

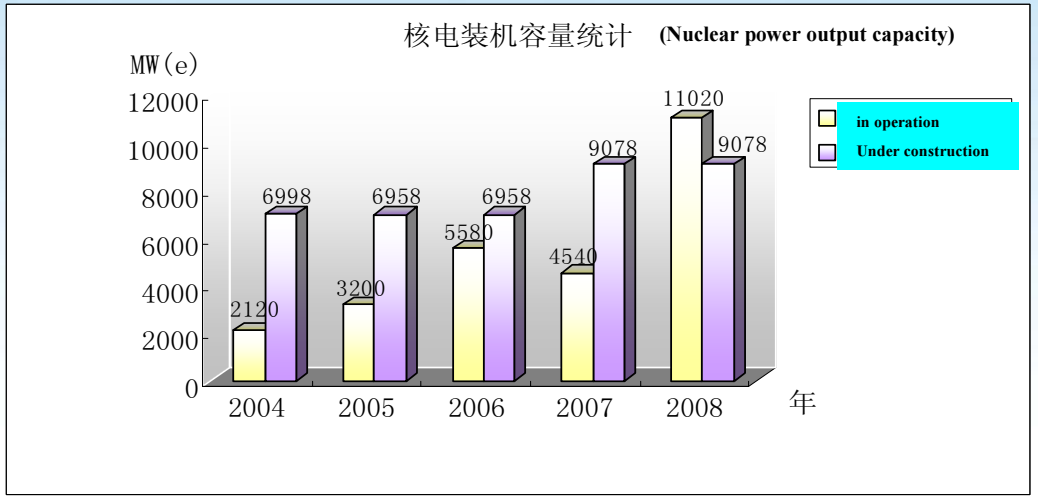
- 11 units (9,078MW) in operation
- 11 units (11,200MW) under construction
- 2.02% of total power capacity

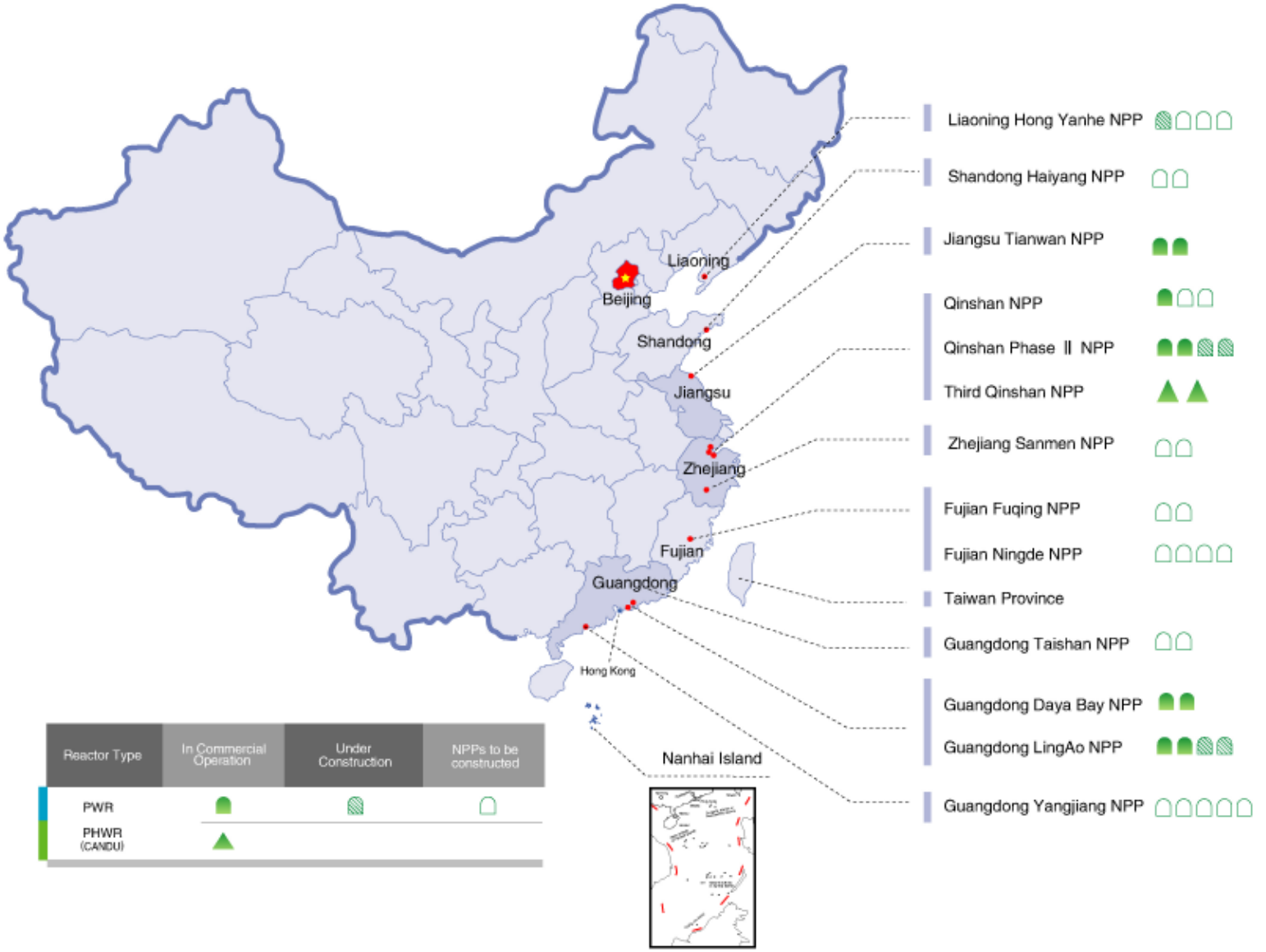
In 2020

- 40 GW nuclear units in operation
- 18 GW nuclear units under construction
- Over 4% of total power capacity

"The spring of nuclear power is coming in china"





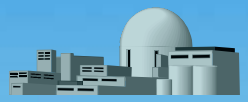

Liaoning
Beijing
Shandong
Jiangsu
Zhejiang
Fujian
Guangdong
Hong Kong
Nanhai Island
Liaoning Hong Yanhe NPP
Shandong Haiyang NPP
Jiangsu Tianwan NPP
Qinshan NPP
Qinshan Phase Ⅱ NPP
Third Qinshan NPP
Zhejiang Sanmen NPP
Fujian Fuqing NPP
Fujian Ningde NPP
Taiwan Province
Guangdong Taishan NPP
Guangdong Daya Bay NPP
Guangdong LingAo NPP
Guangdong Yangjiang NPP
Reactor Type
In Commercial Operation
Under Construction
NPPs to be constructed
PWR
PHWR (CANDU)

NPPs in Operation: 11 Units, 9,078MW

Current situation	Plant		Reactor TYPE	Capacity MW(e)	Project Management	NSSS Supplier	Commercial Operation
In operation	Qinshan phase I		PWR	310	CNNC	SENDRI	1994-04-01
	Gudong daya bay NPP	UNIT 1 UNIT 2	PWR	2×984	CGNPC	Framatome	1994-02-01 1994-05-06
	Qinshan phase II	Unit 1 Unit 2	PWR	2×650	CNNC	CNNC	2002-04-15 2004-05-03
	Ling'ao phase I	Unit 1 Unit2	PWR	2×990	CGNPC	Framatome	2002-05-28 2003-01-08
	Qinshan phase III	unit1 unit2	PHWR	2×700	CNNC	AECL	2002-12-31 2003-07-24
	Tianwan	Unit1 unit2	VVER1000	2×1060	CNNC	Russia OKB	2007-05-17 2007-08-16

NPPs under construction: 11 Units, 11,020 MW

current situation	Plant		Reactor type	Capacity MW(e)	Date of FCD	remark
under construction	Guangdong ling'ao NPP	unit 3	PWR	2×1080	2005-12-15	CRP1000
		unit 4			2006-6-15	
	Qinshan Phase II	unit 3	PWR	2×650	2006-4-28	CNP600
		unit 4			2007-1-28	
	Hongyanhe NPP	unit 1	PWR	2×1080	2007-8-18	CRP1000
		unit 2			2008-3-28	
	Lingde NPP	unit 1	PWR	2×1080	2008-2-18	CRP1000
		unit 2			2008-11-12	
	Fuqing NPP	unit 1	PWR	1080	2008-11-21	CRP1000
	Yangjiang NPP	unit 1	PWR	1080	2008-12-16	CRP1000
	Qinshan PHASE I (Fangjiashan project)	unit 1	PWR	1080	2008-12-26	CRP1000



NPPs to be constructed with approval: 32 Units, 33,400 MWe

current situation	Plant	Reactor type	Capacity MW(e)	remark
to be constructed with approval	Hongyanhe NPP	PWR	2x1080	CRP1000
	SaMen NPP	PWR	2x1250	AP1000
	HaiYang NPP	PWR	2x1250	AP1000
	Lingde NPP	PWR	2×1080	CRP1000
	Qinshan PHASE I (Fangjiashan project)	PWR	1×1080	CRP1001
	Taishan NPP	PWR	2X1700	EPR
	Changjiang NPP	PWR	4×650	CNP600
	Fangchenggang NPP	PWR	6×1080	CPR1000
	Shidaowan NPP	HGTR	1X200	

Recognition of RINPO

- Established in 1982
- A subsidiary of China National Nuclear Corporation (CNNC)
- Employees: ≈ 400

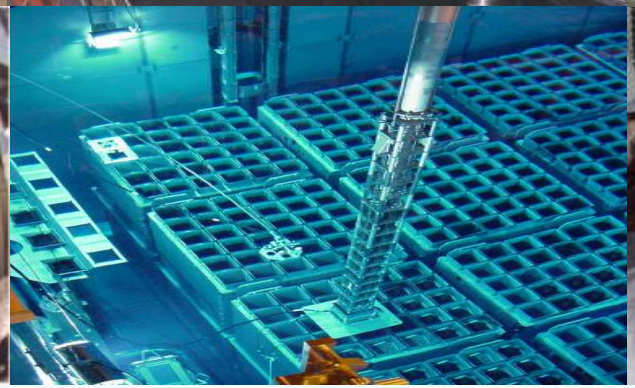
Business Areas

1. Nuclear NDE Services
2. Steam Generator Research, Design, Maintenance and Aging Management Services
3. Simulator R & D, and Virtue Reality Technology Application
4. Operational Experience, Evaluation and Technical Support Services (like INPO in U.S)

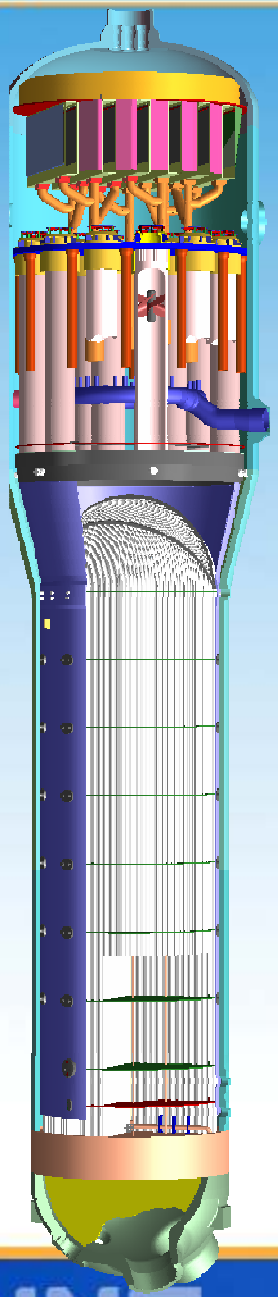
I. Nuclear NDE Services

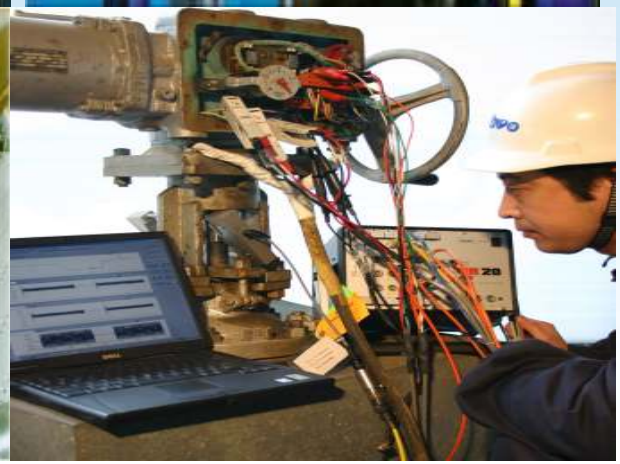




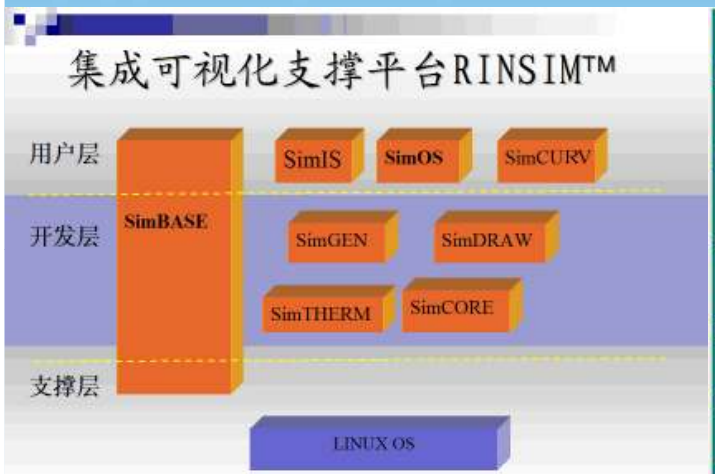


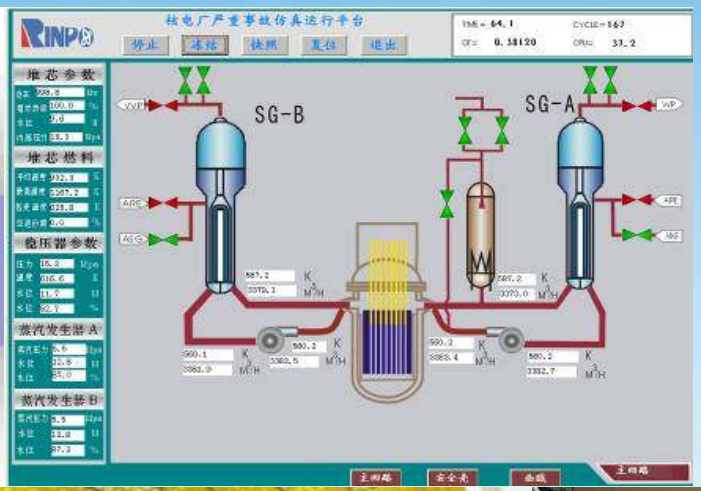

II. Steam Generator Research, Design, Maintenance and Aging Management Services





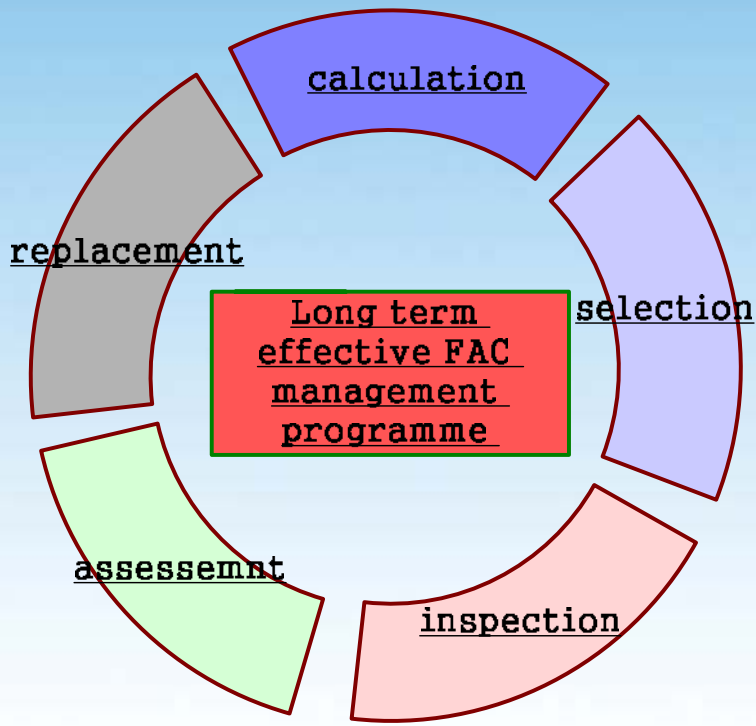
III. Simulator R & D, and Virtue Reality Technology Application





Element of long term FAC management programme

1. FAC phenomena is popular in NPP in operation ,especially in early operation NPP, such as Qinshan I,Qinshan II and Daya Bay NPP
2. Passive management way such as regular inspection and assessment is adopt by the NPP before Japan Mihama Secondary condensate pipe rupture in 2004.
3. Active and systematic management is established under the framework of long term FAC management programme in china operation NPP.



Calculation and identifying susceptible system

1. Susceptible system and location is identifying according to the selection principle recommend by EPRI TR1015425(NSAC-202L-R3), foreign experience feedback and BRT-**CICERO** Predictive software.
2. 10 system are selected as management emphasis:

Single-phase system:

Condensate and feedwater
Auxiliary feedwater
Mositure separator drains
Heater drains
Steam generator blow-down
Reheater drains
Other drains.

two phase system

High and low pressure extraction steam lines
Flashing lines to the condenser (miscellaneous drains)
Feedwater heater vents.

Inspection:

Class A：The pipelines are susceptible to the FAC, most of which are two phase flow pipeline;

Class B: The pipelines will be possible to impact the operation and safety of the station, and all of them are single phase flow over normal temperature. ;

Class C：The pipelines are in normal temperature and their diameter is more than 25mm

Susceptive location

- Elbows
- Down stream of elbow
- T-pipe ;
- Reducer, pipe behind a valve ;
- Down stream of orifice plate;
- Pump outlet ;
- some straight pipe (which is inspected in a certain cycle)

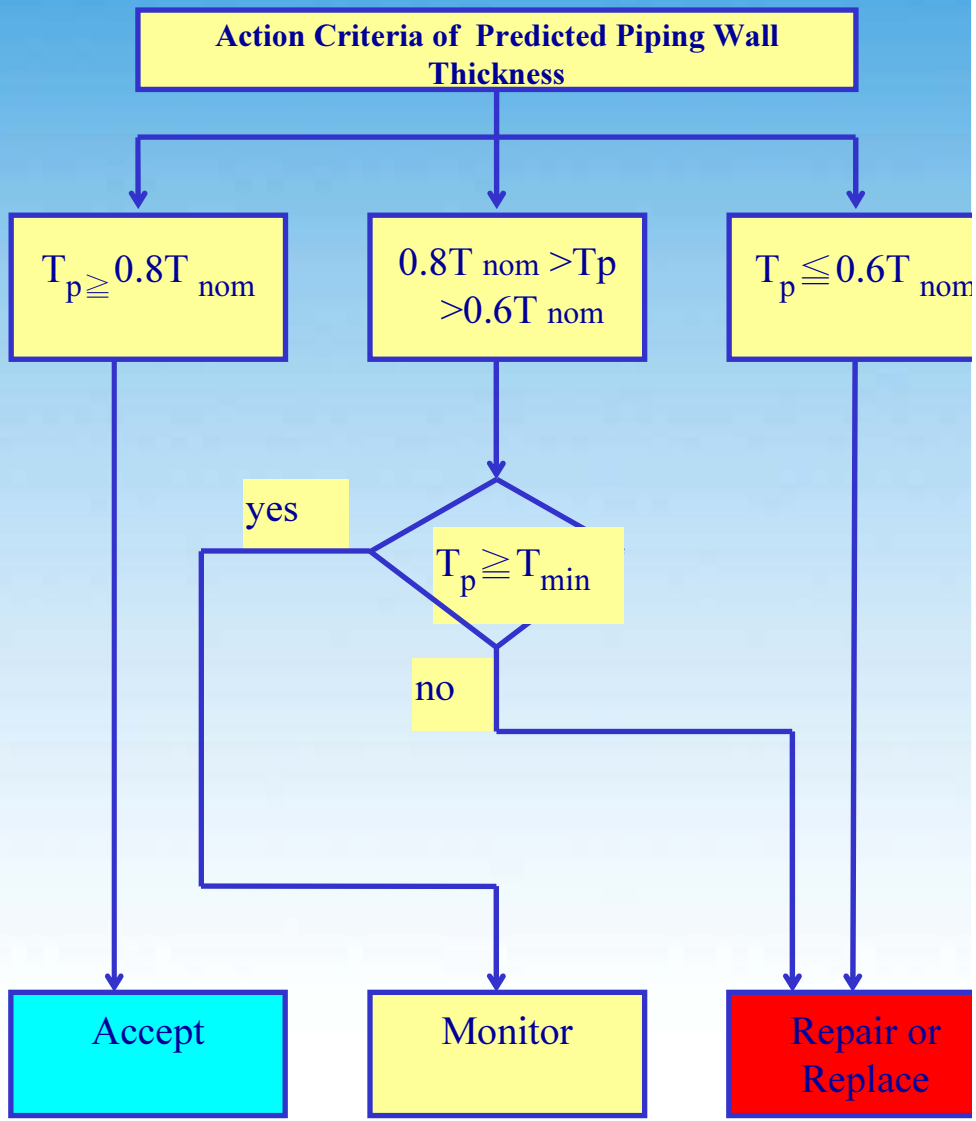
Inspection frequency

- Class A： choose about 20% of pipe fittings during every outage ;
- Class B: choose about 5%--10% of pipe fittings during every outage;
- Class C: choose not more than 5% of pipe fitting during every outage

Assessment:

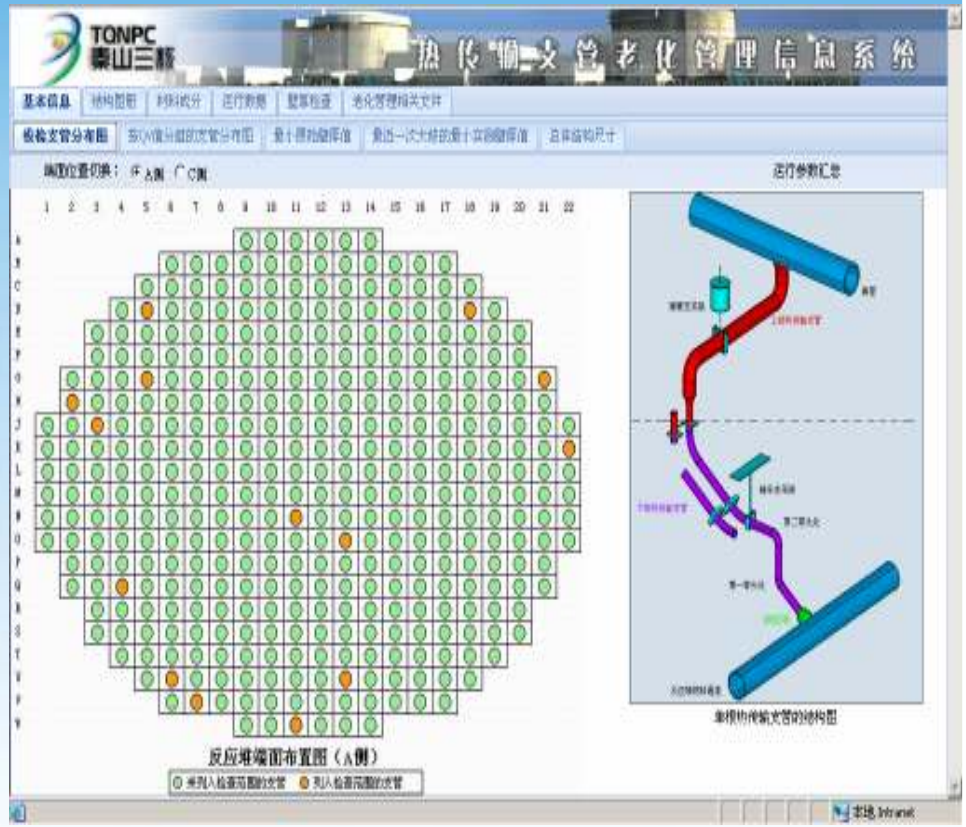
- The minimum thickness Criteria based on elastic mechanics theory is widely adopt for construction judgment by NPP according to ASME CC-N597.

2. The further fitting-for-fitness with limit load Evaluation method based on elastic-plastic theory are expected to adopt in the future by NPP according to ASME BS B31.1(Non safety) or ASME NC(safety)



Operation experience feedback of FAC of CANDU Feeder pipes

1. the material of initial CANDU feeder pipes is ASME SA-106B(**0.02～0.04wt%** Cr)with 30 years design life, the tolerance wear rate is **31 μ m/EFPY**.
2. The inspection results of G-2 and Point Lepreau NPP in 1996 shows the wear rate of 1st elbow of 2in feeder pipes reached 100 μ m/EFPY, 2.5 in feeder pipes reached 127 μ m/EFPY.
3. The inspection results of G-2 and Point Lepreau caused the attention of Qinshan III NPP, a series of engineer qualification test are implemented before the construction of Qinshan III NPP



1. Autoclave test (310 ℃、1.2 m/s, 0.02 wt % Cr SA106B, pH:9.3 ∽ 10.8), testing the influence of pH for wear rate
2. Low flow velocity loop test on H-5 reactor, testing the influence of Fe concentration for wear rate.
3. High flow velocity loop test on U2 reactor, testing the influence of Cr content for wear rate.
4. High flow velocity loop test on H-2 reactor, testing the influence of Cr content for wear rate.
5. Engineer qualification test in Darlington NPP.

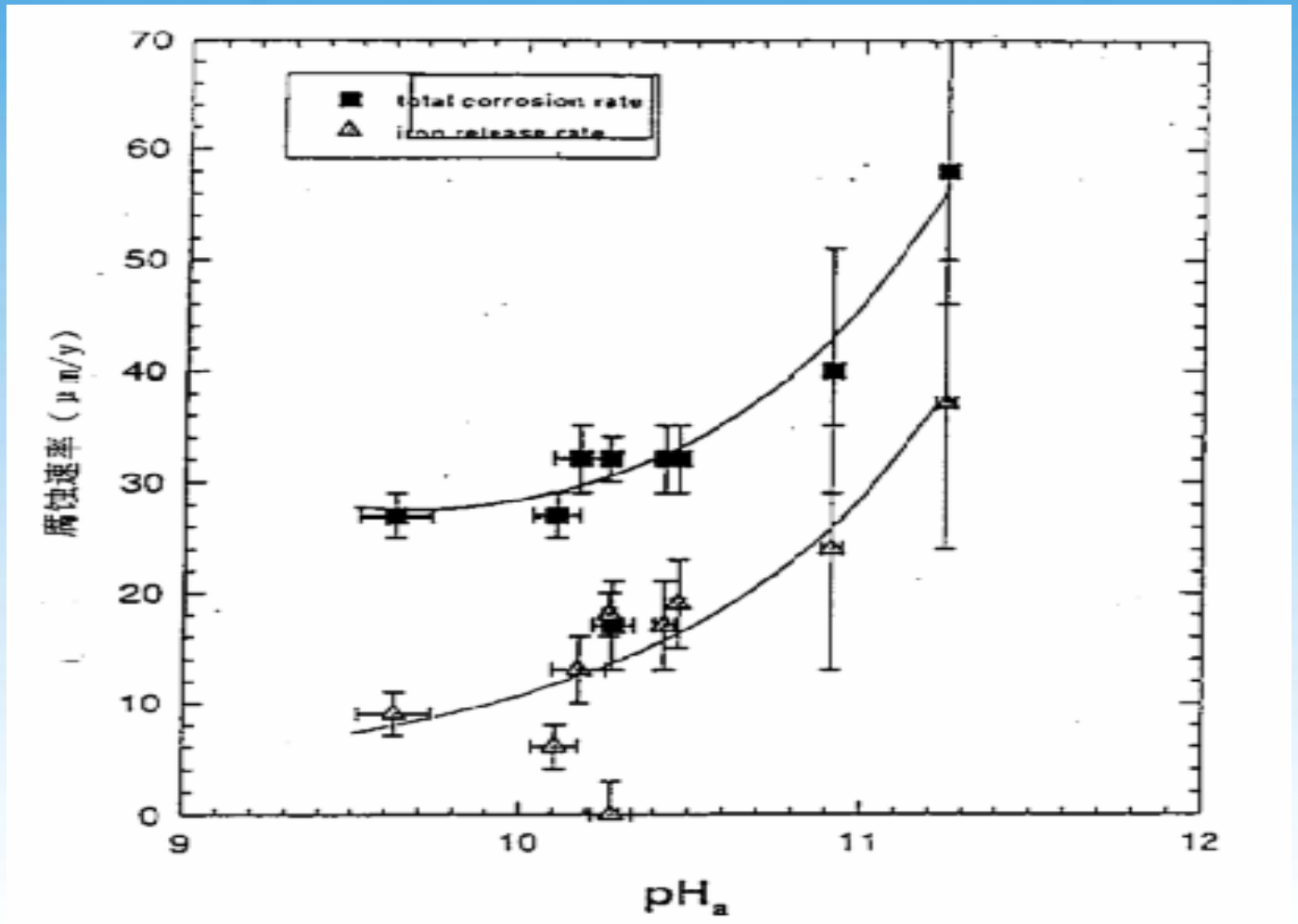


Fig1 Testing results of autoclave test

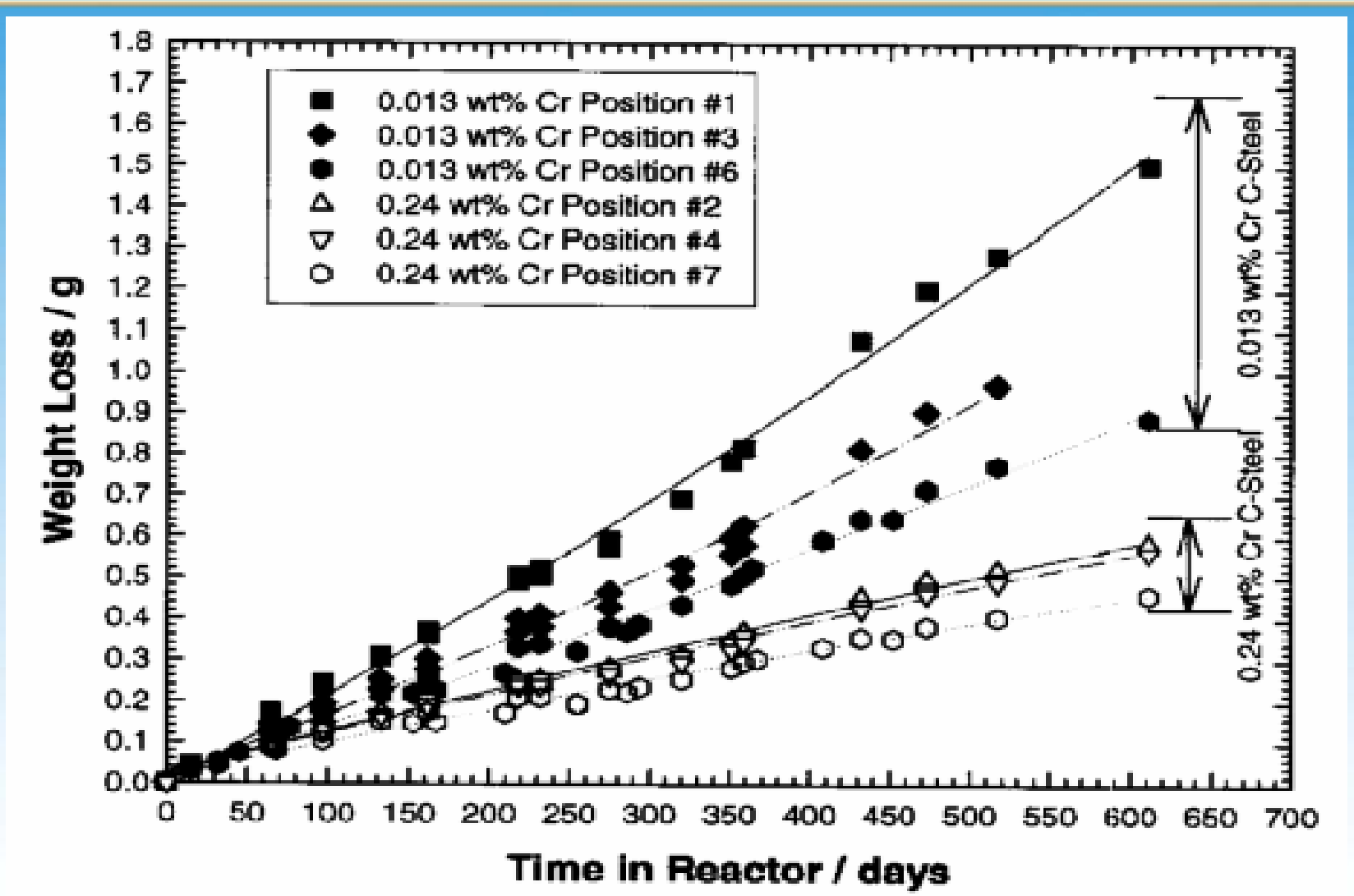


Fig2 Testing results on U2 reactor

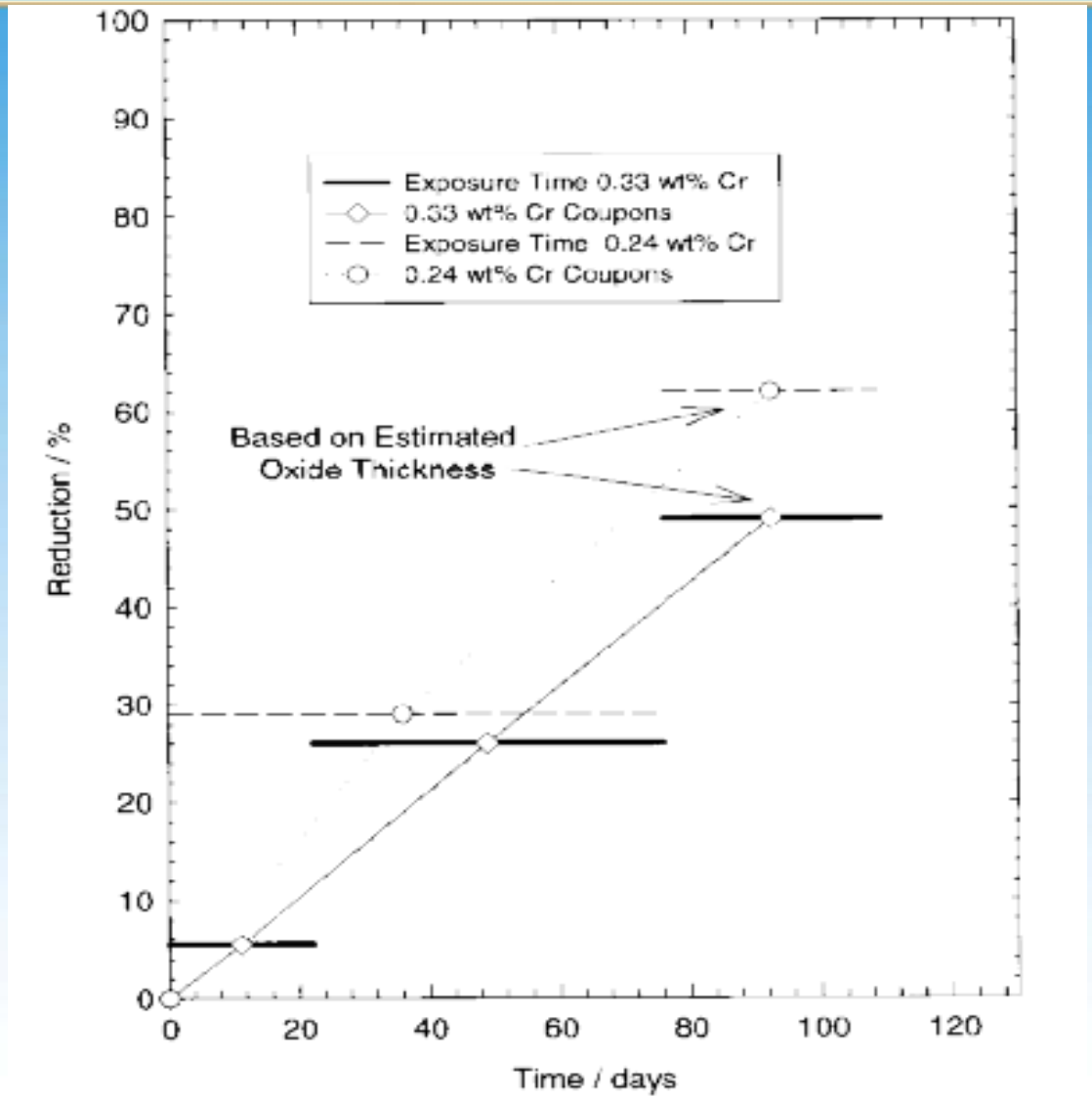


Fig3 Testing results on H2 reactor

Summary of a series of tests:

1. The autoclave test results shows FAC wear rates will increase with pHa.
2. U2 test shows the wears rate of 0.24 wt % Cr is 68% of 0.013wt % Cr during the period of 517~ 611 days. The trend of U2 test is similar with H2 test.

The following material modification and water chemistry parameters optimum is proposed for Qinshan III for the purposed of 40 years design life after the tests:

1. Cr content increase from 0.02～0.04wt% to 0.3～0.4wt%
   (actual control in the range of 0.32wt% ~0.35wt%)
2. pHa decrease from 10.2～10.8 to 10.2~10.4

The inspection results of 3 outages of Qinshan III shows the design modification for feeder pipes FAC control is successful, no obvious wear rate are measured in 40 inspected pipes.

Operation experience feedback of FAC of secondary loop pipes

Wall thickness thinning amount reached 60% and were placed in Qinshan I NPP (total 54 location)

outage	system			number
R5	extraction steam L1	extraction steam L2	Reheating Level 1	19
R6	extraction steam L2			1
R7	extraction steam L1-L3	reheating level1		7
R8	Steam extraction L1-L3	reheating level1	draining of MSR	19
R9	extraction steam L3	extraction steam L1	reheating level1	3
R10	extraction steam L1-L3	reheating level1		5

Wall thinning photos of Steam extraction pipe

Parameters of serious wall thinning systems in Qinshan I NPP

	Pipeline system	type	material	design temperature ℃	design pressure(at a)
1	extraction steam L	Φ323.9×8	St45.8III	236.4	31.05
2	extraction steam II	Φ377×8	A3	214.7	20.33
3	extraction steamIII	Φ529×10	A3	177.2	9.59
4	reheating level1	φ273×7.1	st45.8III	236.4	30.05
5	draining of MSR	φ355.6×8	st45.8III	174.53	9

Characteristic of these pipeline

- Material is carbon steel;
- Temperature more than 150℃ and less than 250 ℃
- • thinned components are located in the flow change area (Geometry)
- two- phase flow (a small number of wall thinning pipe fittings are single phase flow, but so far their wall thinning are not serious) ;

Summary

1. After Japan Mihama accident , FAC issues caused more attention of NPP administration, active and systematic FAC management strategy including “selecting”, “ calculation” , “ inspection”, “ assessment ”, “ replacement ” was established in operation NPP.

2. For NPP under construction, Cr content of secondary loop pipes is required to increase for FAC reason.

3. the most serious FAC occurred in two phase system, such as extraction steam system, reheating system, etc according to the operation experience of Qinshan I NPP.

4. FAC of big diameter (>50mm) pipes have been strictly controlled, but for the small diameter pipes, especially <25mm pipes, it is very difficult for inspection and accuracy prediction with software, the rupture of these pipes occasionally occurred in operation NPP.