Life Assessment Experience for Continued Operation of a CANDU Nuclear Power Plant in Korea

I.S. Jeong, G.H. Ha, W.J. Kim, T.R. Kim
Korea Electric Power Research Institute
H.Y. Roh
Korea Power Engineering Company
S.D. Lee
Korea Hydro and Nuclear Power

CONTENTS

WOLSONG SITE

Korea El

INTRODUCTION

Wolsong Unit 1, the first PHWR in Korea

- Reaching its 30 years design life by 2012
- Wolsong Unit 1 Lifetime Management Study (I), '00.07~'03.01
  - Assess technical and economic feasibility for the continued operation (co) beyond design life
- Wolsong Unit 1 Lifetime Management Study (II), '04.12~'07.05
  - In-depth lifetime evaluation and establishment of aging management programs for CO

REGULATORY REQUIREMENTS (1)

- *Korean nuclear industry follows the periodic safety review (PSR) practice*
- *The notice of the MOST, No. 2005-31*
  - "Guidelines of Technical Criteria for the CO's of Reactors beyond Design Life"
  - For the long term operation (LTO), include aging management
- *PHWR requirements not declared yet but close to issue*
  - Based on the same technical philosophy of the PWR's
  - Lessons learned from PWR experiences to PHWRs could be a strong point

REGULATORY REQUIREMENTS (2)

Contents of the intensified PSR for the LTO

Normal PSR

- Physical condition
- Safety assessment
- Equipment qualification
- Management of Aging
- Safety Performance
- Use of operation experience & research results
- O&M procedure
- Organization & administration
- Human factors
- Emergency plan
- Environmental effects

+

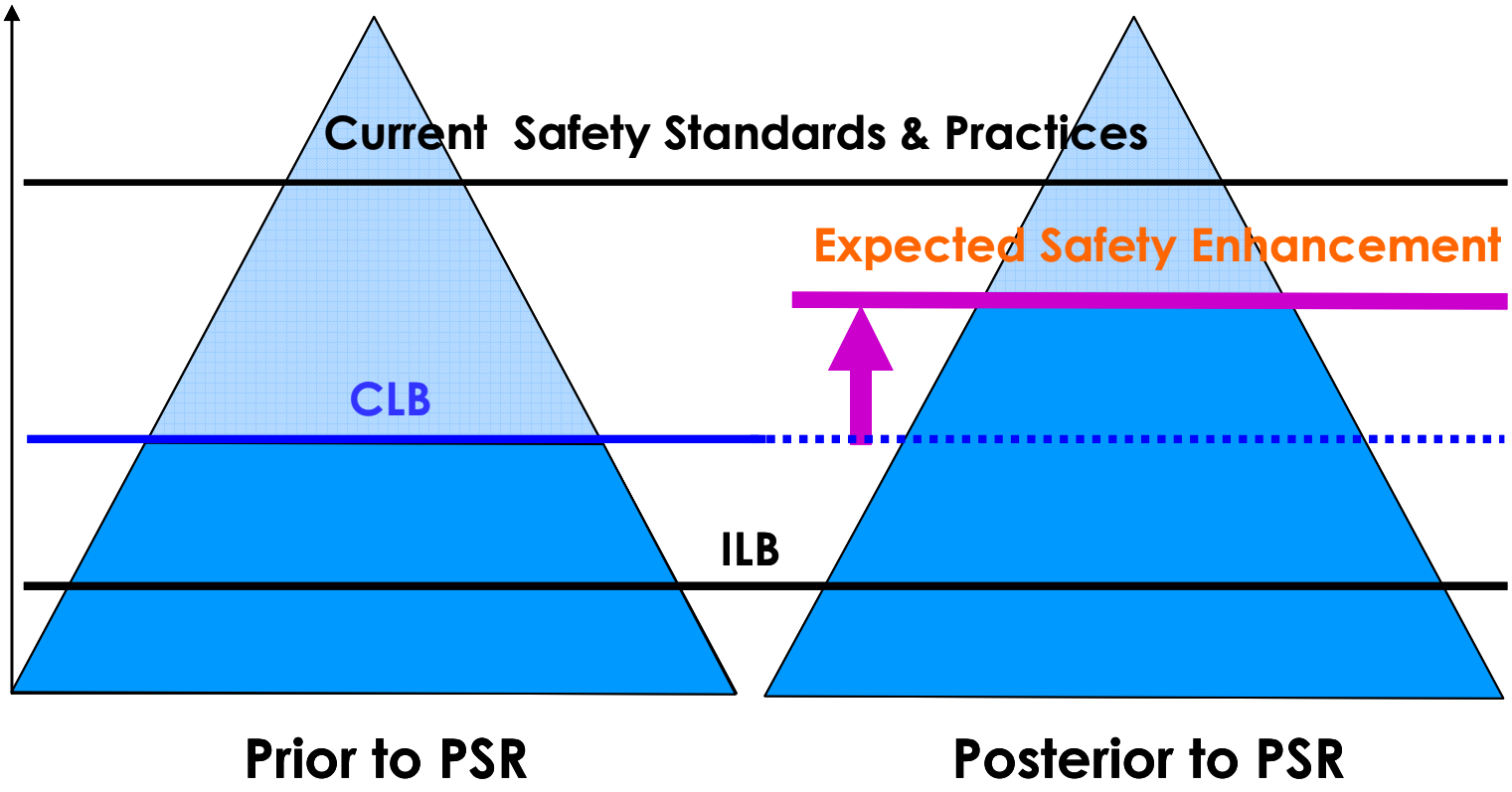
Additional safety criteria for LTO beyond design life

- Detail life evaluation of SSCs
- Time-limited aging analysis (TLAA)
- Aging management program
- Operating experience feedback
- International level of technical criteria
- Field inspection

Intensified PSR

REGULATORY REQUIREMENTS (3)

Safety Enhancement of PSR for the LTO

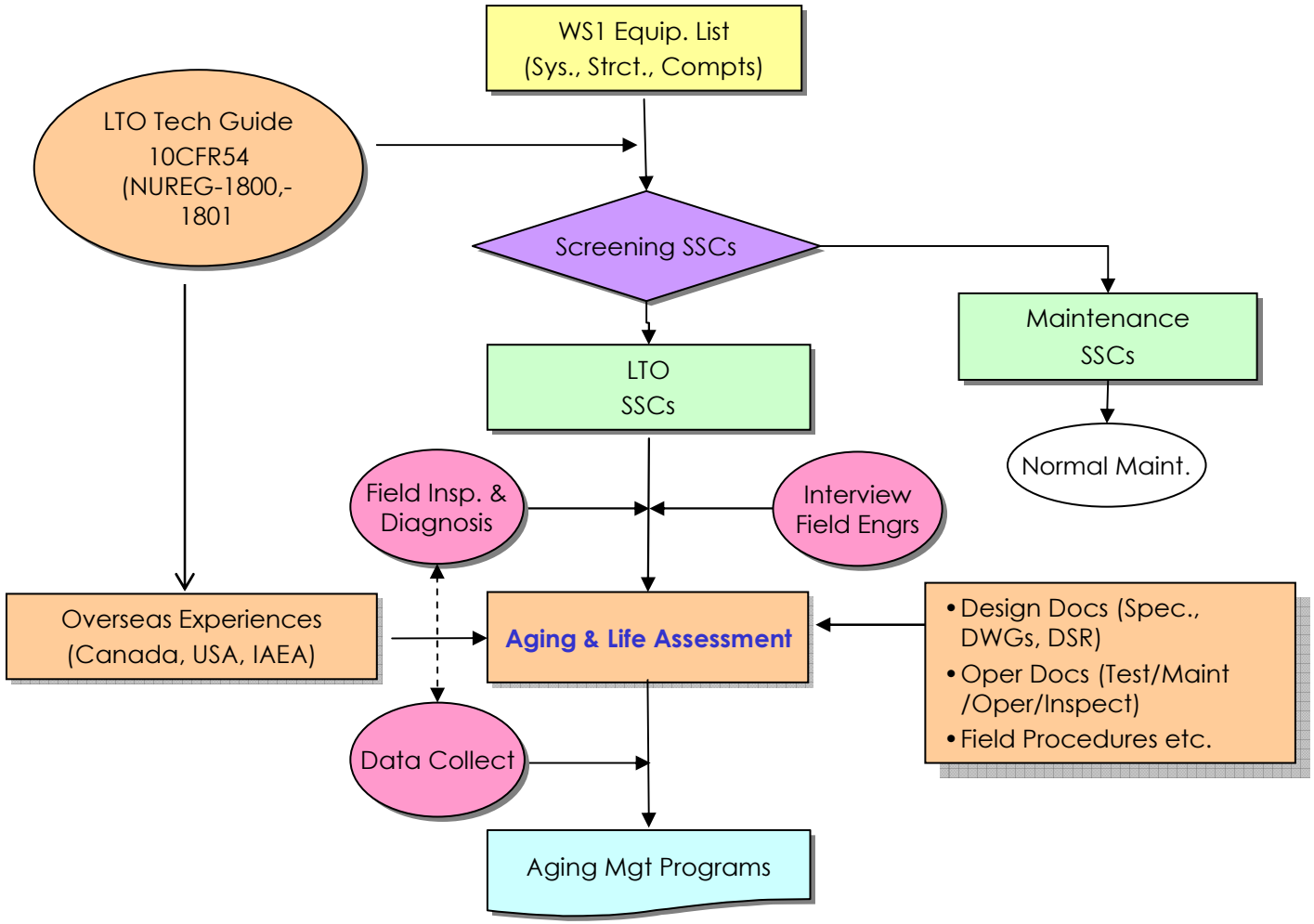


LIFE ASSESSMENT OF WOLSONG UNIT 1

In-detail life evaluation and provisions of aging management programs

- Data collection and review
  - Design, manufacture and installation documents and plant operation and maintenance history
- Determination of physical or functional boundary for SSCs
- Grouping and screening of sub-components within the scopes
- Aging analysis for the screened groups and sub-components
- Technical recommendations and management programs based on the aging evaluation results

Life assessment of structures & components



Screening

10CFR54 criteria screened SSC

- Long-lived passive structures and components of safety related systems
- Non-safety systems that can affect the safe shutdown functions when they are failed
- CANDU safety definitions was used to review safety related systems

Screened 81 out of 130 systems and structures (SCs) important to the LTO

- Life assessment reports of 46 systems and 8 common components/groups were developed

Field inspection & diagnosis (1)

- **Verify current aging status of the SCs**
- **Visual inspections and field diagnosis tests**
  - pipe thickness measurement
  - material property test
  - environment temperature measurement for cable aging assessment
  - performance tests
  - corrosion circumstances analysis of soil for buried commodity
  - and etc.

Field inspection & diagnosis (2)

Buried commodity inspection

Thickness measur't (fire line)

Pipe Coating Check

Closed Interval Potential Survey

Soil Sampling

Field inspection & diagnosis (3)

Temp. monitoring in cable environment

Life assessment in detail (1)

- ***Identify age related degradation mechanisms (ARDMs) and review the aging effects of the ARDMs by evaluating***
  - **Design and material data of the SC with the operational and environmental conditions of the systems**
- ***Qualitative life evaluation as aging management reviews (AMR) of 10CFR54***
- ***Quantitative life evaluation as the TLAA***

Life assessment in detail (2)

Method of life assessment

- MOST Notice No. 2005-31
- Technical references
  - 10CFR54, License Renewal Rule
    - Reg. Guide 1.88, Std Format and Cont. for App. to Renew
    - NUREG-1800, SRP for Review of LRA for NPPs
    - NUREG-1801, GALL Report for AMPs
  - NEI Guideline 93-10, Ind. Gdln for Imp. the Rqts of 10CFR54
  - IAEA TECDOCs (PWR, PHWR)
  - Industry experiences
    - EPRI, Industry Reports
    - Calvert Cliffs/Yankee Atomics/Gilvert
    - W GTRs, AECL templates
    - ASME, ASTM, ACI, CSA

SRP: Standard Review Plan
GALL: Generic Aging Lessons Learned
GTR: Generic Technical Reports
AMP: Aging Management Plan

Life assessment in detail (3)

Aging mechanisms

- Aging mechanisms of the sub-components were reviewed using the aging mechanisms in
  - ASME Section III App. W
  - American Concrete Institutes codes for structures
  - Canadian practices introduced in the IAEA TECDOCs
- Select aging mechanisms with followings;
  - Understanding of the aging mechanisms
  - Susceptible operating environments
  - Functions, materials, design, fabrications, and operating conditions
  - Review technical documents and reports

Life assessment in detail (4)

ASME Section XI, App. W

17 aging mechanisms reviewed

Cat	Aging Mech	Review	Detail Asst?
Corrosion (A)	1. Stress Corrosion Cracking	○ Definitions of Aging Mech. Justify the Aging Env. and Causers ○ Plant Operation Environments, Materials, Experiences ○ Review Aging Phenomena for the System ○ Necessity of Detail Life Assessment ○ Suggest the Strategy and Method of Life Assessment	×
	2. Gen Corrosion & Wastage	Similar Contents as Above	○
	3. Pitting Corrosion	Similar Contents as Above	○
	4. Crevice Cor & Denting	Similar Contents as Above	○
	5. Intergranular Corrosion Attack	Similar Contents as Above	×

Life assessment in detail (5)

Review aging effects

Comp.	Sub-comp.	Material/Environment	Analysis	Aging Mechanism Note 1)				
				A2	A3	A4	A6	C14
Heat Exchangers	Tubes	Ti/Sea Wtr(IS), Demin Wtr(OS)	○Corrosion resistive Ti ○MIC/Fouling inside for sea wtr ○Fretting btwn tubes and tube plate	-	-	-	○	○
	Shell	SS/Dem Wtr(IS), Air(OS)	○Gen Corr by leaking of sea wtr	○	-	-	-	-
	Tube Plate	SS/Demin Wtr	○Fitting, crevice corr. for demin wtr ○Fretting btwnn tubes and tube plate	-	○	○	○	-
	Channel	SS(Ti clad)/Sea Wtr	○Fitting, crevice corr. for demin wtr ○Fretting btwnn tubes and tube plate	-	○	○	○	-
	Supports	CS/Air	○Gen corrosion for CS	○	-	-	-	-
Pumps	Pr Bndry	SS/Demin Wtr	○Fitting, crevice corr. for demin wtr	-	○	○	-	-
	Supports	CS/Air	○Gen corrosion for CS	○	-	-	-	-
Valves	Vv Body	SS/Demin Wtr	○Fitting, crevice corr. for demin wtr	-	○	○	-	-
Ion Exchanger & Filters	Body, Flng, Nz	SS/Demin Wtr	○Fitting, crevice corr. for demin wtr	-	○	○	-	-
	Supports	CS/Air	○Gen corrosion for CS	○	-	-	-	-
Pipes & Supports	Pipes	SS/Dem Wtr(IS), Air(OS)	○Fitting, crevice corr. for demin wtr	-	○	○	-	-
	Supports	CS/Air	○Gen corrosion for CS	○	-	-	-	-

[Note 1] A2 : Gen Corrosion, A3 : Pitting, A4 : Crevice Cor, A6 : MIC/Fouling, C14 : Erosion/Fretting

Life assessment in detail (6)

Detail life assessment

Aging -SCs	Data	Aging Effect/Degradation	Assessments
Corr-RCP01	❍ Material: A351 Type CF8M CASS ❍ Des. T.: 650°F ❍ Des. Pr.: 2485psig	Aging Effects ❍ Loss of material Degradation ❍ CS comp. (IS corr.) ❍ Bolts (OS Corr.)	❍ No experiences in RCS piping ❍ Low inside corrosion of austenitic stainless steel for the protective film on the surface ❍ Good Water chemistry control of RCS. Low fluid velocity relatively. No bolting connection ❍ No findings from site walkdown and inspections ❍ Modified water chemistry and boron leak detection program would be proper for the LTO ❍ Justify a modified AMP item
Corr-RCP02	❍ Material: A351 Type CF8M CASS ❍ Des. T.: 650°F ❍ Des. Pr.: 2485psig	Aging Effects ❍ Loss of material Degradation ❍ CS comp. (IS corr.) ❍ Bolts (OS Corr.)	❍ No experiences in RCS piping ❍ Low inside corrosion of austenitic stainless steel for the protective film on the surface ❍ Good Water chemistry control of RCS. Low fluid velocity relatively. No bolting connection ❍ No findings from site walkdown and inspections ❍ Modified water chemistry and boron leak detection program would be proper for the LTO ❍ Justify a modified AMP item
Corr-RCP03	❍ Material: A351 Type CF8M CASS ❍ Des. T.: 650°F ❍ Des. Pr.: 2485psig	Aging Effects ❍ Loss of material Degradation ❍ CS comp. (IS corr.) ❍ Bolts (OS Corr.)	❍ No experiences in RCS piping ❍ Low inside corrosion of austenitic stainless steel for the protective film on the surface ❍ Good Water chemistry control of RCS. Low fluid velocity relatively. No bolting connection ❍ No findings from site walkdown and inspections ❍ Modified water chemistry and boron leak detection program would be proper for the LTO ❍ Justify a modified AMP item

Life assessment in detail (7)

System life assessment

BSI	System	Cmpts	Assessment Results
33350	Purification Circuit	Purification Hx, Purification Cooler, Ion Exchanger, Vvs, Piping and Supports	◆Aging Mechanisms : SCC, general cor., fouling, FAC ◆Aging Assessment : Hx fouling O.K., TLAA (fatigue) and FAC no limit to LTO ◆Recommendations : Mgt of closed cooling circuit sys, water chemistry, ISI and FAC ➢ Transient counting for fatigue control ➢ Provide Hx. performance test procedure ➢ Mitigate thermal stratified piping
33410	Shutdown Cooling System	Shutdown Clg Pp, Shutdown Clg Hx, Vvs, Piping and Supports	◆Aging Mechanisms : SCC, general cor., pitting, crevice cor., fouling, FAC ◆Aging Assessment : Hx fouling O.K., TLAA (fatigue) and FAC no limit to LTO ◆Recommendations : Mgt of closed cooling circuit sys, water chemistry, ISI and FAC ➢ Transient counting for fatigue control ➢ Provide Hx. performance test procedure ➢ Mitigate thermal stratified piping

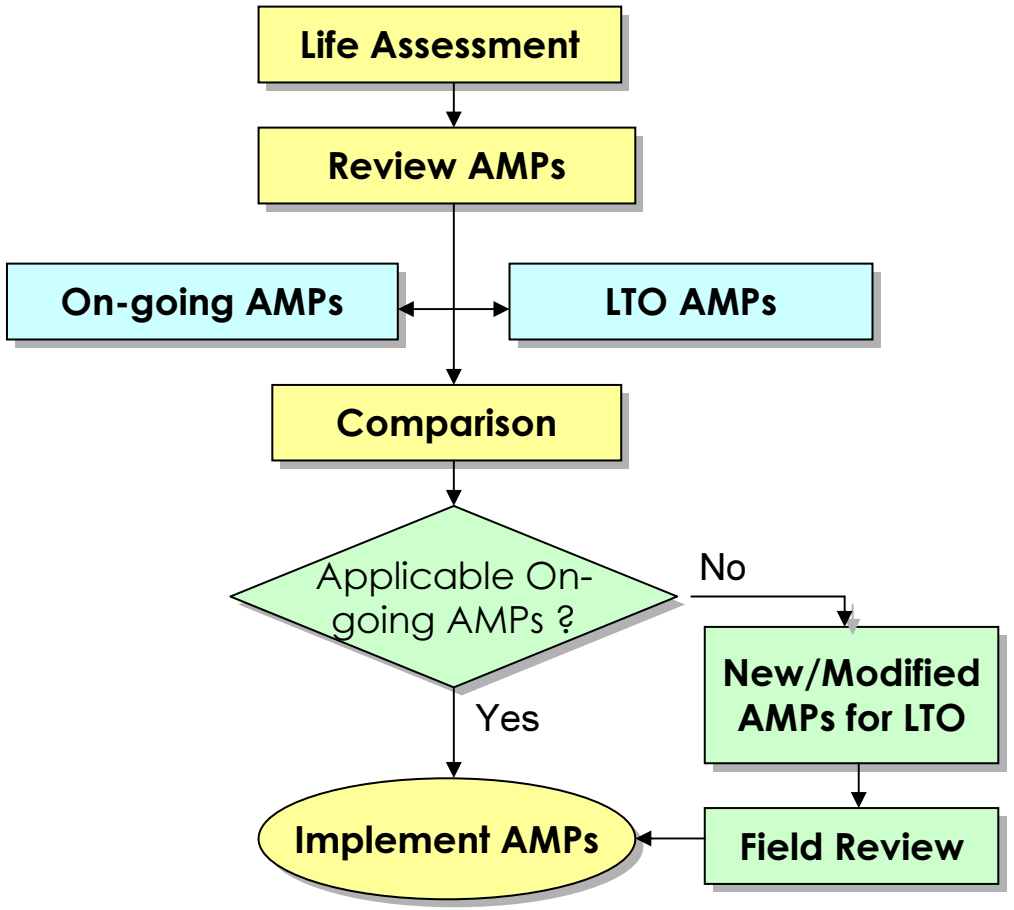
Life assessment in detail (8)

Component group life assessment

Cmpt Group	Major Sub-cmpts	Assessment Results
Valves	Valve body and bonnet in pressure boundary	◆Scope : Valves of 29 systems (gate, globe, ball, diaphragm, butterfly, check) ◆Aging Mechanisms : erosion/erosion-corrosion, FAC, thermal embrittlement, fatigue ◆Aging assessment ▪ erosion/erosion-corrosion, FAC : Vvs on thin thickness piping ➢ Inspection by NSAC-202L-R3 (VT, RT) ▪ thermal embrittlement : 63332-PCV5, PCV6 ➢ ASME Section XI IWB Table 2500-1 ▪ fatigue : no limit to LTO ◆Recommendations ➢ Vv insp. plan for those on thin thickness piping ➢ ISI plan for thermal embrittlement suspicious Vvs (63332-PCV5, PCV6)

Aging management programs (1)

Review of aging management program



Aging management programs (2)

CANDU unique AMPs for the LTO application

- Reactor assembly
- Fuel channels
- Feeders
- Non-metallic liner of containment building

Aging management programs (3)

System AMPs

BSI	System	Cmpts	AMPs	MOST Notice of AMP
33310 33320	Pressure and Volume Control System	PZR, Degasser cooler, Degasser Condenser, Pps, Vvs, Piping and Supports	◆Performance test of degasser clr ◆ISI for themal embrittlement suspicious Vvs (63332-PCV5, PCV6) ❖Fatigue monitoring system ❖maintenance program for the bolts of man-way and supports	◆1. ISI of safety class 1,2,3 components ◆2 .Supports ISI ◆7. Chemistry control ◆23. Closed cool'g wtr sys. ❖CASS therm. Embrit. ❖15. Bolt tight integrity
33350	Purification Circuit	Purif. Hx, Purif. cooler, Ion exch, tower, Vvs	◆Perf. test of Purif. Hx and Purif. cooler ◆Thermal stratification piping mgt (piping line 3335-18, 19) ❖Fatigue monitoring system	◆7. Chemistry control ◆23. Closed cool'g wtr sys.

CONCLUSIONS

- ***For the long-term operation of a CANDU reactor***
  - An one-through process of In-detail life assessment introduced the comprehensive experiences of PLiM project in Korea
  - PSR should evaluate plant safety including the aging assessments and AMPs
- ***PHWR requirements soon issued based on the same technical philosophy as the PWR's***
  - Lessons learned from PWR experiences could be a strong point of CANDU industry worldwide

Thank You and God Bless You All in Jesus