



**Spring 2019 Workshop on Age-Related
Degradation of Reactor Vessels and Internals**
U.S. Nuclear Regulatory Commission Headquarters, May 23-24, 2019

**Operating Experience (OpE) on
RV Internals, RV Head Penetrations, and RCS Small Bore
Nozzles in Korea**

**May 24th,
2019**

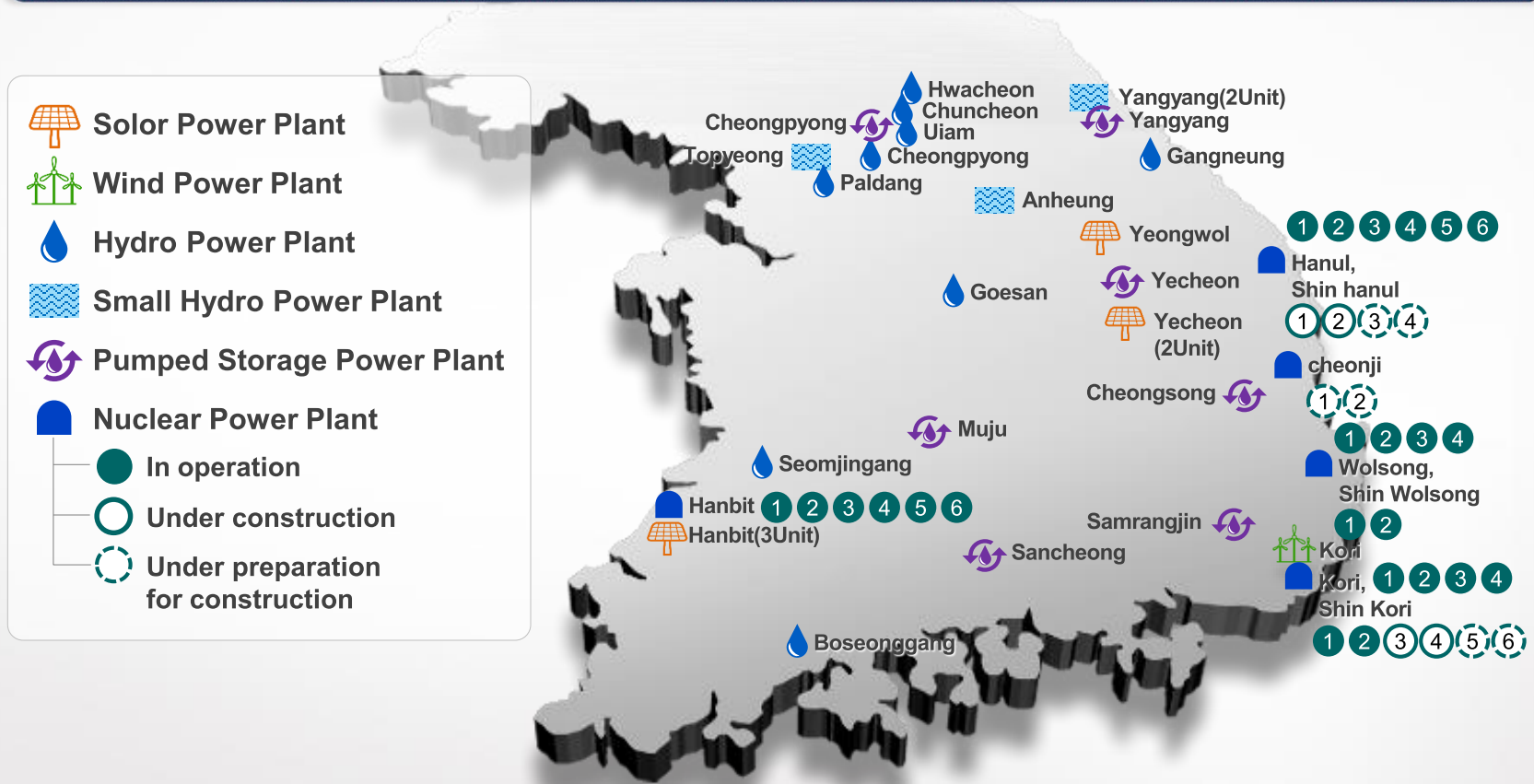


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Summary of KHNP

- The largest power generation company in Korea
- Supplying about 30% of the nation's electric power
- Working relentlessly to create sustainable growth as a trusted global energy leader



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TOPIC 1

OpE on Reactor Internal in KOREA

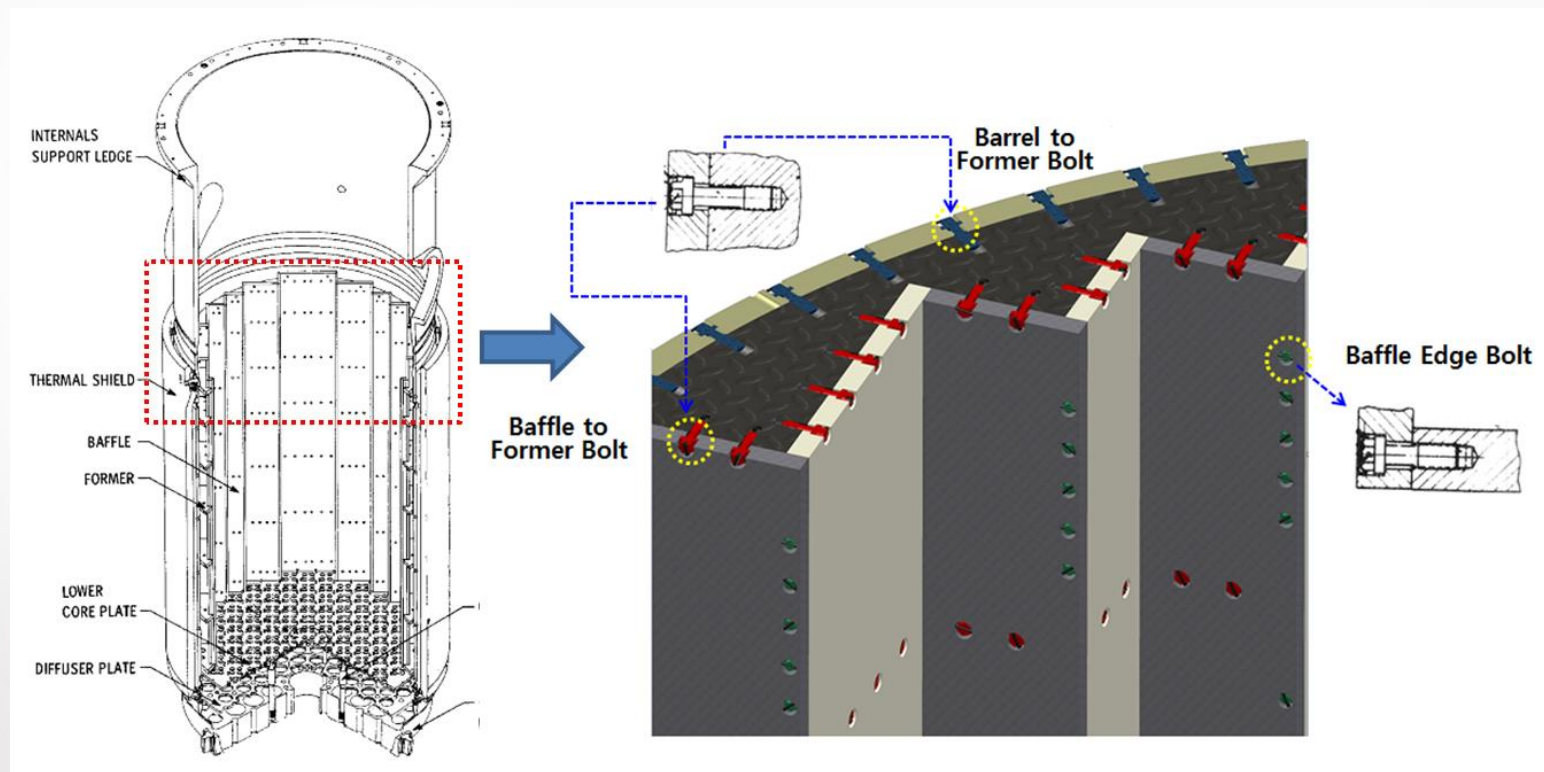


2015 Kori Unit 1 Baffle Bolts Inspections

- Kori Unit 1, 2 loop Westinghouse reactor
 - Commercial operation in 1976 and had 40 years.
 - Shutdown permanently Since June 16th, 2017
- Bolts are 316 stainless steel with hex head design with a locking bar
- All 728 baffle to former bolts were UT examined and VT-3 examined
- No back-wall signal from UT in eight baffle former bolts

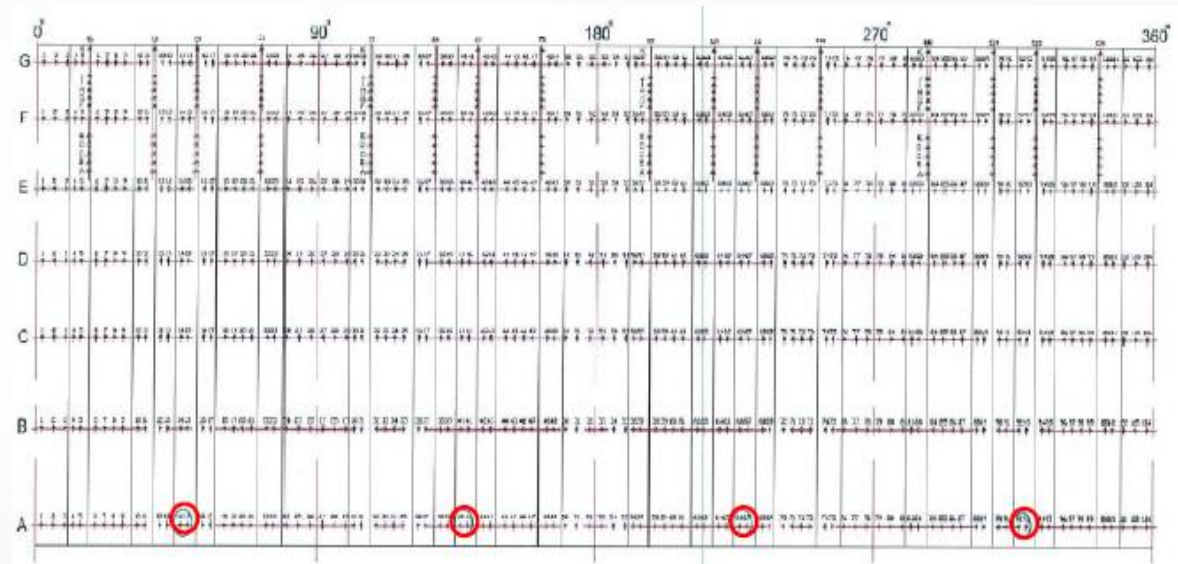
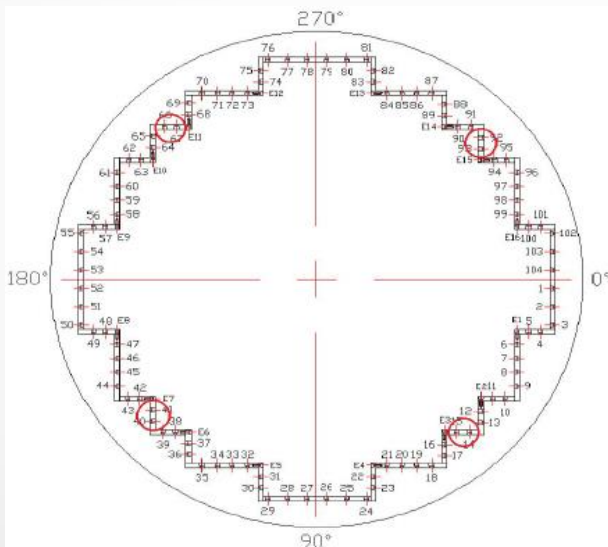
2015 Kori Unit 1 Baffle Bolts Inspections

- 5/18 ~25, 2015 : Inspection of UT for Baffle Bolts
 - Baffle Former Bolts (BFBs) : 728 EA (UT and VT)
 - Baffle Edge Bolts : 176EA (VT)



2015 Kori Unit 1 Inspection Findings on BFBs

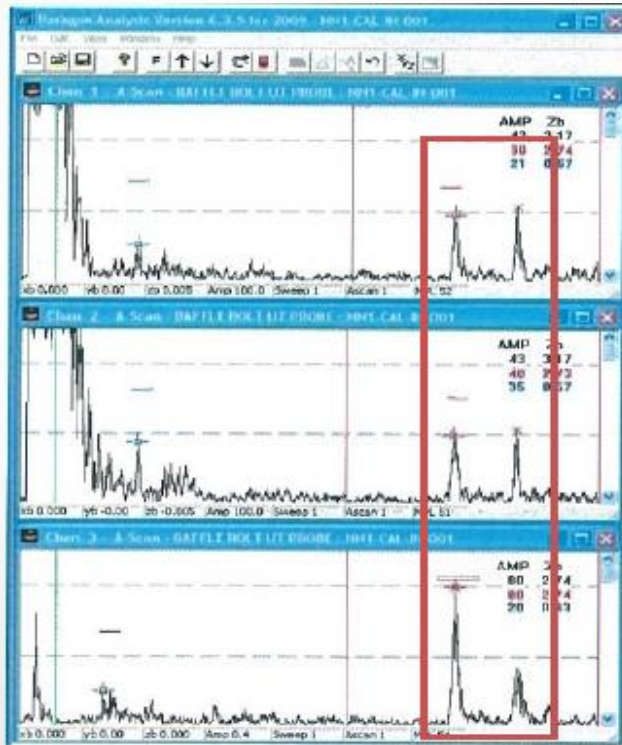
- 5/25, 2015 : No back-wall signals in 8 Baffle Former Bolts
- Defect unknown locations (DUL): 45°, 135°, 225°, 315° each 2 EA



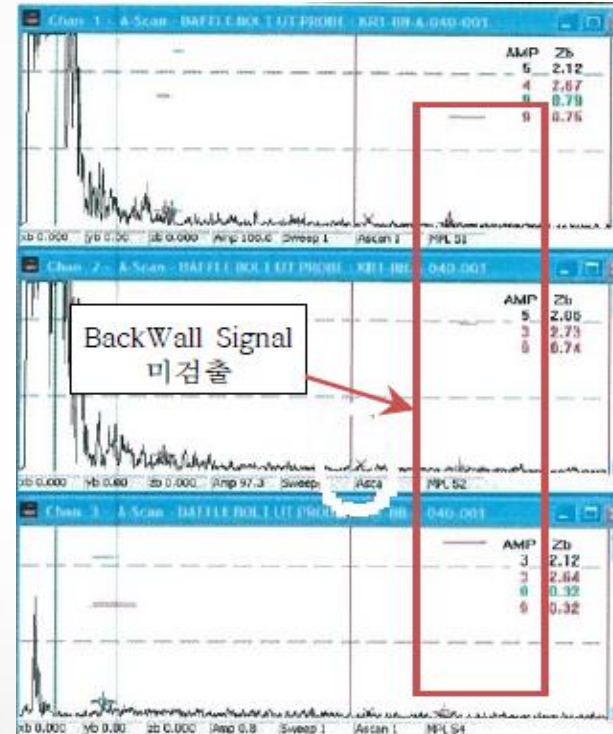
2015 Kori Unit 1 Inspection Findings on BFBs

- Analysis of Signals from UT(2 elements, 3channels)

Sound Bolts

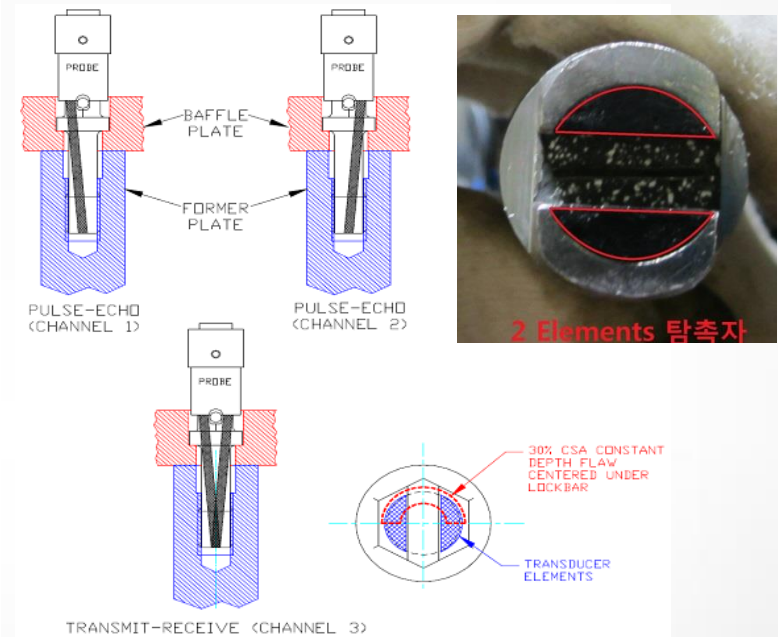
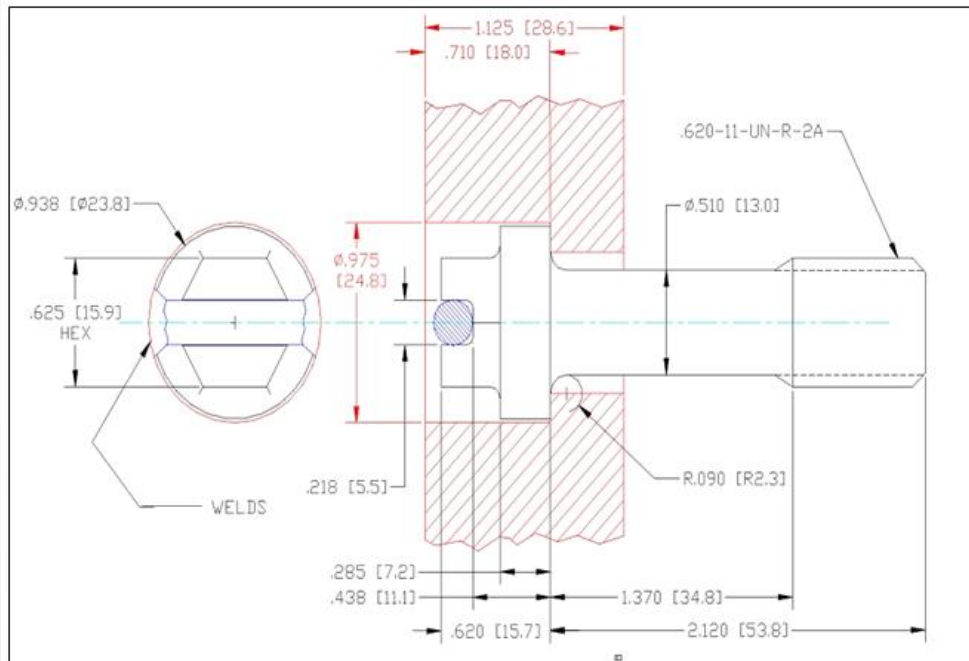


Defect Unknown Location



2015 Kori Unit 1 Inspection Findings on BFBs

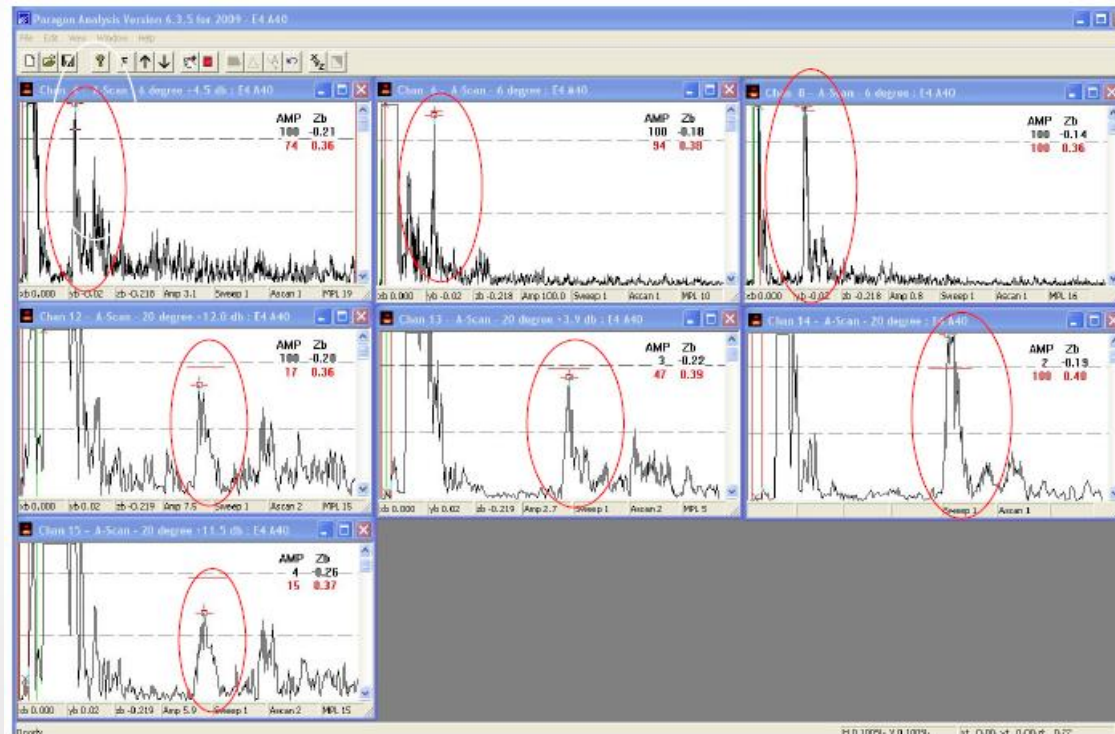
- Signals from UT(2 elements, 3channels)



2015 Inspection Findings on BFBs of Kori Unit 1

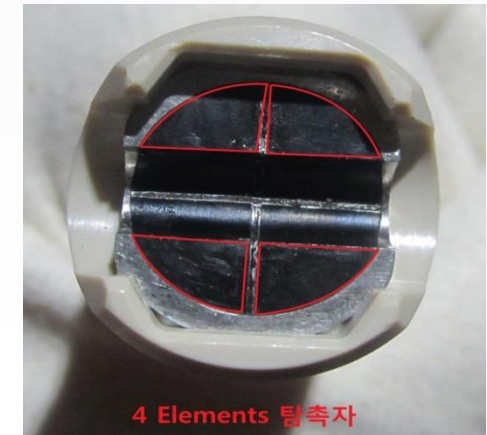
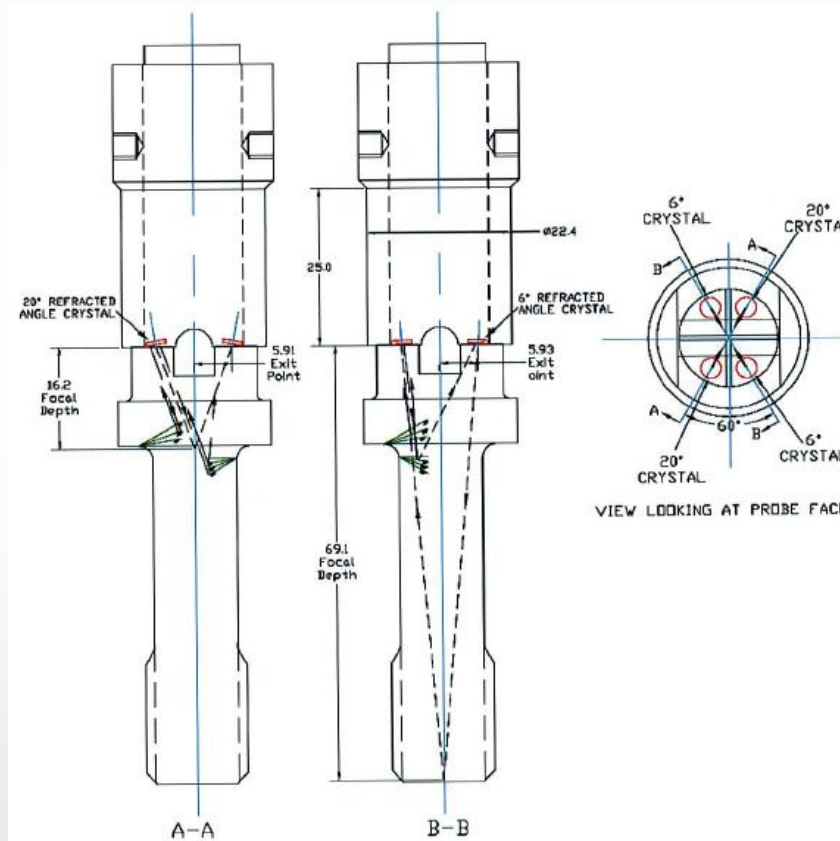
- Analysis of Signals from UT(4 elements, 16channels)

Defect Locations for bolts with DUL



2015 Inspection Findings on BFBs of Kori Unit 1

- Analysis of Signals from UT(4 elements, 16channels)
 - 20° Refracted Angle Crystal, 6° Refracted Angle Crystal



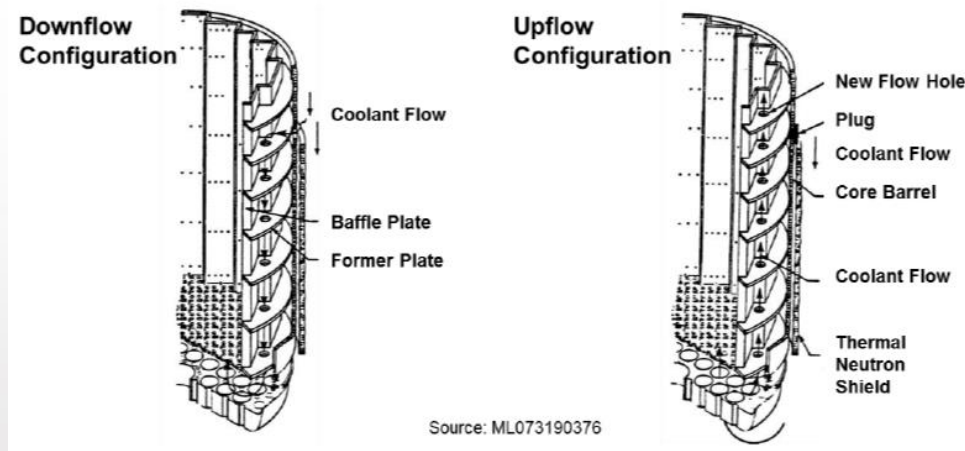
2015 Kori Unit 1 Inspection Findings on BFBs

- No back-wall signals in 8 BFBs were identified as DUL.
- UT with 4 Element probes found defects in shank which was located back locking bar.

Identification of Bolts	Inspection Results for Baffle Former Bolts		
	1999	2006	2015
	FRAMATOME	KPS	KPS
A14	Back Wall Signal	Back Wall Signal	Defect Unknown Location
A15	Back Wall Signal	Back Wall Signal	Defect Unknown Location
A40	Back Wall Signal	Back Wall Signal	Defect Unknown Location
A41	Back Wall Signal	Back Wall Signal	Defect Unknown Location
A66	Back Wall Signal	Back Wall Signal	Defect Unknown Location
A67	Back Wall Signal	Back Wall Signal	Defect Unknown Location
A92	Back Wall Signal	Back Wall Signal	Defect Unknown Location
A93	Back Wall Signal	Back Wall Signal	Defect Unknown Location

2015 Kori #1 Inspection Findings on BFBs

- OpE of Coolant Flow : Converted Up-flow
 - WEC plants have a “down-flow” baffle barrel region design, fuel degradation due to baffle jetting could be an indicator of potential baffle bolt degradation.
 - WEC plants which were the most susceptible to baffle-jetting related fuel degradation have been converted to up-flow.
 - Kori Unit 1 was converted to up-flow in 4 cycle operation after commercial operation in 1976.



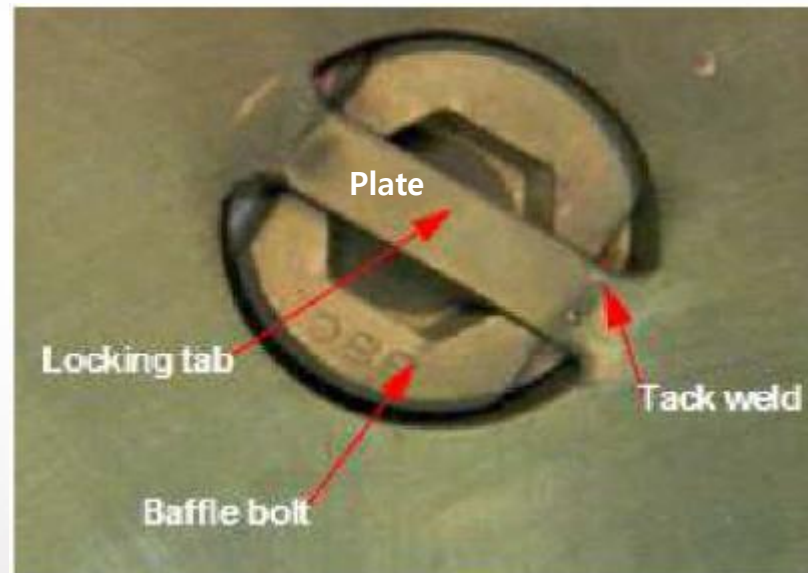
2015, Kori #1 Inspection Findings on BFBs

Comparison of Bolt Design

- Westinghouse 4 Loop, down flow reported lots of bolt degradation.
- D.C. Cook 2, 4 Loop, down-flow : Plate type locking bar, tack weld to baffle plate.
- Kori 1, 2 Loop, converted up-flow: Round type locking bar, welded to baffle plate.



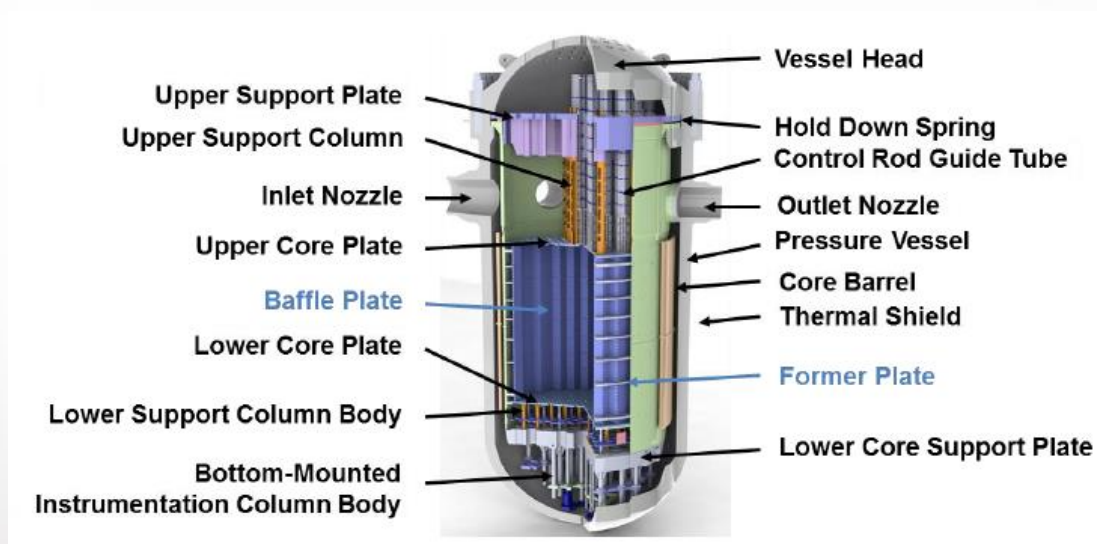
Kori #1



D.C. Cook #2

Reactor Internals Inspection Program Overview

- To Develop guidance to manage aging on RV internals in Korea
- MRP-227 I&E Guideline : What and When is to be inspected
 - Inspection and evaluation requirements for reactor internal components
- MRP-228 Inspection Standard : How to inspect
 - NDE methodology requirements to support MRP-227



Post 2015 Kori #1 Inspection Findings on BFBs

- 2016 : 100% VT and 25% UT Inspection for 200 bolts were done with no additional indications.
- 2020 : Pull 16 bolts out from Kori#1
- 2021 : Inspection and evaluation procedures of reactor internals
- 2023 : Hot cell testing of BFBs in KAERI

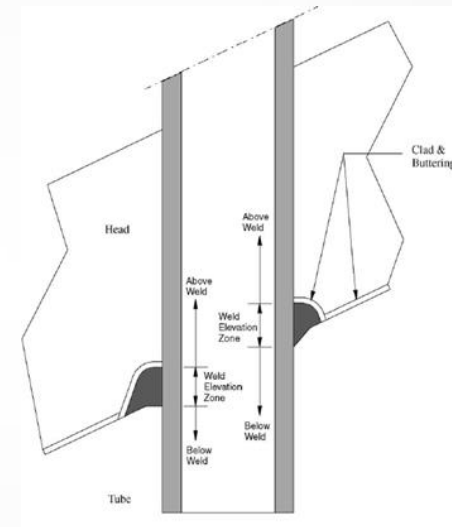
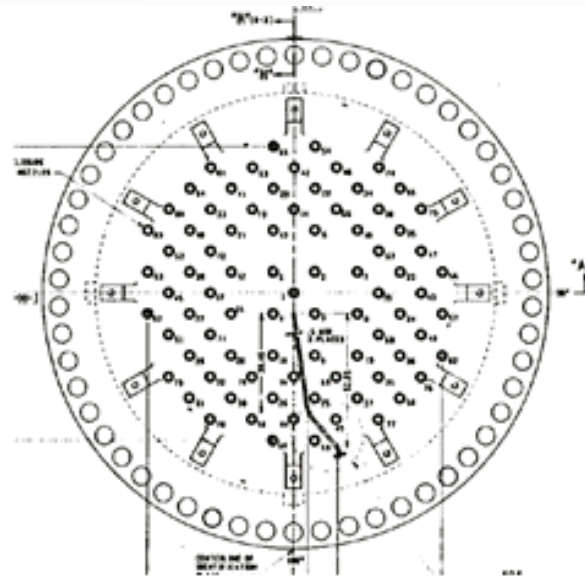
TOPIC 2

OpE on RV Head Penetrations in KOREA



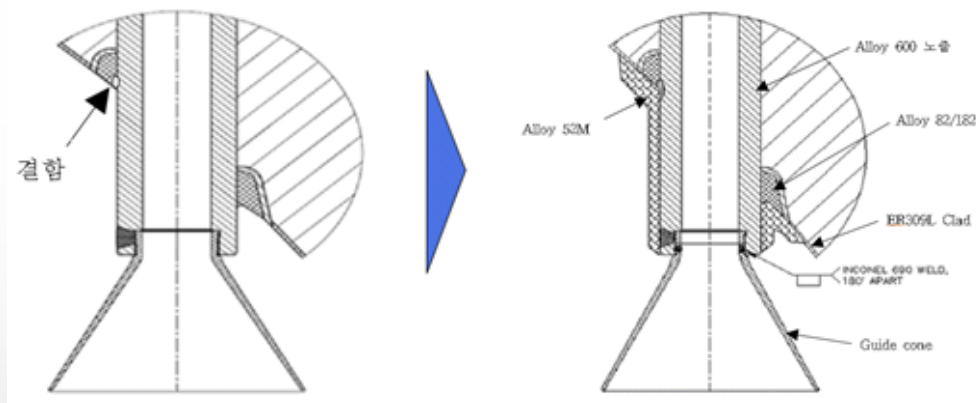
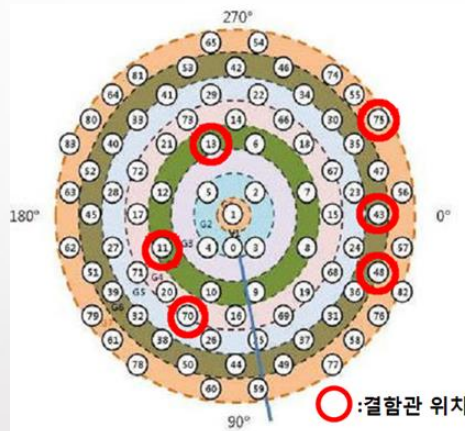
2012 RVHP Inspection Results in Hanbit#3

- Hanbit#3 started the commercial operation in 1995
- 11/12, 2012 : Inspection of UT for RVHP
 - Reactor Head Penetrations : 85EA (UT and ET)



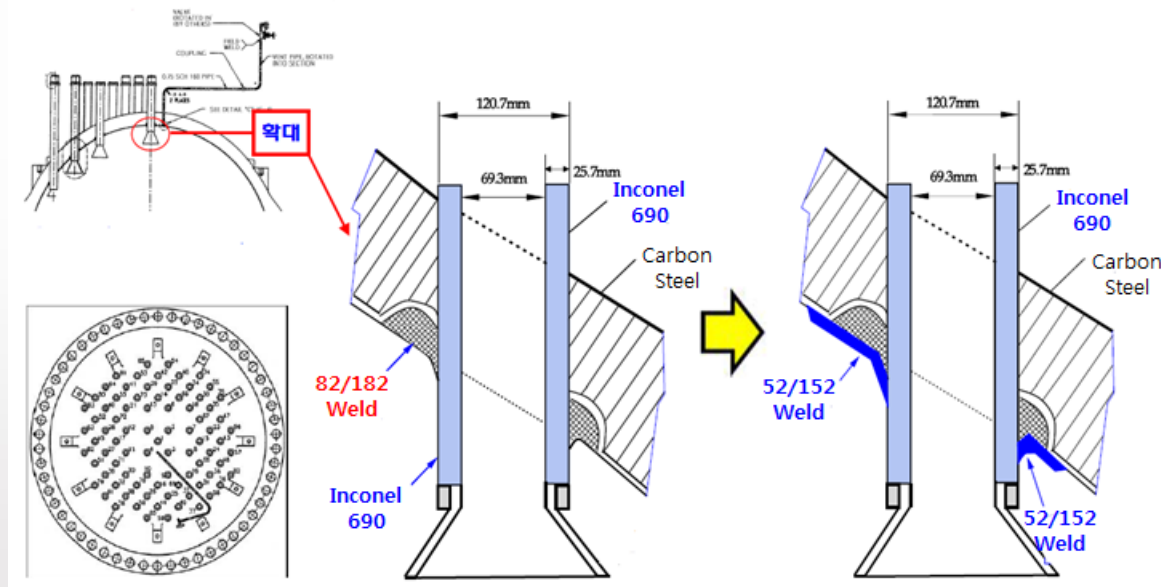
2012 RVHP Inspection Results of Hanbit#3

- UT detected six flaws : P11, P43, P70, P75, P13, P48
- All flaws were oriented axially and located in CRDM tube near the location of the J-groove weld toe
- Liquid penetrant examinations confirmed the existence, location, and orientation of the identified flaws and none of the flaws presented a leakage path to the upper surface of the RVHP
- Six penetrations were repaired with the embedded flaw technique



POST 2012 RVHP Inspection Results of Hanbit#3

- Replacement of Reactor Vessel Closure Head
 - CRDM Nozzles(Alloy 600→690), J-groove weld(82/182→52/152)
 - Hanbit#3&4(2015), Hanwul#1&2(2022)
- Preventive Maintenance of Reactor Vessel Closure Heads
 - CRDM Nozzles(Alloy 690), J-groove weld(82/182→52/152)
 - Hanwul#3&4, Hanbit#5&6(~2022) using seal weld technique



TOPIC 3

OpE on RCS Small Bore Nozzles in KOREA

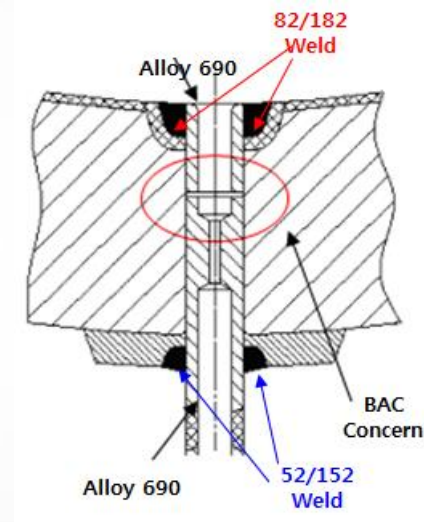


2016 Hanwul#3 Small Diameter Nozzle Inspection

- Hanwul Unit 3, 2 loop CE reactor
 - Commercial operation in 1996 and had ~20 EFY
- VT Inspection of instrument nozzles in RCS Hot Leg
 - Temperature nozzle : 10EA, Sampling nozzle : 1E
 - Pressure measure nozzle : 8EA
- Nozzle Material : Tube(Alloy 690), Weld(82/182)
- A Leak was discovered from sampling nozzle in Mar. 2016

2016 Hanwul#3 Inspection Results of Sampling Nozzle

- Leak was discovered from sampling nozzle during visual inspection for evidence of boric acid deposits
 - Crack was short, axial and located near the J-groove welds to be attached nozzle to the hot leg piping
- The leak was repaired using half nozzle repair
- The plant qualified a UT technique to inspect the low alloy steel base metal for general corrosion
- There has been no indication of general corrosion of low alloy steel base metal



POST 2016 Hanwul#3 Sampling Nozzle Leak

- 1st 2019 ~ 2021 : Small bore nozzles of RCS Hot Leg Pipings
 - Nozzles(Alloy 690), J-groove weld(**82/182**→**52/152**)
 - Hanbit#3&4, Hanwul#3&4, Hanbit#5&6 (**total 113EA**)
 - Preventive Maintenance : Half nozzle repair with pad or nod-pad
- 2nd 2021 ~ 2024 : Heater sleeve nozzles of Pressurizer
 - Nozzles(Alloy 690), J-groove weld weld(**82/182**→**52/152**)
 - Hanbit#3&4, Hanwul#3&4, Hanbit#5&6 (**total 258EA**)
 - Preventive Maintenance : Half nozzle repair with pad or nod-pad

Chapter **3**

Conclusions



Summary

- 2015, Kori Unit 1, WEC 2 loop reported the indications of cracking of Baffle-former bolts for the first time in Korea.
 - To investigate the potential for plants to experience a similar aging effect and get down to work on the project to manage this aging effect for PWR Internals in Korea.
- 2012, Hanbit Unit 3, CE 2 loop, UT detected flaws in six CRDM penetrations. All the reported flaws were oriented axially and located in the CRDM nozzles near the location of the J-groove weld.
 - 2015, reactor heads of Hanbit 3&4 were replaced with Alloy 690 CRDM nozzles and 52/152 J-groove welds.
 - 82/182 J-groove welds of reactor heads for Hanwul 3&4 and Hanbit 5&6 are scheduled to be overlay welded with 52/152 weld metal.
- 2016, Hanwul Unit 3, CE 2 loop, leak was discovered from RCS hot leg sampling nozzle to be attached hot leg piping.
 - Half nozzle technique will be implemented to small bore nozzle attached to RCS hot leg piping and pressurizer heater sleeve.

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**THANK
YOU**