

# **Working Group on Codes and Standards**

## **International workshop on In-Service Inspection**

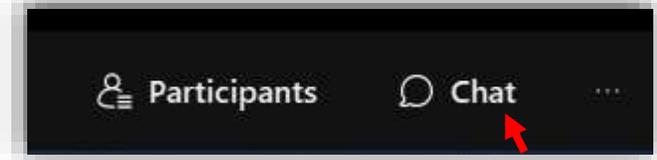
**11-14 April 2022**

**Working Group on Codes and Standards**

**Workshop on In-Service Inspection**

# **Welcome**

**Day 1 – Monday 11 April 2022**



**To contact us, please use the chat function**

**To ask a question, please use the Q&A section**



# POLL #1

## Opening remarks



**Dr David RUDLAND**

Senior Technical Advisor for Nuclear  
Power Plant Materials  
US Nuclear Regulatory Commission



**Dr Sangmin LEE**

Korean Institute for Nuclear Safety

## Structure of the workshop

- **Session 1:** Reactor vessel ISI programmes and additional regulatory requirements - interval, coverage, qualification, etc.
- **Session 2:** Evolution of NDE techniques
- **Session 3:** Extending ISI intervals
- **Session 4:** Design for inspection

## Session 1

**Reactor vessel ISI programmes and additional regulatory requirements - interval, coverage, qualification, etc.**

## Agenda of Day 1

Time*	Topic
11:00-11:15 AM	Opening of the workshop : <b>Dr David RUDLAND</b> (US NRC) and <b>Dr Sangmin LEE</b> (KINS, Korea)
11:15-12:35	Presentations: <ul style="list-style-type: none"> <li>- <b>Mr Steven TAYLOR</b> (ONR, United Kingdom): <i>RPV ISI in United Kingdom</i></li> <li>- <b>Mr Michael BENSON</b> (NRC, United States): <i>RPV ISI in the United States</i></li> <li>- <b>Ms Haruko SASAKI</b> (NRA, Japan): <i>Reactor vessel ISI programmes and regulatory requirements in Japan</i></li> <li>- <b>Mr Young Eui KWON</b> (KINS, Korea): <i>Regulatory status on In-Service Inspection programme for reactor vessel in Korea</i></li> </ul>
12:35-13:05 (30min)	Panel discussion and questions from the audience
13:05-13:15 (10min)	Break
13:15-14:15	Presentation: <ul style="list-style-type: none"> <li>- <b>Mr Adrien THIBAUT &amp; Ms Clémentine PERON</b> (ASN, France): <i>RPV ISI in France</i></li> <li>- <b>Ms Jolana RYDLOVA</b> (SUJB, Czech Republic): <i>RPV ISI in the Czech Republic</i></li> <li>- <b>Mr Peter DEAK</b> (OAH, Hungary): <i>Application of ASME at ISI of VVER-440 Units</i></li> </ul>
14:15-14:45 (30min)	Panel discussion and questions from the audience
14:45-15:00 (15 min)	Conclusion of day 1

\*Paris time



**Mr Steven TAYLOR**

Office for Nuclear Regulation, United Kingdom



Office for  
Nuclear Regulation

# Reactor Pressure Vessel ISI

Sizewell B PWR UK

# Content

RPV Design and Manufacture

RPV Inspection

Inspection Validation

Regulatory Footprint

# RPV Design and Manufacture

- ASME III BPVC technical requirements
- Administrative requirements adapted for UK context
- Additional safety requirements to justify the claim that gross failure can be discounted impacted:
  - Design
  - Materials
  - Construction
  - Examination

# RPV Inspection

	Forgings	Circumferential Welds	Nozzle Welds
Framatome (Manual)	Pre-Stress Relief	Pre-Stress Relief	Pre-Stress Relief
		Post Stress Relief	Post Stress Relief
BEL (Automated)	Post Stress Relief		Post Stress Relief
		Post Hydrotest	Post Hydrotest
RRA	Nozzle Radii PSI	PSI	PSI

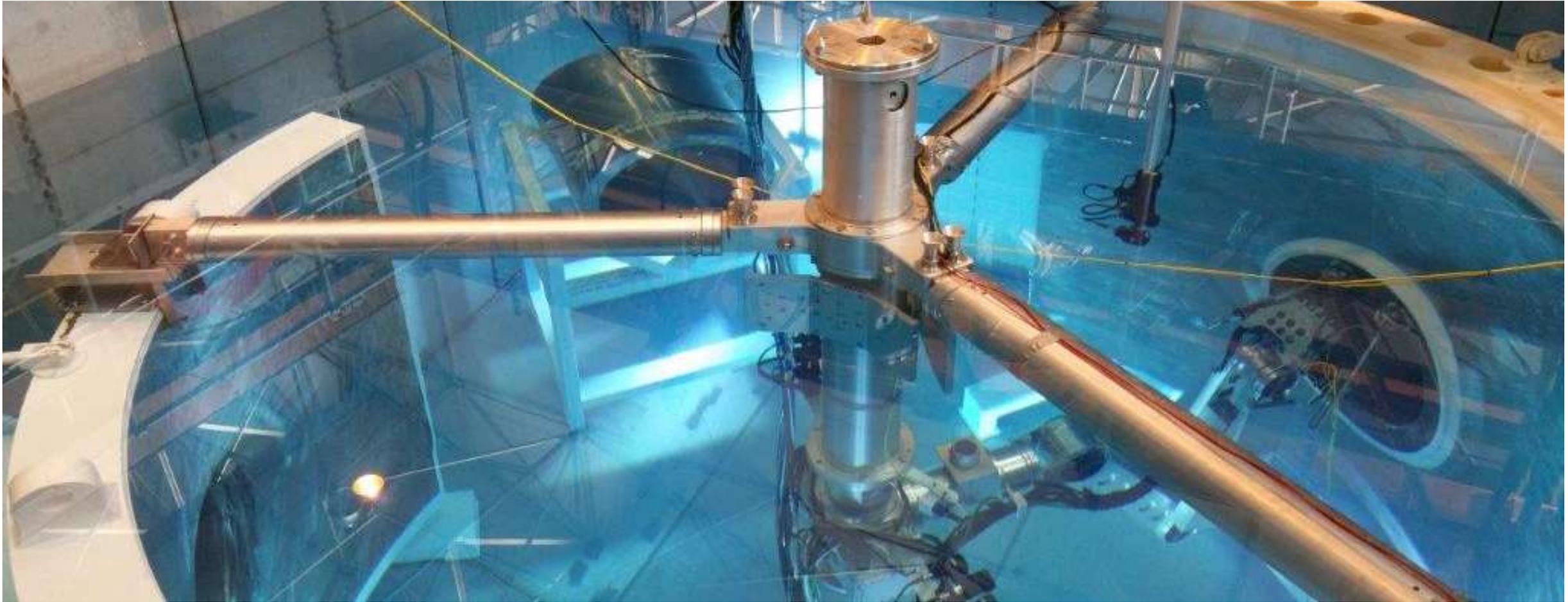
- RPV manufacturing inspection requirements and methods generally in accordance with ASME III and V.
- Significant changes made in examination requirements mainly involving an enhanced programme of ultrasonic inspections to improve redundancy and diversity and to demonstrate a high reliability and confidence in inspection capability.
- Ultrasonic inspection strategy involved three independent inspection organisations and the Inspection Validation Centre.
- The PSI inspections provided the baseline for ISI. PSI and ISI use the same equipment and procedures.
- ISI requirements generally in accordance with ASME XI with appropriate adaptations to meet UK administrative and validation requirements.
- The IIA endorsed all inspection procedures, witnessed inspection validation and actual inspections to ensure the procedures were applied correctly.
- Where degradation or ageing mechanisms have challenged integrity additional inspection has been used to assure ongoing operability.

The content in this presentation represents the opinions of the author, and is a product of professional research. It does not represent the position or opinions of the Office for Nuclear Regulation, nor the official position of any staff members.

# Inspection Validation

- The Inspection Validation Centre (IVC) provides a report and certification for the ultrasonic inspection.
- UKAS Accredited Independent Body
- Qualification of the procedure, equipment and personnel.
- Dynamic approach to qualification.
- Full size test pieces containing appropriate defects arranged in a large tank.
- Operators are subject to a written exam and interview prior to practical trials.
- Inspector qualification lasts 3 years.
- Qualification is usually for detection and characterization only.
- Inspection data is usually analysed by two independent organisations.

# Inspection Validation



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# Regulatory Footprint

- The UK regulatory regime is non-prescriptive.
- ONR are a sampling organisation.
- During manufacture regulatory focus would generally be on the processes and procedures with a limited number of inspections to ensure procedures are implemented correctly.
- ONR takes benefit from the activities of the IVC, INA and IIA or other agencies.
- ONR consider and approve as necessary modifications.
- Regulatory interventions during periodic shutdown.
- Working level meetings.
- Influence safety improvements.

# Further Reading

- Sizewell B Reactor Pressure Vessel (Geraghty, Colet)
- Manufacture of the Sizewell B Reactor Pressure Vessel (Chapelle)
- Sizewell B Reactor Pressure Vessel Pre-Service Inspection (Ludlam, Kelsey, Shand)
- Validation of Inspections for the Sizewell B Reactor Pressure Vessel (Waites, Leyland)
- Validated Automated Ultrasonic Inspections of the Sizewell B Reactor Pressure Vessel (Dijkstra, Farley)
- The Role of the Independent Inspection Agency (Cobblestone)
- These articles can be found in the Journal of the British Nuclear Energy Society, December 1992, Volume 31, Number 6.



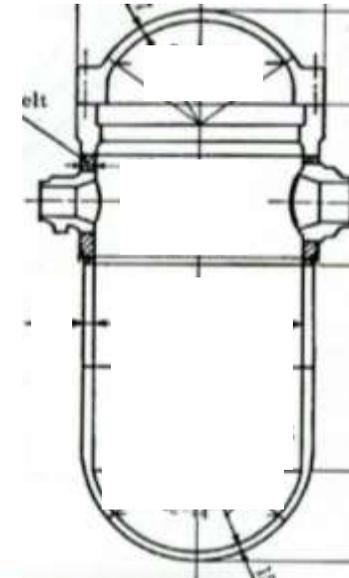
**Mr Michael BENSON**

Nuclear Regulatory Commission, United States

# Reactor Pressure Vessel Inservice Inspection Requirements in the U.S.

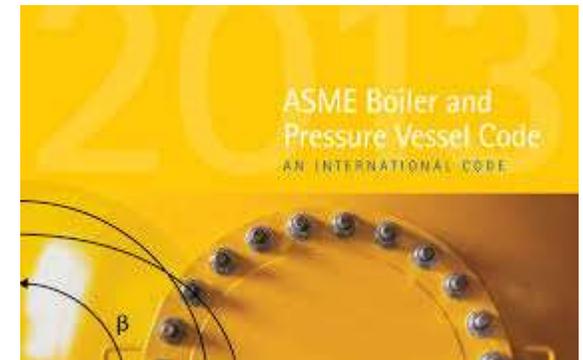
Michael L. Benson  
*U.S. Nuclear Regulatory Commission*

International ISI Workshop  
April 11-14, 2022  
Virtual Workshop



# Regulations vs. Consensus Standards

- Inservice inspection requirements for U.S. nuclear power plants are set forth in Title 10 of the Code of Federal Regulations 50.55a (10 CFR 50.55a)
- American Society of Mechanical Engineers (ASME) Boiler & Pressure Vessel Code, Section XI, Division 1 (BPV XI) is incorporated by reference (IBR) in 10 CFR 50.55a
- The rules of BPV XI, therefore, become law subject to conditions in 10 CFR 50.55a(b)(2) upon IBR



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# Rules of BPV XI, Subsection IWA (2021 Edition)

- General requirements applicable to all examination activities under BPV XI
- Programmatic in nature
- IWA-2400 requires an inservice inspection (ISI) program consisting of plans and schedules
  - Interval dates and inspection periods
  - Applicable Edition and Addenda of BPV XI
- An ISI interval is a time period during which all the examination requirements of BPV XI must be met (see IWA-2430(a))
- The current BPV XI ISI interval is 10 years



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# Rules of BPV XI, Subsection IWB (2021 Edition)

- Examination requirements for ASME Class 1 components
- Table IWB-2500-1 provides a complete listing of components in scope of BPV XI and defines required method, extent, and frequency of the exam.
  - Organized according to Examination Categories
  - Each category is organized according to Item Numbers
- Figures in IWB illustrate applicable weld geometries and exam volumes

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# Rules of BPV XI, Subsection IWB (2021 Edition)

- Examination Category B-A, Pressure Retaining Welds in Reactor Vessel
  - Item Nos. B1.10-B1.12: vessel shell welds
  - Item Nos. B1.20-B1.22: vessel head welds
  - Item No. B1.30: shell-to-flange weld
  - Item No. B1.40: head-to-flange weld
  - Item No. B1.50-B1.51: repair welds

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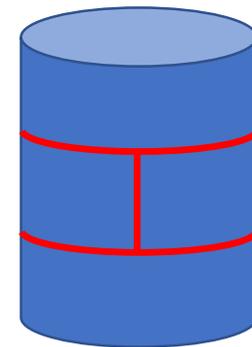
# Rules of BPV XI, Subsection IWB (2021 Edition)

- Examination Category B-D, Full Penetration Welded Nozzles in Vessels
  - Item Nos. B3.90: nozzle-to-vessel welds
  - Item Nos. B3.100: nozzle inner radius section

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# BPV XI Rules for Items B1.10-B1.12 (2021 Edition)

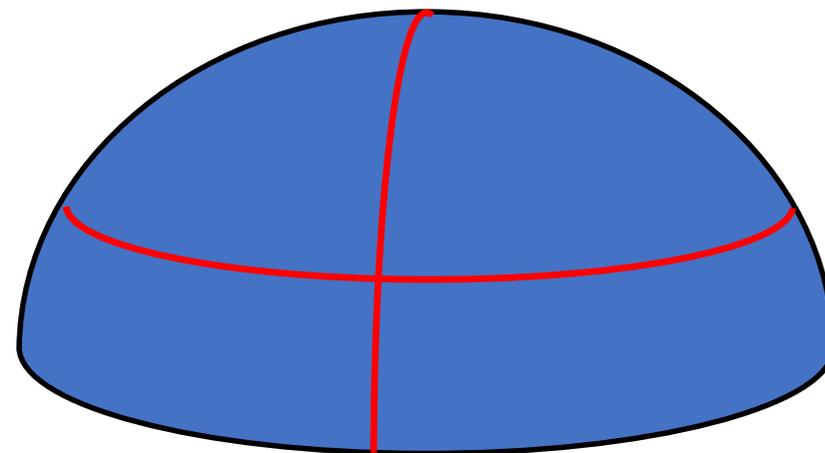
- Circumferential and longitudinal reactor vessel shell welds
- Method: Volumetric exam
- Frequency: Once during the first ISI interval and each successive interval
- Extent: All welds, “essentially 100%” of defined volume
- Essentially 100%: IWA-2200(c) – greater than 90% of the defined volume



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# BPV XI Rules for Items B1.20-B1.22 (2021 Edition)

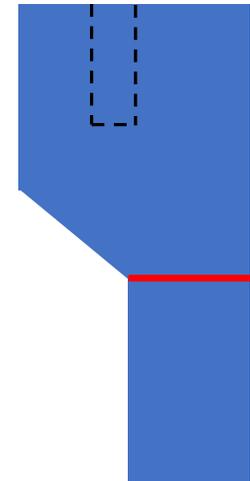
- Circumferential and meridional reactor vessel head welds
- Method: Volumetric exam
- Frequency: Once during the first ISI interval and each successive interval
- Extent: “Accessible length” of all welds, essentially 100% of defined volume



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# BPV XI Rules for Item B1.30 (2021 Edition)

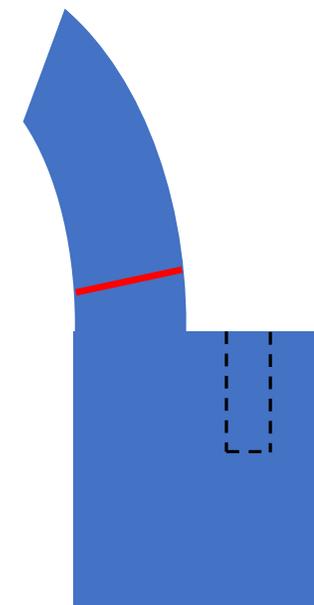
- Reactor vessel shell-to-flange weld
- Method: Volumetric exam
- Frequency: Once during the first ISI interval and each successive interval
- Extent: Essentially 100% of the defined volume



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# BPV XI Rules for Item B1.40 (2021 Edition)

- Reactor vessel head-to-flange weld
- Method: Volumetric and surface exam
  - Surface exam only may be used if a previous volumetric exam did not detect a flaw that exceeds acceptance criteria
- Frequency: Once during the first ISI interval and each successive interval
- Extent: Essentially 100% of the defined volume



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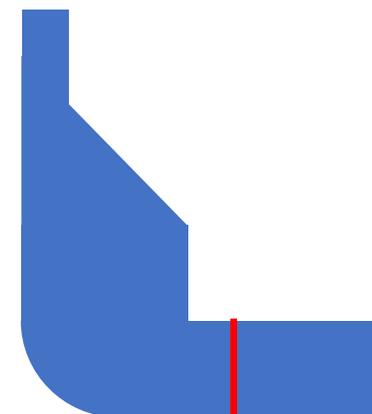
# BPV XI Rules for Items B1.50-B1.51 (2021 Edition)

- Repair welds exceeding 10% of the nominal wall thickness
- Method: Volumetric and surface exam
  - Surface exam only may be used if a previous volumetric exam did not detect a flaw that exceeds acceptance criteria
- Frequency: Once during the first ISI interval and each successive interval
- Extent: Essentially 100% of the defined volume

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# BPV XI Rules for Item B3.90 (2021 Edition)

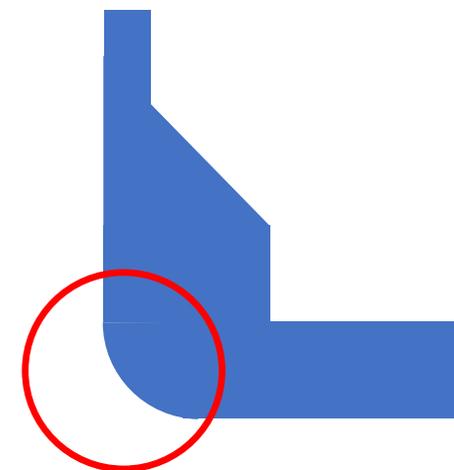
- Nozzle-to-vessel welds
- Method: Volumetric
- Frequency: Once during the first ISI interval and each successive interval
- Extent: All nozzles, essentially 100% of the defined volume
- IWB-2500(f) allows 25% sample, as opposed to all nozzles



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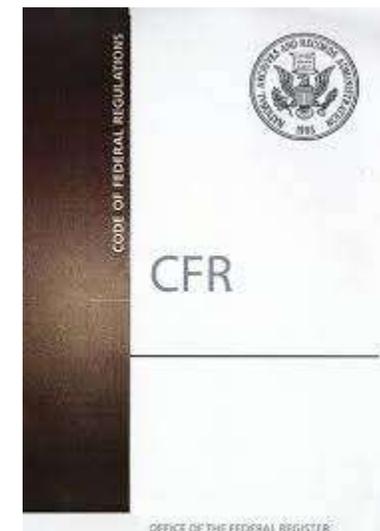
# BPV XI Rules for Item B3.100 (2021 Edition)

- Reactor vessel nozzle inside radius
- Method: Volumetric
- Frequency: Once during the first ISI interval and each successive interval
- Extent: All nozzles, essentially 100% of the defined volume
- IWB-2500(f) allows 25% sample, as opposed to all nozzles
- IWB-2500(g) allows visual exam in lieu of the volumetric exam, under certain conditions



# Related Conditions in 10 CFR 50.55a(b)(2)

- (xvi), (xviii), (xix), (xxii), and (xxiv) are miscellaneous conditions related to nondestructive examination
- (xxi)(B) conditions on use of IWB-2500(f) and (g)
  - Requires a plant-specific evaluation
  - Not permitted for plants with a renewed license
  - Not permitted for newer plants licensed under 10 CFR 52



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# Summary

- ASME BPV XI, Subsection IWB, Categories B-A and B-D
- Conditions on ASME BPV XI in 10 CFR 50.55a(b)(2)
- Related items
  - RPV-related Code Cases
  - Alternatives under 10 CFR 50.55a(z)



**Ms Haruko SASAKI**

Nuclear Regulation Authority, Japan

# *Reactor vessel ISI programs and regulatory requirements in Japan*

*April 2022*

*Haruko Sasaki*

*April 2022 International ISI workshop*

*OECD/ NEA Committee on Regulatory Activities Working Group on Codes and Standards*

# 1. Regulatory Requirements

*Regulatory requirements for ISI are defined in the Technical Ordinance of NPP.*

## **Article 18 Prevention of breakage due to cracks during operation**

- 1 There shall be no cracks or other defects that cause its destruction during operation in Class 1 equipment, class 1 support structure, class 2 equipment, class 2 support structure, class 3 equipment, class 4 pipe, reactor containment vessel, reactor containment vessel support structure and core support structure.*
- 2 There shall be no cracks or other defects that penetrate the pressure-resistant portion during operation in the pressure-resistant portion of Class 1 equipment.*

*ISI program is defined in the Interpretation of cracks and other defects that cause destruction for nuclear power plant.*

- (1) Perform the nondestructive test according to **JSME S NA1 Rule on Fitness-for-Service for Nuclear Power Plants** with additional requirements based on the NRA technical evaluation.*
- (2-1) For cracks, holes and other damage detected by the test, if there is a possibility of progress, identify the shape and size and perform the evaluation according to the Code with additional requirements.*
- (2-2) As a result of the evaluation, cracks that conform to the Code with additional requirements are NOT treated as defect.*

## 2. RPV Inspection Program (JSME S NA1 -2012)

*Inspection Interval :*

- 10 years (until 3<sup>rd</sup> interval) or 7years (from 4<sup>th</sup> interval)

*Inspection coverage, method and frequency :*

- *Full Penetration Welded Nozzles in Vessels (Examination Category B-D)*

Parts Examined	Examination method	Extent and Frequency of Examination
<i>Nozzle-to-Vessel Welds</i>	Volumetric	<i>Essentially 100% of all nozzles</i>
<i>Nozzle Inside Radius Section</i>	Volumetric	<i>Essentially 100% of all nozzles</i>

- *Pressure Retaining Dissimilar Metal Welds In Vessel Nozzles (Examination Category B-F)*

Parts Examined	Examination method	Extent and Frequency of Examination
<i>100A or Larger Nozzle-to-Safe End Butt Welds</i>	Volumetric and surface	<i>Essentially 100% of all nozzles</i>
<i>Less Than 100A Nozzle-to-Safe End Butt Welds</i>	surface	<i>Essentially 100% of all nozzles</i>
<i>Nozzle-to-Safe End Socket Welds</i>	surface	<i>Essentially 100% of all nozzles</i>

– *Pressure-Retaining Welds in Vessel (Examination Category B-B)*

<i>Parts Examined</i>	<i>Examination method</i>	<i>Extent and Frequency of Examination</i>
<i>Reactor Vessel</i>		
<i>Shell welds; Circumferential</i>	<i>Volumetric</i>	<b><i>7.5% of weld length or 10% of Circumferential weld length and 5% Longitudinal weld length</i></b>
<i>Shell welds; Longitudinal</i>		
<i>Head welds; Circumferential</i>		
<i>Head welds; Longitudinal (including Meridional)</i>		

### 3. *Technical issue of JSME Code*

- *International practices of examination frequency for Pressure-Retaining Welds in Reactor Vessel are essentially 100% of all welds.*
- *JSME Code requirements are different from international practice.*
- *NRC reduced examination frequency of the welds based on the technical basis.*

***Should NRA require the licensees to examine essentially 100% of all welds in reactor vessel?***

## 4. PFM evaluation by JAEA

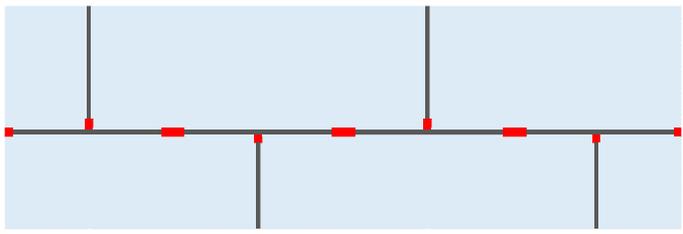
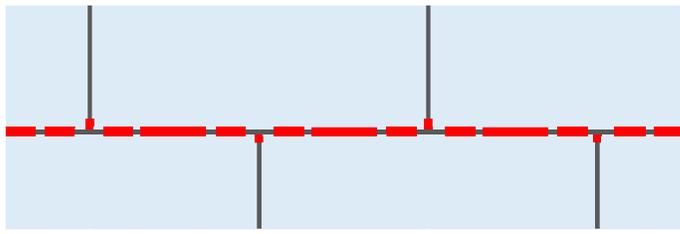
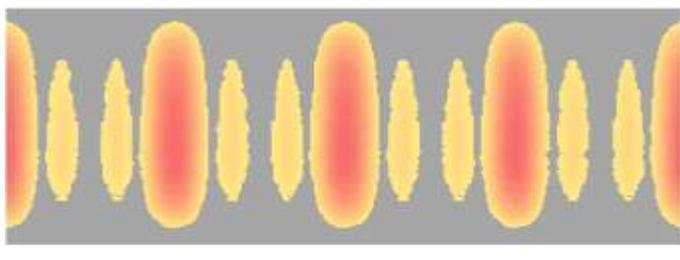
JAEA evaluated influence of examination frequency by PFM.

- The evaluation conditions are followings;

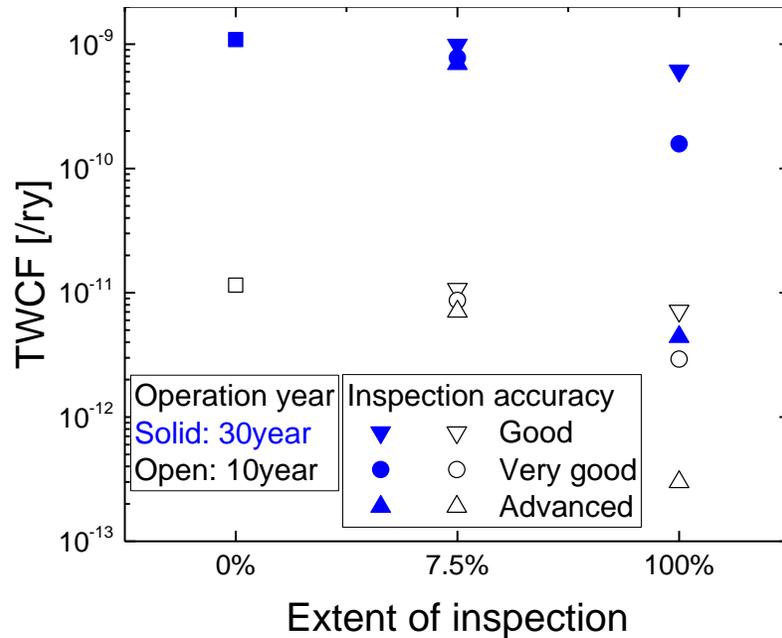
(1) Analysis conditions

Items	Conditions	Remarks
Target	Welds in reactor core region of PWR's RPV	Reactor type with high fluence
Material degradation	Neutron irradiation embrittlement	Material degradations considered in reactor core region of RPV
Transients	PTS events	PTS transients considered in embrittled PWR's RPV (LBLOCA, SBLOCA, MSLB, etc.)
Operation year	10, 30 year	8, 24 EFPY is assumed.
Timing of NDE	Last year in inspection interval	Timing with the highest fluence is assumed for conservative evaluation.

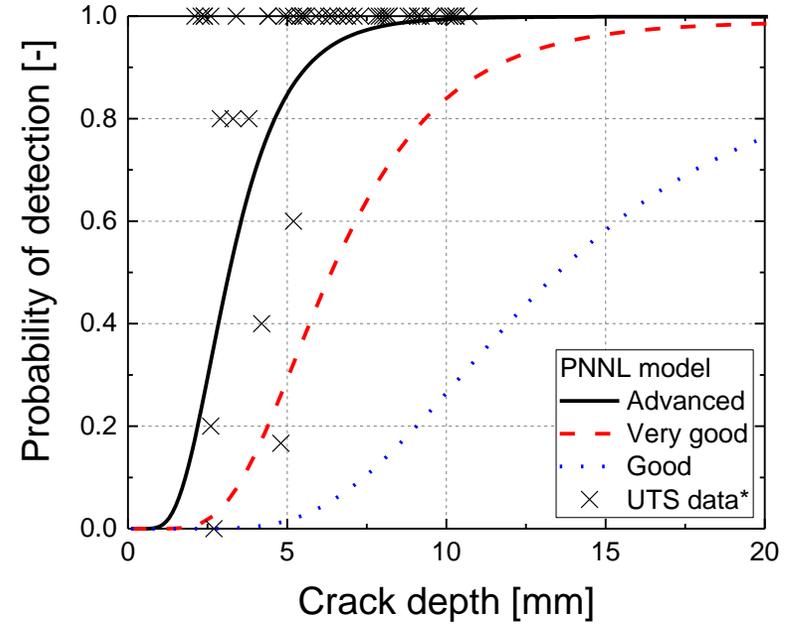
(2) Relationship between neutron fluence and extent of inspection at the timing of NDE

Timing of NDE	10 year	30 year
Examined Welds (Red region)		
Neutron fluence distribution (Gray region mean that fluence does not exceed $10^{23}\text{n/m}^2$ )		

- There is no significant difference between TWCF of 7.5% inspection and 100% inspection, if the accuracy of the inspection corresponds to “Good” performance.



TWCF against extent of inspection



Probability of detection curves

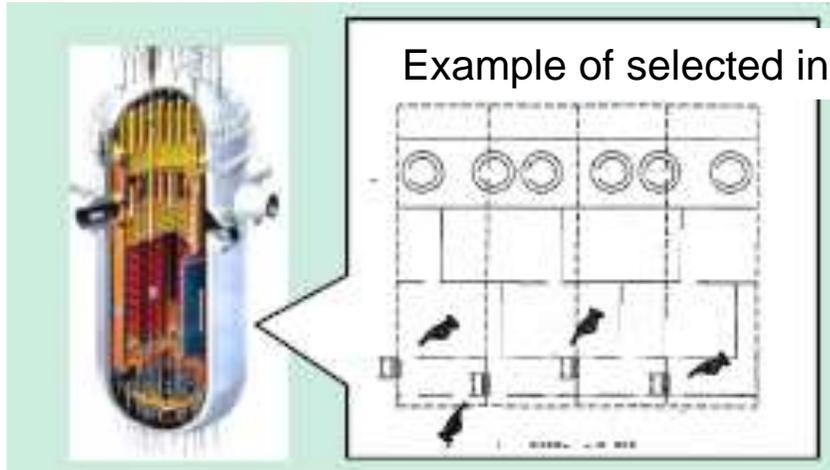
Technical evaluation report of JSME S NA1-2012/2013/2014 Rule on Fitness-for-Service for Nuclear Power Plants and related standards

\* UTS: Japanese project related to non-destructive inspection.

## 5. Hearing from JSME and Licensee

[JSME]

- It is no need to change the Code requirement from 7.5% to essentially 100% since there is no evidence (ex. progressing defect).



5th meeting materials elated to hearing of licensee's opinion on new regulatory requirements

[Licensee]

- We also consider that there is no need to change the examination frequency of the welds.
- However, we prepare to examine essentially 100% of the welds as further safety improvement.
- We are ready to use PFM for our RPV inspection plan change based on the result of first RPV 100% inspection.

## 6. Regulatory requirement change

*NRA Commissioner's opinions*

- Inspection frequency should be as same as international level.*
- Exemption of inspection should be studied from the other country practices (including PFM) especially US-NRC.*

*NRA endorsed JSME S NA1 2012 edition with additional requirements.*

- RPV inspection frequency: 7.5% ⇒ essentially 100%*
- If there is a technical basis (ex. PFM based on the inspection results) that can be achieved requirements of the Technical Ordinance, it is judged the Technical Ordinance are met.*
- It is necessary to ensure that the radiation exposure should not be increased significantly by performing inspections on parts that have not been inspected before.*
- Regarding proposals to change inspection plan for reducing the radiation exposure of inspectors, NRA staff will preferentially assess the technical validity of the inspection plan changes.*

## 7. Summary

- *NRA endorsed JSME S NA1 2012 edition in the Interpretation of cracks and other defects that cause destruction for nuclear power plant with additional requirements.*
- *Licensees are ready to use PFM for their RPV inspection plan change based on the result of first RPV 100% inspection.*
- *NRA staff will preferentially assess the technical validity of the inspection plan changes.*



**Mr Young Eui KWON**

Korean Institute for Nuclear Safety

# Regulatory Status on In-Service Inspection Programme for Reactor Vessel in Korea

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Korea Institute of Nuclear Safety

KINS, the Cornerstone for the Safe Korea



# Contents

**I** General Regulatory Status

**II** General ISI Requirements

**III** Reactor Vessel ISI

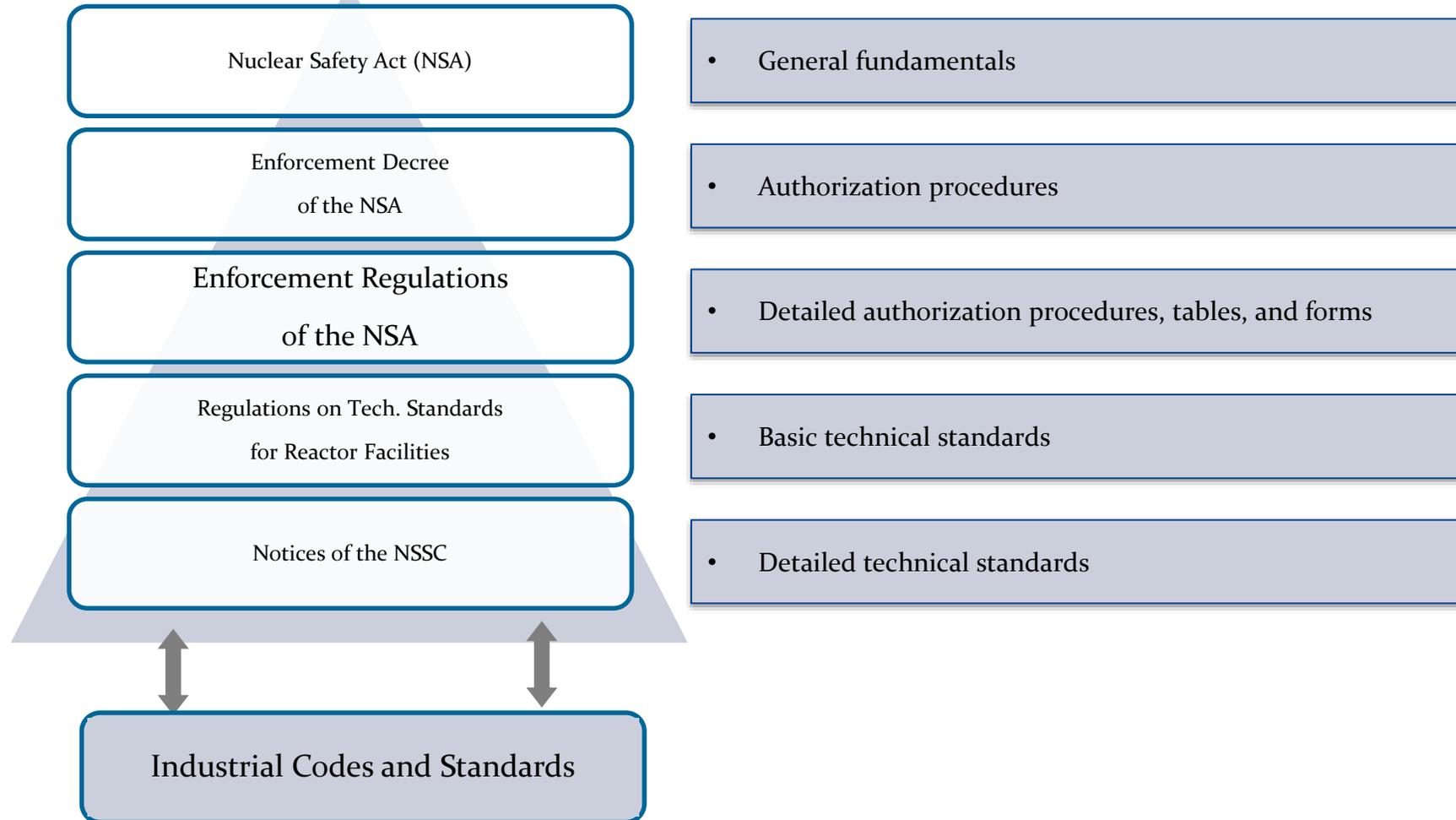
**IV** Recent experience in RV ISI

**V** Conclusion



# I. General Regulatory Status

## Regulatory Framework in Korea



## Nuclear Safety Acts

- **Article 21 (Standards for License)**

(1) The standards for the operation license as referred to in Article 20 shall be as follows:

1. Technical capabilities necessary for the operation of the nuclear power reactor and related facilities, as provided for in the Regulations of the Commission, shall be available;
2. Performance of the nuclear power reactor and related facilities shall conform to the technical standards as prescribed by the Regulations of the Commission in such a way that there may not be any impediment to the protection against radiation damages to human bodies, materials and the general public caused by radioactive materials, etc.;

(…)

## Nuclear Safety Acts

- **Article 26 (Safety Measures for Operation, etc.)**

(1) In case a nuclear power reactor operator operates a nuclear reactor for power generation and related facilities, he or she shall take the following measures in accordance with the matters prescribed in the Regulations of the Commission for the safety of human bodies, material objects and the public. (…)

1. Measures related to the radiation dose to be exposed to, etc.;
2. Measures related to the operational safety of the nuclear reactor;
3. Measures related to the self-inspections of the nuclear reactor facilities;
4. Measures related to the inspections and testing during the operation of the nuclear reactor facilities;
5. Other measures prescribed by Presidential Decree in regard to the safety of nuclear reactors for power generation and related facilities.

## Regulation on Technical Standards for Nuclear Reactor Facilities, Etc.

- **Section 3 Operation of Reactor Facilities, Article 50 (Scope of Application)**
  - (1) As regards safety actions that the operator of a nuclear power reactor must take as provided in Article 26 of the Act and Article 41 of the Decree, the provisions of Articles 51 through 66 shall apply.
  - (2) As regards technical capabilities as provided in Subparagraph 1 of Article 21 of the Act, the provisions of Articles 54, 55, 56, 57, 58 and 63 shall apply.

(...)

## Regulation on Technical Standards for Nuclear Reactor Facilities, Etc.

- **Article 63 (Testing, Monitoring, Inspection and Maintenance)**

(1) According to Subparagraphs 3 through 5 of Article 26 (1) of the Act and Subparagraphs 3 of Article 41 of the Decree, the operator of a nuclear power reactor shall establish a testing, monitoring, inspection and maintenance program for structures, systems, and components, considering the importance of the structures, systems, and components to safety, in order to maintain the safety functions and performance of safety-related structures, systems, and components as assumed and intended in design. And each of the following actions shall be taken as determined and publicly notified by the Nuclear Safety and Security Commission:

1. The degree of degradation in materials and performance of safety-related structures, systems, and components due to ageing shall be monitored and evaluated, and necessary measures shall be taken;
2. For the pumps and valves necessary for safe shutdown, core cooling, and mitigation of accident consequences, their performance and degree of degradation due to ageing shall be monitored and evaluated, and necessary measures shall be taken;

(...)

### Notice of the Nuclear Safety and Security Commission

- **Regulation on the Inservice Inspection of Nuclear Reactor Facilities(Notice No. 2016-11)**

Article 1 (Purpose)

Article 2 (Scope of Application)

Article 3 (Definitions)

Article 4 (Inspection Intervals and Initial Date)

Article 5 (Inspection Baseline Data)

Article 6 (Applicable Codes and Regulatory Guides)

Article 7 (Reflection of Operating Experience, etc.)

Article 8 (Submission of Inspection Plan)

Article 9 (Report for Inspection Results)

Article 10 (Repair and Replacement)

Article 11 (Performance Demonstration of Nondestructive Examination)

Article 12 (Certification and Qualification)

Article 13 (Alternative Application and Relief Request)

### Regulation on the Inservice Inspection of Nuclear Reactor Facilities

- **Article 6 (Applicable Codes and Regulatory Guides)**

- (1) The codes and regulatory guides specified in the following subparagraphs shall apply to the inspection:
  1. The Korea Electric Power Industry Code (KEPIC) MI (editions and addenda from 2000 edition to 2009 addenda) or the equivalent ASME Code Sec. XI (editions and addenda from 1995 edition to 2008 addenda) shall apply to inservice inspections of pressurized water reactors (PWRs). (…)
- (2) The effective editions and addenda of inservice inspection codes which are applied to the new inspection interval defined in Article 4 shall be as follows:
  1. For PWRs, the latest editions and addenda effective one year prior to the commencement of the inspection interval out of the KEPIC MI or the equivalent ASME Code Sec. XI defined in Subparagraph 1 of Paragraph 1 shall apply;
  4. If the KEPIC and the equivalent ASME Code contradict each other, or if the codes are interpreted differently by the stakeholders, the interpretation of the Nuclear Safety and Security Commission shall apply.

### Regulation on the Inservice Inspection of Nuclear Reactor Facilities

- **Article 7 (Reflection of Operating Experience, etc.)**

The Nuclear Safety and Security Commission may require the operator to reflect the operational experience and lessons learned from accidents that have occurred at domestic or international nuclear power plants.

- **Article 11 (Performance Demonstration of Nondestructive Examination)**

(1) Among the NDE methods to be performed during the inservice inspection, the installer or operator shall conduct a performance demonstration of ultrasonic examination (UT) on the safety-related facilities and eddy current examination (ECT) on the steam generator tubes.

(2) The codes for the UT performance demonstration of the PWR and PHWR shall apply to Article 6 (1) 1 and 2, and the effective edition and addenda of the codes shall comply with Article 6 (2).

### Regulation on the Inservice Inspection of Nuclear Reactor Facilities

- **Article 13 (Alternative Application and Relief Request)**

(1) The operator may apply other codes or regulatory guides that are similar to those defined in this Notice or utilize the newly-developed examination methods or procedures (referred to as “alternative application”). In addition, the operator may request relief or exemption from any part of the codes (referred to as a “relief request”). An alternative application or relief request shall be executed within the extent that it does not degrade the reliability of the reactor facilities or the integrity of the related facilities and shall be any of the cases defined in the following subparagraphs:

### Regulation on the Inservice Inspection of Nuclear Reactor Facilities

- **Article 13 (Alternative Application and Relief Request)**

(1)

1. Case that the examination can neither be performed nor meet the codes specified in Article 6 due to limitations in the design, configuration and materials of the components and systems subject to inspections or tests;
2. Case that the workers are anticipated to be over-exposed to an excessively high dose of radiation in spite of the considerable protective actions taken;
3. Case that quality and safety are maintained at the acceptable level according to the current technical standards; or
4. Case that quality and safety improvements made during the inspection according to the codes specified in Article 6 do not compensate for the difficulty and risk of the work activities.

## Reactor vessel status in Korea

- Plant list of Alloy 600 material RV

Plant	KR2	KR34/HB12	HU12	HB34	HB56, HU34
Type	W/H	W/H	Framatome	CE	CE
Upper head nozzle	Alloy 690/52/152 (Replaced)	Alloy 600/82/182	Alloy 600/82/182	Alloy 690/52/152 (Replaced)	Alloy 690 Alloy 52/152
BMI nozzle	Alloy 600/82/182	Alloy 600/82/182	Alloy 600/82/182	Alloy 600/82/182	Alloy 690 Alloy 52/152

## General Inservice Inspection Plan – Code Requirements

- KEPIC MIB – Inspection Period and Method

TABLE MIB 2411-1 INSPECTION PROGRAM

Inspection Interval	Inspection Period, Calendar Years of Plant Service Within the Interval	Minimum Examinations Completed, %	Maximum Examinations Credited, %
All	3	16	50
	7	50 <sup>&lt;1&gt;</sup>	75
	10	100	100

NOTE: <1> If the first period completion percentage for any examination category exceeds 34%, at least 16% of the required examinations shall be performed in the second period.

## General Inservice Inspection Plan – Code Requirements

- KEPIC MIB – Inspection Period and Method

Examination Category	Examination Area
B-A	Pressure Retaining Welds in Reactor Vessel
B-B	Pressure Retaining Welds in Vessels Other Than Reactor Vessels
B-D	Full Penetration Welded Nozzles in Vessels
B-F	Pressure Retaining Dissimilar Metal Welds in Vessel Nozzles
B-G-1	Pressure Retaining Bolting, Greater Than 2 in. in Diameter
B-G-2	Pressure Retaining Bolting, 2 in. and Less in Diameter
B-J	Pressure Retaining Welds in Piping
B-K	Welded Attachments for Vessels, Piping, Pumps, and Valves
B-L-2	Pump Casings
B-M-2	Valve Bodies
B-N-1	Interior of Reactor Vessel
B-N-2	Welded Core Support Structures and Interior Attachments to Reactor Vessels
B-N-3	Removable Core Support Structures
B-O	Pressure Retaining Welds in Control Rod Drive and Instrument Nozzle Housings
B-P	All Pressure Retaining Components
B-Q	Steam Generator Tubing

## General Inservice Inspection Plan – Code Requirements

TABLE MIB 2500-1(1) EXAMINATION CATEGORIES

EXAMINATION CATEGORY B-A, PRESSURE RETAINING WELDS IN REACTOR VESSEL							
Item No.	Parts Examined	Examination Requirements/ Fig. No.	Examination Method	Acceptance Standard	Extent and Frequency of Examination		Deferral of Examination to End of Interval
					First Inspection Interval	Successive Inspection Intervals	
B1.10	Shell welds	MIB 2500-1 MIB 2500-2	Volumetric	MIB 3510	All welds <sup>&lt;2&gt;</sup>	Same as for first interval	Permissible
B1.11	Circumferential						
B1.12	Longitudinal						
B1.20	Head welds	MIB 2500-3	Volumetric	MIB 3510	Accessible length of all welds <sup>&lt;2&gt;</sup>	Same as for first interval	Permissible
B1.21	Circumferential						
B1.22	Meridional						
B1.30	Shell-to-flange weld	MIB 2500-4	Volumetric	MIB 3510	Welds <sup>&lt;2&gt;</sup>	Same as for first interval	Permissible <sup>&lt;3&gt;&lt;5&gt;</sup>
B1.40	Head-to-flange weld						
B1.50	Repair welds <sup>&lt;3&gt;</sup>	MIB 2500-1 and -2	Volumetric	MIB 3510	All weld repair areas	Same as for first interval	Permissible
B1.51	Beltline region						

# III. Reactor Vessel ISI

## General Inservice Inspection Plan – Code Requirements

<u>REACTOR PRESSURE VESSEL</u>						<u>INSPECTION INTERVAL</u>							
KEPIC MI CAT.	KEPIC MI ITEM	RI-ISI ITEM	COMPONENT/ LINE NO.	WELD ID/ EXAM ITEM ID	DESCRIPTION CONNECTION TYPE	EXAM. METHOD	0-32		33-64		65-108		
							MONTH OUTAGE						
							1	2	3	4	5	6	7
B-A	B1.30		RPV (S-T001)	C1	VESSEL TO FLANGE	MECH UT	-	X	-	-	-	-	-
B-A	B1.30		RPV (S-T001)	C1	VESSEL TO FLANGE	MECH UT	-	-	-	-	-	X	-
B-A	B1.11		RPV (S-T001)	C2	UPEER SHELL TO MID. SHELL	MECH UT	-	-	-	-	-	X	-
B-A	B1.11		RPV (S-T001)	C3	MID. SHELL TO LOWER SHELL	MECH UT	-	-	-	-	-	X	-
B-A	B1.11		RPV (S-T001)	C4	LOWER SHELL TO LOWER HEAD	MECH UT	-	-	-	-	-	X	-
B-A	B1.22		RPV (S-T001)	C5	MERIDIONAL WELD	MECH UT	-	-	-	-	-	X	-
B-A	B1.40		RPV (S-T001)	CH-C1	HEAD TO FLANGE	MT	-	-	-	-	-	X	-
B-A	B1.40		RPV (S-T001)	CH-C1	HEAD TO FLANGE	UT	-	-	-	-	-	X	-
B-A	B1.12		RPV (S-T001)	L1	LONG-W UPPER SHELL 95	MECH UT	-	-	-	-	-	X	-
B-A	B1.12		RPV (S-T001)	L2	LONG-W UPPER SHELL 215	MECH UT	-	-	-	-	-	X	-
B-A	B1.12		RPV (S-T001)	L3	LONG-W UPPER SHELL 335	MECH UT	-	-	-	-	-	X	-

(LTP Extracted)

## General Inservice Inspection Plan – Augmented Inspection

- **Integrated Guidelines for Management of Alloy 600 Locations(KHNP Document)**
  - (1) Regulatory body demanded investigation of guidelines for management of Alloy 600/82/182 components from KHNP reflecting international operation experiences.
  - (2) In the guidelines, Alloy 600/82/182 components are listed and applicable codes and standards for each component, such as ASME Code Case N-729, N-722, N-770, are presented.
  - (3) For augmented inspection of RV head, ASME Code Case N-729, N-722 are applied.
  - (4) The guidelines were approved as topical report and have been applied in each plant.
  - (5) KINS is in the process of amending ISI notice to include those augmented inspection.

# III. Reactor Vessel ISI

## General Inservice Inspection Plan – Augmented Inspection

REACTOR PRESSURE VESSEL				INSPECTION INTERVAL							PIPE SEG. ID	PAST OUTAGE	REMARKS	
KEPIC MI CAT.	KEPIC MI ITEM	RI-ISI ITEM	COMPONENT/ LINE NO.	WELD ID/ EXAM ITEM ID	0-32 MONTH OUTAGE		33-64 MONTH OUTAGE		65-108 MONTH OUTAGE					
					1	2	3	4	5	6	7			
NOT REQ'D	NOT REQ'D		RPV (S-T001)	UPPER HEAD PENETRATION NOZZLE	X	-	-	X	-	-	X			원전 Alloy 600 재질기기 검사프로 그램 이행안(개정 1_19.9) ASME Code Case N-729-4
NOT REQ'D	NOT REQ'D		RPV (S-T001)	UPPER HEAD PENETRATION NOZZLE	X	-	-	X	-	-	X			원전 Alloy 600 재질기기 검사프로 그램 이행안(개정 1_19.9) ASME Code Case N-729-4
NOT REQ'D	NOT REQ'D		RPV (S-T001)	UPPER HEAD PENETRATION NOZZLE	X	-	-	X	-	-	X			원전 Alloy 600 재질기기 검사프로 그램 이행안(개정 1_19.9) ASME Code Case N-729-4
NOT REQ'D	NOT REQ'D		RPV (S-T001)	LOWER HEAD PENETRATION NOZZLE	X	-	X	-	X	-	X			원전 Alloy 600 재질기기 검사프로 그램 이행안(개정 1_19.9) ASME Code Case N-722-1
NOT REQ'D	NOT REQ'D		RPV (S-T001)	LOWER HEAD PENETRATION NOZZLE	-	-	-	-	X	-	-			원전 Alloy 600 재질기기 검사프로 그램 이행안(개정 1_19.9) ASME Code Case N-722-1
NOT REQ'D	NOT REQ'D		RPV (S-T001)	LOWER HEAD PENETRATION NOZZLE	-	-	-	-	X	-	-			원전 Alloy 600 재질기기 검사프로 그램 이행안(개정 1_19.9) ASME Code Case N-722-1
NOT REQ'D	NOT REQ'D		RPV (S-T001)	BFB	-	-	-	-	-	X	-			BOLT TACK WELD 검사
NOT REQ'D	NOT REQ'D		RPV (S-T001)	BFB	-	-	-	-	-	X	-			
NOT REQ'D	NOT REQ'D		RPV (S-T001)	BFB	-	-	-	-	-	X	-			

### Leakage at Bottom-Mounted Instrument penetration of KR2

- **Status of leakage at BMI penetration of KR2**
  - (1) Start of commercial operation : 1983.7.
  - (2) Leakage found : 2020.3., #36 penetration
  - (3) Material of BMI nozzle and J-groove weld: Alloy 82/182
  - (4) No defect was detected in the nozzle by UT
  - (5) Crack was found on the J-groove weld by E-VT
  - (6) Estimate leak-path : Crack through J-groove weld
  - (7) Repair : half nozzle repair

### Preventive maintenance of RV upper head J-weld of HB5

- **Status of RV upper head of HB5**
  - (1) Start of commercial operation : 2002.5.
  - (2) Material of J-groove weld: Alloy 82/182
  - (3) Material of penetration nozzle: Alloy 690
  - (4) Planned preventive maintenance method: Three layer of on-lay welding on the J-groove surface using Alloy 52M material
  - (5) NDE result before on-lay welding: 1 penetration of leakage found, 34 Penetrations of unacceptable PT indications found among 83 Penetrations
  - (6) Seal weld repair(four layer of on-lay welding) was conducted for penetrations unacceptable indication found

### Regulatory Status on In-Service Inspection Programme in Korea

- General regulatory status in Korea from Nuclear Safety Act to Industrial codes and standards is presented.
- As a general ISI requirement, NSSC notice “Regulation on the Inservice Inspection of Nuclear Reactor Facilities” is introduced.
- Reactor vessel ISI programme including code inspection and augmented inspection is covered.
- Two recent operational experiences in RV ISI is presented.

# Thank you for your attention.



## Panel discussion and Q/A from the audience

**Working Group on Codes and Standards  
Workshop on In-Service Inspection**

**Break**

**Workshop will resume in 10 minutes**

Day 1 – Monday 11 April 2022



**Mr Adrien THIBAUT and Ms Clémentine PERON**

Autorité de Sûreté Nucléaire, France

# CSWG

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## In-service inspection

# Presentation of France Reactor Pressure Vessels (RPV)

Adrien THIBAULT  
Clémentine PERON  
ASN



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*Rockville – 2022*

# Presentation Outline



## 1. In-service inspection program

Focus on NDE Qualification in France

## 2. In-service inspection of RPV

## 56 reactors in operation 3 and 4 loop PWR

- 32 – 900 Mwe
- 20 – 1300 Mwe
- 4 – 1450 Mwe

Reactors were built from 1970' to early 2000

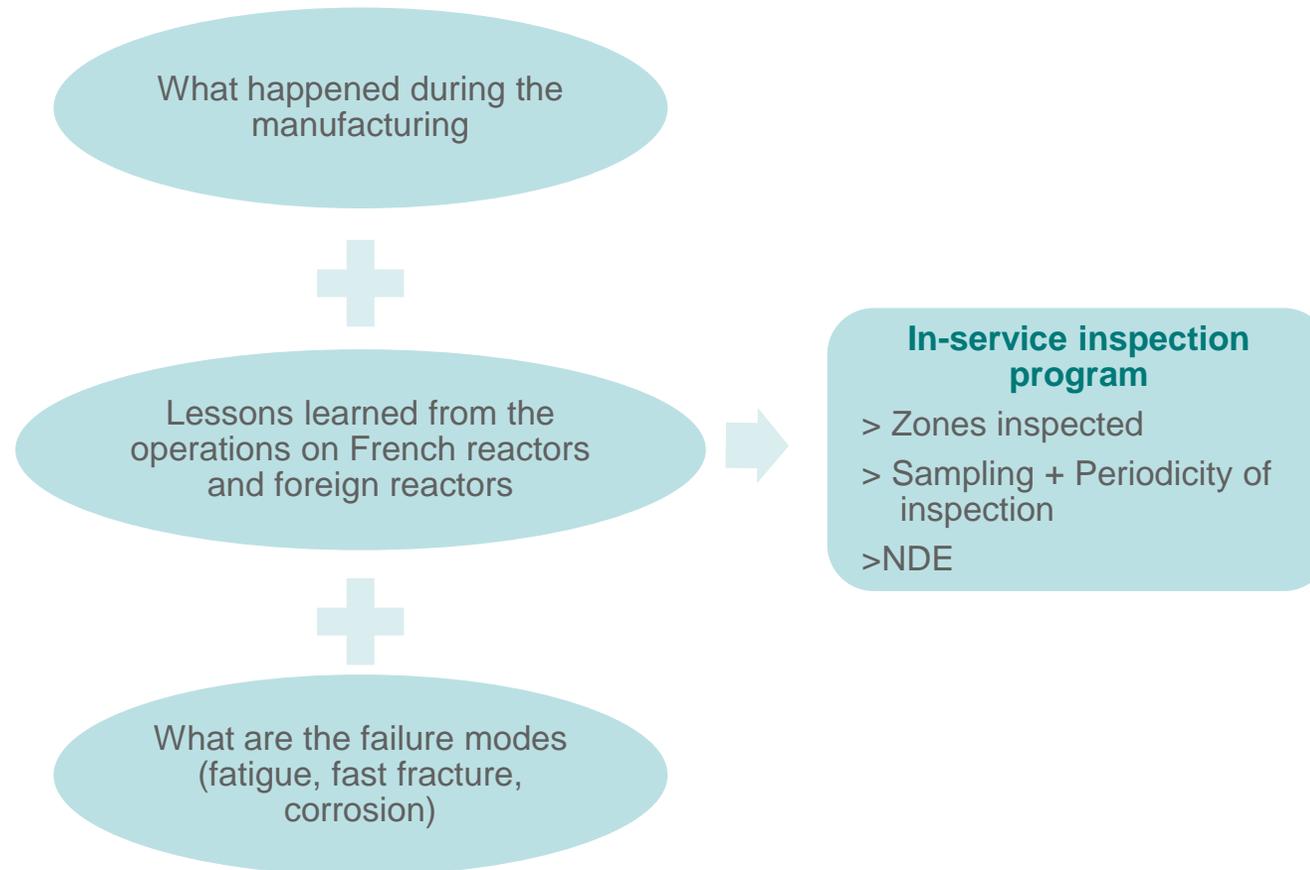
## 1 reactor under construction 4 loop PWR

- EPR (1600 Mwe)



## How the in-service inspection program is defined

The program is based on :



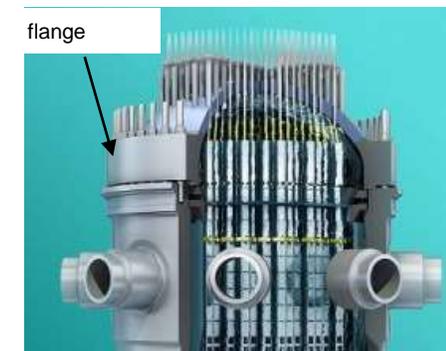
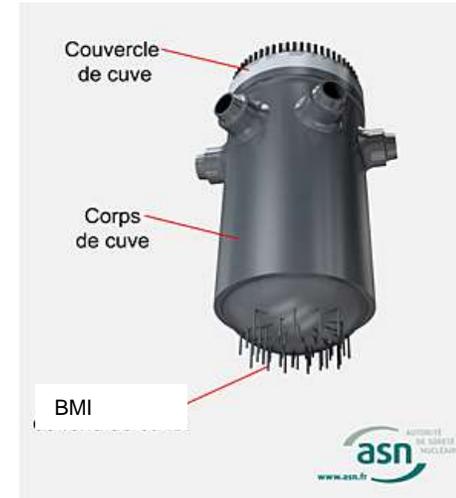
## In-service inspection program (primary and secondary system)

### Where

- Inspection of zones where degradation is expected (fatigue, corrosion...)  
Example : IGSCC of BMI
- Inspection of zones where degradation is not expected (can be by sampling)  
Example : thread of the flange

### When

- Periodicity of inspection is based on mechanical studies (critical crack length and velocity of propagation) and NDE performance



## In-service inspection program (primary and secondary system)

### How

- Qualified NDE and operators (focus on the qualification on the next slides)
- Inspection program must be updated at least every 10 years and submitted to regulator before implementation

### What if cracks are found

- Repairs must be carried out
- Possible to delay repairs (for complex repairs) if mechanical justification is provided
  - safety coefficients must be applied on stresses as followed in fracture mechanics calculation

Transients	$K_{Ic}$ or $J_{0,2mm}$	$J_{3mm}$
Normal operation	1,3	2
Accident conditions ( $10^{-2}$ >frequency> $10^{-4}$ )	1,1	1,6
Accident conditions ( $10^{-4}$ >frequency> $10^{-6}$ )	-	1,2

## Process

Qualification body is composed of expert (50% of EDF experts and 50% from other companies)

Experts independence is required (EDF employee must work in departments not related to electricity production)

## Operators

Qualified by an NDE qualification body (independent from EDF)

Dedicated qualification for each specific type of testing (e.g. UT, RT...)

Standard : ISO 9712

**Process and operators are qualified separately  
However, operators are specifically trained for each qualified NDE**

## Three qualification types for the process

### Conventional

- Defense in depth examination
- Qualification is mainly a performance demonstration (no specific defects are expected)
- Example : thread of the bolt (RPV head)

### “General”

- Defects might appear (international feedback, conception study)
- Potential defects are sought
- Example : zones where usage factor  $> 1$  : fatigue cracks are expected but have never been found

### “Specific”

- Defects have occurred and are well known
- Example : BMI where IGSCC have been found

NOTE : Qualification is not required for specific NDE techniques performed a few times. However, results have to be guaranteed by experts.

# Presentation Outline

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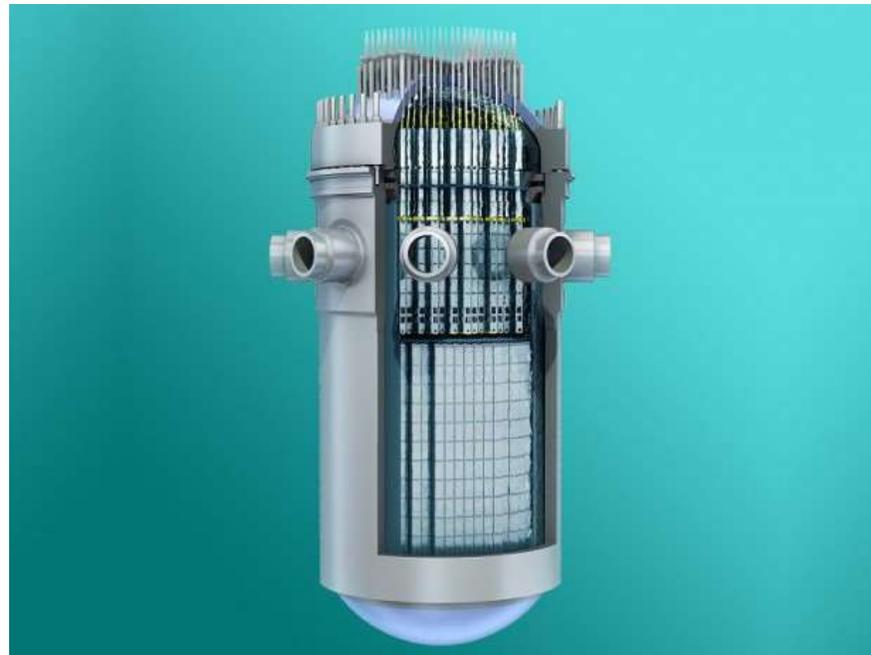
## 1. In-service inspection program

Focus on NDE Qualification in France

## 2. In-service inspection of RPV

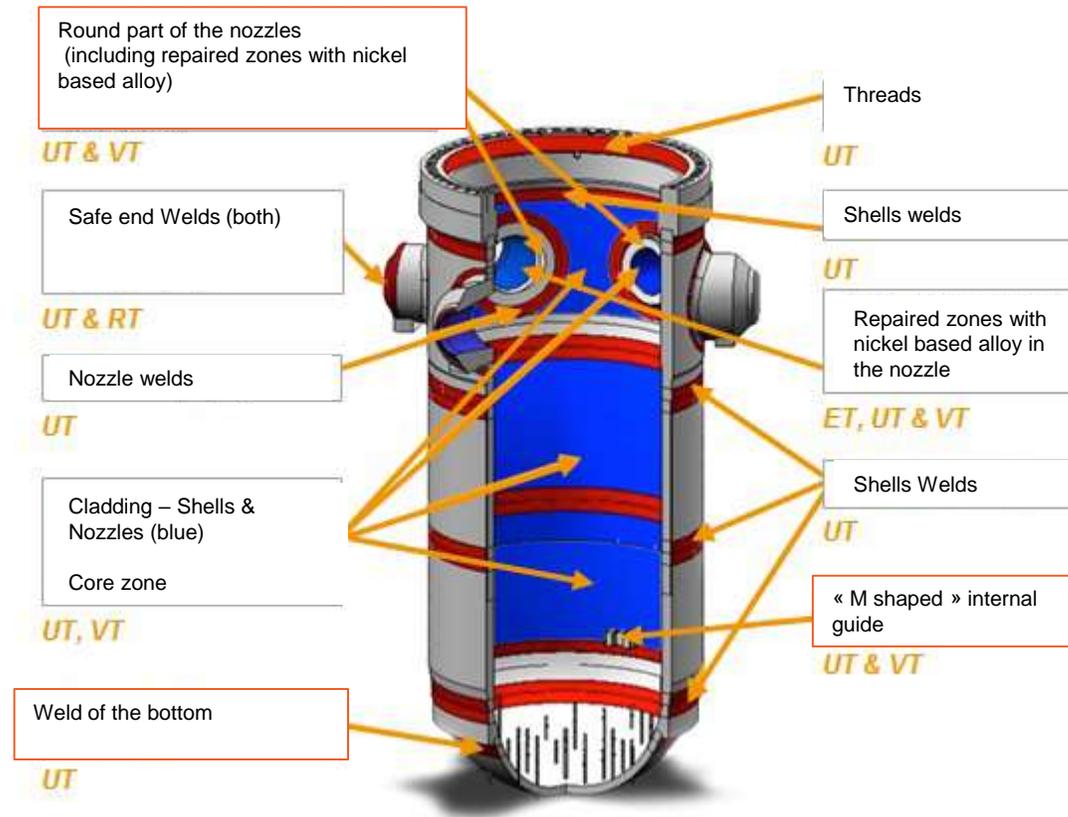
## 2 types of zones inspected

- Zones where an ageing mechanism is identified
- Other zones (defense in depth examination)



Degradation Mechanism	Zones
Irradiation ageing	Core zone shells and welded joint
Thermal ageing	Parts in low alloy steel (RPV body flange and closure head, nozzle support rings, lower and upper domes, nozzles, transition flange, welded joints) Dissimilar metal welds with dilution zone anomalies on the outlet nozzles
Fatigue	Shells and welded joints in core zone, RPV and closure head flange, tappings, nozzles, lower and upper domes, studs, thin-lipped seals of CRDM
Boric acid corrosion	Parts in low alloy steel (RPV closure head and wall, RPV lower head). However, all parts are coated
Atmospheric corrosion	Dissimilar metal welds
Stress corrosion in primary system environment	Zones made out of nickel-based alloy: radial guides, bottom-mounted instrumentation (BMI) penetrations, closure head adapters and vent, nozzle repairs in Inconel Zones made out of stainless steel: thin-lipped seals of adapters

## In-service inspection Machine (MIS)



Framatome movie (50s)

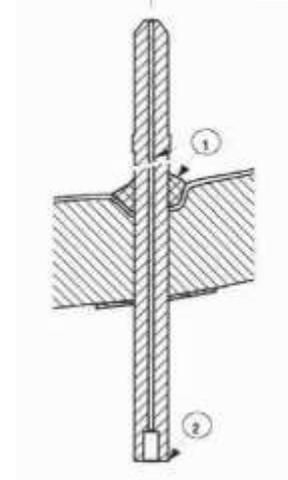
<https://www.youtube.com/watch?v=G6sd4lo0ixY>

## In-service inspection – other zones not inspected with MIS

- Closure head (UT/ET for welds and VT)
- Bottom Mounted Instrumentation (UT for welds)
- Studs and nuts (ET/PT)
- Control rod drive mechanisms (VT)

## Every ten years

- Hydrostatic testing (1,2 x design pressure= 206 bar (3000 psi))



### Defects detection

Detection of defects in 2 BMI due to Stress Corrosion Cracking

2011- Gravelines 1: removed and plugged

2016 - Cattenom 3 : defected part with the crack removed

### Modification of the ISI program of the BMI

Before 2011, the BMI of only 12/58 RPV were inspected

→ New ISI program is the inspection of all the BMI

Since 2020, each BMI has been inspected at least once

NDE	Qualification	Objective	Frequency	Inspected zone	Inspected plants	Existing defects
UT (TOFD)	Specific	SCC	10 years	Inner and outer skin of BMI	All	Yes
VT	Conventional	Leak detection from under the RPV	10 years (before and after hydrostatic testing) Every 40 months if last UT were performed more than 6 years before	BMI from the exterior	All	No leakage detected in France

# In-service Inspection of RPV

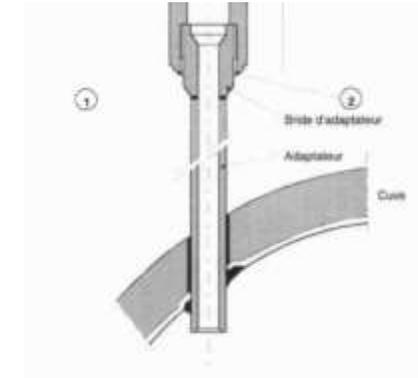
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## Focus on Vessel head adapters

### Replacement of the vessel head adapters

All vessel heads with Inconel 600 adapters have been replaced (last one in 2009)

Adapters are now made of Nickel Alloy 690 (NC30Fe) and welding material is Alloy 152/52 (NC30Fe)



### ISI Program

Inspection by sampling

NDE	Qualification	Objective	Frequency	Inspected zone	Inspected plants	Existing defects
ET and UT and VT	no	SCC (longitudinal)	10 years	Base metal and weld interface → +/-50 mm on both sides of the weld	3/56	None on the replaced vessel head
PT and VT	No	Surface-breaking defects	10 years	Weld	3/56	None on the replaced vessel head

Mechanical justification for the worst case scenario :

→hypothetical flaws of 5x25mm in the worst zone during pressurized thermal shock (size of the smallest flaws that the qualified UT can detect)

Mechanical justification of specific underclad defects from manufacturing

Temperature of refueling water storage tank (RWST) for 2 reactors > 20°C (instead of 7°C)

### ISI Program

Inspection of all the RPV

NDE	Qualification	Objective	Frequency	Inspected zone	Inspected plants	Existing defects
UT	Specific	Underclad defect	10 years	25mm thick from inner side	All	Yes
UT	Conventional	-	10 years	Welds	All	No
UT	-	Hydrogen flakes (Tihange and Doel feedback)	-	All thickness	7/56 done 5/56 more by 2025	No





**Ms Jolana RYDLOVA**

State Office for Nuclear (SUJB), Czech Republic



# **WGCS International Workshop on Mechanical Codes and Standards: In-Service Inspection**

## **In-Service Inspections of RPV in the Czech Republic**

**Jolana Rýdlová**  
**State Office for Nuclear Safety, Czech Republic**

**April 11-14, 2022**  
**organized by OECD/NEA and US NRC, online**



## Outline

- NPPs in the Czech Republic
- Standards and codes used in design, construction and operation (short information)
- Reactor
- RPV – parts, materials
- ISI Programme
- RPV NDT ISI – basis, methods, scope, requirements and criteria



## NPPs in the Czech Republic

Dukovany NPP  
 WWER 440/213  
 4 units  
 6 main circulation loops

Put into operation in 1985-1987, now in LTO

Operator: CEZ Company



### Design

USSR/ engineering project: LOTEK (now part of Atomenergoprojekt)  
 // detailed project: Energoprojekt Prague, (former)Czechoslovakia

### Manufacturers of components:

From **USSR**: e.g. main circ. pumps, surge line piping

From **Czechoslovakia**: e.g. Skoda Pilsen, Vitkovicke zelezarny, Modranske strojirny – RPV, SG, steam line piping, feedwater piping...

Temelin NPP  
 WWER 1000/320  
 2 units  
 4 main circulation loops

Put into operation in 2000 and 2002

Operator: CEZ Company





## Standards and codes used in design, construction and operation (1)

- Construction of Dukovany and Temelin NPPs: agreement between (former) USSR and (former) Czechoslovakia – aim: to use Soviet design and Soviet standards “as far as possible”
  - **Basic design – USSR, detailed design documentation USSR and Czechoslovakia**
  - In 80ties, cooperation within association “**Interatomenergo**” / elaboration of technical standard documentation, ended in 1990
  - Under Czechoslovak Atomic Energy Commission (regulator in Czechoslovakia) issued
    - orders – e.g. in 1978 concerning ensuring the nuclear safety during design, licensing and construction of NPPs
    - commented requirements and instructions as outcomes from the “Interatomenergo” cooperation
- Examples of Russian standards (welding, ISI, mechanical)**
- Basic rules for welding and cladding of components and structures of nuclear power stations, and of experimental and research nuclear reactors and facilities (OP-1513-72)
- and inspected in line with
- Rules for inspection of welds and cladding of components and structures of nuclear power stations and experimental and research nuclear reactors and facilities (PK-1514-72).
  - Rules of strength calculation for equipment and pipelines of nuclear power plants (PNAEG-7-002-86)



## Standards and codes used in design, construction and operation (2)

After 1990:

- NPPs designed acc. to Russian standards – in Czechoslovakia no such standards in early 1990ties
- Normative Technical Documentation of the Association of Mechanical Engineers (AME, in Czech: Asociace strojních inženýru, A.S.I. - further “NTD A.S.I.”) - started with Section III – strength analyses of equipment and piping
  - In general, based on the philosophy of ASME Code Section III
  - Represents the Russian standards NTD SEV incl. appendices from revisions, as such was close to PNAE G-7-002-86
  - After 2000: Section I: Welding and Section II: Materials
  - Gradually developed new sections:
    - Section IV for evaluation of residual life of NPPs of WWER type,
    - Section V for destructive testing
    - Section VI for ventilation systems in NPPs of WWER type
    - Section VII for NDT inspections
      - In 2015 issued NP-084-15 - Rules for in-service inspection of base metal, welds and cladding of equipment, pipelines and other elements of nuclear power plants (Russian standard) – compulsory for Russia territory - accounted for in the Section VII of NTD A.S.I.



## Standards and codes used in design, construction and operation (3)

### “NTD A.S.I.”, Section VII: NDT inspections of NPPs of WWER type

- Requirements are given based on the history of the equipment design
- Russia area of the project/NPP design
  - Equipment designed in line with
    - Rules of construction and safe operation of the equipment of nuclear power stations and of experimental and research nuclear reactors and facilities (1973)
    - Basic rules of welding and cladding of components and structures (...) (OP-1513-72) and inspected in line with
      - Rules for inspection of welds and cladding of components and structures (...) (PK-1514-72).
- Czech area of the project/NPP design
  - Equipment designed in line with
    - CSN standards (Czech or Czechoslovak)
    - industry standards
    - EN and ISO standards

#### Content:

##### Rules for inspections

- preoperational
- operational
- specific

##### Requirements for

- carrying out inspections incl. req. for equipment
- evaluation of findings
- supervision of NDT inspections carrying out and evaluation
- inspection documentation

##### Qualification of NDT systems

##### Qualification of personnel



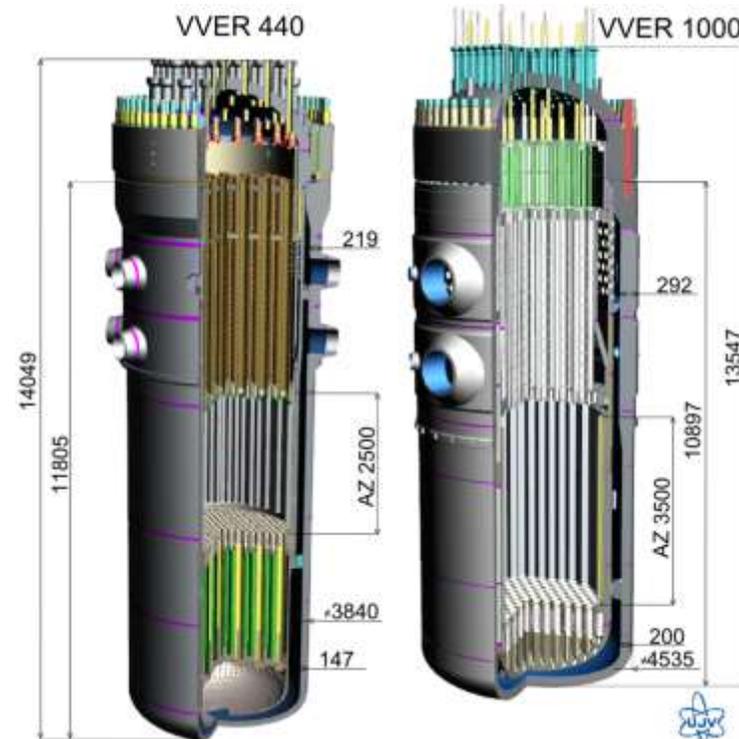
## Standards and codes used in design, construction and operation (4)

- VERLIFE: Guidelines for Integrity and Lifetime Assessment of Components and Piping in WWER NPPs during Operation, IAEA (2013), to be published
- CSN (Czech technical standards) – often: harmonized European standards (EN ISO)
- ASME, KTA, RCC-M
  - in specific analyses (e.g. pipe rupture postulations)
  - when used for the design/manufacturing of a component (e.g. valves)
    - applied together with recommendations of the manufacturer of such component



## Reactor and its components

- **Reactor** – system of following main components:
  - **Reactor pressure vessel (RPV)**, which comprises a cylindrical part including all nozzles (to RCP and SAOZ) and safe ends (to RCP) and an elliptical bottom head (further *RPV body*)
  - **Upper block**, consisting of the vessel head itself and vessel head nozzles
  - **Flange**, which consists of a part of the vessel head and of a part of the cylindrical vessel ensuring tightness of the main flange joint, of a floating flange (Dukovany) and bolts
  - **Reactor internals**
  - **Control rod drives**
- **RPV – safety class 1**
- Pressure vessels are made from forgings, i.e., from cylindrical rings and plates forged into domes. The spherical part of the vessel bottom was stamped from forged plate.



- Manufacturer: Skoda Pilsen, (now Skoda JS) Czech Republic

**Presentation is focused on RPV**

Figures provided by UJV Rez, a.s.



## RPV in Dukovany NPP - WWER 440/2013

### Material

**15CH2MFA**

### Component

flange ring, upper and lower nozzle ring, smooth short rings (2pcs), smooth long ring, bottom, partition ring, I&C nozzle, MCP nozzle, ECCS nozzle

**08CH18N10T**

safe end to the main circulation piping nozzle, safe end to the ECCS nozzle, bracket for cavity guide

**Sv10CHMFT**

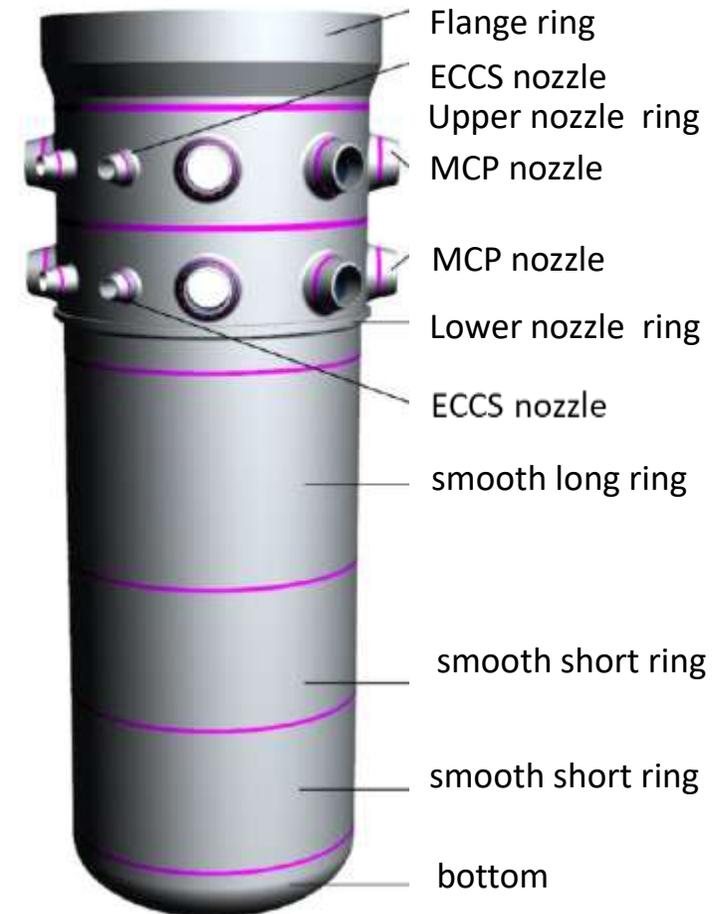
RPV circumferential welds

**Sv07CH25N13**

RPV cladding 1st layer

**Sv08CH19N10G2B**

RPV cladding 2nd layer





## RPV in Temelin NPP - WWER 1000/320

### Material

15CH2NMFA

15CH2NMFAA

Sv12CH2N2MA

Sv12CH2N2MAA

Sv07CH25N13

Sv04CH20N10G2B

### Component

flange, nozzle rings, bottom, partition ring, main circulation piping nozzle, ECCS nozzle, I&C nozzles

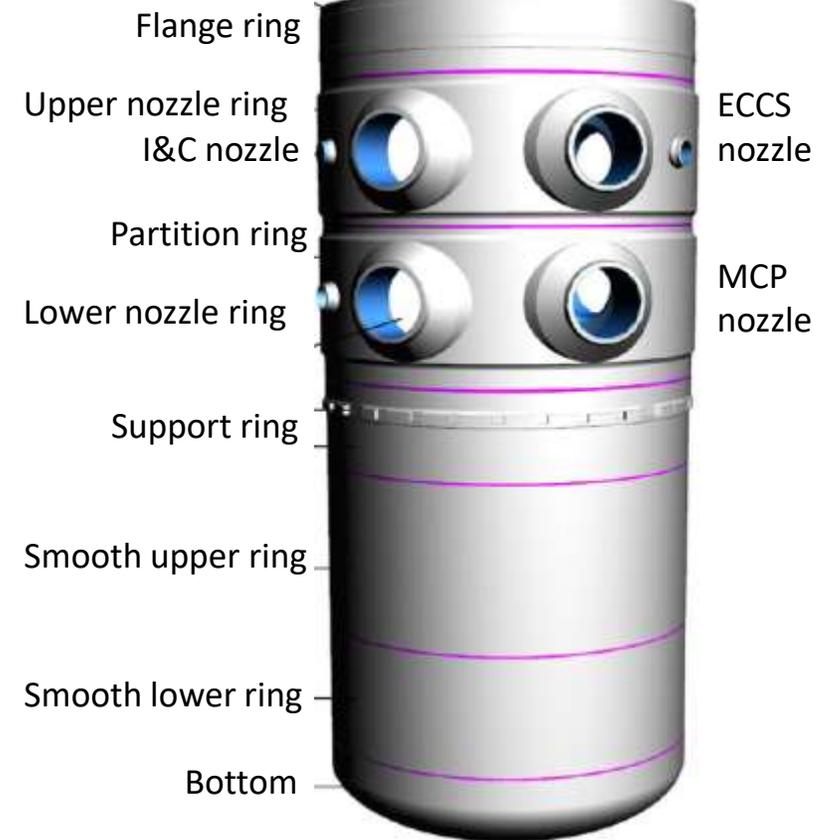
support ring, smooth upper ring, smooth lower ring

RPV circumferential welds, except for welds in beltline

RPV circumferential welds beltline area

RPV cladding 1st layer

RPV cladding 2nd layer





## NDT and ISI Programme

**NDT inspections are part of the ISI programme** (other: e.g. pressure testing, I&C inspections ...)

- NDT as part of ISI: aim is to monitor reactor condition and to evaluate the effects of operating conditions and degradation mechanisms

**ISI Programme** was developed on the basis of

- Original Soviet regulations for NPPs,
  - Technical specifications and
  - Individual Quality Assurance Programme for reactor established by the manufacturer
- 
- ISI Programme is a living document modified on the basis of operating experience and development of the relevant knowledge.
- 
- **ISI Programme is approved by SÚJB.**



## ISI Programme – regulatory framework

**Act No. 263/2016 Coll. (Atomic Act):** requirements to ensure quality of selected equipment and regular verification of its compliance with technical requirements

**Decree No. 329/2017 Coll., on design of nuclear facility,** e.g. § 30 :

- In the design requirements for inspections and tests of selected equipment shall be defined
- Method used and frequency of these inspections and tests shall sufficiently verify equipment reliability

**Decree No. 358/2016 Coll., on requirements for assurance of quality and technical safety and assessment and verification of conformity of selected equipment** - § 16 and § 17, Annexes 6 and 8, e.g.:

- Scope of and method for verifying conformity of selected equipment with technical requirements, Requirements on inspections
- Method for documenting verification of conformity of selected equipment in use with technical requirements and the content of this documentation; ISI Programme shall contain:
  - concrete position of the inspection
  - method applied
  - acceptable criteria
  - frequency of inspection



## NDT In-service inspections of RPV – methods

- ultrasonic pulse-echo testing method
- time-of-flight diffraction (TOFD) ultrasonic testing method (for sizing of defects)
- eddy-current testing method
- indirect visual testing (high resolution cameras)
  
- *MKS automated system (testing from the inside – BM, WM, cladding)*
- *USK-213 / SK-187 system (Dukovany / Temelin, testing from the outside – BM, WM)*
  - *manufacturer: Skoda JS*

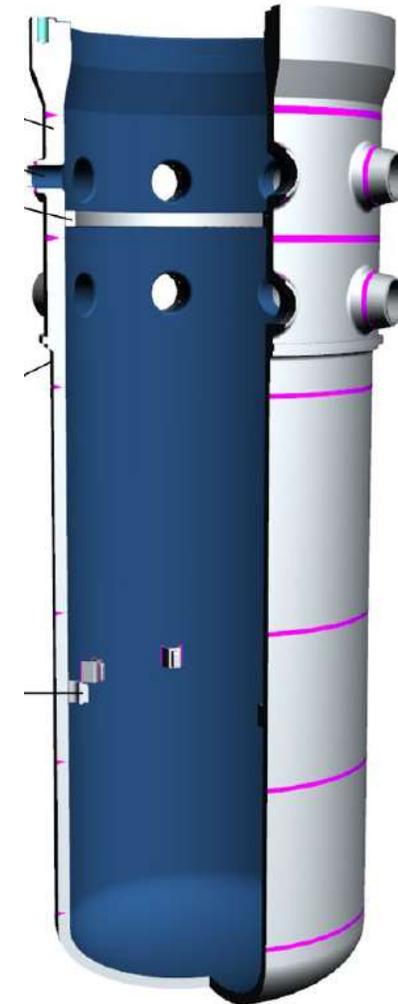
**In-service inspections ET (Eddy Current Testing) and UT (Ultrasonic Testing) of RPVs are qualified according to ENIQ (for reliable identification and sizing of defects)**

On the basis of Doel3 (Tihange2) hydrogen flakes issue, inspections for Czech RPV were reviewed – it was found that methods were acceptable and sufficient to discover potential laminar defects.



## NDT In-service inspections of RPV – scope

- all circumferential welds incl. parts above/below
- whole core area (Dukovany) and whole cylindrical part (Temelin) including welds and cladding
- RPV bottom
- nozzles to RCP and SAOZ piping, incl. cladding
- safe ends between nozzles and RCP piping, including welds





## NDT In-service inspections of RPV – requirements and criteria

- Original document assigned by the (Soviet) designer: Regulations for testing welded joints and cladding of flanges and structures of nuclear power plants and nuclear research reactors and facilities (PK 1514-72) - applied without exception at the beginning of operation
- Gradually included new specific criteria - new methods of detection (e.g. TOFD, ET)
- **Requirements for inspections are defined by manufacturer Skoda JS**
  - **specific procedures for all steps of inspections including evaluation of results**
  - **included in the ISI Programme**
- **Evaluation of findings:** comparison of defect size with permissible values (“NDT A.S.I.”, Section IV) - when out of the range: sent for a specific assessment
- *Since start of NPPs operation – care of the reactor (incl. maintenance and ISI) carried out by the manufacturer (Skoda JS)*



## “NTD A.S.I.”, Section IV: Evaluation of Residual Lifetime of Components and Piping in WWER Type NPPs

Main parts	<p>Evaluation of resistance of RPV against brittle fracture (<i>for equipment in general in a Specific Case</i>)</p> <p>Evaluation of resistance of equipment against fatigue damage,</p> <p>Evaluation of resistance of equipment against corrosion-mechanical damage</p> <p><b>Evaluation of residual lifetime of equipment with defects found during in-service inspections</b></p> <p>Evaluation of residual lifetime of RVI</p>
Appendices (with relevance to ISI)	<p>App. X: Schematization of defects (from ISI)</p> <p><b>App. XI: Tables with permissible values - RPV, PRZ, SG</b> - elaborated specifically for WWER 440/213, 440/230 and 1000/320 types of NPP</p> <p><b>App. XII: Evaluation of findings</b> – those outside the tables in App. XI – how to evaluate (safety factor on size, fatigue crack growth incl. environmental effect) – such defect: brittle fracture evaluation req.</p> <p>App. XIII: austenitic steel piping (based on Z factor)</p> <p>App. XIV: ferritic steel piping (based on Z factor)</p>



**Thank you for your attention**

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**Mr Peter DEAK**

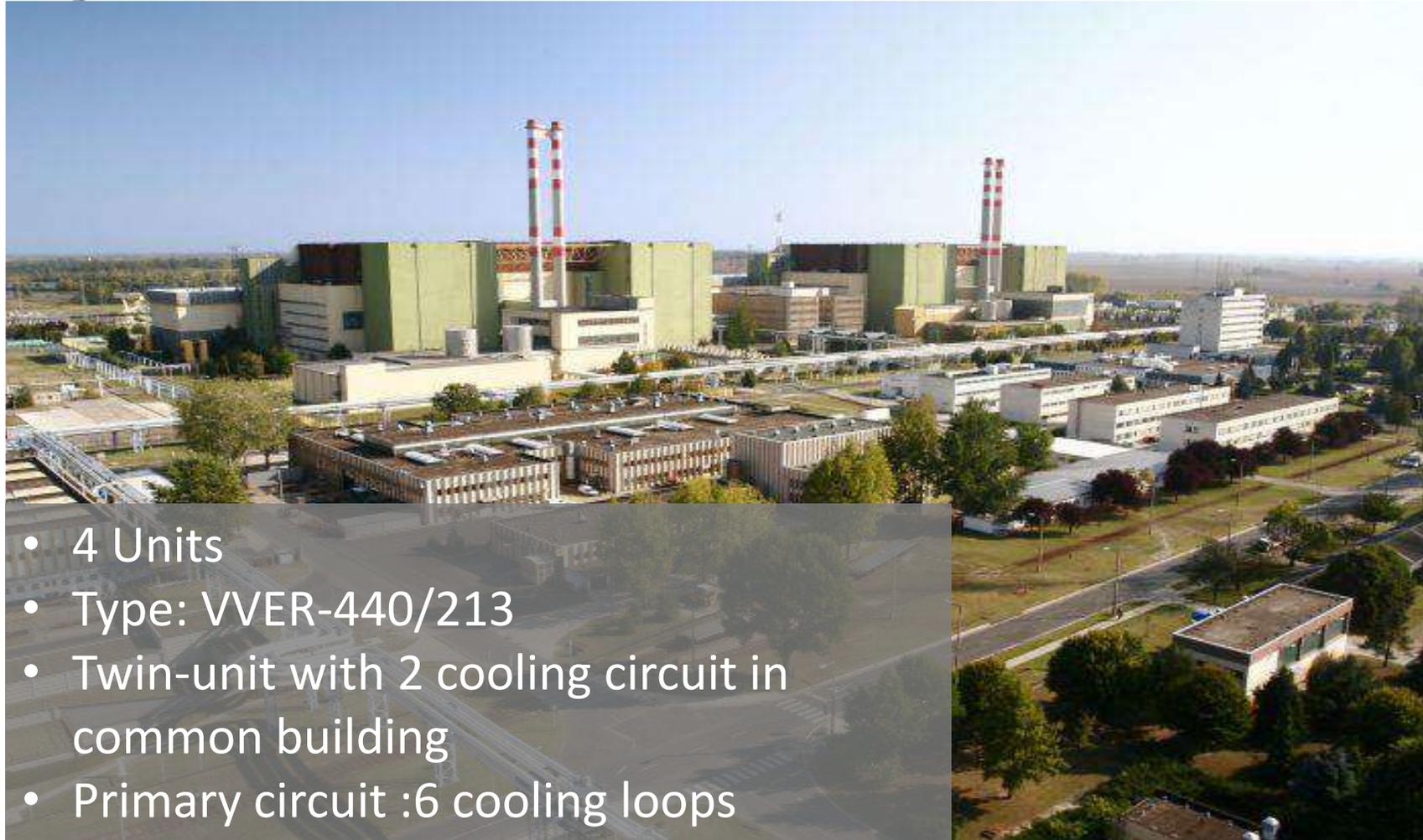
Hungarian Atomic Energy Authority

# Application of ASME at ISI of VVER-440 Units

Péter Deák

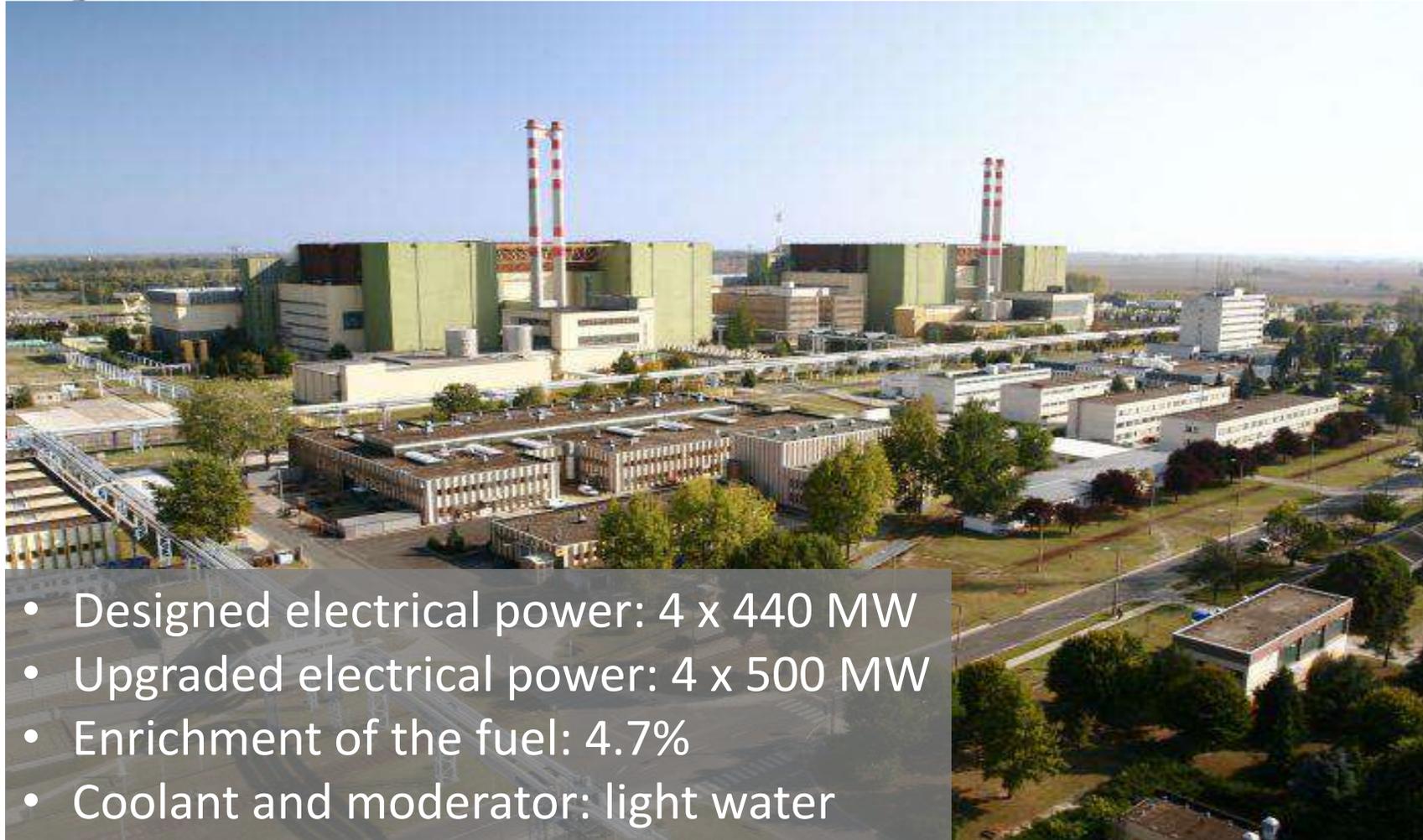
Hungarian Atomic Energy Authority

# Paks Nuclear Power Plant



- 4 Units
- Type: VVER-440/213
- Twin-unit with 2 cooling circuit in common building
- Primary circuit :6 cooling loops

# Paks Nuclear Power Plant



- Designed electrical power: 4 x 440 MW
- Upgraded electrical power: 4 x 500 MW
- Enrichment of the fuel: 4.7%
- Coolant and moderator: light water

# Paks II Nuclear Power Plant Constuction



- 2 Units
- Type: VVER-1200/AES-2006
- Generation: III+
- Units in own containment buildings
- Primary circuit :4 cooling loops

## Long Term Operation (LTO)

- Commission of units: 1983-1987
- Original designed lifetime: 30 years
- Licence renewal adapting US NRC methods
- Example Finland's VVER type units in Loviisa NPP
- Additional 20 years

# Requirements and guidance on pre-conditions for LTO

Adaption of US NRC 10CFR54 (License Renewal) approach into NSCs as basis

- long lived passive SSC

- TLAAs & AMPs for essential systems

Active components treated with plant programs

- 10CFR50.65; e.g. Maintenance Rule – Maintenance Effectiveness Monitoring

- Other active components - repair and replacement program (if applicable)

- Equipment qualification for electrical & I&C components

## Regulatory body requirements

Adaption of ASME BPVC (2001) Section III, XI and O&M Development of ISI program and the qualification of ISI systems according to ENIQ method.

HAEA required the assessment of the design basis (strengths and fatigue analysis) based on ASME BPVC Section III.

Remove unnecessary conservatives

Reconstitution of the design basis was also required by HAEA as a pre-requisite of the LTO program

Collection of design basis documents

Calculations & drawing were missing – recalculate & revalidate drawings

Design basis changed – modifications

# ASME adaption in Hungary

## Implementation of ASME – complex approach

Promote implementation of strength calculations applying state-of-art methods and codes/standard – ASME BPVC Sec. III.

Implementation of in-service inspections – ASME BPVC

Sec. XI for ISI and modify ISI interval from 4 (original Russian) to 8 years (later 10 years, see next slide)

New challenge – NPP original design based on Russian standards, not ASME BPVC Sec. III. (material property)

Regulatory requirements in Regulator Guide RG 3.25 – Review of Strength calculations at pressure vessels in operation

## Examples for difficulties

Repair and replacement according to IWA-4000 – independent from construction class – goal is restore original property and operational condition

Plant's specific SSCs: Main Gate Valve

## ASME adaption in Hungary

Quality ISI instead of quantity ISI

8 year period based on ASME

2012-2013 C-15 project started (outages in 15 months intervals instead of 12 months)

Till end of LTO increased to 10 years interval (C12→C15)

In 2008 NPP adapt ASME BPVC Sec. III, XI and parts of O&M codes (edition 2001) and issued as Hungarian Standards (translated) – No. 27003, 27011 and 27020

Agreement with ASME organization



## ASME adaption in Hungary

Inspection plan – not full adaption, similar

Just principals, based on operational experience of main components of NPP

- ISI programs reviewed in accordance with C-15
- TWO level methods and criteria document approved by authority
- Important to be able to detect new degradations
- Implementation of new maintenance strategy – Effectiveness monitoring
- Maintenance, ISI and IST should be harmonized
- C15 decrease doses during outage



Országos Atomenergia Hivatal

## ASME adaption

### Inspection plan content

Inspection Plan in accordance with ASME BPVC Sec. III. IWA-2420

Difficulties: VVER units Inspection Plan is quite detailed

- Large number of equipment (eg.: 6 SGs)

- Long, complicated pipelines

- Only confinement, many special equipment to retain possible radioactivity

### Non-destructive Testing Framework Programs

- Reactor and its components

- Primary circuit pipeline

- Steam generators

- Pressurizer

- Hydro accumulators

- Local leakage tests (border of confinement)

- Secondary circuit equipment (has effect to primary circuit safety equipment)

# ISI experience

Transition period – shortened in some cases, BUT  
 ISI implementation = 100% !!

4 to 8 years

8 to 10 years

Inspection period	Calendar year	Minimum inspection ratio [%]	Maximum inspection ratio can be considered [%]
Periods of inspection interval	3	16	50
	7	50	75
	10	100	100

# Application of ENIQ methodology in Hungary

Qualification of personnel and procedures

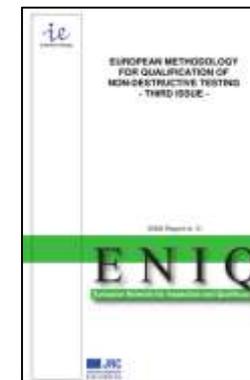
The **qualification of ISI/NDE** systems (procedures, equipment and personnel) is carried out by the **European Network for Inspection and Qualification (ENIQ)** as well as related IAEA document

NPP has Maintenance Training Centre

NPP staff performs most of ISI programs

Other ISI company (international) only help to perform specific inspections (eg.: RPV internal UT&ET)

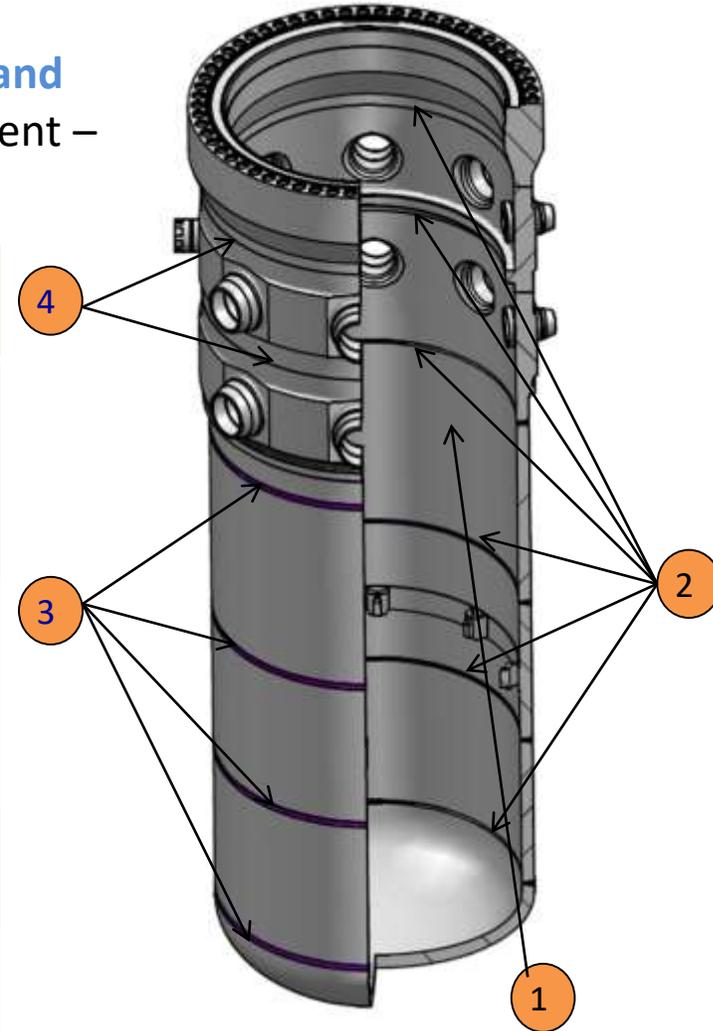
During qualification of ISI the program should be implemented same time as in real conditions of NPP inspection



# Qualification of ISI system

ISI Qualification - **European Network for Inspection and Qualification** as well as related IAEA, WENRA document – mandatory.

No	Inspection area	NDT Method	Insp. org.	Date
1	Cladding from ID	Mechanized UT	ŠKODA	2004
		Mechanized. ET	INETEC	2011
2	Shell welds from ID	Mechanized. ET	ŠKODA	2008
		Mechanized UT	INETEC	2011
3	Lower part shell welds from OD	Mechanized. ET	ŠKODA	2008
		Mechanized UT	INETEC	2011
4	Nozzle shell welds from OD	Mechanized UT	Paks NPP	2014



## ISI program experience

RPV - Inspection from both side (from inside and outside)

Volumetric inspection 100% - 10 years interval.

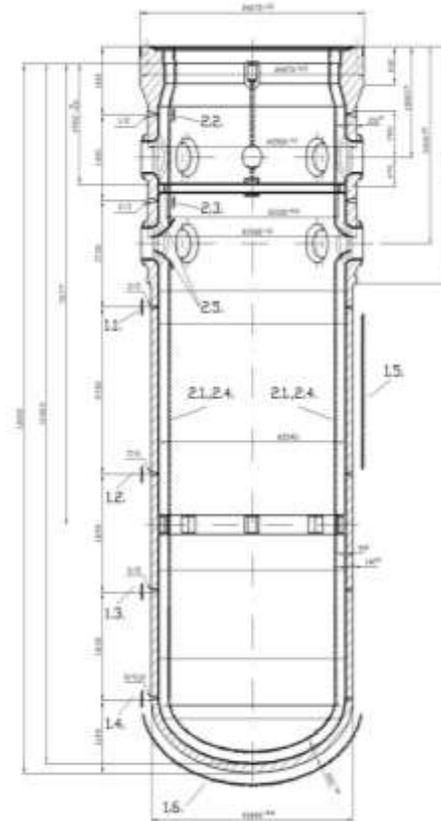
**Leakage test** of the pressure boundary of the coolant system of the nuclear reactor shall be performed **following refueling before restarting the reactor**, and its pressure test shall be executed **at the end of the ISI cycle**.

**Pressure test.** Until 1993 the test pressure value was 192 bar (operations pressure at nominal power is 123 bar). In 1993 the value was allowed by the RB to reduce to 164 bar. **After the introduction of the ASME** remained in Hungarian regulations and practice.

Additional acoustic emission tests were introduced during pressure tests.

Pressure & leakage tests performed after the period, but not right after shut down

Pressure retaining time during test (with insulation 4h, w/o 10 min)



## Conclusion

In Regulatory aspect the adaption of ASME resulted positive.

- quality ISI instead of quantity ISI
- training level of operating personnel increased
- change in engineering approach
- new RPV surveillance program justified the LTO

## Panel discussion and Q/A from the audience

# Conclusion of day 1

**Working Group on Codes and Standards  
Workshop on In-Service Inspection**

**Thank you for your participation today  
and see you all tomorrow!**