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NSJ-XX-A005 Rev.0

# Welding Technology for Advanced BWR

## - Potential Cooperation with Polish Companies for first Nuclear Power Plant in Poland -

October 17, 2018

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Hitachi-GE Nuclear Energy, Ltd.

# Today's Main Topics

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1. Introduction
 1-1 Hitachi Construction Experience
 1-2 Outline of ABWR Building

2. Fabrication Technologies of Reactor Internals (RIN)
 2-1 Outline of Reactor Internals (RIN)
 2-2 Applicable Codes and Standards for RIN
 2-3 Fabrication Sequence of RIN (Core Shroud)
 2-4 Key Technologies for RIN Fabrication

3. Welding Quality Control
 3-1 Potential Cooperation in Poland
 3-2 Quality Control for Welding
 3-3 Supply Chain Establishment

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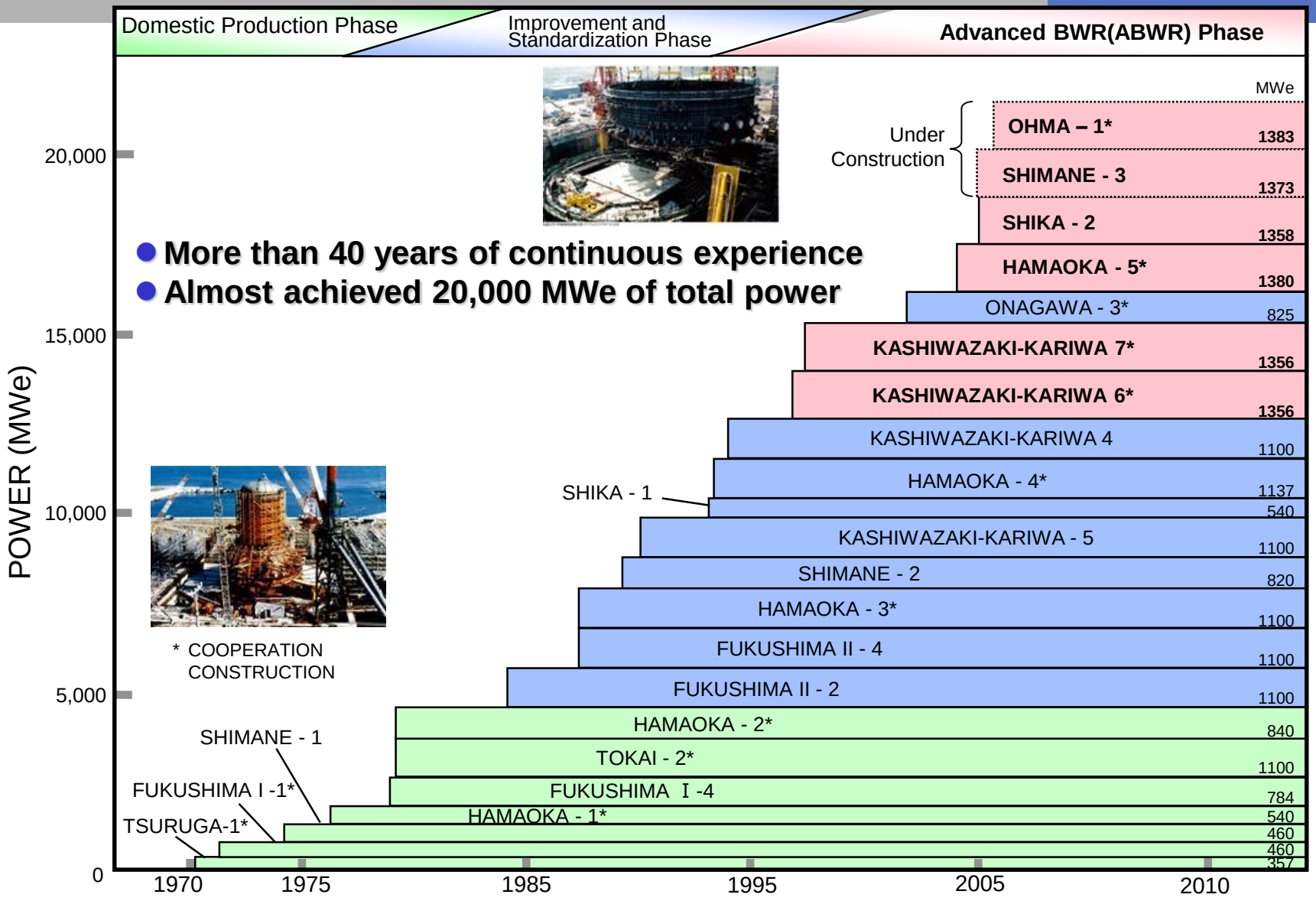
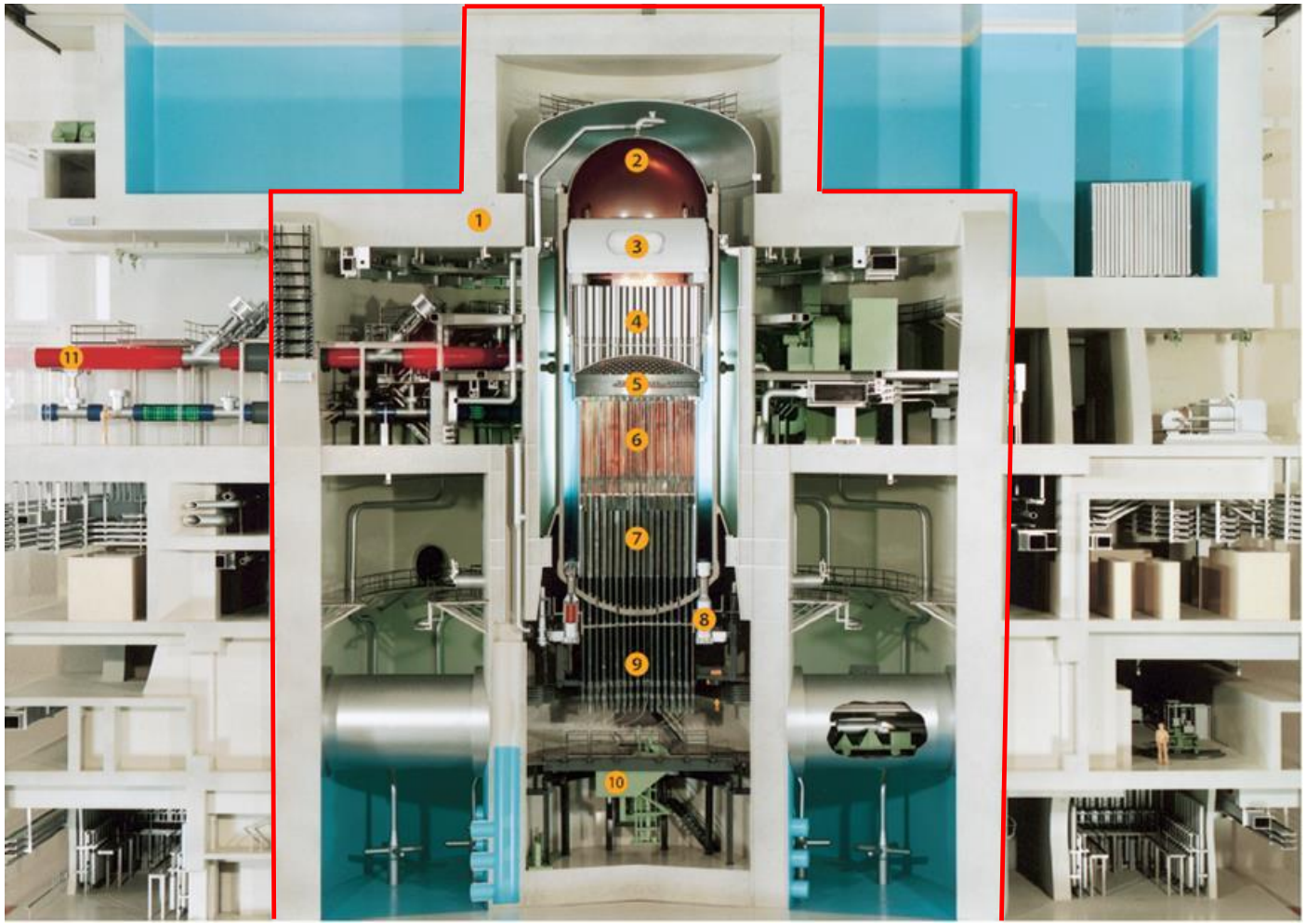
# 1. Instruction
# 1-1 Hitachi Construction Experience



# 1. Instruction
# 1-2 Outline of ABWR Building




① Reinforced Concrete Containment Vessel

② Reactor Pressure Vessel

③ Steam Dryer

④ Steam Separator

⑤ High Pressure Core Flooder Sparger

⑥ Fuel Assembly

⑦ Control Rod

⑧ Reactor Internal Pump

⑨ Fine Motion Control Rod Drive System

⑩ Control Rod Drive Mechanism Handling Machine

⑪ Main Steam Piping

Cross-sectional Model of ABWR Building

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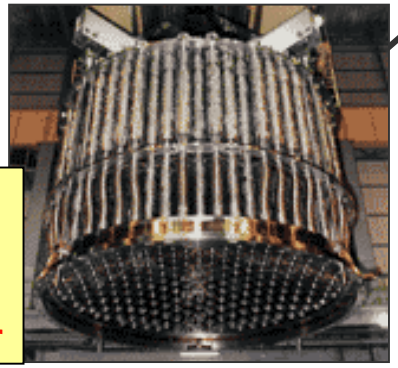
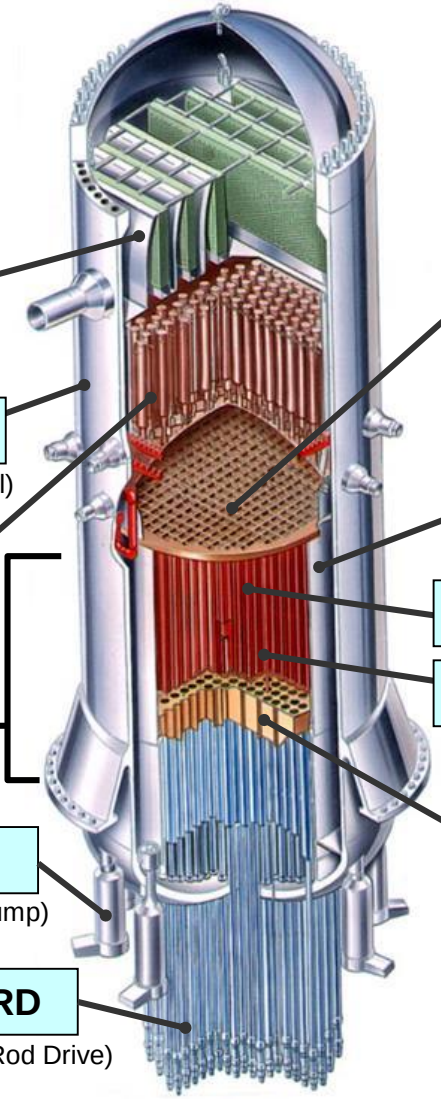
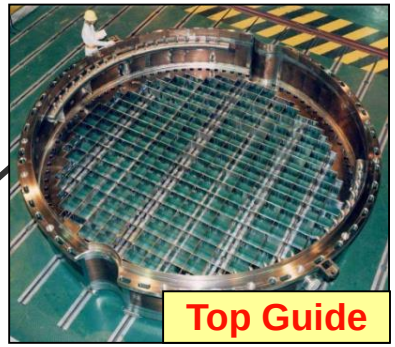
# 2. Fabrication Technologies of RIN
# 2-1 Outline of Reactor Internals (RIN)

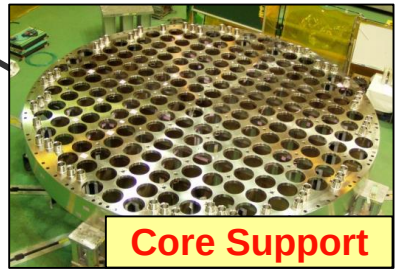
Since RIN has the important roles such as dehumidifying water vapor, supporting fuel and forming reactor coolant flow channels in RPV, its required high quality and high precision fabrication.






Cross-sectional Image of RPV and RIN

# 2. Fabrication Technologies of RIN
# 2-2 Applicable Codes & Standards for RIN

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(1) Applicable standard for RIN:

ASME Section Ⅲ – Division 1 Subsection NG "Core Support Structures"
(JSME S-NC1 for Japanese domestic plant)

Abstract of Applicable ASME Code for RIN

| Article | Content | Related Section |
|---|---|---|
| NG-2000 | Material<br>Especially important sub - article<br>NG-2400 : Welding Material | Section Ⅱ Materials Part C |
| NG-3000 | Design | |
| NG-4000 | Fabrication and Installation<br>Especially important sub - article<br>NG-4200 : Forming, Fitting and Aligning<br>NG-4300 : Welding Qualifications<br>NG-4400 : Rules Governing Marking, Examination and Repairing Welds<br>HG-4600 : Heat Treatment | Section Ⅸ Welding and Brazing Qualification |
| NG-5000 | Examination | Section Ⅴ |
| NG-8000 | Nameplate, Stamping with Certification Mark and Report | |

Note: Hitachi-GE holds the N-type certificate to comply with above ASME codes.

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(2) Qualification of Welding Procedures for RIN (Austenitic stainless steel)

| Requirements | ASME Sec.Ⅲ NG-4300<br>ASME Sec.Ⅸ | EN ISO 15607<br>ISO 15614-1 |
|---|---|---|
| ① Butt joint with full penetration | Specified | Specified |
| ② Fillet weld | Specified for nonpressure-retaining fillet welds, but not mandatory<br>(① qualify ②) | Specified |
| ③ T-joint with full penetration | —<br>(③ is included in ①) | Specified |
| ④ Branch connection with full penetration | —<br>(④ is included in ①) | Specified |

# 2. Fabrication Technologies of RIN
# 2-2 Applicable Standard for RIN

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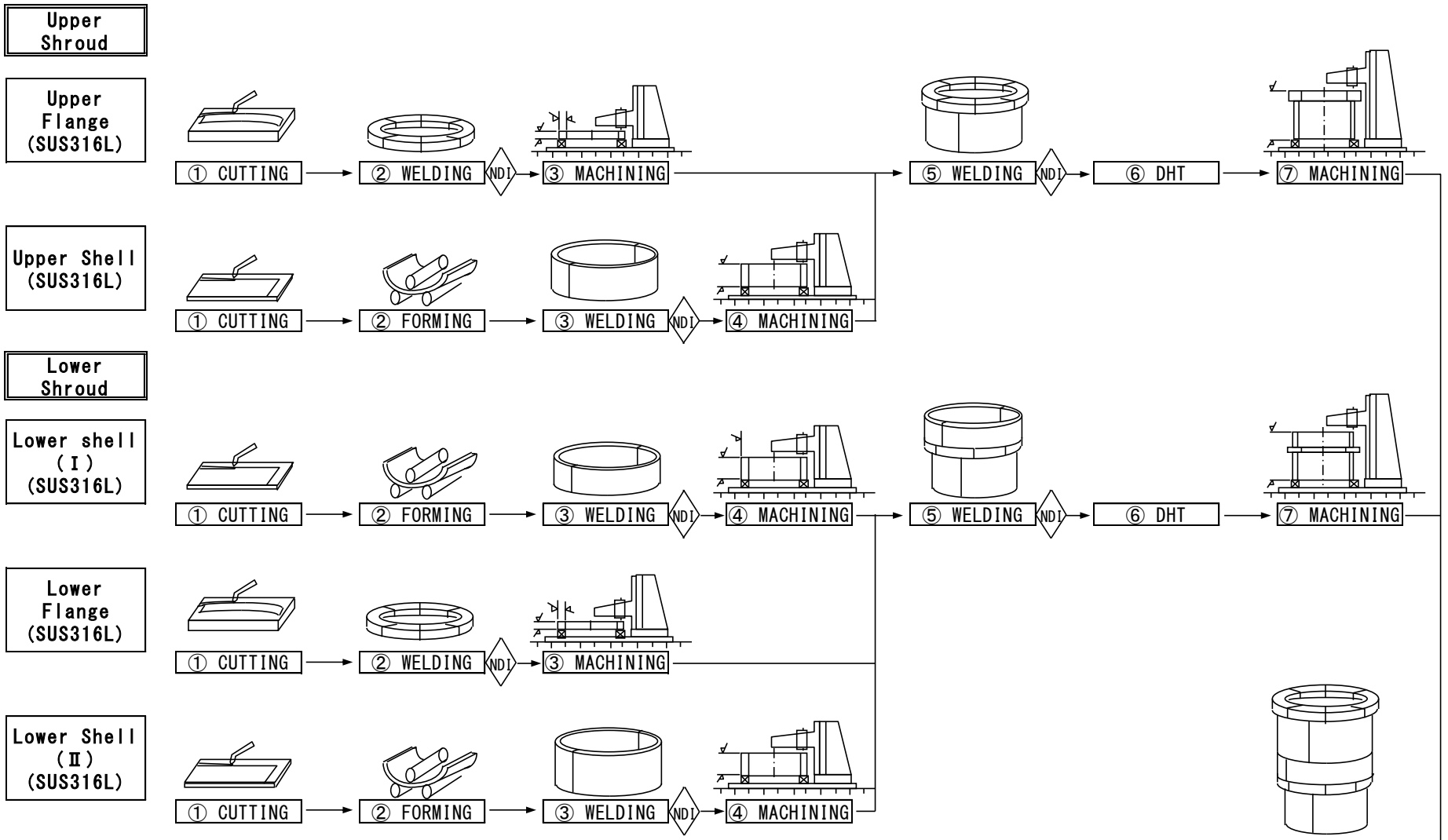
(3) Qualification of Welders for RIN

| Requirements | ASME Sec.III NG-4300<br>ASME Sec.IX | EN ISO 9606-1 |
|---|---|---|
| ① Butt weld | Specified | Specified |
| ② Fillet weld | Specified<br>(① qualify ②) | Specified<br>(① do not qualify ② or vice versa) |
| ③ Branch connection | —<br>(③ is included in ①) | (a) For angle ≧60°,<br>qualified by butt welds in pipes<br>(b) For angle ＜60°,<br>qualified by product standard |

# 2. Fabrication Technologies of RIN
# 2-3 Fabrication Sequence of RIN



# 2. Fabrication Technologies of RIN
# 2-4 Key Technologies for RIN Fabrication

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**(1) Mitigation of Stress Corrosion Crack (SCC) Risk**

(a) Specifying welding materials:

- Low carbon material (Stainless steel)

(b) Specifying cold work process:

- Managing strain ratio and surface hardness
- Polishing after grinding work (Removing hardened layer)

(c) Mitigating residual tensile stress caused by welding:

- Water Jet Peening

**(2) High Quality and High Productivity**

Applying narrow groove welding joint:

- Lower welding heat input
- Mitigate residual stress

(3) Dimensional Stability

Preventing in-service deformation caused by residual stress releasing:

- Low temperature dimensional stabilizing heat treatment

**Items (1)(a) and (2) would be detailed on the following pages.**

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## (1) Mitigation of SCC Risk

### (a) Specifying Welding Materials for Low Carbon Material (Stainless Steel)

Typical welding materials specification (for Japanese ABWR plant)

1) Chemical component: C≦0.020 % (Hitachi Spec. to prevent sensitization)
2) Mechanical property: Equal to or greater than the base material spec.

Specification of Chemical Component of Stainless Steel Welding Materials

| | Japanese Industrial Standards | Chemical Component (Mass Percent) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | C* | Si | Mn | P | S | Ni | Cr | Mo |
| GTAW | JIS Z 3321 YS 316L ** | ≦0.020 | ≦0.65 | 1.0 ～2.5 | ≦0.03 | ≦0.03 | 11.0 ～14.0 | 18.0 ～20.0 | 2.0 ～3.0 |
| SMAW | JIS Z 3221 ES 316L*** | ≦0.020 | ≦1.00 | 0.5 ～2.5 | ≦0.04 | ≦0.03 | 11.0 ～14.0 | 17.0 ～20.0 | 2.0 ～3.0 |
| SAW | JIS Z 3324 S 316L*** | ≦0.020 | ≦1.00 | 0.5 ～2.5 | ≦0.04 | ≦0.03 | 11.0 ～16.0 | 17.0 ～20.0 | 2.00 ～3.00 |

GTAW: Gas Metal Arc Welding
SMAW: Shielded Metal Arc Welding (Manual metal-arc welding)
SAW : Submerged Arc Welding

*: Hitachi's specification
**: Filler metal
***: Deposited metal

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# (1) Mitigation of SCC Risk

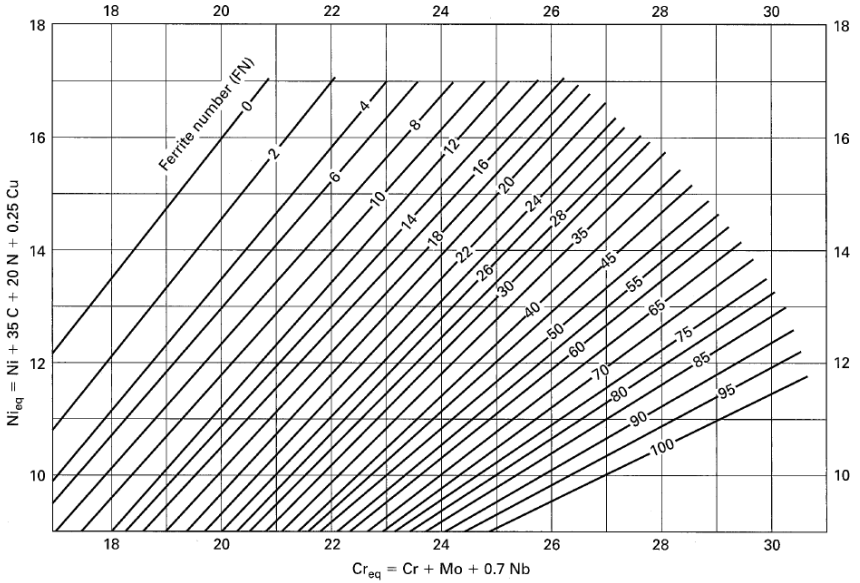
## (a) Specifying Welding Materials for Low Carbon Material (Stainless Steel)

ASME Sec.III NG-2400 “Welding Material” requirement

① Chemical analysis test
Analyzed elements for Chromium and Cr-Ni stainless material
C, Cr, Mo, Ni, Mn, Si, P, S, V, Cb+Ta, Ti, Cu
(No specific elements, only report)

② Delta Ferrite Determination
(i) Method
- Magnetic measuring instrument and
- Chemical analysis (WRC-1992 Diagram)

(ii) Acceptance standards
Minimum 5 FN



# 2-4 Key Technologies for RIN Fabrication (2) High Quality and High Productivity

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## ◆ Application of Narrow Groove Welding Joint

Table : Available welding method

| Welding Method |  LASER welding (Super Narrow groove) |  Submerged arc welding (SAW) |  Fully mechanized GTAW welding (Narrow groove) |  Manual metal-arc welding (SMAW) |  Manual GTAW welding |
|---|---|---|---|---|---|
| Example of Application Joint | Longitudinal joint and Circumferential joint of shell | | | Welding of parts such as lag block | |
| Welding position | Flat, Horizontal & Vertical position | Flat position | All position | All position | All position |
| Deposition efficiency (1>2 >3 >4) | 1 High Efficiency due to narrow groove | 2 High current (high heat input) | 3 High Efficiency due to narrow groove | 4 | 5 |
| Total Welding activity | ◎ Dedicated facility | × Setup of shell that are tailored to flat position | ○ Setting of welding head rail | △ | △ |

Total Welding activity : Good ◎ > ○ > △ > ×

# 2-4 Key Technologies for RIN Fabrication (2) High Quality and High Productivity

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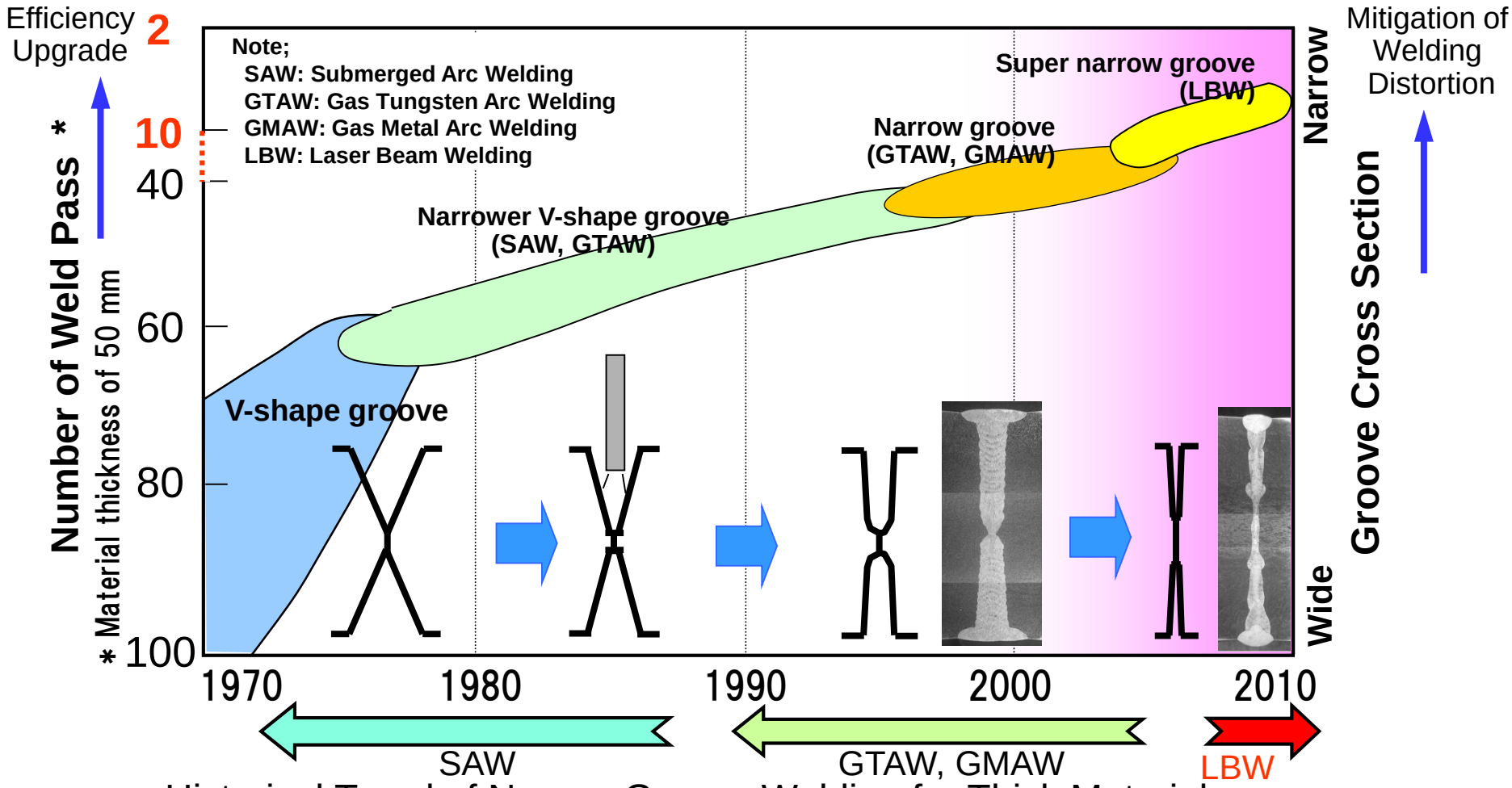
## ◆ Application of Narrow Groove Welding Joint




Historical Trend of Narrow Groove Welding for Thick Material

# 2-4 Key Technologies for RIN Fabrication (2) High Quality and High Productivity

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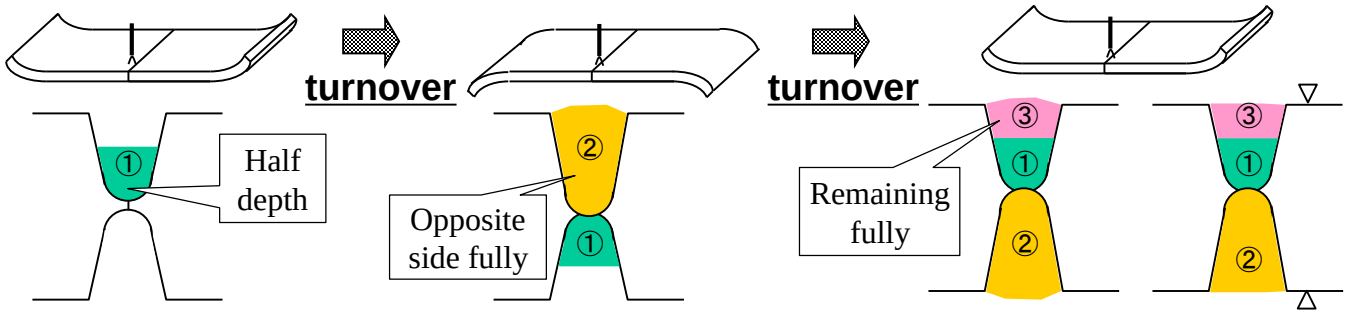
## ◆ Application of Narrow Groove Welding Joint

**Improvement of fabrication sequence**

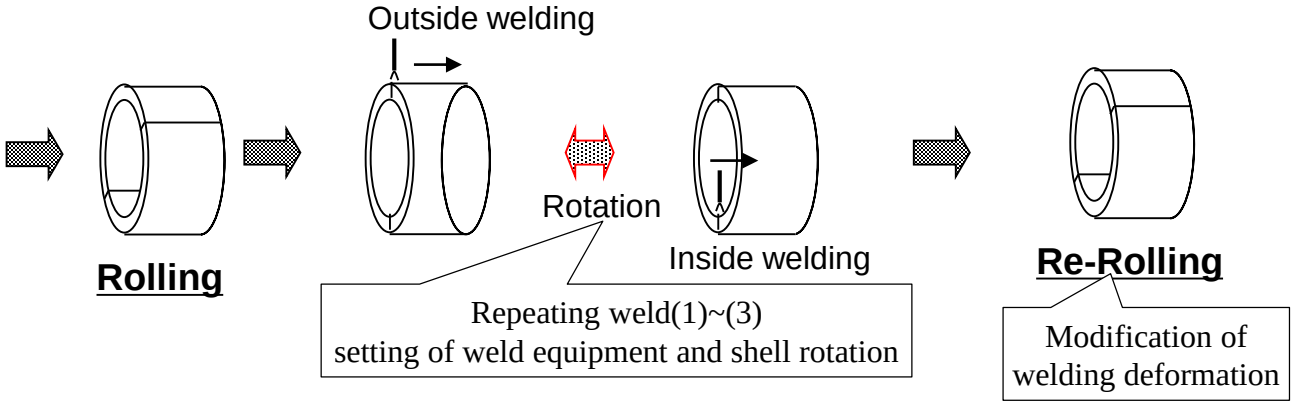
**《before improvement》 Longitudinal joint welding procedure by SAW**

Turn over the product for each step in order to reduce weld deformation




**Weld (1) in flat position** | **Weld (2) in flat position** | **Weld (3) in flat position** | **Grinding & Polishing**

Fig. Submerged arc welding (SAW)




**Rolling** | **Re-Rolling**

**Weld (4) in flat position**

Fig. Rolling

# 2-4 Key Technologies for RIN Fabrication (2) High Quality and High Productivity

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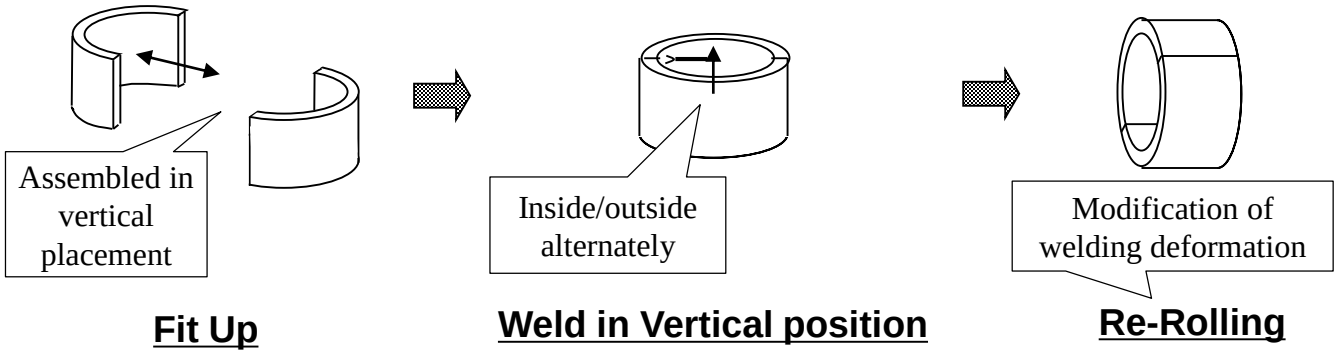
## ◆ Application of Narrow Groove Welding Joint

### Improvement of fabrication sequence

➢ To achieve Narrow Groove → Mechanized GTAW ／ LASER welding → Vertical Position

**《after improvement》**

**Longitudinal joint welding procedure by Mechanized GTAW or LASER welding**



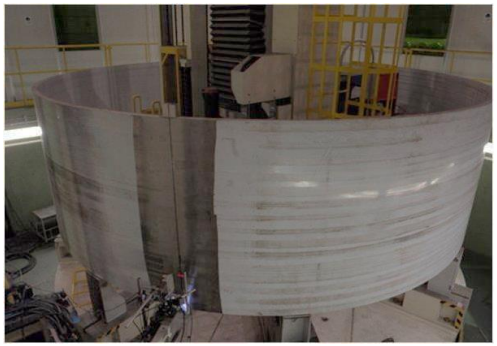



Fig. LASER welding (outside)

### Improvement History of fabrication sequence

| | | | | |
|---|---|---|---|---|
| **Welding method transition** | **Submerged arc welding (SAW)** | ⇨ | **Mechanized TIG welding ( narrow groove joint)** | ⇨ **LASER welding (super narrow groove joint)** |
| **Improved points** | **1. Reduce welding distortion by narrow groove and alternately build-up<br>2. Save setup time by assembling and welding in vertical placement** | | | |

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# 3. Welding Quality Control
# 3-1 Potential Cooperation in Poland

## Feature of NPP Construction

(NPP : Nuclear Power Plant)

**What's Demanded for NPP**

**Safety** | **Reliability** | **Profitability**

Nuclear Safety Culture

Quality Control

**"Construction"** is a key matter of the NPP business.

### What's the feature of NPP construction?

- ✓ Long Period Work
- ✓ Large Work Volume
- ✓ Many Documents & Record
- ✓ Traceability
- ✓ Many Interfaces with Project Participants

Large Volume!!

**Cooperation with Polish Companies for the First NPP in Poland**

- ➢ Quality Control required for NNP
- ➢ Highest standards of Nuclear Safety Culture

# 3-2 Quality Control for Welding
# (1) Why QC is Required?

Welding ; **Special Process** (defined in various Codes and Standard)

Quality of welding depends on following;

- ✓ Establishment of Quality Management System for welding and relevant process
- ✓ Adequacy of Welding Process Specification (WPS) based on Welding Procedure Qualification (PQR)
- ✓ Adequate assignment of Welding personnel who have necessary capabilities
  - ➢ Welder and Welding Operator
  - ➢ Welding Engineer
  - ➢ Examiner and Inspector
  - ➢ Welding Supervisor
- ✓ Adequate test and inspection

(1) ISO 9000 family "Quality Management Systems"
(2) ISO 3834 "Quality Requirements for Fusion Welding of Metallic Materials"

Ref.:Overview of Welding and Jointing Technologies, The Japan Welding engineering Society (SANPO PUBLICATIONS)

# 3-2 Quality Control for Welding
## (2) QC in accordance with Codes and Standards

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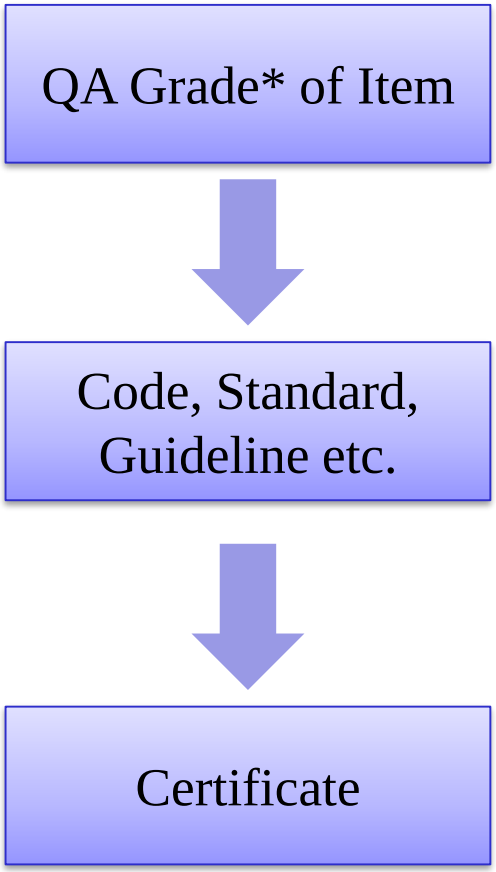
### (a) Quality Control Required for NPP




Item : Product, Equipment, Piping etc.

* QA Grade is identified by Hitachi's Costumer dependent on factors including, but not limited to, the Nuclear Safety Classification, engineering complexity, supply chain performance and project schedule.

Code, Standard, Guideline : ISO, PED, ASME etc.

Quality Control is required in accordance with these applicable Code, Standard, Guideline etc.

i.e.
- ISO Certificate (ex. ISO 9000)
- PED Certificate**
- ASME Certificate

** PED Certificate is required for pressure equipment other than items specially designed for nuclear use.

# 3-2 Quality Control for Welding
## (2) QC in accordance with Codes and Standards
### (b) Quality Management System Requirement to Supplier

Degree of QA Grade: High ↕ Low

| QA Grade | ASME NQA-1 | IAEA GSR Part 2 | ISO 9001 |
|---|---|---|---|
| A | X | X | |
| B | X | X | |
| C | - | X*1 | X |
| D | If specified in a Contract, comply with the Contract | | |

*1 If required in a Contract.

**(1) ASME NQA-1 (Nuclear Quality Assurance -1)**

- ✓ "Quality Assurance Requirements for Nuclear Facility Applications"
- ✓ Regulatory standard issued and maintained by ASME.
- ✓ For QA Grade A and B, Suppliers shall comply with the applicable element of the requirement of NQA-1 for quality assurance arrangements.
- ✓ Maintaining ASME N-Type Certification is acceptable.

**(2) IAEA GSR Part 2 (General Safety Requirements Part 2)**

- ✓ "Leadership and Management for Safety"
- ✓ To establish requirements that support Principle 3 "Leadership and Management for Safety" and Principle 8 "Prevention of Accidents" of Fundamental Safety Principles.
- ✓ For QA Grade A and B, and Grade C if required in Contract, Supplier shall also comply with the requirements of IAEA GSR Part 2.
- ✓ The suppliers shall be assessed by Hitachi for compliance with IAEA GSR Part 2.

**(3) ISO 9001**

- ✓ For QA Grade C, Suppliers have the option to comply with either NAQ-1 or ISO 9001.

# 3-2 Quality Control for Welding
## (2) QC in accordance with Codes and Standards
## (b) Supplier Program Requirements for Welding

| QA Grade | ASME Code Sec. III and IX | ISO 15609, ISO 15614 ISO 9606-1 | Test Lab. for PQR and WPQR |
|---|---|---|---|
| A | X | - | X |
| B | X | - | X |
| C | - | X | X |
| D | If specified in a Contract, comply with the Contract | | |

### (1) ASME Code Sec.III and IX

- ✓ For QA Grade A and B, Supplier who perform welding shall comply with the applicable sub-section requirements of ASME Code Sec.III and Sec.IX for welding.
- ✓ Where agreed with Hitachi, ISO standard specified in (2) may be applied as alternatives.

### (2) ISO 15609, ISO 15614 and ISO 9606-1

- ✓ For QA Grade C, Supplier who perform welding shall comply with the requirements of ISO 15609, ISO 15614 (ex-EN288) for welding procedure specification (WPS) qualification, and EN ISO 9606-1 for welder qualification.
- ✓ Where agreed with Hitachi, ASME Code Sec.III and Sec.IX specified in (1) may be applied as alternatives.

### (3) Test Laboratory for PQR and WPQR

- ✓ For QA Grade A and B, all associated tests for PQR and WPQR shall be performed by a test laboratory within the scope of its accreditation in accordance with ISO 17025.

## (b) Supplier Program Requirements for NDE

| QA Grade | SNT-TC-1A | ISO 9712（EN 473） |
|---|---|---|
| A | X | - |
| B | X | - |
| C | - | X |
| D | If specified in a Contract, comply with the Contract | |

### (1) SNT-TC-1A

- ✓ Recommended Practice “Personnel Qualification and Certification in Nondestructive Testing” issued and maintained by the American Society for Nondestructive Testing (ASNT).
- ✓ SNT-TC-1A provides guidelines for employers to establish in-house certification programs for the qualification and certification of NDE personnel.
- ✓ For QA Grade A and B, Suppliers whose personnel perform NDE shall be qualified in accordance with the recommended guidelines of SNT-TC-1A for the qualification of NDE personnel.
- ✓ When agreed with Hitachi, ISO standards (e.g. ISO 9712) may be applied as alternatives.

### (2) ISO 9712

- ✓ For QA Grade C, Suppliers shall qualify NDE personnel in accordance with an accredited national scheme in accordance with ISO 9712.
- ✓ When agreed with Hitachi, SNT-TC-1A may by applied as alternatives.

# Supply Chain Establishment

**”Hitachi-GE Nuclear Energy, Ltd. and its partner company GE-Hitachi Nuclear Energy, Ltd. have already engaged with potential Polish companies in terms of engineering, procurement and construction of new nuclear build, and will continue to engage and develop a Polish Supply Chain to maximize the involvement of Polish suppliers for the new nuclear build in Poland.”**

# Thank you for your listening.