IRID

Subsidy Project of Decommissioning and Contaminated Water Management in FY 2017 Supplementary Budget

Development of Technology for Construction of Water Circulation System in Primary Containment Vessel

Final Research Report for FY 2019

August 2020

International Research Institute for Nuclear Decommissioning (IRID)

Contents

Major technical terms and abbreviations

Technical terms and abbreviations	Descriptions
Fuel debris	Melted fuel and other solidifies that are produced under high temperatures through melting with control rods and structures inside the primary containment vessel and reactor pressure vessel, after which they cooled and re-solidified.
1F	Fukushima Daiichi Nuclear Power Station
RPV	Reactor Pressure Vessel
PCV	Primary Containment Vessel
D/W	Dry Well: among PCV, a vessel that is flask-shaped and designed to contain the RPV
S/C	Suppression Chamber: doughnut-shaped container installed in the basement floor of the reactor building
R/B	Reactor Building
Penetration	Various penetrations (cavities) are designed in PCV (ex. The penetration No.6 is referred to as X-6 penetration.)
Torus room	A room containing the torus-shaped (doughnut-shaped) S/C located in the basement of the reactor building.
JAEA Naraha	The Naraha Center for Remote Control Technology Development, Japan Atomic Energy Agency (JAEA) is a demonstration facility established for technological development required for decommissioning of 1F.
Liquid / gas phases system	The system designed to confine contaminated water and air and prevent them from leaking.
Boundary	In this project, the boundary indicates the range of the boundary to confine contaminated water and air.
Mock-up test	A test conducted by using a full-sized test facility or equipment that is a reproduction of the application target.
MT/PT/UT/RT/VT	Non-destructive test methods. From left, MT: magnetic particle testing, PT: penetrant testing, UT: ultrasonic testing, RT: radiographic testing, VT: visual testing
WJ	Water jet: cutting with high-pressurized water squirted out of small-diameter nuzzle
Extension pipe	A guide pipe to access inside D/W and S/C from the 1st floor of R/B

List of related projects

Abbreviations	Project name
Advancement of Retrieval Method and System Project	Advancement of Retrieval Method and System of Fuel Debris and Internal Structures
Upgrading of Fundamental Technology Project	Upgrading of Fundamental Technology for Retrieval of Fuel Debris and Internal Structures
PCV Investigation Project	Development of Technology for Identifying Leakage Points in PCV
PCV Repair Technology Project	Development of Repair Technology for Leakage Points in PCV
Project for Detailed Investigation technology inside PCV	Development of Technology for Detailed Investigation inside PCV
Project for Investigation inside PCV	Development of Technology for Investigation inside PCV
Project for Investigation inside RPV	Development of Technology for Investigation inside RPV
Project for Identification of Conditions inside Reactor	Upgrading of Comprehensive Identification of Conditions inside Reactor
Criticality Control Project	Development of Technology for Criticality Control of Fuel Debris
Water Circulation Project	Development of Technology for Construction of Water Circulation System in PCV
Water Circulation Full-scale Test Project	Development of Technology for Construction of Water Circulation System in PCV (full-scale test)
Corrosion Control Technology for RPV/PCV	Development of Corrosion Control Technology for RPV and PCV
Project for Further Increasing Retrieval Scale	Development of Technology for Further Increasing the Scale of Retrieval of Fuel Debris and Internal Structures

1. Research background and purpose

Background and purpose of this project

In order to retrieve fuel debris for the decommissioning of 1F, environmental improvement is important to reduce risks caused by retrieval work and to ensure the safety. After the liquid phase and gas phase systems for environmental improvement was developed under the *Advancement of Retrieval Method and System Project*, the plant operator is currently proceeding with engineering for the system development. This project aims to develop technology which can be applicable to the site, for accessing and connecting inside PCV to intake water within the water circulation system.

Project overviews

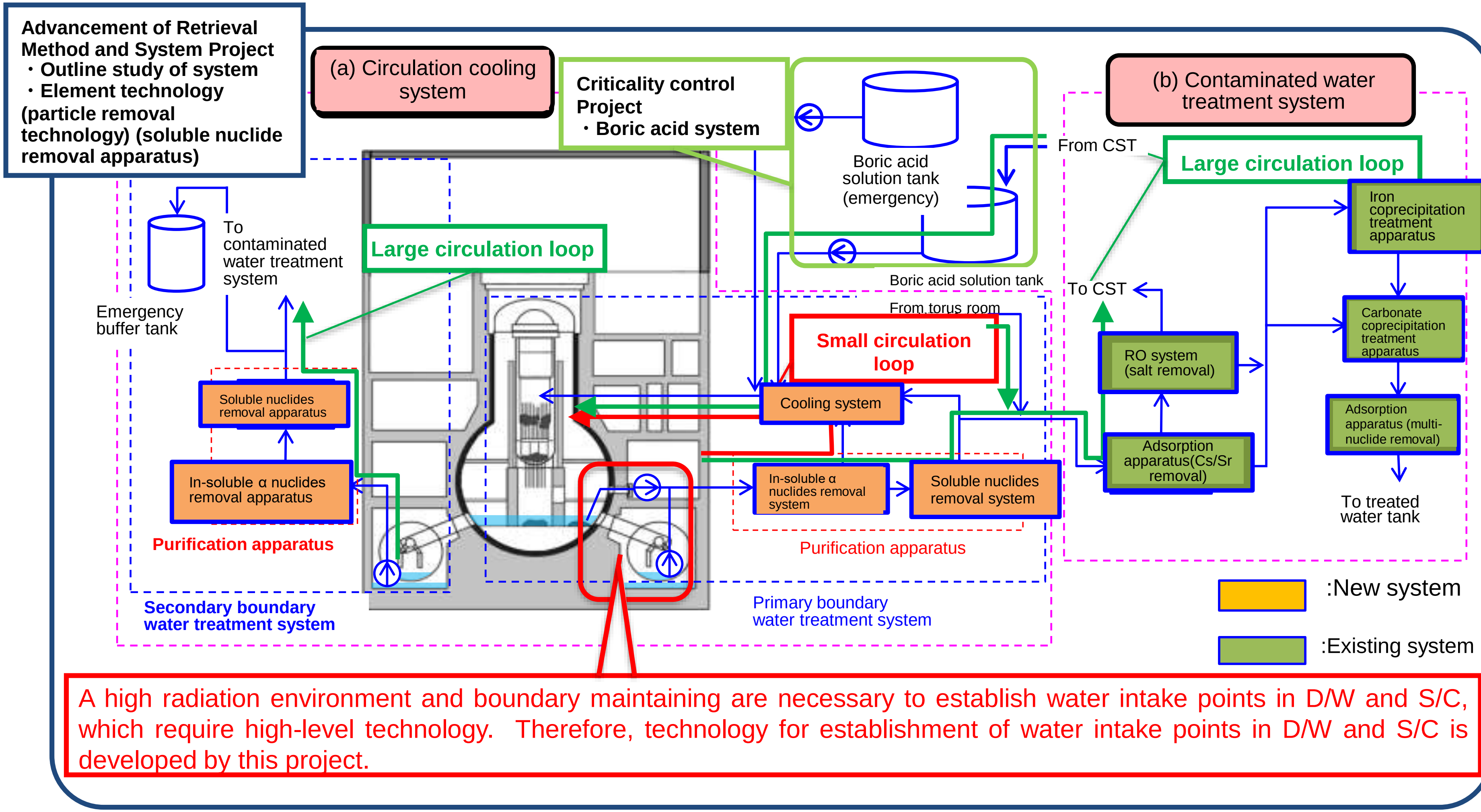
As part of environmental improvement to ensure the safety during fuel debris retrieval work, a safe water control in PCV is significant. To implement the safe water control system, it is necessary to develop a small circulation loop of the reactor water injection line (PCV circulation cooling) for reducing the circulation line area of contaminated water. Establishment of the water intake structure that can directly take water from PCV is necessary to establish the small circulation loop. Therefore, confinement functions of the gas/liquid phases and long-term integrity are required for the water intake structure. Additionally, installation and operation of the system will be required to use remote operated equipment in a high radiation environment site. A high-level technology for design, establishment and maintenance that is required is developed in this project.

Accessing and connecting technology which has high on-site feasibility is developed for the water circulation system in cooperation with relevant project, *Advancement of Retrieval Method and System Project,* and verified in actual scale accordingly.

As for D/W water intake establishment technology that is part of the water circulation system, element technology is developed and verified. As for S/C water intake establishment technology, element technology is developed and verified up to actual scale.

This project report describes achievements of the Water Circulation Project for 2 years during fiscal years 2018 and 2019.

1. Research background and purpose



Remarks: See Reference 2 for necessity of establishing PCV circulation cooling (small circulation loop) system and water intake structure as well as developing access technology.

Fig. Water circulation system during fuel debris retrieval (conceptual drawing)

● Development points: Technology for water intake part establishment (1/3) No.6

To respond to requirements by the Advancement of Retrieval Method and System Project, technology for establishment of access and water intake parts to take water into PCV is developed, which is quite difficult.

Advancement of Retrieval Method and System Project

Establishment of water circulation system

Establishment of PCV water intake opening is required, which will be a starting point of circulation.

Water Circulation Project, Water Circulation Full-scale Test Project

Development of technology for accessing and connecting PCV

Work in the area adjacent to PCV with high radiation dose

【Required functions】

- Prevention of leakage and spread of radioactive materials
- Reduction of radiation exposure for workers
- Maintaining long-term functions during fuel debris retrieval
- Maintenance of system equipment
- Function maintaining for external events (earthquake)
- Water intake from low water levels of D/W and S/C

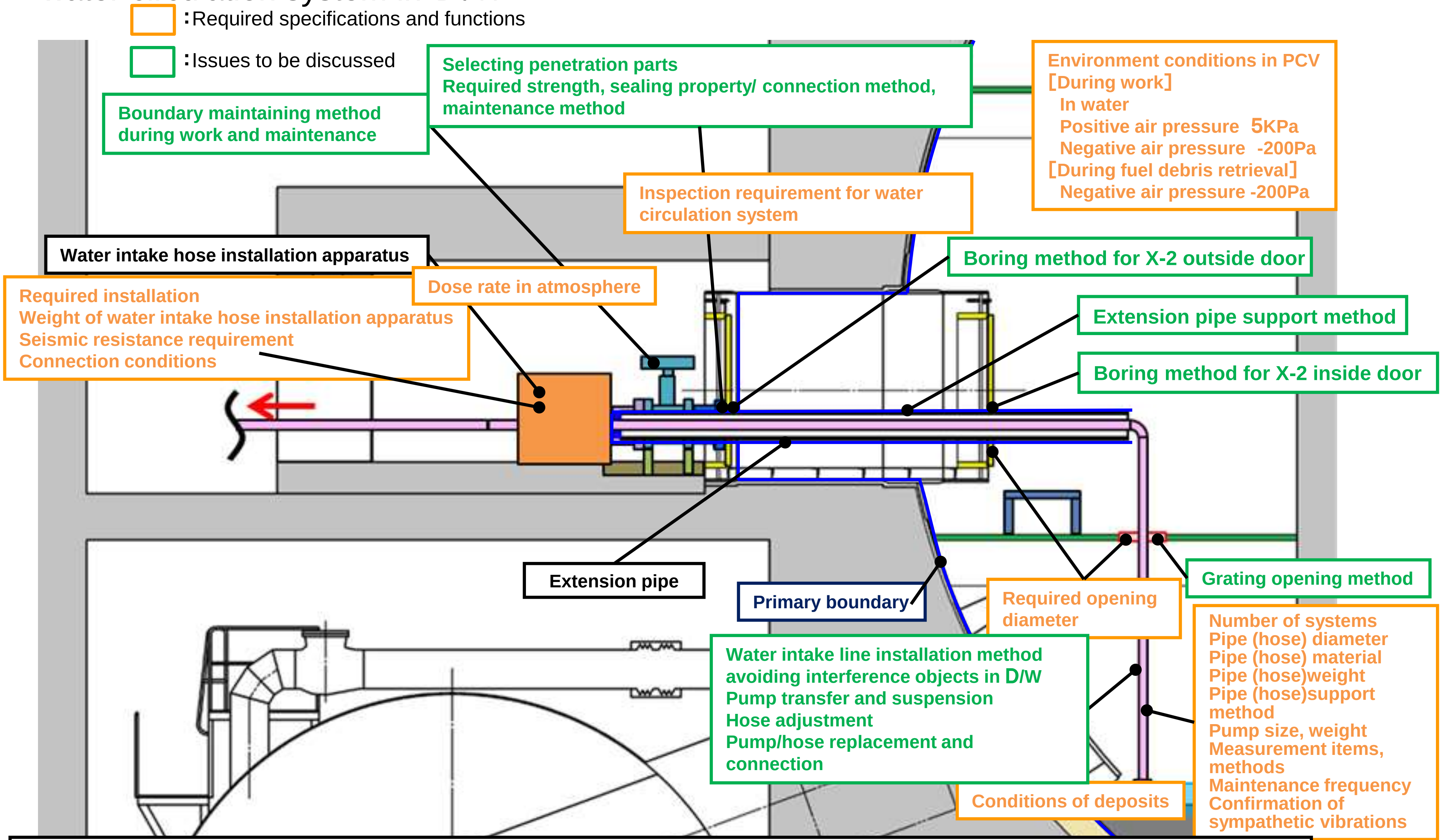
【Development points】

- Connection structure with earthquake-resistance strength and sealing property
- Remote operation work
- Boundary maintaining during work
- Boundary maintaining during system equipment maintenance
- Maintenance for connection parts
- Access to low water levels of D/W and S/C

The required specifications and functions for access and water intake part of water circulations were examined in this project, and then development effort will be made to solve technological issues. Descriptions are given in the figures on the following slides.

- Development points: Technology for water intake part establishment (2/3)

① Required specifications and functions of technological development for establishment of water circulation system in D/W



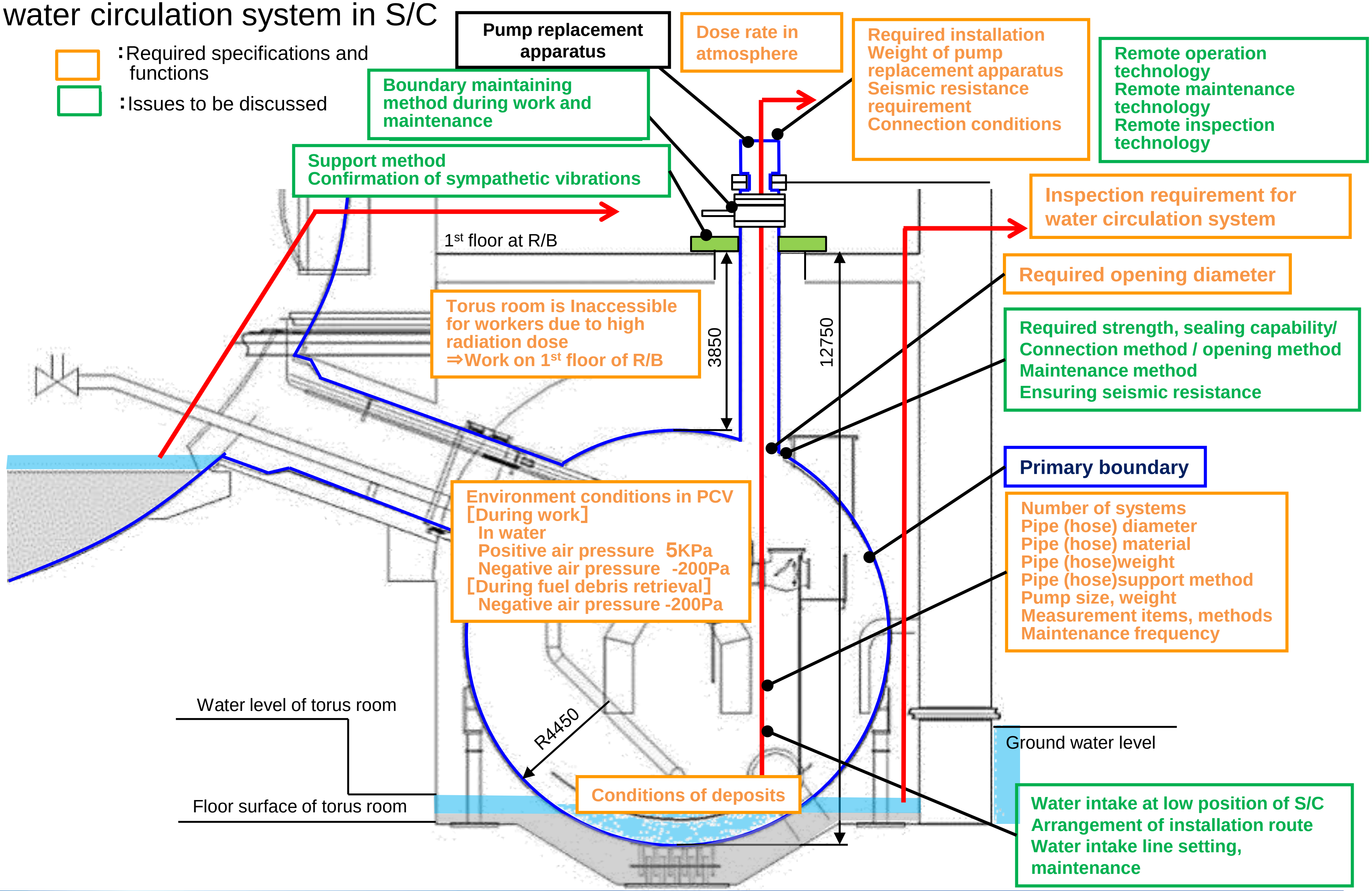
A penetration section for D/W water intake part is selected according to required layout of the water circulation system. This figure is an example of X-2 water intake.

● Development points: Technology for water intake part establishment (3/3) No.8

② Required specifications and functions of technological development for establishment of water circulation system in S/C

(orange box) : Required specifications and functions

(green box) : Issues to be discussed



2. Project goals

➢ Level of achievement (1/2)

According to the definitions of the technology readiness levels (TRL) as below, expectation levels at times of goal achievement in full-scale tests are established and R&D is conducted.

Levels	Definitions applicable to this project	Phases
7	Practical application completed	Actual operation
6	Technology demonstration in operational environments	Field demonstration
5	Prototype equipment is developed and demonstrated in a simulated environment such as manufacturing plant.	Demonstration in operation
4	Prototype-level function test conducted as part of process for technology development and engineering	Research for practical application
3	Technology and engineering are developed by applying and combining with existing knowledge. Or, technology and engineering are developed based on basic data, in which there is little existing knowledge.	Application research
2	Technology and engineering for specific fields, in which existing knowledge can rarely be utilized, are developed, and required specifications are set.	Application research
1	Basic details of targets for technological development and engineering are clarified.	Basic research

2. Project goals

➢ Level of achievement (2/2)

- Development of technology for the establishment of water circulation systems inside PCV

Items	Criteria for determining goal achievement
Technology for accessing and connecting inside D/W	Element tests pertaining to the technology for remotely operating the connection parts should be completed at the factory and the acceptance criteria of the element tests should be met. Or else, the issues to be resolved and the resolution policy should be clearly specified. (Target TRL at completion: 4)
Technology for accessing and connecting inside S/C	Element tests pertaining to the technology for remotely operating the connection parts should be completed at the factory and the acceptance criteria of the element tests should be met. Or else, the issues to be resolved and the resolution policy should be clearly specified. (Target TRL at completion: 4)
	Element tests pertaining to the technology for remotely inspecting access routes while in service at the time of establishment, should be completed at the factory and the acceptance criteria of the element tests should be met. Or else, the issues to be resolved and the resolution policy should be clearly specified. (Target TRL at completion: 4)
	Element tests pertaining to the technology for remotely carrying out maintenance of the connection parts while in service at the time of establishment, should be completed at the factory and the acceptance criteria of the element tests should be met. Or else, the issues to be resolved and the resolution policy should be clearly specified. (Target TRL at completion: 4)

3. Implementation items, their correlations, and relations with other research

3.1 Review of the overall project and hold points (HP)

Water Circulation Project

(1) Organization of technical specifications for the advancement of the water circulation system in PCV, review of work plans, and drawing up of development plans

① Review of the system and technology for water circulation inside D/W

Organization of technical specifications considering the site environment

Work of constructing the access route
・Review of the maintenance plan

Identifying development challenges and drawing up of development plans

Environmental Conditions
Layout requirements
Seismic requirements
Number of systems
Pipe (hose) specifications (diameter)
Etc.

Development results of other projects and past technologies

HP1

(2) Development and verification of element technologies for accessing and connecting inside PCV

Development and verification of element technologies

HP2

Water Circulation Full-scale Test Project

(1) Full-scale verification of technology for accessing and connecting inside PCV

Full-scale verification

② Review of the system and technology for water circulation using the S/C

Organization of technical specifications considering the site environment

Work of constructing the access route
・Review of the maintenance plan

Identifying development challenges and drawing up of development plans

Environmental Conditions
Layout requirements
Seismic requirements
Number of systems
Pipe (hose) specifications (diameter)
Etc.

Development results of other projects and past technologies

HP3

Development and verification of element technologies

HP4

Drawing up of full-scale test plans

HP4

Full-scale verification

Integrity confirmation after welding the connection parts

Validation of the water circulation system boundary

[HP1] ・Validity of the required specifications and functions
・Necessity of development
・Validity of the development plans

[HP2] ・Level of achievement with respect to the required specifications and functions, determined during the element tests

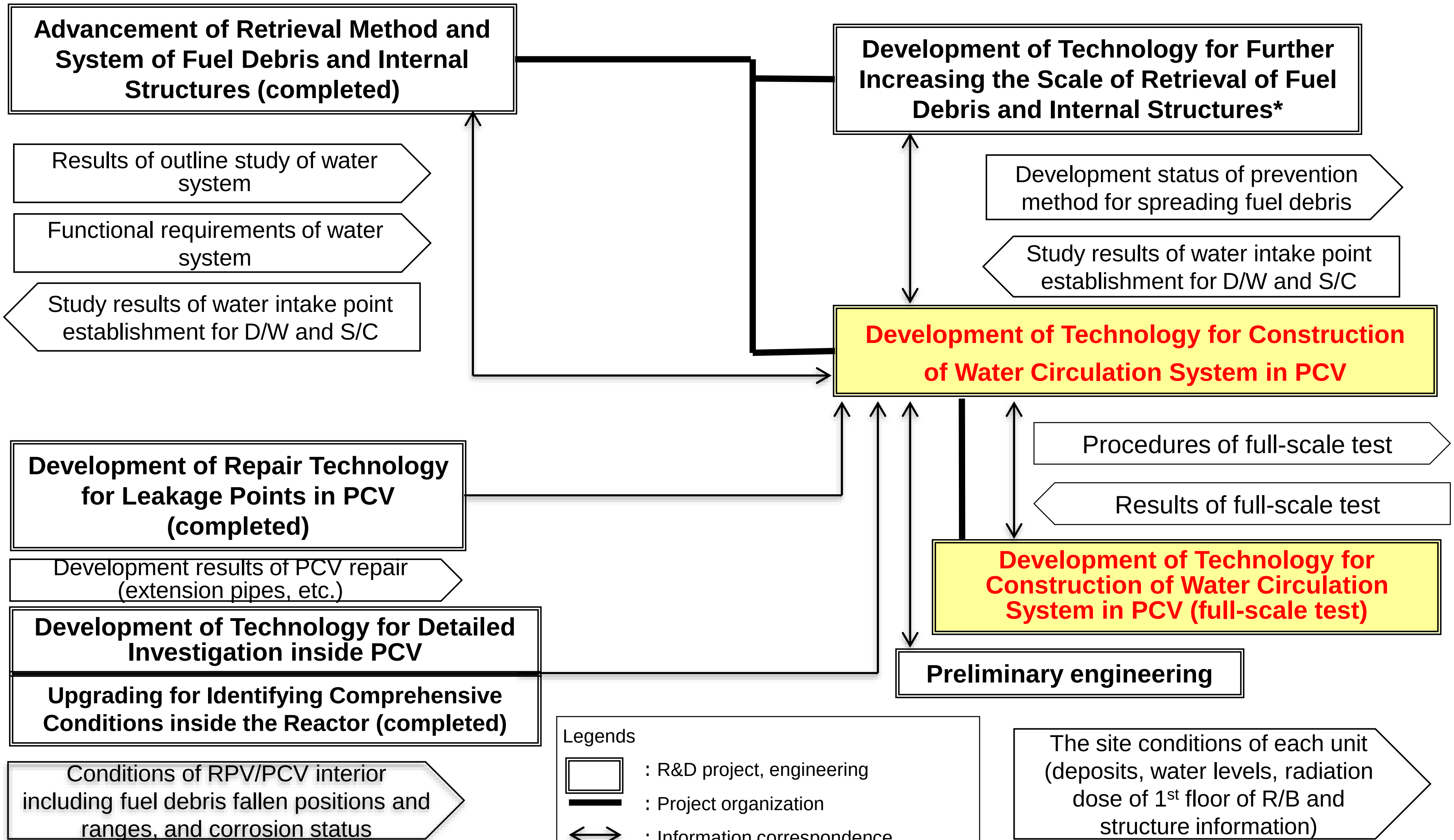
[HP3] ・Validity of the required specifications and functions
・Necessity of development
・Validity of the development plan

[HP4] ・Level of achievement with respect to the requirement specifications and functions, determined during the element tests
・ Validity of full-scale test plans

Legend
(solid box): Applicable to the Water Circulation Technology Development Project, Water Circulation Full-scale Test Project
(dashed box): Not applicable to the Water Circulation Technology Development Project, Water Circulation Full-scale Test Project

3. Implementation items, their correlations, and relations with other research

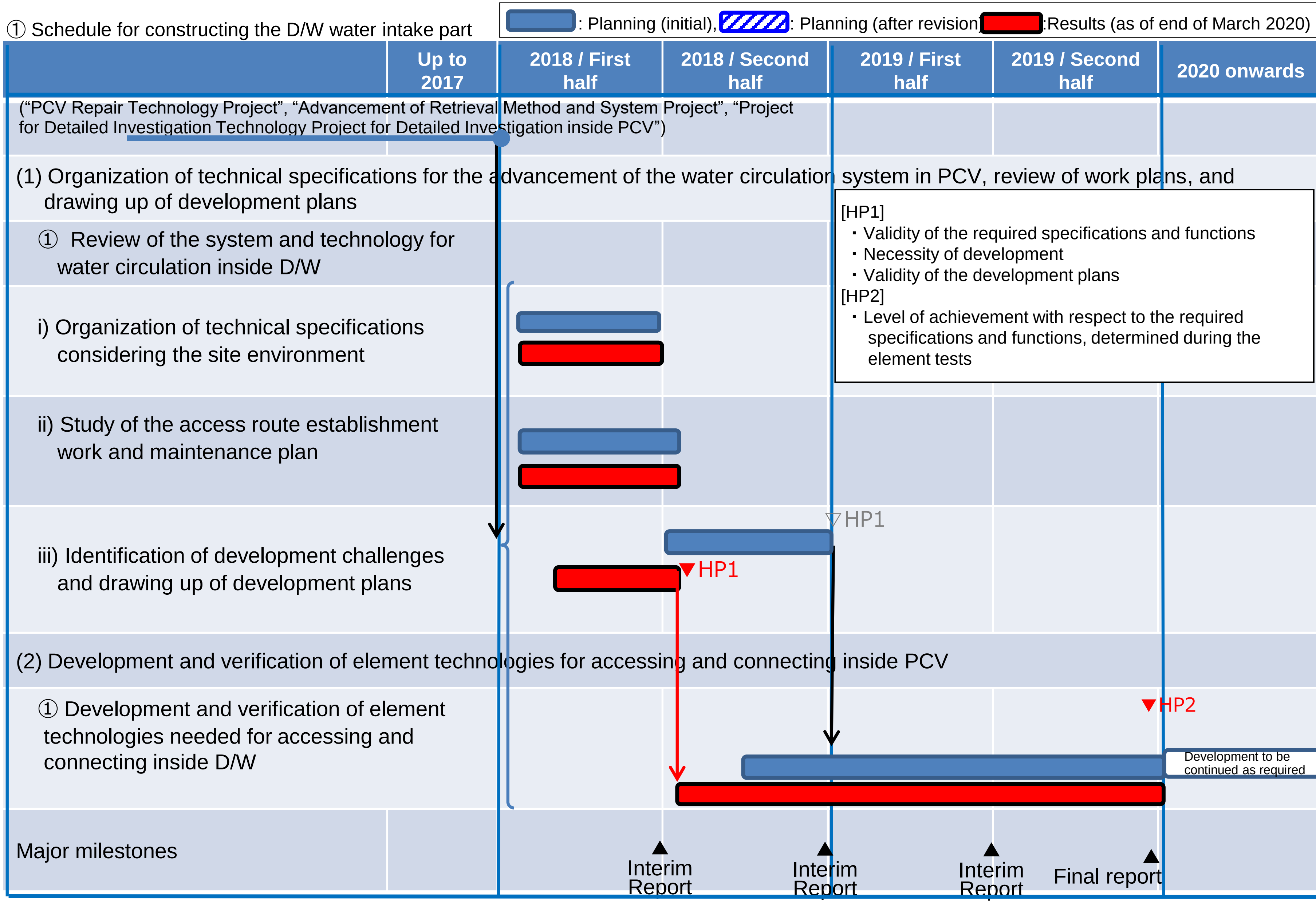
3.2 Relations with other research



*This project was named as *Development of Technology for Retrieval of Fuel Debris and Internal Structures,* when the project started. According to the development plan of decommissioning research in FY 2020 disclosed at the 75th Secretariat Team Meeting for Countermeasures for Decommissioning and Contaminated Water Treatment, the project name was changed to *Development of Technology for Further Increasing the Scale of Retrieval of Fuel Debris and Internal Structures*.

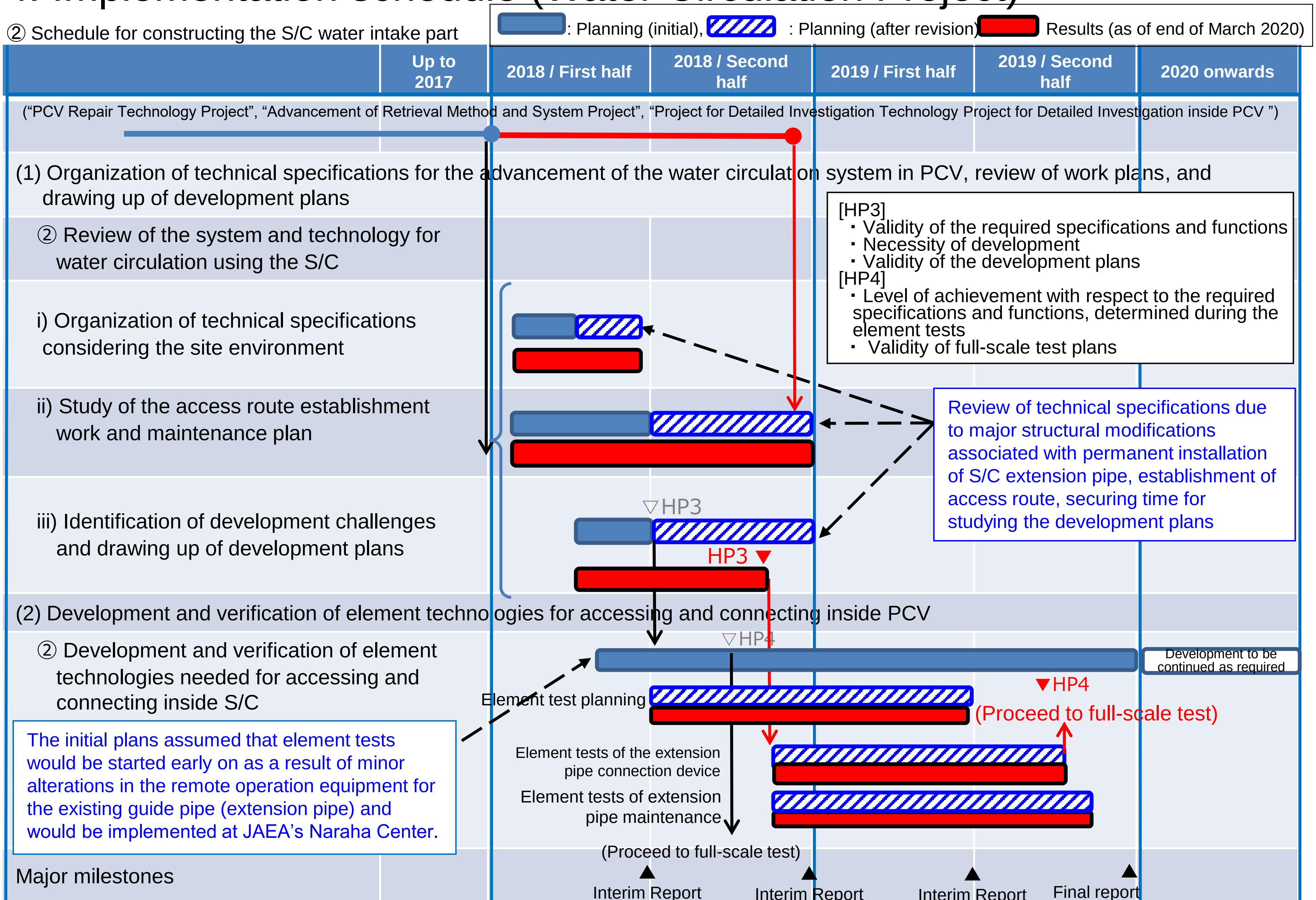
4. Implementation schedule (Water Circulation Project)

① Schedule for constructing the D/W water intake part



4. Implementation schedule (Water Circulation Project)

② Schedule for constructing the S/C water intake part



5. Project organization chart (Water Circulation Project)

International Research Institute for Nuclear Decommissioning (IRID): Headquarter

○ Overall project planning and coordination of overall technology
○ Coordination of technology management including technological development
○ Management of research and development

Tokyo Electric Power Company Holdings, Inc. : Research partner

Toshiba Energy Systems & Solutions Corporation

(1) Examining of technical specifications for upgrading of water circulation systems in PCV, study of work plan and development planning
(2) Development and verification of element technology for accessing and connecting inside PCV
・Development and verification of element technology for accessing and connecting inside S/C

Hitachi-GE Nuclear Energy, Ltd.

(1) Examining of technical specifications for upgrading of water circulation systems in PCV, study of work plan and development planning
(2) Development and verification of element technology for accessing and connecting inside PCV
・Development and verification of element technology for accessing and connecting inside S/C

IHI Corporation
○ Element test for accessing and connecting inside S/C

Toko Corporation (Chugai Technos Corporation)
○ Element test for assessing and connecting inside D/W

Hitachi Power Solutions Co., Ltd.
○ Design support of accessing and connecting inside PCV

6. Implementation details

(1) Examining of technical specifications for upgrading of water circulation systems in PCV, study of work plan and development planning

① Study of the water circulation system and technology for inside D/W

i) Organizing technical specifications considering the site environment

ii) Study of access route establishment work and maintenance plan

iii) Identification of development challenges and preparation of development plan

② Study of the water circulation system and technology by using S/C

i) Organizing technical specifications considering the site environment

ii) Study of access route establishment work and maintenance

iii) Identification of development challenges and preparation of development plan

(2) Development and verification of element technology for accessing and connecting inside PCV

① Development and verification of element technology required for accessing and connecting inside D/W

②Development and verification of element technology required for accessing and connecting inside S/C

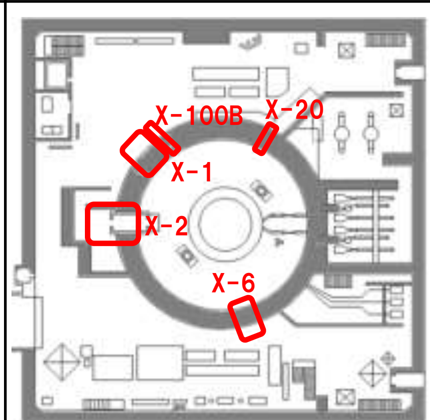
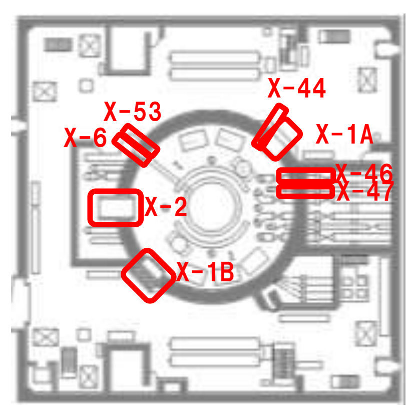
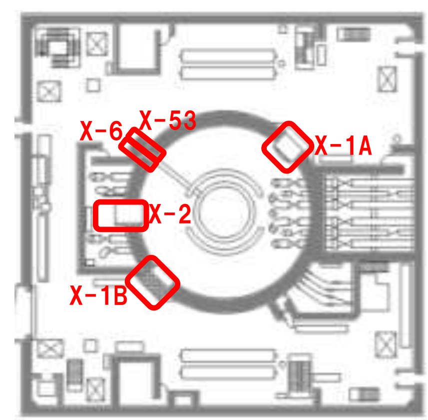
(1)①i)-1 Results of organizing technical specifications related to establishment of access route for D/W water intake

- The technical specifications related to establishment of access route for D/W water intake in this project were organized as shown in the following table, based on the results of clarifying site conditions.

No.	Items	Technical specifications	Remarks
1	Access route into PCV	Assuming that existing through holes will be used, new through holes shall not be made. The access routes for large scale retrieval and existing through holes shall be used.	
2	Environmental radiation rate	[R/B 1st floor] 10mSv/h	
3	Water level inside D/W	Shall be lower than the 1st floor grating	
4	Sediment deposits in D/W	Shall be considered. However, removal work shall be outside of the scope of technological development. <u>The technical configuration shall be such that the water intake point inside D/W can be changed depending on the status of removal of sediment deposits.</u>	
5	Interference objects inside D/W	Shall be considered as removed.	Assuming that the remote operated equipment has been installed inside D/W and interference objects have been removed.
6	Water intake position inside D/W	Water intake shall be at the pump pit. [Reason] The effective and reasonable D/W water intake point shall change depending on the actual conditions (sediment deposits, interference objects, work environment outside PCV, etc.) Moreover, it is assumed that there would be changes in stages, during the activities for fuel debris retrieval. Due to these reasons, at this point in time the position cannot be specified. Hence in this project, specific technology shall be developed assuming that the pump pit would be the water intake position, as it is at a distance from the access opening, and is believed to be the most difficult position in terms of establishment, since pipes would have to be laid inside the PCV by means of the remote operated equipment, so that if another location is to be used as the water intake position, this technology can be applied there as well.	
7	Number of systems (maximum)	Normal: 2, Emergency: 2 (can be portable as well)	
8	Water intake pipe (hose) diameter (maximum)	[When pump is installed inside PCV] 50A [When pump is installed outside PCV] 100A	
9	Pump external dimensions / weight	[When installed inside PCV] Φ0.28m×0.75mH / weight 80kg/unit (submersible pump) [When installed outside PCV] 1.5mL×0.6mL×0.5mH, 500kg/unit (vacuum pump)	The pump size shall be revised as required considering workability.

(1)①i)-2 Identification of candidate access openings for D/W water intake from among the existing penetrations, and comparative study pertaining to feasibility

- From among the penetrations made on the R/B 1st floor in each unit, a comparative study was conducted targeting the penetrations that opened up the inside of PCV.
- As a result of considering the workability at the penetration site (height at which the penetration is made, its internal diameter, dose rate in the surrounding space), penetrations that would be highly effective as water intake, and that have a higher possibility of being used as water intake for D/W in each unit are listed in the table below.
- From among the various types of penetrations, X-1(1A/1B), X-2 and X-6 that were identified in common between the units were taken up as representative penetrations, and the access routes for D/W water intake were specifically studied in (1)①ii).

Penetration types	1F-1	1F-2	1F-3
Hatch (with shield plug)	X-1	X-1A, 1B	X-1A, 1B
Hatch (double door)	X-2	X-2	X-2
Pipe, back-up	X-6	X-6	X-6
	X-20	X-44	X-53
	X-100B	X-46.47	
		X-53	
Layout of candidate penetrations for water intake			

(1)① ii)-1 Study on the method of establishing access route for the D/W water intake (1/2)

- It is efficient to use existing penetrations as the access route for the D/W water intake, and hence prospective penetrations were identified as candidates in (1)①i).
- With respect to the technology for constructing the access routes using existing penetrations, since this method has been implemented in other projects, as also related technologies are currently being studied or are undergoing element tests, the applicability of existing technologies to the candidate penetrations was studied and the necessity of developing the technology for constructing the access routes was put into perspective.
- Examples of existing technologies (including those that are currently under development as part of various projects) that would be useful in constructing the access route for the D/W water intake are as follows:

  a. [New extension pipe establishment technology] 1F-1: Technology for connecting the extension pipe for X-2 penetration "Project for Detailed Investigation Technology inside PCV"
  b. [Shield opening technology] 1F-2/3: BSW opening and sealing technology "Upgrading of Fundamental Technology Project"
  c. [Penetration remote connection technology] 1F -2/ 3: Technology for the connection with X-6 penetration "Project for Detailed Investigation Technology inside PCV"

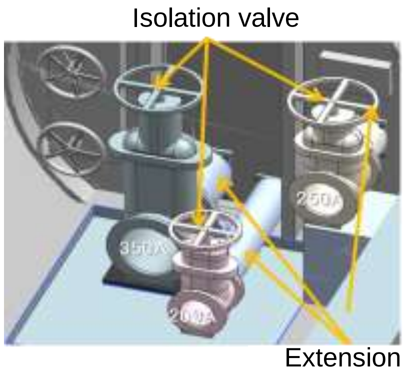


Figure. Technology for connecting the extension pipe for X-2 penetration

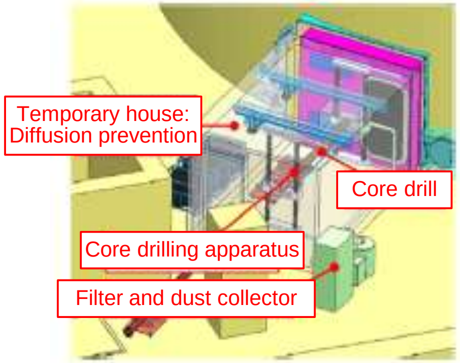


Figure. BSW opening and sealing technology

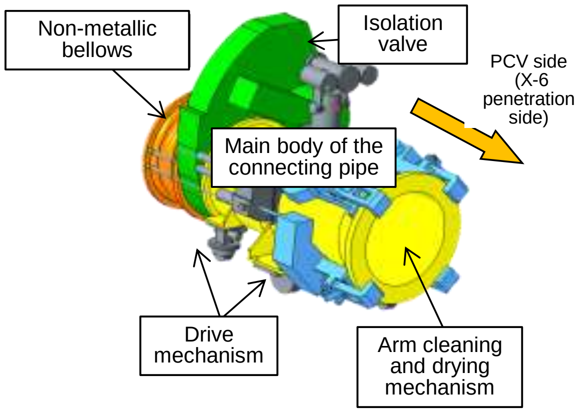


Figure. Technology for connection with X-6 penetration

Candidate penetrations		X-1	X-1A		X-1B		X-2			X-6		
Unit		1F-1	1F-2	1F-3	1F-2	1F-3	1F-1	1F-2	1F-3	1F-1	1F-2	1F-3
Applicability of existing technologies	(a) X-2 extension pipe connection	△	△	△	△	△	○	△	△	△	△	△
	(b) BSW opening	△	△	△	△	△	ー	△	△	ー	ー	ー
	(c) X-6 connection	ー	ー	ー	ー	ー	ー	ー	ー	△	△	△

[Legend] ○: Can be applied (without issues), △: Can be applied (with issues), ×: Cannot be applied, ー: Not applicable

✓ Applicability of existing access route establishment technologies:
Although there are aspects that need to be studied in detail with respect to application, it is anticipated that the existing technologies can be applied.

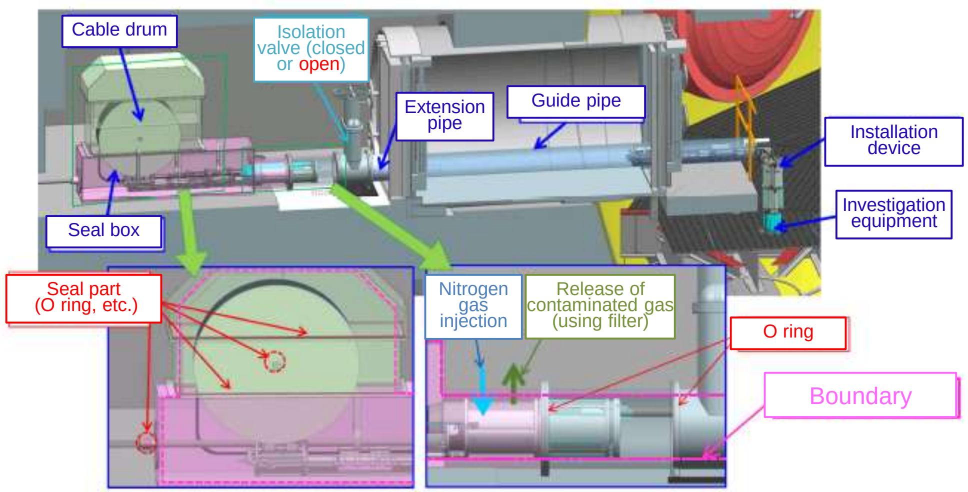
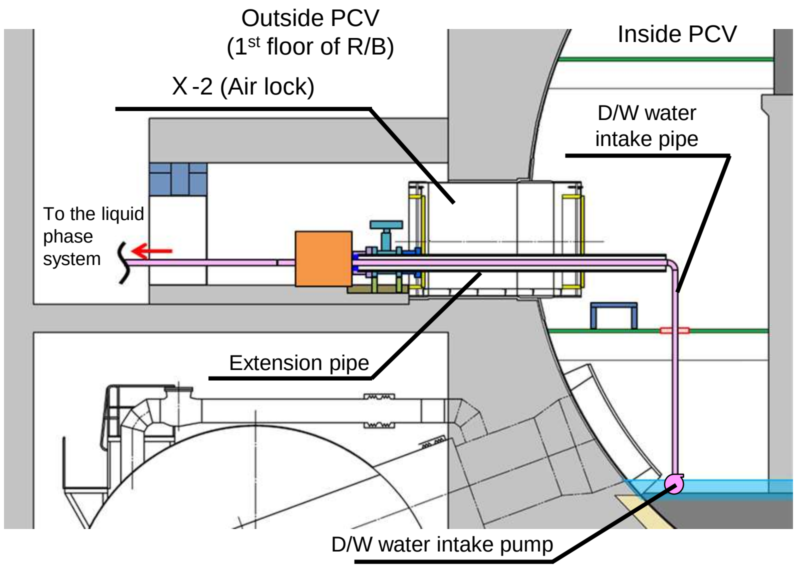


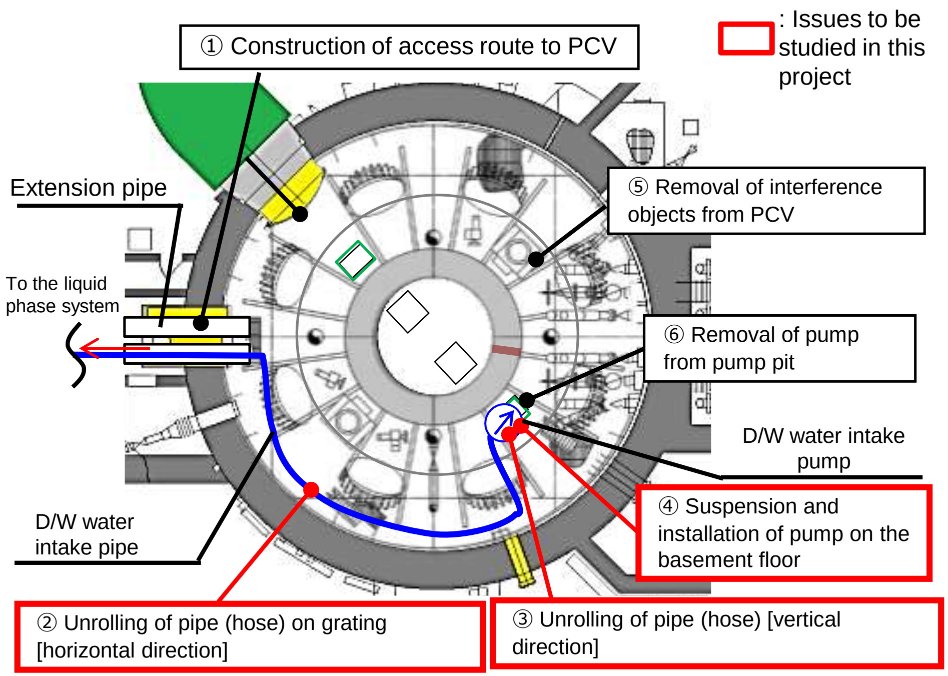
Figure. Example of access route establishment for the equipment for detailed investigation inside PCV*

*: (Source) Development of Technology for Detailed Investigation inside PCV PJ Study material

(1)① iii)-1 Identification and organization of challenges in developing the system and technology for water circulation inside D/W, and drawing up development plans

- Issues in developing the technology for constructing the water circulation system in D/W





[Examples of applicable existing technologies]

Issues	Examples of existing technologies
① Construction of access route to PCV	Technology for installing extension pipes (Project for Detailed Investigation inside PCV), technology for connecting the access tunnel (Advancement of Retrieval Method and System Project for 1F-1 X-2)
⑤ Removal of interference objects from PCV	Technology for removal of interference objects outside the pedestal (Upgrading of Fundamental Technology Project)
⑥ Removal of pump from pump pit	

Studies will be conducted to resolve the issues of unrolling (horizontal or vertical direction) the pipe (hose) inside the PCV and suspension and installation of pump on the basement floor.

6. Implementation details

(1) Examining of technical specifications for upgrading of water circulation systems in PCV, study of work plan and development planning

① Study of the water circulation system and technology for inside D/W

i) Organizing technical specifications considering the site environment

ii) Study of access route establishment work and maintenance plan

iii) Identification of development challenges and preparation of development plan

② Study of the water circulation system and technology by using S/C

i) Organizing technical specifications considering the site environment

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iii) Identification of development challenges and preparation of development plan

(2) Development and verification of element technology for accessing and connecting inside PCV

① Development and verification of element technology required for accessing and connecting inside D/W

②Development and verification of element technology required for accessing and connecting inside S/C

(1) Organization of technical specifications for the advancement of the water circulation system in PCV

[Purpose]
To draw up the technology development plan for the establishment of a water intake opening in the S/C.

[Issues]
i) Organization of technical specifications considering the site environment
ii) Study of the access route establishment work and maintenance plan
iii) Identification of development challenges and drawing up of development plans

[Overview of results] i) Organization of technical specifications considering the site environment

■ Safety and system functional requirements and goals of this project (planned) with respect to each defense-in-depth level of the gas phase boundary during fuel debris retrieval

Protection level	FP barrier against gas phase leakage	
	System functional requirements*1	Goals of this project (S/C water intake part)
1	Openings aligned with the existing damage points and other new connection parts should satisfy the study conditions for the system (Amount of in-leak when securing the required differential pressure: 1000 m^3/h or less).	Slight increase in the primary boundary opening area: (1 mm^2)*2 or less
2	Same condition as level 1	Increase in the primary boundary opening area: (2 cm^2)*3 or less
3	Level 3 includes a policy of confinement at the secondary boundary and there is no direct requirement regarding the primary boundary	-

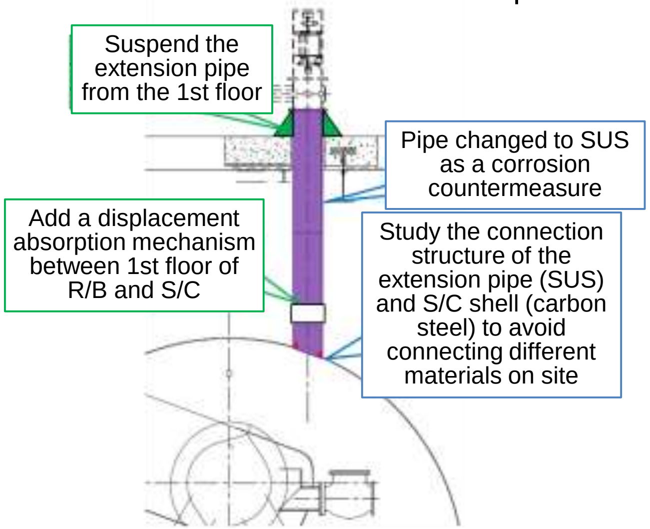
*1: Incorporating the progress of the Advancement of Retrieval Method and System Project
*2: Assuming that the current 1F-2 gas phase opening area (1 cm^2) is an increase in the number of openings for the entire system, the S/C intake is set to 1% of the total amount.
*3: Assuming that the rupture (2 cm^2) of a small diameter pipe (15A) is an increase in the number of openings for the entire system, the S/C water intake is considered to be the same as the total amount.
(Presuming that a single event occurred at the water intake opening)

■ Conformance to the functional requirements of the gas phase boundary with respect to the extension pipe for the S/C water intake opening

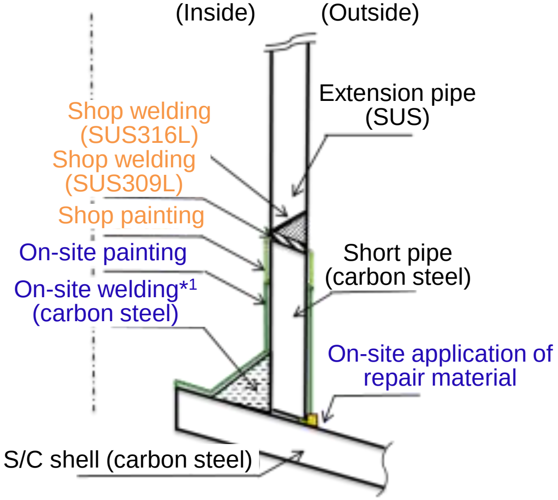
Protection level		Monitoring	Prevention	Mitigation
1	System functional requirements	-	① Should have sufficient strength against the load acting on the S/C water intake opening ② Should be able to control corrosion of the structural members ③ Should be able to confirm the absence of abnormality by VT and absence of leakage by leakage test from the inside of the water intake structure at the time of completion of work, and should be able to confirm the absence of abnormality by VT from the inside of the water intake structure during the maintenance of the water circulation system.	-
	Policy of conformance with requirements	-	①-1 A displacement absorption mechanism should be added between 1st floor of R/B and S/C and the extension pipe should be suspended from the 1st floor to control the excessive stress at the joints with the S/C shell. ①-2 The necessary throat thickness should be ensured in consideration of the joint efficiency of the weld. ②-1 Openings due to corrosion should be prevented by securing a corrosion allowance during work. ②-2 The progress of corrosion should be controlled by using an anti-corrosion coating. ②-3 The coating should be repaired when necessary to control corrosion in accordance with VT results during the maintenance of the water circulation system. ③ The absence of abnormality should be confirmed by VT and absence of leakage should be confirmed by leakage test from the inside of the water intake structure at the time of completion of work, and the absence of abnormality should be confirmed by VT from the inside of the water intake structure during the maintenance of the water circulation system.	-
2	System functional requirements	It should be possible to detect the presence of leakage from the S/C water intake opening when an increase in leakage is detected in the negative pressure management system.	It should be possible to prevent non-ductile fracture of boundary components.	It should be possible to stop or control leakage.
	Policy of conformance with requirements	The presence of leakage should be confirmed by leakage or other tests when an increase in openings is detected through the monitoring of the exhaust flow rate of the PCV internal pressure / negative pressure management system.	Non-ductile fracture should be prevented by using ductile material.	Leakage should be stopped or controlled by applying repair material to the leakage points.

(Supplement) ○ Level 3 includes a policy of confinement at the secondary boundary and there is no functional requirement for the extension pipe at the primary boundary.
○ The following response measures are assumed after restoration from an abnormality:
・Remove the water intake apparatus from the S/C water intake opening, and stop or control the leakage by closing the S/C opening.
・During the period when the leakage is stopped or controlled by closing the S/C opening, repair the leakage points or close the S/C water intake opening.

■ Structure of the S/C water intake part



Structure adopted in this project



Welding of carbon steel pipes

■ Development goals for the S/C water intake part

① Welding of S/C joints

- Weld S/C joints with joint efficiency equivalent to 0.35

Mutatis mutandis application of the specified joint efficiency of 0.35 * for core support structures

*: JSME Rules on Design and Construction CSS-3150: Only visual testing
Joint efficiency of one-side fillet weld

- Weld quality should not vary due to the following, and a stable weld quality must be ensured:
  - ✓ Establishment of appropriate welding conditions (torch angle, torch rotation speed, etc.)
  - ✓ Establishment of welding procedures (addition of clockwise rotation of torch, etc.)
  - ✓ Gap tolerance settings
  - ✓ Automatic welding by controlling the program for appropriate trajectory and torch aiming position according to the measured gap
  - ✓ Development of indicated value and actual value records for weld parameters

② Inspection during work

- VT: Use the camera to ensure that there are no harmful incidents such as cracks or undercuts, overlaps, craters, slag inclusion, blowholes, etc. (Mutatis mutandis application of CSS-4222(2) specifications)
- DT: Prescribed throat thickness and leg length are satisfied
- Leakage test: Confirm the absence of leakage through the air pressure test on the extension pipe (inside).

③ Maintenance inspection and repairs (Supposed to be conducted once in 10 years)

- VT: There is no abnormal onset of rusting in the extension pipe (inside and outside).
- Repair coating: In accordance with the results of VT, repair the coating through remote operations.

④ Level 2 inspection and repairs

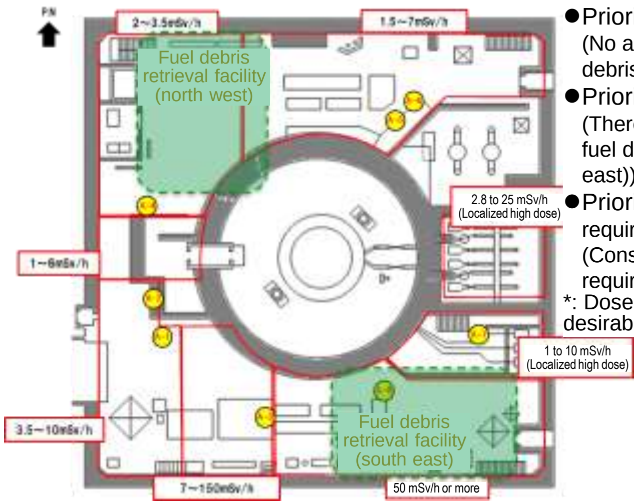
<Inspection>

- VT: There is no abnormality in the extension pipe (inside and outside).
- Leakage test (air pressurization): Temporarily close the extension pipe (inside) and make sure that there is no leakage due to air pressurization.
- Leakage verification (foaming test): Utilize the negative pressure within the PCV and make sure that there is no leakage from the extension pipe (inner surface) by means of a foaming test.
- Leakage test (tracer gas): Utilize the negative pressure within the PCV, and make sure that there is no leakage in the S/C connection parts based on the tracer gas from the extension pipe (outer surface).

<Repair>

- Repair of leakage points: Remotely repair leakage points by applying a coating agent from the extension pipe (inside and outside).
  (For repairs from the inside, the inside of the extension pipe needs to be airtight as the flow of air inward to the repair point at PCV negative pressure is stopped by temporary closing the pipe.)
- VT: The state of the repair points can be verified.

■ Layout plan for S/C water intake part (Study results for S/C water intake part layout: Example of Unit 1)

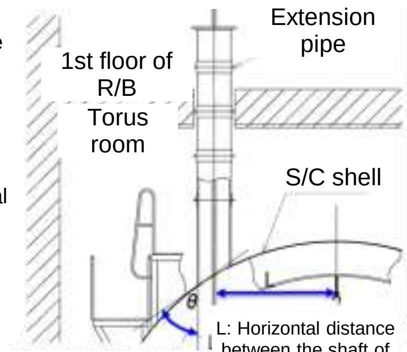


- ●Priority A (No area interference with fuel debris retrieval facility)
- ●Priority B (There is area interference with fuel debris retrieval facility (south east))
- ●Priority C (high level of technical requirements) (Construction of new access route required)

*: Dose reduction measures are desirable or indispensable.

[Study results]

- In Units 1 to 3, 8 or more S/C water intake openings can be placed at 66° or more of θ in the figure.
  ⇒ Develop welding apparatus with the said angle θ set to 66° or more.
- The interference objects in the torus room need to be removed remotely.
  ⇒ Conduct a conceptual study on the procedure of removal of the typical interference objects in the torus room (pipes, cable trays, air conditioning ducts, and handrails) using the PCV bottom part repair apparatus (FRM).
- The study on the removal of interference objects from 1st floor of R/B will be considered as future engineering scope as necessary, and will be out of scope of this project.
- The impact of interferences of the structures inside S/C (vent pipes, vent headers, and downcomers) and the water intake apparatus needs to be verified, but the extent of impact is expected to be small due to the flexible hose.
- High dose areas are included in the selected points, and hence dose reduction measures are essential.



θ: Angle between the extension pipe axial direction and the tangent to the S/C shell meridional direction at the lowermost position of the extension pipe

L: Horizontal distance between the shaft of the extension pipe and the center of S/C (The position where θ is 66° or more, is at 1330 mm or less in Unit 1, and 1500 mm or less in Units 2 and 3)

ii) Study of the access route establishment work and maintenance plan

■ Procedure for establishment of S/C water intake part

STEP1 Removal of interference objects from torus room as preliminary work
- **Removal of interference objects from torus room**
- **Installation of base plate**
- **Carrying in and fixing of installation cart**

→

STEP2 Pre-treatment of S/C surface
- **Peeling off the coating**
- **Grinding extra banking of welds**
- **Surface marking**

→

STEP3 Fabrication and inspection of extension pipe
- **Measurement of S/C surface**
- **Creation of a 3D model and creation of groove drawings**
- **Processing of extension pipe grooves**
- **Fabrication of extension pipe [welding and inspection of lower, middle, and upper parts]**

→

STEP4 Positioning of extension pipe and S/C surface
- **Polishing of S/C surface**
- **Installation of the positioning apparatus**
- **Finding the amount of deviation of the extension pipe**
- **Positioning**
- **Measurement of weld gaps**

→

STEP5 Welding of extension pipe and S/C surface
- **Welding**
- **Weld cleaning [polishing and suction], weld inspection [VT]**
- **Weld treatment [grinder]**
- **Weld inspection [DT (throat thickness)]**

→

STEP6 From support to pressure resistance of extension pipe
- **Supporting extension pipe**
- **Unfixing of bellows**
- **Installation of isolation mechanism**
- **Weld pressure resistance and leakage test**

→

STEP7 Inner surface coating of welds
- **Pre-treatment for coating**
- **Coating of welds**

→

STEP8 Holing of S/C surface
- **Holing by means of WJ**

→

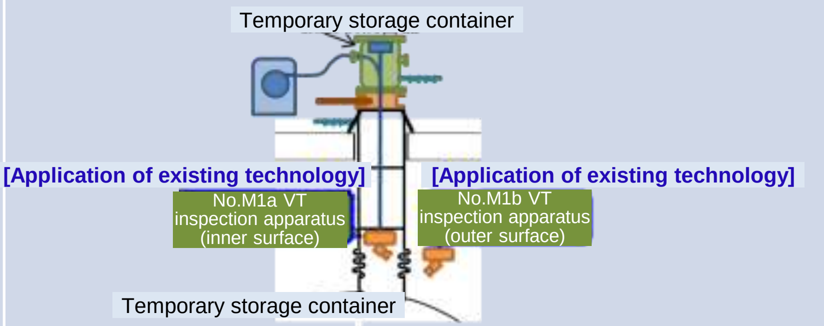
STEP9 Outer surface treatment of welds
- **Filling of gaps**
- **Pre-treatment for coating**
- **Coating**

■ Procedure for maintenance of S/C water intake part

	Inspection	Repair
During maintenance	[Procedure 1] VT of extension pipe and S/C joint (inner and outer surface of extension pipe)	[Procedure 1] Coating pre-treatment at coating degradation points (inner and outer surface of extension pipe); [Procedure 2] Coating repair at coating degradation points (inner and outer surface of extension pipe)
Level 2	(Inside the extension pipe) [Procedure 1] VT of extension pipe and S/C joint; [Procedure 2] Identification of leakage points by means of a leakage test (air pressurization) *; [Procedure 3] Identification of leakage points by means of a leakage test (State of negative pressure in PCV). (Outside the extension pipe) [Procedure 1] VT of extension pipe and S/C joint; [Procedure 2] Identification of leakage points by means of a leakage test (State of negative pressure in PCV)	(Inside the extension pipe) [Procedure 1] Airtightness inside the extension pipe; [Procedure 2] Surface cleaning of leakage points; [Procedure 3] Repair of leakage points; [Procedure 4] Post-repair VT. (Outside the extension pipe) [Procedure 1] Surface cleaning of leakage points; [Procedure 2] Repair of leakage points; [Procedure 3] Post-repair VT

During maintenance – Inspection

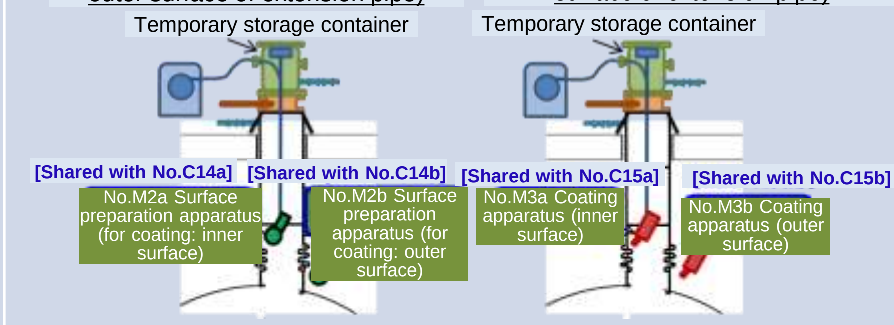
[Procedure 1] VT of extension pipe and S/C joint (inner and outer surface of extension pipe)



During maintenance – Repair

[Procedure 1] Coating pre-treatment at coating degradation points (inner and outer surface of extension pipe)

[Procedure 2] Coating repair at coating degradation points (inner and outer surface of extension pipe)



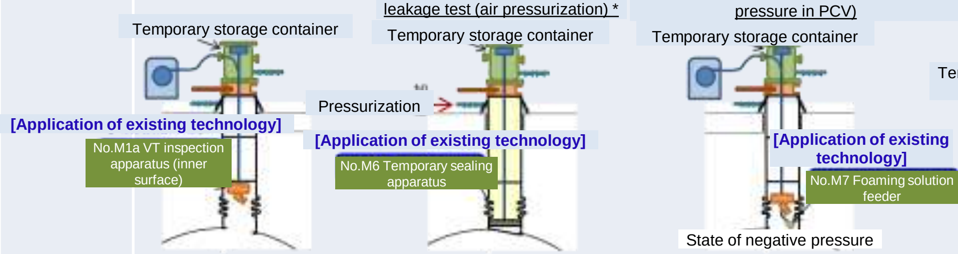
Level 2 – Inspection

(Inside the extension pipe)

[Procedure 1] VT of extension pipe and S/C joint

[Procedure 2] Identification of leakage points by means of a leakage test (air pressurization) *

[Procedure 3] Identification of leakage points by means of a leakage test (State of negative pressure in PCV)

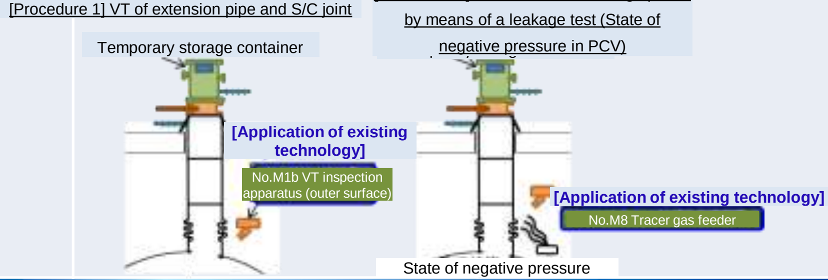


*: Close the lower end of the extension pipe with a temporary sealing apparatus, and perform a local leakage test of the S/C water intake part (including the temporary storage container). If leakage is found, move the apparatus step by step and narrow down the pressurization range to identify the leakage location.

(Outside the extension pipe)

[Procedure 1] VT of extension pipe and S/C joint

[Procedure 2] Identification of leakage points by means of a leakage test (State of negative pressure in PCV)



Level 2 – Repair

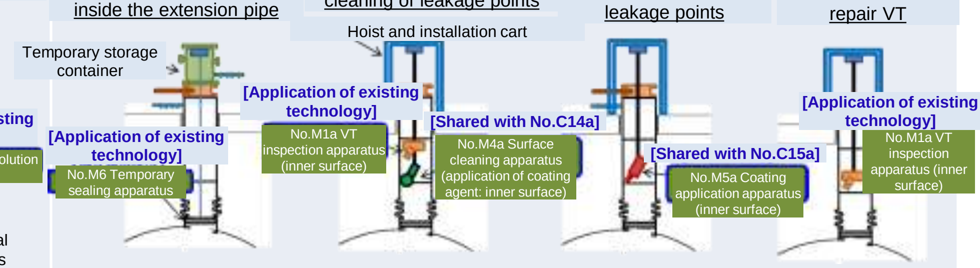
(Inside the extension pipe)

[Procedure 1] Airtightness inside the extension pipe

[Procedure 2] Surface cleaning of leakage points

[Procedure 3] Repair of leakage points

[Procedure 4] Post-repair VT

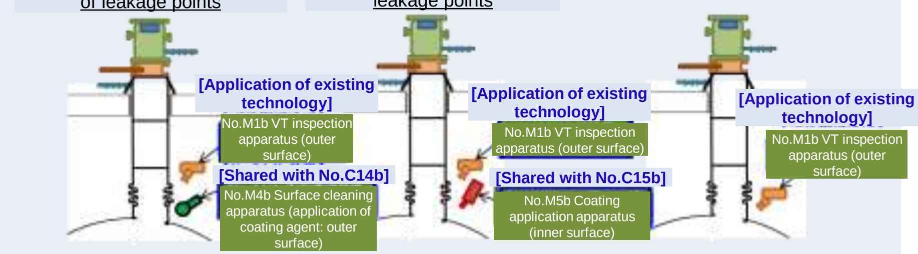


(Outside the extension pipe)

[Procedure 1] Surface cleaning of leakage points

[Procedure 2] Repair of leakage points

[Procedure 3] Post-repair VT



iii) Identification of development challenges and drawing up of development plans

[red box]: Test targets in this project

<Apparatus used for establishment of S/C water intake part>

No.	Apparatus	Applicability of existing technology	Policy of response in this project
C1	Interference removal apparatus (FRM)	2	▲
C2	S/C surface treatment apparatus (peeling off of the coating)	2	▲
C3	Extra banking removal apparatus (S/C joints)	No.C10b can be applied	▲
C4	Marking apparatus	2	▲
C5	Shape measuring scanner	3	-
C6	Extension pipe joint welding apparatus	2	▲
C7	Weld bead treatment apparatus (for welding extension pipe joints)	No.C10b can be applied	▲
C8	Positioning apparatus	1	O*
C9	Gap measuring apparatus (with DT function)	2	△
C10a	S/C surface polishing apparatus (floating rust removal) among the weld cleaning apparatus	No.C10b can be applied	▲
C10b	Bead treatment apparatus among the weld cleaning apparatus	1	O*
C10c	Pipe inner surface cleaning apparatus (suction) among the weld cleaning apparatus	3	▲
C11	S/C joint welding apparatus	1	O*
C12	Guide ring removal apparatus	0	▲ (Since a feasible outlook was obtained)
C13	Isolation mechanism	3	▲
C14a	Surface preparation apparatus (for coating: inner surface)	No.C10b Can be applied	▲
C14b	Surface preparation apparatus (for coating: outer surface)	2	▲
C15a	Coating apparatus (inner surface)	3	▲
C15b	Coating apparatus (outer surface)	2	▲
C16	Storage container	2	▲
C17	WJ holing apparatus	3	▲
C18	Other common apparatus	2	▲* (Fabrication of simple apparatus in the full-scale test project for combination)
C19	Surface cleaning apparatus (Application of coating material: outer surface)	Shared with No.C14b	▲
C20	Coating apparatus (outer surface)	Shared with No.C15b	▲

<Apparatus used for maintenance of S/C water intake part>

No.	Apparatus	Applicability of existing technology	Policy of response in this project
M1a	VT inspection apparatus (inner surface)	2	▲
M1b	VT inspection apparatus (outer surface)	2	▲
M2a	Surface preparation apparatus (for coating: inner surface)	Shared with No.C14a	▲
M2b	Surface preparation apparatus (for coating: outer surface)	Shared with No.C14b	▲
M3a	Coating apparatus (inner surface)	Shared with No.C15a	▲
M3b	Coating apparatus (outer surface)	Shared with No.C15b	▲
M4a	Surface cleaning apparatus (Application of coating material: inner surface)	Shared with No.C14a	▲
M4b	Surface cleaning apparatus (Application of coating material: outer surface)	Shared with No.C14b	▲
M5a	Coating apparatus (inner surface)	Shared with No.C15a	▲
M5b	Coating apparatus (outer surface)	Shared with No.C15b	▲
M6	Temporary sealing apparatus	2	△
M7	Foaming solution feeder	2	▲
M8	Tracer gas feeder	2	▲

(Legend)
Applicability of existing technology
3: Can be diverted 2: Can be applied 1: Difficult to apply or not applicable 0: Existing technology absent but can be designed
Policy of response in this project
O: Prototype unit function test, △: Element test, ▲: Only desk study, □: Design and manufacturing, - : Out of scope, ( ): Improvement, *: 1/1 scale combination test for verification of remote workability

[Summary of the review of the system and technology for water circulation using S/C]
- Examining of required functions for the S/C water intake part
- Examining of design specifications and requirements for the S/C water intake part
- Layout planning for S/C water intake part
- Formulation of work procedures for the establishment and maintenance of S/C water intake part
- Drawing up of technology development plan for the establishment and maintenance of S/C water intake part

6. Implementation details

(1) Examining of technical specifications for upgrading of water circulation systems in PCV, study of work plan and development planning

① Study of the water circulation system and technology for inside D/W

i) Organizing technical specifications considering the site environment

ii) Study of access route establishment work and maintenance plan

iii) Identification of development challenges and preparation of development plan

② Study of the water circulation system and technology by using S/C

i) Organizing technical specifications considering the site environment

ii) Study of access route establishment work and maintenance

iii) Identification of development challenges and preparation of development plan

(2) Development and verification of element technology for accessing and connecting inside PCV

① Development and verification of element technology required for accessing and connecting inside D/W

②Development and verification of element technology required for accessing and connecting inside S/C

(2)①-1 Overall work step plan up to the construction of the water circulation system inside D/W

- Study was conducted on the overall work steps during the development and verification of element technology required for accessing and connecting inside D/W.

Drop in D/W water level (only in 1F-3)
・Up to the level of 1st floor of R/B

↓

Construction of access route inside the PCV for large-scale retrieval

↓

Removal of interference objects inside the PCV

↓

Construction ① and operation of water circulation system
- Installation of vacuum pump outside PCV
- Insertion of hose inside PCV
- Installation of hose (on the deposits)

↓

Deposit removal

↓ Construction ② of water circulation system

Unrolling of pipe inside PCV

↓

Suspension and installation of submersible pump (in the pump pit)

↓

Switching of the water intake pump (to a pump in the pit)

↓

Operation of the water circulation system (Water level can be controlled at the bottom of D/W or lower)

Pre-conditions for D/W water intake

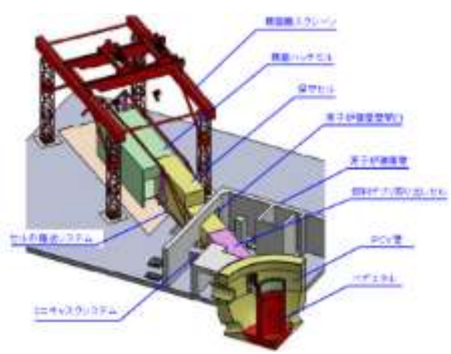
✓ For water intake through the pump pit, it is necessary to lay pipes in the PCV with remote apparatus.

✓ The access route for large-scale fuel debris retrieval should be used as the route for carrying the remote apparatus in and out.

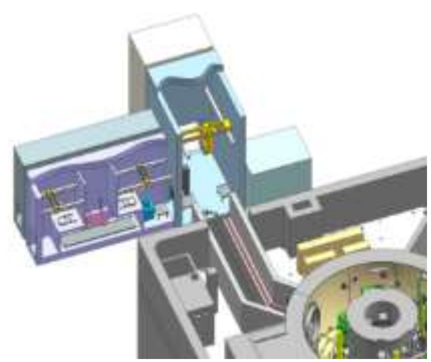
Example of access route inside PCV for large-scale retrieval

✓ Multiple ideas have been studied for the access route, and the confinement method for the access route is being considered.

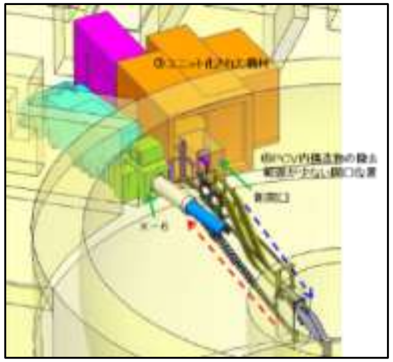
✓ The use of the said access route for large-scale fuel debris retrieval is planned to be used as the carrying-in/out route for the work inside the D/W. Note that this study presumes that apparatus such as the remote apparatus and pump are carried in by providing an opening to allow the remote apparatus to be carried in, such as by opening the X-1 penetration.



Access route in PLAN-A#



Access route in PLAN-B#



Access route in PLAN-C#

(Yellow box) : Scope of study in this project

#: For details on the access routes (PLAN-A, PLAN-B, and PLAN-C), see the reports on Subsidy Project of Decommissioning and Contaminated Water Management in the FY2014 Supplementary Budgets “Project for Advancement of Retrieval Method and System of Fuel Debris and Internal Structures” and Subsidy Project of Decommissioning and Contaminated Water Management in the FY2016 Supplementary Budgets “Advancement of Retrieval Method and System of Fuel Debris and Internal Structures”.

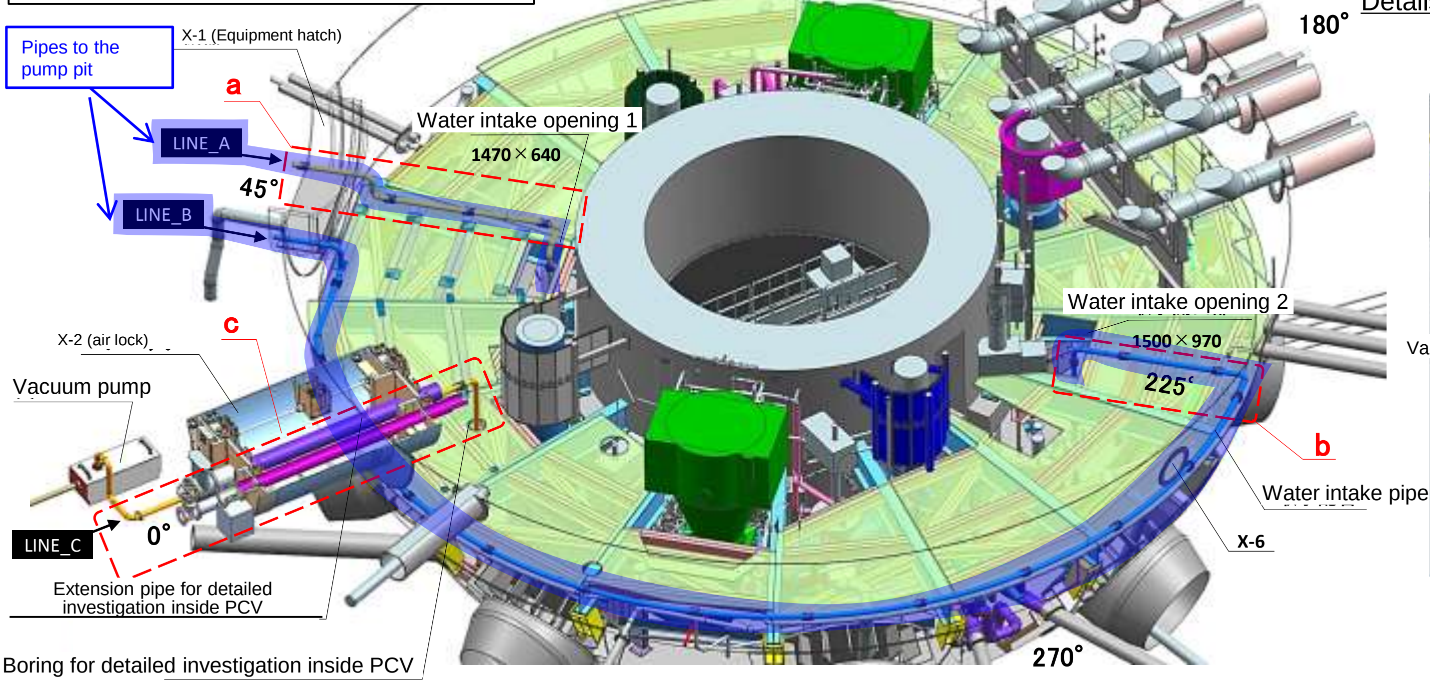
(2)①-2 Details of issues in laying pipes inside D/W

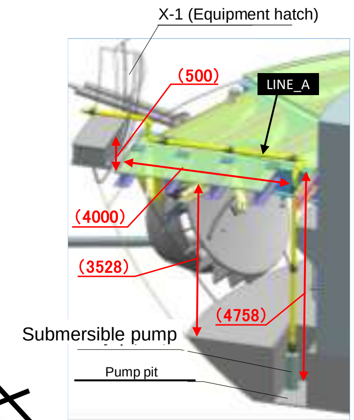
● Example of establishment of D/W water intake line in 1F-1

[Example of approach to D/W water intake line]

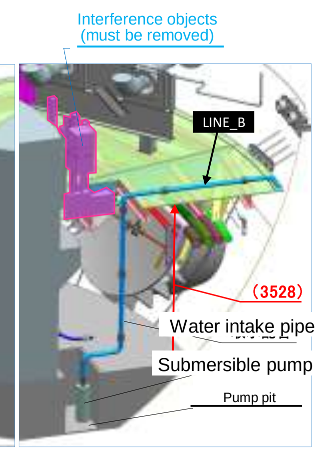
- Intake the water from the pump pit since the water level is controlled below the D/W bottom.
- Install the submersible pumps in the pump pit. (Considering the extent of freedom available to install the pump outside the PCV)
- Install the submersible pumps in different pump pits for the sake of multiplexing.
- Install a vacuum pump in front of X-2 in consideration of the failure of two submersible pumps. Install a hose at the bottom of D/W.

LINE_A: About 10 m (About 2 m x About 6 pipes)
LINE_B: About 35 m (About 2 m x About 20 pipes)
LINE_C: About 15 m (About 2 m x About 8 pipes)

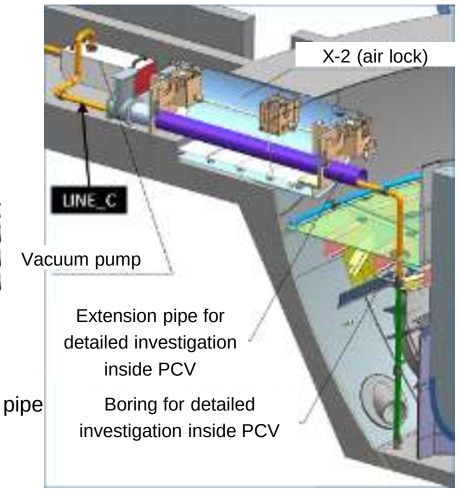




Details of part a



Details of part b



Details of part c

- ✓ Level 1 facility: Submersible pump x 2 (Water intake position: pump pit) / Via the access tunnel installed at X-1
- ✓ Level 2 facility: Vacuum pump (Water intake position: D/W bottom) / Via the extension pipe installed at X-2

(2)①-3 Results of detailed study of the method of laying pipes inside D/W and preliminary test results

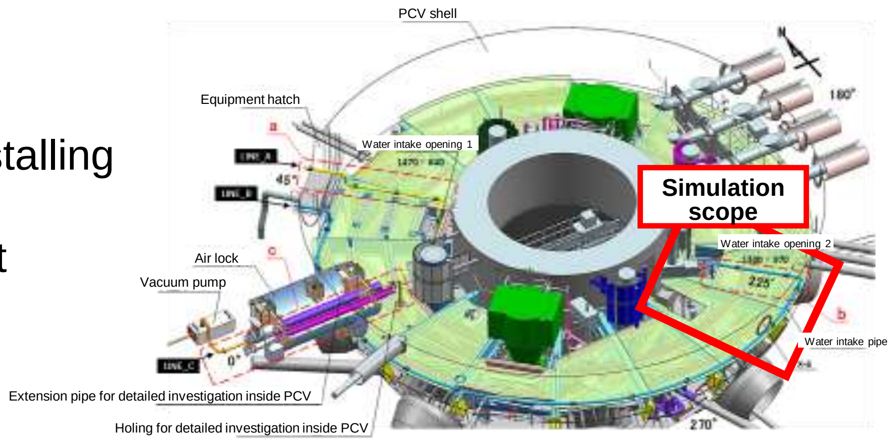
ID	Item	Issue details	Proposed solution (Results of detailed study)	Desk study	Preliminary test	Element test	Remarks
1	Pipe connection parts	The structure should allow connection using remote apparatus.	Use an auto-lock coupler for easy connection with the remote apparatus. (Not welded in consideration of replaceability)	O	O	-	Incorporated in ID.4
		Method of aligning the connecting pipes	Prepare apparatus (jig) that can remotely attach and detach the coupler.	O			
		Method of inspecting the connection parts	Visually verify leaks in pipe connection parts using a remote surveillance monitor.	O	O	-	
2	Pipe replacement	When partially replacing a pipe after the pipe is laid, it is necessary to absorb the displacement at the connection parts.	Use flexible metal hoses on the ground floor, and pressure-resistant rubber hoses made of radiation environment rubber on the basement floor.	O	O	-	
3	Pump suspension	Method of suspending a pipe-connected pump into the pump pit	A remote apparatus for connecting pipes and an auxiliary apparatus for suspension (mobile lifting machine) are combined to suspend the pump while supporting its own weight.	O	-	O	
4	Connection of pipes	In order to extend the pipes to the basement floor, it is necessary to connect the pipes while the pipes are suspended.	It is difficult to connect the pipes while they are being suspended, so suspend the pump and the pressure-resistant rubber hoses made of radiation environment rubber as a unit.	O	-	O	Incorporate ID.1 and 2
		Connection structure of pipes on the grating and pipes to the basement floor	Connect the pipes using a coupler.	O	-	O	
5	Pump installation	Method of fixing the pump inside the pump pit	A pump fixing container is set in the pit in advance, and the pump is installed on it. ⇒Upon conducting a detailed study, the pump was fixed with a fixing jig.	O	-	O	
6	Pump replacement procedure	Study of the procedure for replacing a pump installed inside the pump pit	Confirm an optimum replacement procedure through element test.	O	-	O	

Element tests conducted

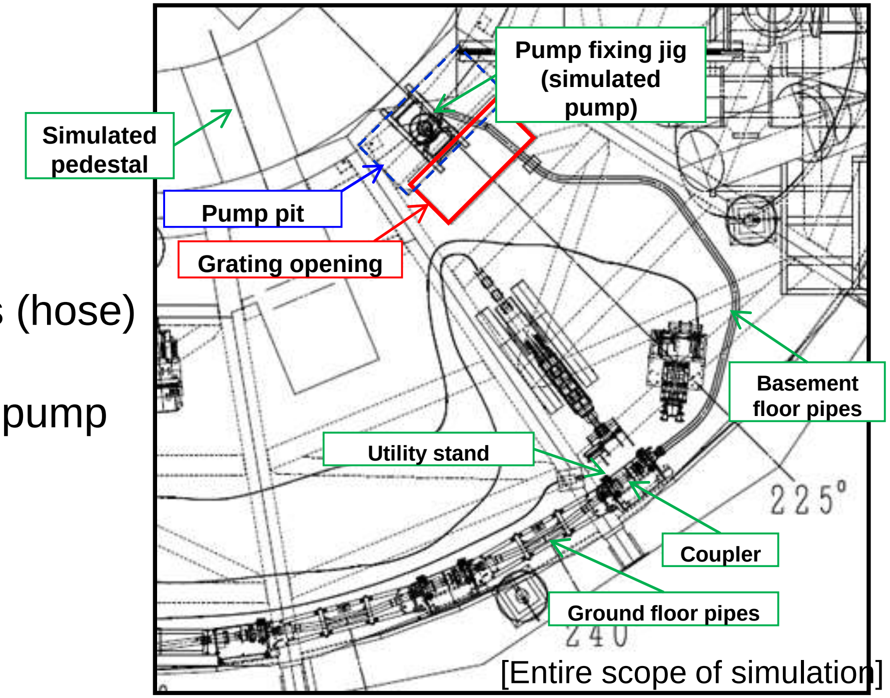
- Preliminary tests were conducted to verify the feasibility of the study results for the used pipes, structure of the connection parts, and the inspection method of the connection parts.
- The above study results were incorporated in the element test to verify the feasibility of the pipe and pump installation method inside the D/W by suspending the pump to the basement floor ⇒ connecting the pipes ⇒ installing the pump.
- After verifying the above, the feasibility of the pump replacement procedure was verified through element tests.

(2)①-4 Element test plan for the method of laying pipes inside D/W

- Purpose of the test
  - ✓ Verification of feasibility of the methods of installing pipes and pumps inside D/W
  - ✓ Verification of feasibility of pump replacement method
- Items to be verified
  - ✓ Pipe (hose) connection method
  - ✓ Pipe (hose) and pump suspension method
  - ✓ Pump fixing method
  - ✓ Pump replacement method
- Expected outcome
  - ✓ Feasibility of the method of connecting pipes (hose) remotely
  - ✓ Feasibility of the method of installing (fixing) pump inside D/W
  - ✓ Feasibility of pump replacement method and replacement procedure



Scope of simulation in element tests



[Entire scope of simulation]

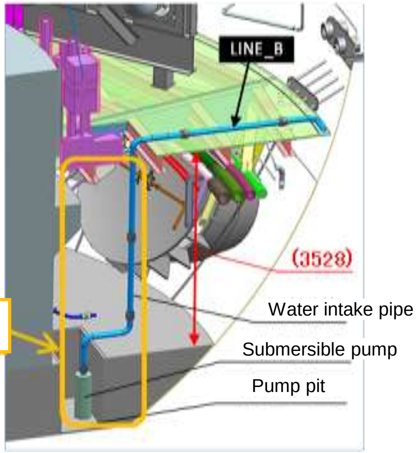
(2)①-4 Element test plan for the method of laying pipes inside D/W

(2) Element test items, test procedure, and criteria

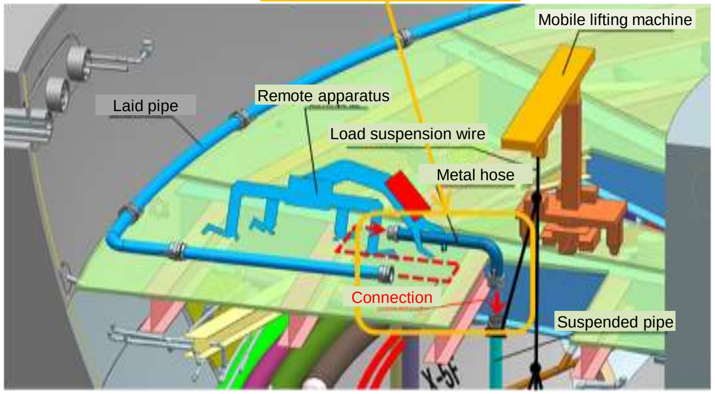
ID	Test items	Test procedure	Criteria	Remarks
1	Pump suspension and installation (fixed)	(1) Use a transport apparatus (gantry lifting machine, etc.) to suspend a simulated pump with a connected pipe (hose) into the pump pit. (2) Fix the simulated pump inside the pump pit using the pump fixing jig. (3) Confirm that the simulated pump is fixed.	・A pump with pipes connected can be suspended into the pump pit and can be installed (fixed). ・The pump installation status can be verified and monitored with a camera.	
2	Connection of pipes	Use a mobile, flexible structured work arm to connect the pipes (hose) on the grating and pipes (hose) connected to the simulated pump.	・The pipes on the grating and the pipes on the basement floor can be connected. ・After connection, a flow rate of 10 m^3/h is satisfied. (Note)	
3	Pump replacement procedure (recovery of pump)	(1) Use a mobile, flexible structured work arm to separate the pipes (hose) on the grating and the pipes (hose) connected to the pump. (2) Use a transport apparatus (gantry lifting machine, etc.) to lift and recover the simulated pump.	The pump installed in the pump pit can be lifted and recovered.	

(Note) A simulated pump simulating the dimensions and mass was used for pump suspension, installation, and recovery.
To check the flow rate, the simulated pump was replaced with a pump satisfying 10 $m^3/h^{\#}$, and the flow rate was verified. # Flow rate based on the “system” side requirement.

①Pump suspension and installation



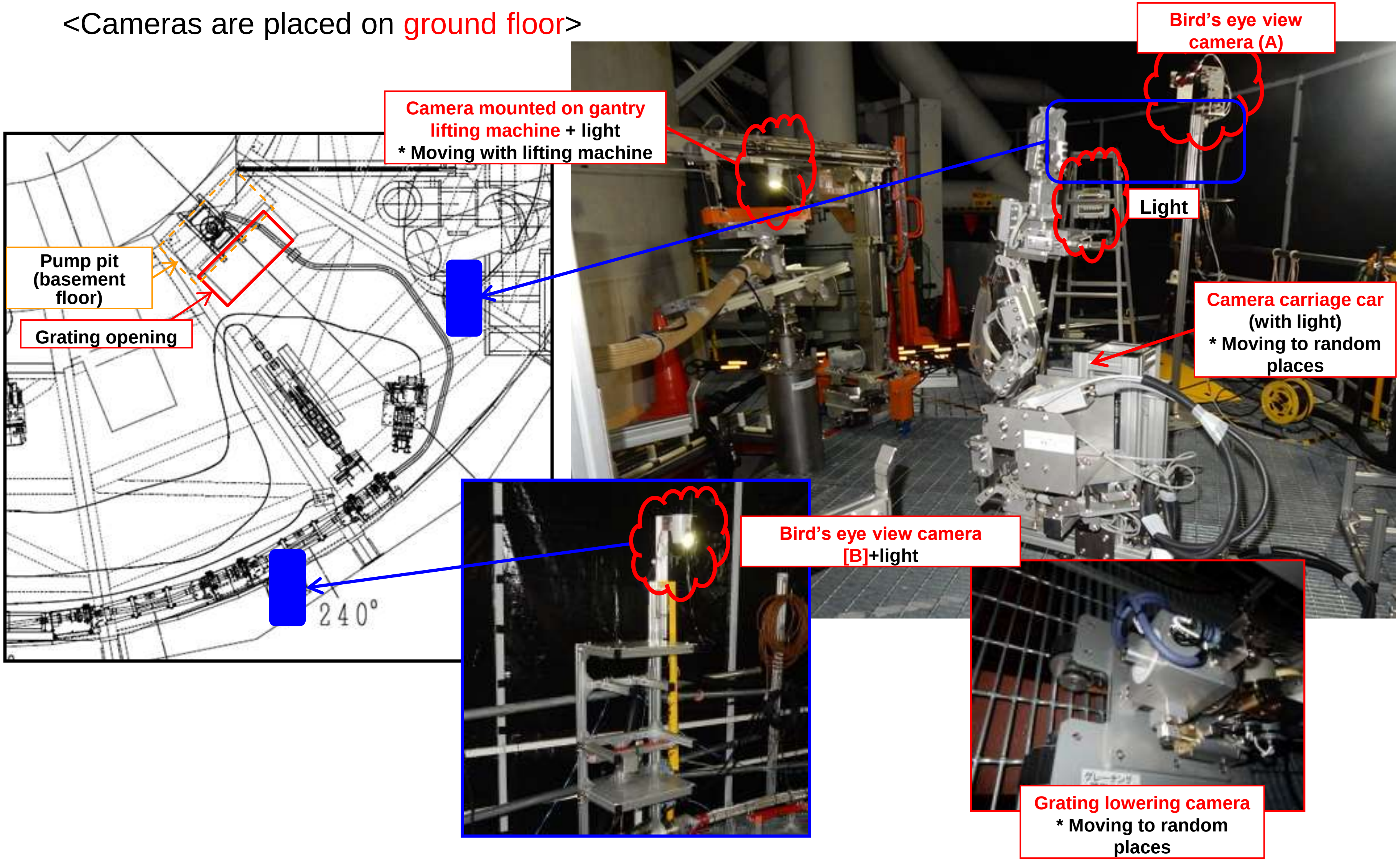
②Connection of pipes



(2) ①-5 Results of element test

(1) Pump suspension and installation (fixed): 1/4

<Cameras are placed on ground floor>

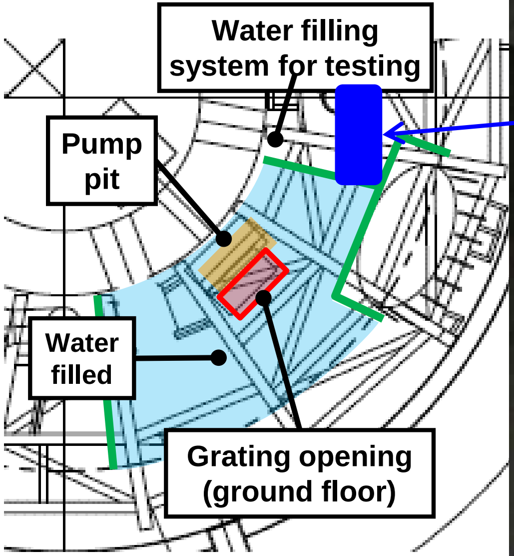


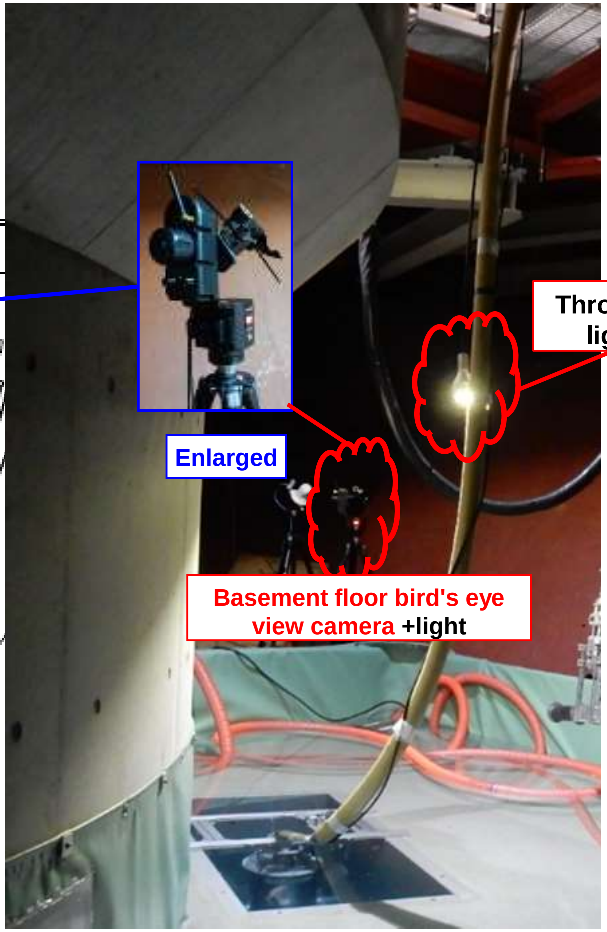
Remote monitoring by using fixed bird's eye view camera and mobile device-mounted camera

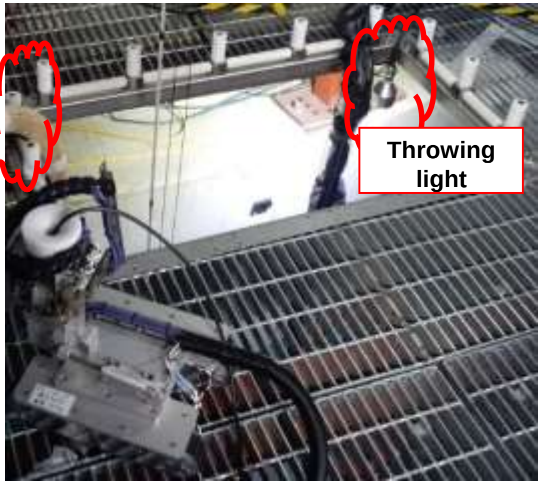
(2) ①-5 Results of element test

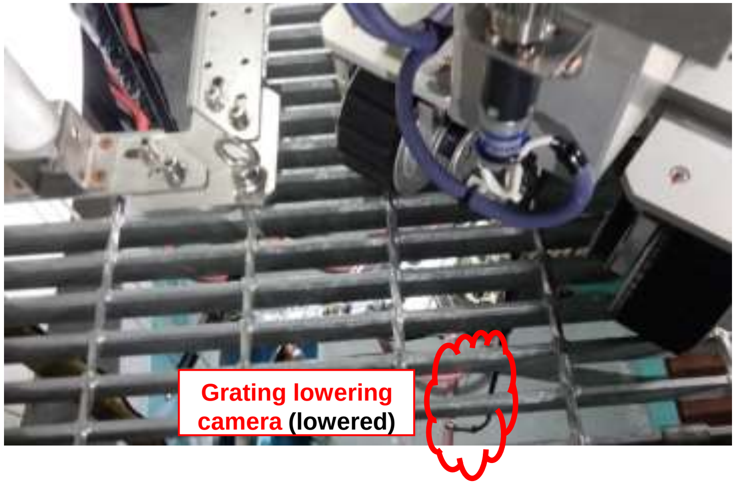
(1) Pump suspension and installation (fixed): 2/4

< Cameras are placed on basement floor>









Remote monitoring by using fixed bird's eye view camera and mobile grating lowering camera

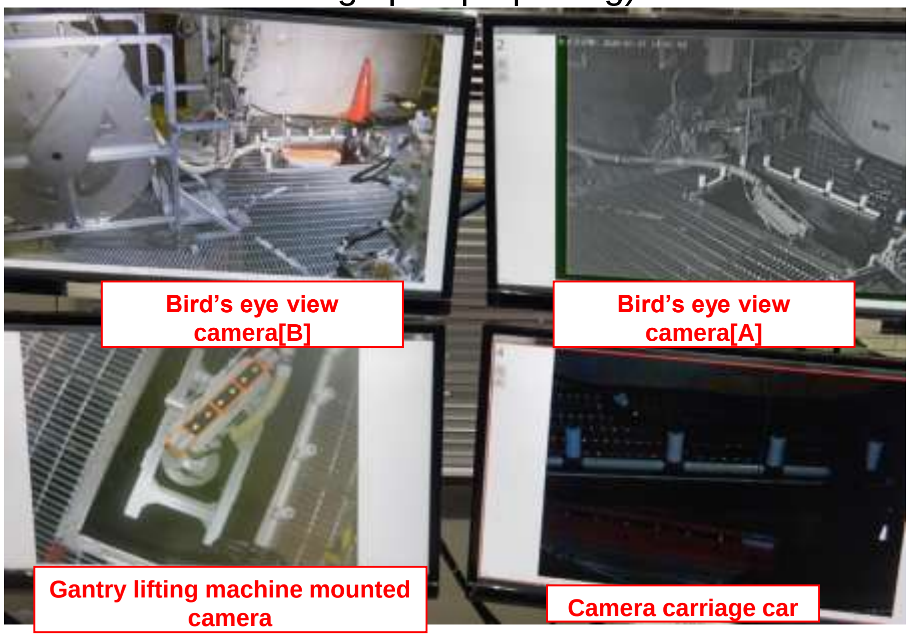
(2) ①-5 Results of element test

(1) Pump suspension and installation (fixed): 3/4

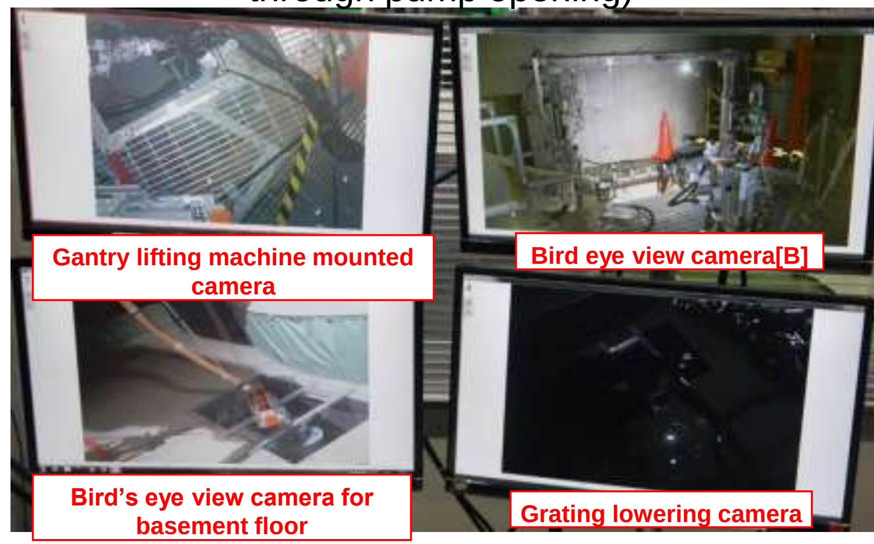
<Major work monitoring method>

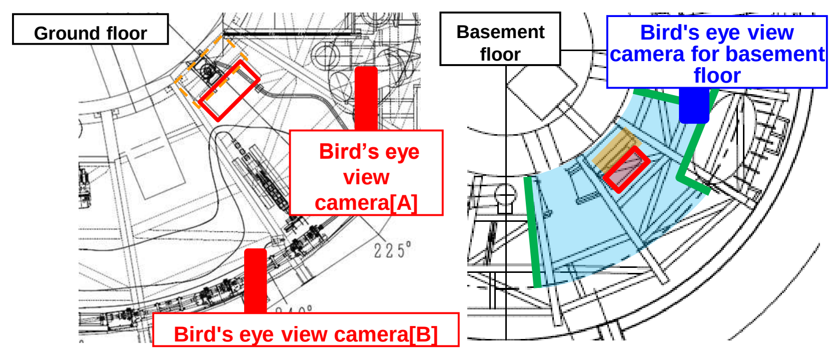
- During work on the ground floor: Bird's eye view camera x 2, gantry lifting machine mounted camera and camera carriage car
- During work on the basement floor: Bird's eye view camera for the basement floor and grating lowering camera

During work on the ground floor (until passing through pump opening)



During work on the basement floor (after passing through pump opening)

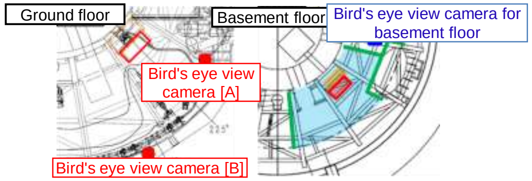




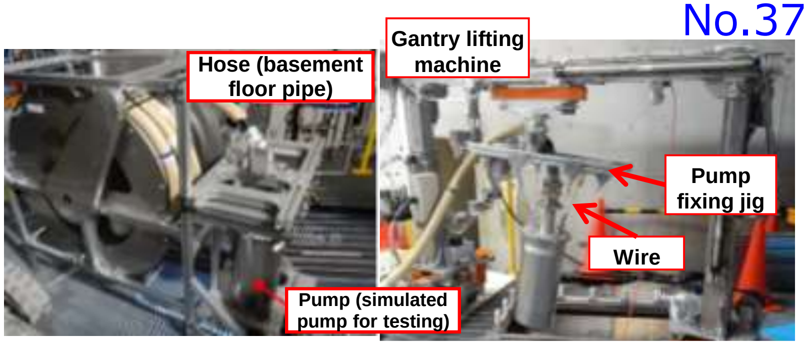
Camera setting

(2)①-5 Results of element tests

(1) Pump suspension and installation (fixed): 4/4



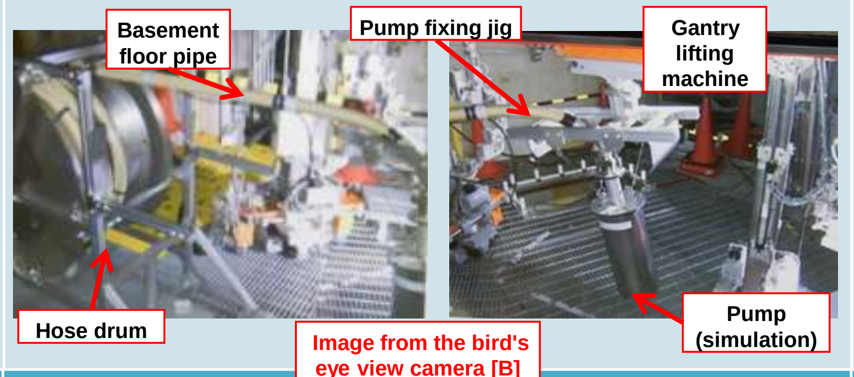
Camera installation



<Test results>

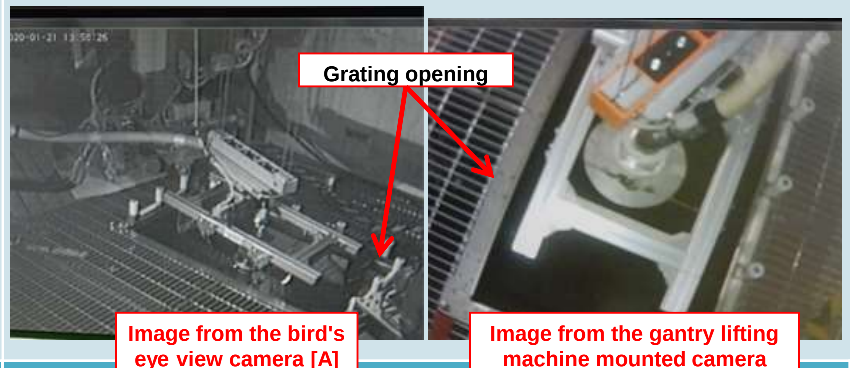
STEP 1. Transport the pump to the opening

Work status



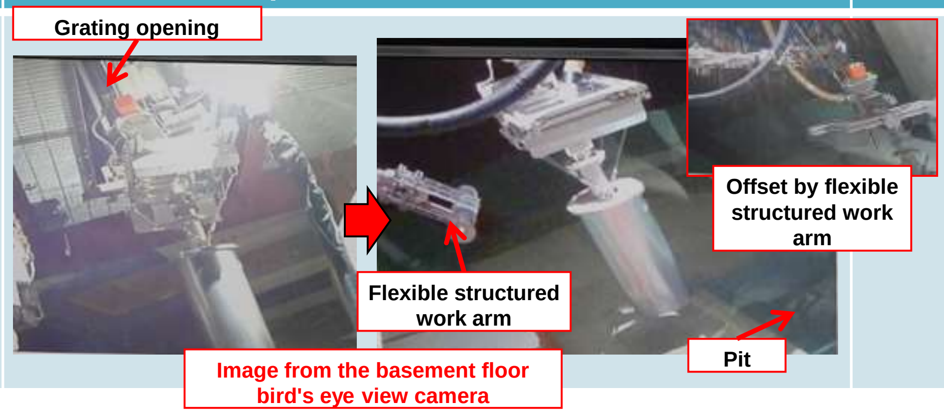
STEP 2. Suspend the pump from the opening

Work status

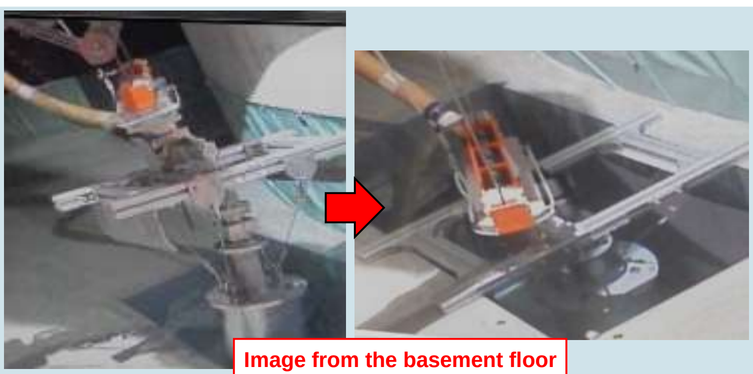


STEP 3. Suspend to the basement floor

Work status



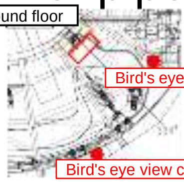
STEP 4. Install the pump in the pit



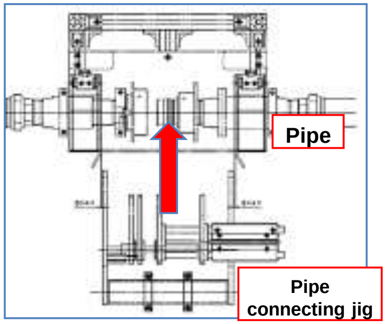
It was confirmed that the pump can be installed in the pit by remote operations

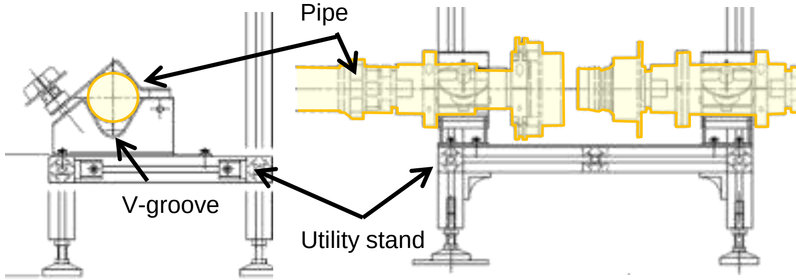
(2)①-5 Results of element tests

(2) Connection of pipes: 1/2

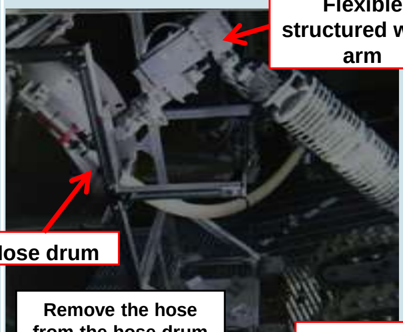
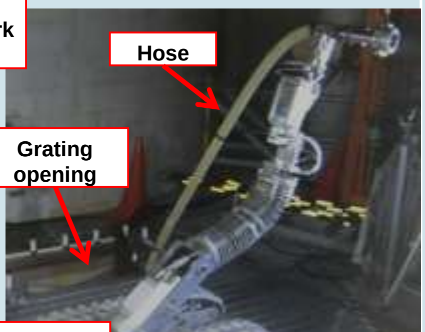
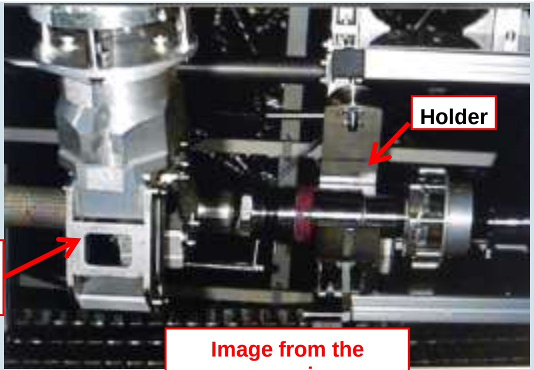


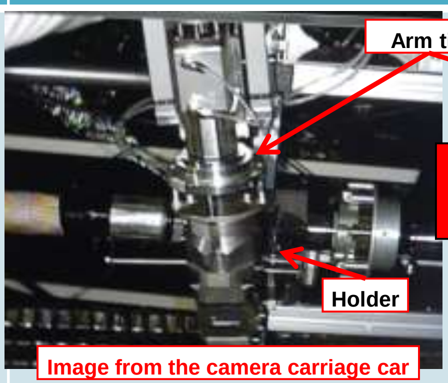
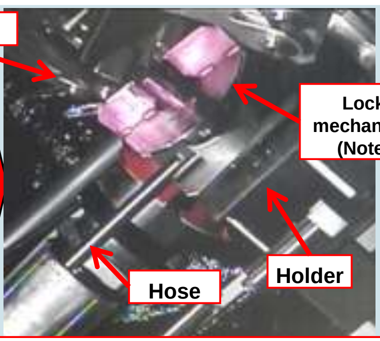
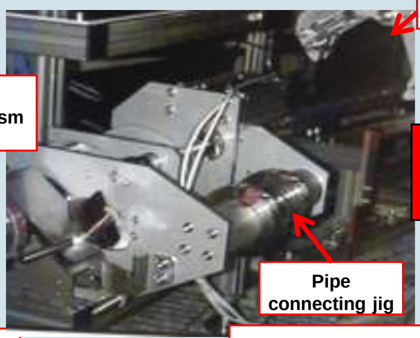
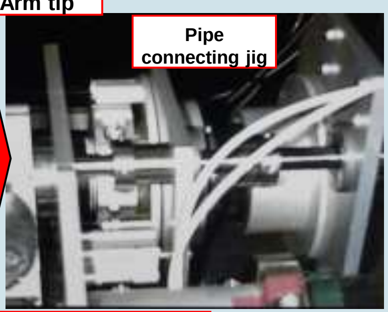
Camera installation





<**Test results**>

STEP	1. Draw the basement floor pipe	2. Install the basement floor pipe on the utility stand
Work status	 	

STEP	3. Close the holder and fix the pipe	4. Install the pipe connecting jig to connect the pipes
Work status	 	 

It was confirmed that the basement floor pipe (hose) and ground floor pipe can be connected by remote operations.

(Note) Lock mechanism: Holder is locked by turning the knob.

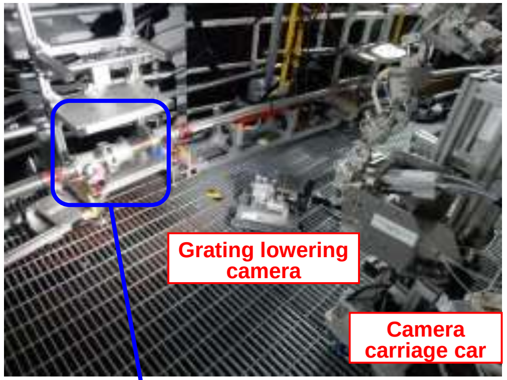
(2)①-5 Results of element tests

(2) Connection of pipes: 2/2

<**Results of flow rate and leakage verification**>

- The pump in the pit was replaced from a simulated pump to a pump satisfying 10 m³/h.
- The flow rate was confirmed to be 14.4 m³/h.
- Absence of leakage from the pipe connection parts was remotely verified.

Example of leakage



Equipment layout

When directly verified

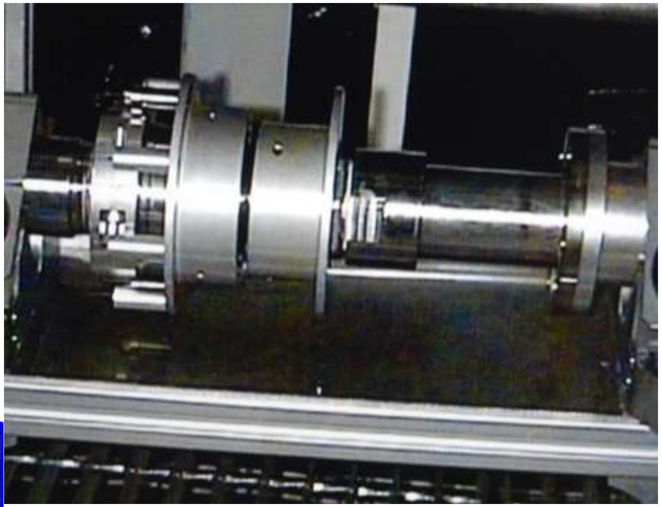


Image from the camera carriage

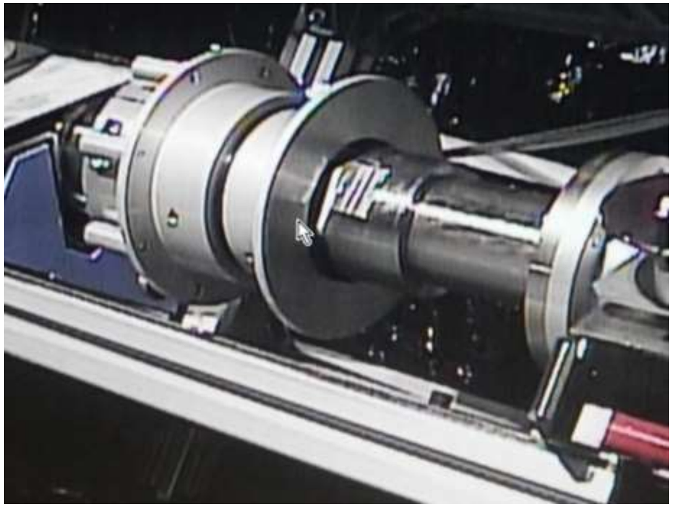


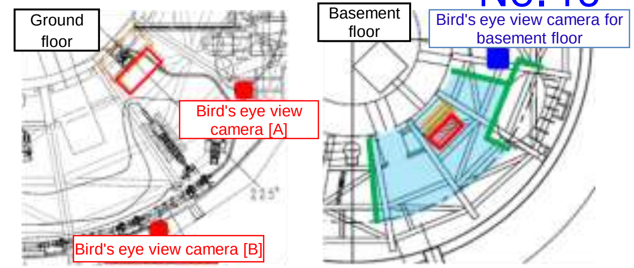
Image from the grating lowering camera

Specifications for submersible pump
- **Model: 50PN21.5** (Tsurumi Manufacturing)
- **Discharge rate: 12 m³/h**
- **Total pump head: 14.5 m**
- **Dimensions: 196 x 295 x 435 mm**
- **Weight: 15.9 kg**

It was confirmed that the specified flow rate is satisfied and that remotely monitored images allow monitoring that is almost the same as direct verification.

(2)①-5 Results of element tests

(3) Pump replacement procedure

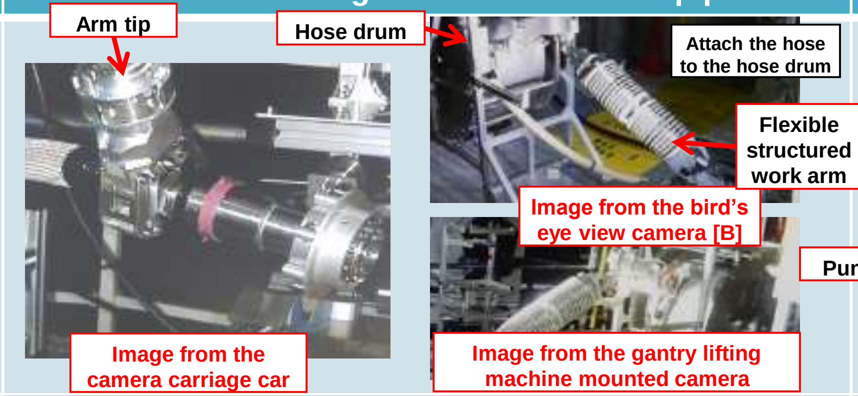


Camera installation

<**Test results**> #Camera installation and work monitoring method is the same as that for pump suspension.

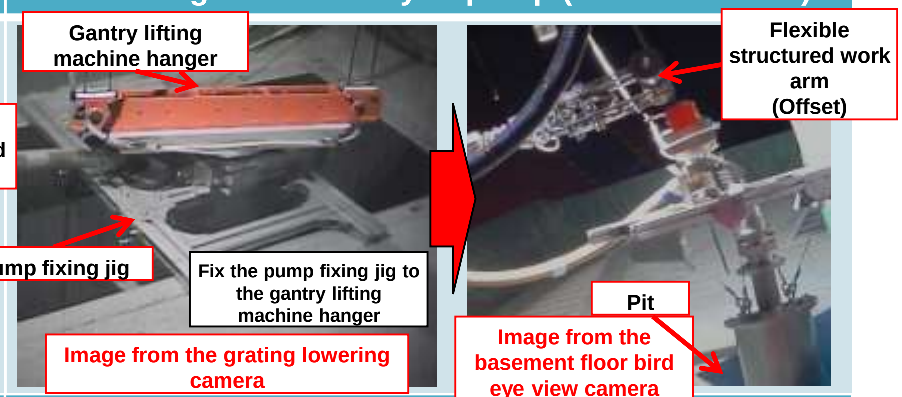
STEP: 1. Disconnecting the basement floor pipe

Work status



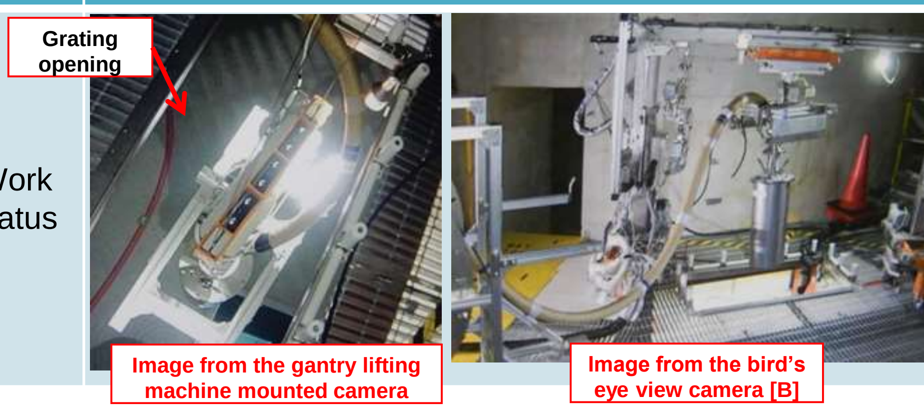
STEP: 2-1. Lifting and recovery of pump (basement floor)

Work status



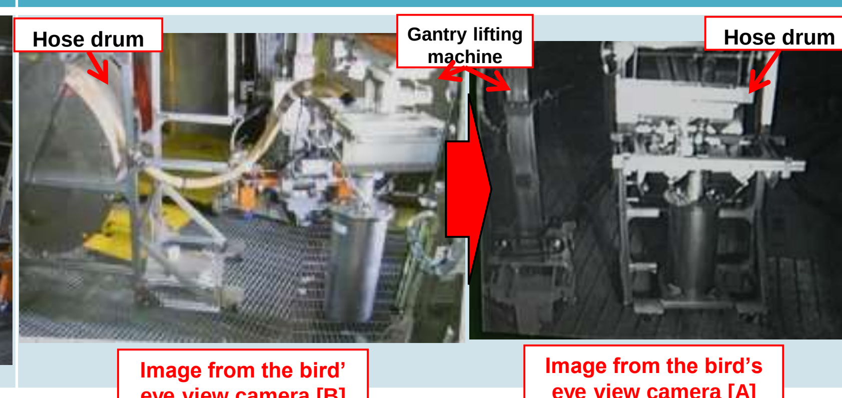
STEP: 2-2. Lifting and recovery of pump (ground floor)

Work status



STEP: 3. Transport the pump with the transport apparatus

Work status



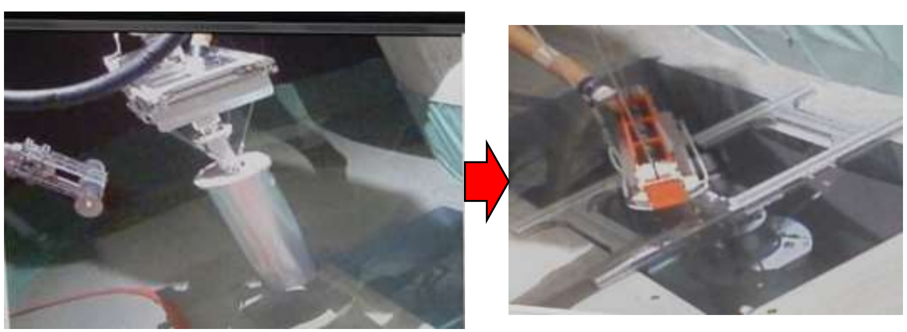
It was confirmed that a remotely installed pump can be recovered.

(2)①-5 Results of element tests

(4) Summary of test results

ID	Test items	Criteria	Test results	Remarks
1	Pump suspension and installation (fixed)	・A pump with pipes connected can be suspended into the pump pit and can be installed (fixed). ・The pump installation status can be verified and monitored with a camera.	・The test results confirmed that a pump with hose connected can be suspended into the pump pit by a gantry lifting machine, and can be installed in the pit (pump is fixed by a pump fixing jig). ・The test results confirmed that the pump installation status can be verified (monitored) by means of the basement floor bird's eye view camera.	
2	Connection of pipes	・The pipes on the grating and the pipes on the basement floor can be connected. ・After connection, a flow rate of 10 m^3/h is satisfied. (Note)	・The test results confirmed that the pipes laid on the grating and the hose connected to the pump on the basement floor can be connected with a flexible structured work arm and pipe connecting jig. ・The test results confirmed that the flow rate after connection is 14.4 m^3/h which satisfies the specified flow rate.	
3	Pump replacement procedure (recovery of pump)	The pump installed in the pump pit can be lifted and recovered.	The test results confirmed that the pump installed in the pump pit can be lifted out and recovered by a gantry lifting machine.	

(Note) A simulated pump simulating the dimensions and mass was used for pump suspension, installation, and recovery.
To check the flow rate, the simulated pump was replaced with a pump satisfying 10 m^3/h, and the flow rate was verified.



Pump suspension and installation

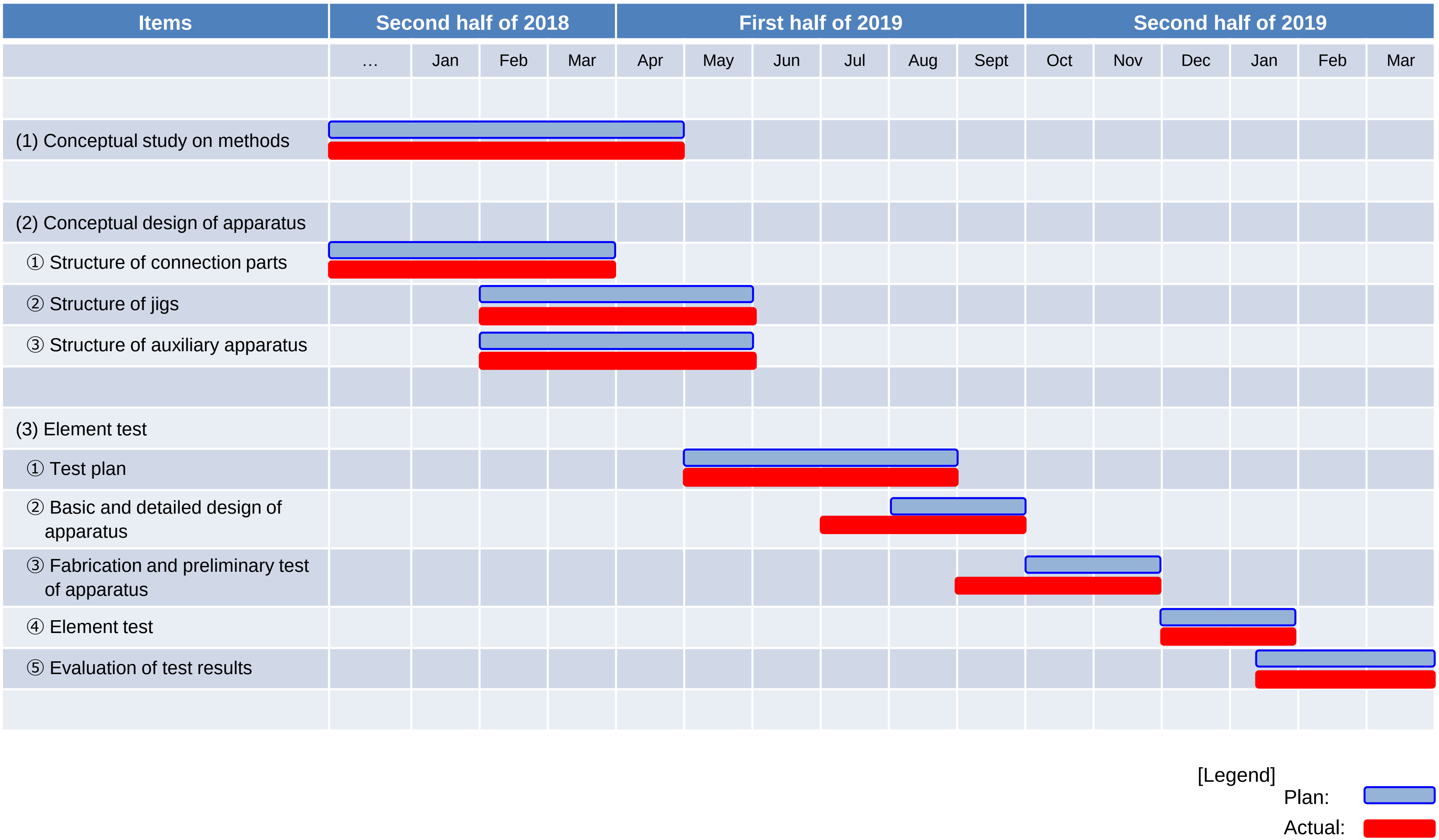
Connection of pipes

Recovery of pump

Since all the criteria were satisfied, the feasibility of the methods of installation and replacement of pipes and pump inside the D/W was verified.

(2)①-5 Element test results and issues

(5) Test schedule



6. Implementation details

(1) Examining of technical specifications for upgrading of water circulation systems in PCV, study of work plan and development planning

① Study of the water circulation system and technology for inside D/W

i) Organizing technical specifications considering the site environment

ii) Study of access route establishment work and maintenance plan

iii) Identification of development challenges and preparation of development plan

② Study of the water circulation system and technology by using S/C

i) Organizing technical specifications considering the site environment

ii) Study of access route establishment work and maintenance

iii) Identification of development challenges and preparation of development plan

(2) Development and verification of element technology for accessing and connecting inside PCV

① Development and verification of element technology required for accessing and connecting inside D/W

② Development and verification of element technology required for accessing and connecting inside S/C

(2) Development and verification of element technology for accessing and connecting inside PCV

② Development and verification of element technology required for accessing and connecting inside S/C

1) Development and verification of marking apparatus, positioning apparatus, and gap measuring apparatus

2) Development and verification of S/C surface polishing apparatus, weld bead treatment apparatus, and S/C joint welding apparatus

3) Development and verification of temporary sealing apparatus

4) Schedule for the development of technology for establishment of S/C water intake part

(2) Development and verification of element technology for accessing and connecting inside PCV
② Development and verification of element technology required for accessing and connecting inside S/C

[Purpose]
Establishment of element technology for the establishment and maintenance of S/C water intake opening

[Issues]
1) Development and verification of marking apparatus, positioning apparatus, and gap measuring apparatus
2) Development and verification of S/C surface polishing apparatus, weld bead treatment apparatus, and S/C joint welding apparatus
3) Development and verification of temporary sealing apparatus

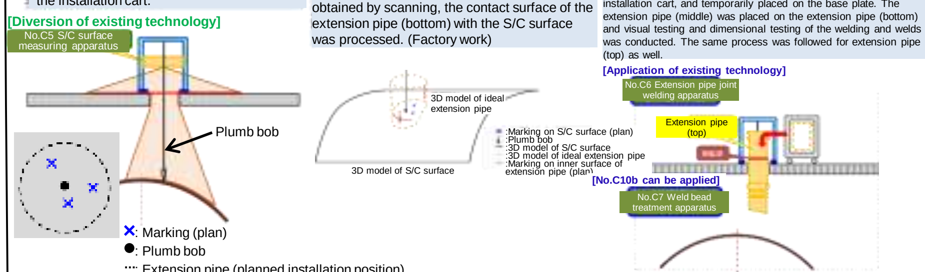
[Overview of results]
1) Development and verification of marking apparatus, positioning apparatus, and gap measuring apparatus

■ Procedure for aligning the S/C water intake part

・Measurement of S/C surface
The shape of the S/C surface was measured by mounting a shape measuring scanner on the installation cart.

・Creation of a 3D model of the S/C surface
・Processing of the grooves at the bottom of the extension pipe
Based on the shape measurement results obtained by scanning, the contact surface of the extension pipe (bottom) with the S/C surface was processed. (Factory work)

・Insertion/ welding/ inspection of extension pipe (bottom/ middle/ top)
A transport cart with a mounted extension pipe was carried in. The installation cart and the transport cart were connected, the extension pipe (bottom) was lowered with the hoist of the installation cart, and temporarily placed on the base plate. The extension pipe (middle) was placed on the extension pipe (bottom) and visual testing and dimensional testing of the welding and welds was conducted. The same process was followed for extension pipe (top) as well.

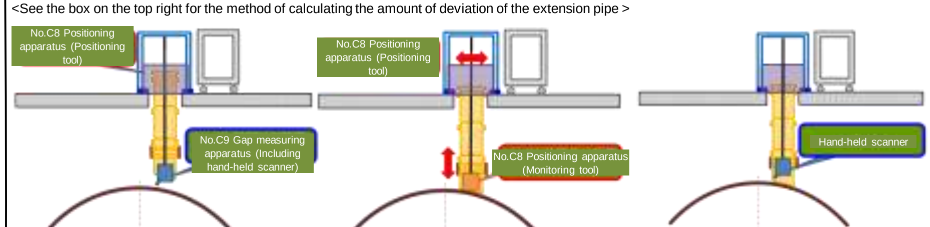


・Preparation work for positioning of the extension pipe
An positioning apparatus (positioning tool) was installed and connected to the extension pipe. Thereafter, the extension pipe was installed on the S/C. A gap measuring apparatus (including a hand-held scanner) was inserted to obtain the positional relationship (amount of deviation) between the extension pipe and the S/C prior to positioning.

・Positioning of the extension pipe
The hand-held scanner was pulled up and using the positioning apparatus (monitoring tool) instead for observation, the extension pipe was moved (translation/rotation) based on the numeric values obtained by the previous procedure, and the gap was set to less than 5 mm.

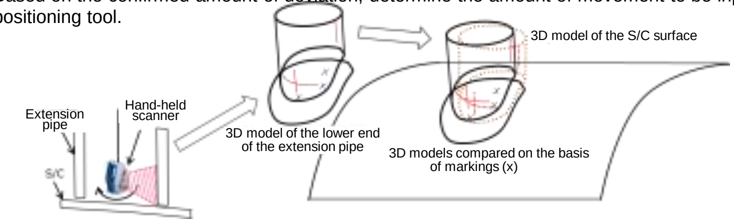
・Measurement of extension pipe gaps
The monitoring tool was pulled up and the hand-held scanner was inserted. The entire circumference of extension pipe and S/C surface was measured, and it was confirmed that there were no gaps of 5 mm or more that cannot be welded.

<See the box on the top right for the method of calculating the amount of deviation of the extension pipe >



- Method of calculating the amount of deviation of the extension pipe

①Lower the extension pipe on to the S/C.
②Use a hand-held scanner (3D) to acquire the scan data of the entire circumference on the inside of the extension pipe and create a 3D model of the lower end of the extension pipe (including the S/C surface).
③Superimpose the 3D model of the lower end of the extension pipe created by the hand-held scanner (procedure ② above) and the 3D model of the S/C surface created by the shape measuring scanner, and check the amount of deviation in the 3D position and inclination of the extension pipe (x, y, z axis x total 6 items of translation and rotation).
④Based on the confirmed amount of deviation, determine the amount of movement to be input into the positioning tool.



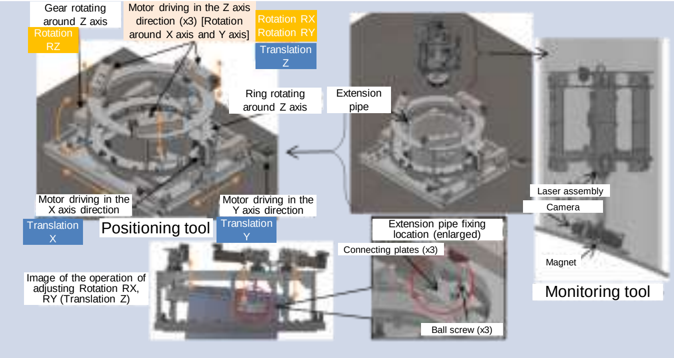
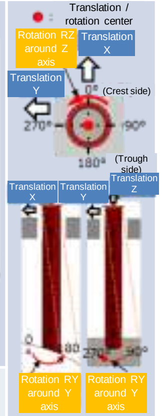
Superimposition of the 3D model of the S/C surface and the 3D model of the lower end of the extension pipe

■ Setting the target accuracy for positioning

Items	Factor	Target accuracy	Maximum gap estimated	Remarks
(1) Measurement error in comparison with the ideal shape of the lower end of the extension pipe				
① Measurement of S/C surface	Measurement	±0.5 mm	1.0 mm	
② Creation of a 3D model of the S/C surface	Model creation	(Being considered)	1.0 mm [Target]	Specific modeling method is determined by using a 1/1 scale combination test
③ Processing the grooves at the bottom of extension pipe	Processing	±1.0 mm	2.0 mm	
④ Peripheral welding of extension pipes	Processing (remote)	-	No impact	Bending occurs due to welding deformation, but it is within the adjustable range of the positioning apparatus.
(2) Positioning of extension pipe				
① Measurements by the hand-held scanner (Preparation work)	Measurement (Model)	±0.05 mm	0.05 mm	
② Positioning	Apparatus driving force (Minimum movement unit)	0.5 mm	0.5 mm	
(3) Measurement of extension pipe gaps				
① Measurement of extension pipe gaps	Measurement (Model)	±0.05 mm	0.05 mm	
Total			4.60 mm	5.0 mm [Target gap]

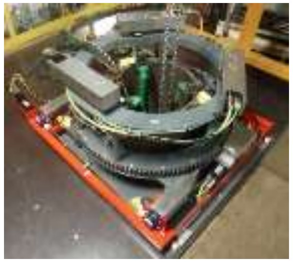
⇒From the target gap of 5 mm, set the target accuracy of each process in this way.

■ Specifications of positioning apparatus

Items	Specifications	Remarks
Configuration of apparatus		
Basic functions	(1) The gap at the bottom of the extension pipe can be adjusted to 5 mm or less. (2) The upper part of the extension pipe can be fixed and the entire weight of the extension pipe can be supported. (3) It is possible to adjust the 3 translational axes (X, Y, Z) and 3 rotational axes (RX, RY, RZ) of the extension pipe by remote operations. (4) The camera of the monitoring tool can be fixed on the S / C by remote operations. (5) When adjusting positions remotely, it is always possible to check whether the gap between the lower end of the extension pipe and the S/C is 5 mm or less for multiple representative directions. (6) The extension pipe can be removed after welding	

[Overview of positioning apparatus]

- The positioning apparatus is a device used to remotely align the extension pipe to the gap between the S/C surface and the extension pipe with a threshold limit value of 5 mm or less for the welding work before welding the S/C surface and extension pipe.
- The positioning apparatus comprises the positioning tool and monitoring tool. These tools are connected to the control panel with a cable, and can be operated remotely by operating the touch panel, levers, and switches on the operation panel while checking the monitor screen output from the apparatus.
  - Positioning tool: This apparatus is installed on the floor of 1st floor of R/B. It is fixed with connecting plates at 3 points of the apparatus and the upper end flange of the extension pipe, gripping the extension pipe, and adjusts the position of the lower end of the extension pipe by translation (X,Y,Z) and rotation (X,Y,Z) of each axis by the driving power of the servo motor.
  - Monitoring tool: An apparatus that is installed on the surface of the S/C in the extension pipe and monitors and verifies the gap between the extension pipe and S/C surface with nine cameras mounted on the camera box



Positioning tool

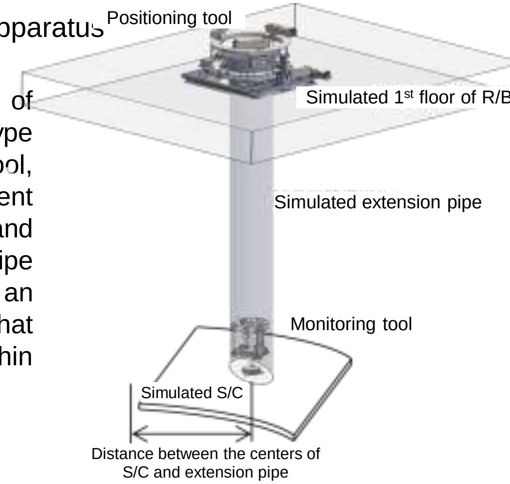
Monitoring tool

Monitor, operation panel

■ Unit function test of positioning apparatus

- **Purpose of the test**

To grip the flange at the upper end of the extension pipe with the prototype positioning apparatus (positioning tool, monitoring tool) for the establishment of the S/C water intake structure, and align it, using an extension pipe simulating the actual shape and an S/C test specimen, and to confirm that the extension pipe can be set within the specified gap.



Simulation scope				Remarks
1st floor of R/B – Hole diameter			650 mm	
1st floor of R/B – Flatness			No floor slope	
Distance between 1st floor of R/B - S/C			About 4100 mm	Equivalent to 1F-3
Distance between the centers of S/C and extension pipe			1500 mm	Maximum distance for the site where water intake part is planned to be constructed #1
S/C		Inner radius	4450 mm	Equivalent to 1F-2/3
		Thickness	15.9 mm	Actual: 17 mm
		Material	Carbon steel	
Extension pipe	Lower end	Outer diameter	540 mm	
		Inner diameter	521 mm	Actual: 520 mm
		Material	Carbon steel	
		Shape	On-site processing with grinder in accordance with S/C simulation	Actual: NC processing based on scan data
	Other than lower end	Outer diameter	559 mm	Actual: 552 mm#2
		Inner diameter	521 mm	Actual: 520 mm
		Material	Carbon steel	Actual: Stainless steel
	Flange	Outer diameter	720 mm	
	Structure (welds)		Not simulated	
Torus room interference objects			Interference objects assumed to have been removed	
Environment (Brightness, temperature, humidity)			Not simulated	

- Unit function test of positioning apparatus (Details and results) (1/2)

No.	Test details	Items to be verified (Criteria)	Test results	Remarks
0	Lift the extension pipe with a crane, insert a temporary support material between the extension pipe and the hole on the floor, temporarily fix the extension pipe, and remove the extension pipe from the crane.	-	-	
1	Use the crane to install the positioning tool. The installation position should align with the markings provided on the floor in advance.	Positioning tool can be installed. (Check for interference with the extension pipe and temporary support material)	Good	
2	Verify the installation position of the positioning tool, and fix the positioning tool to the floor with bolts.	-	Good	
3	Remove the rod that connects the connecting plates, and rotate the three connecting plates 180°. Raise the connecting plates until they touch the flange. After that, fasten the connecting plates and the flange with bolts.	Positioning tool and extension pipe can be connected.	Good	
4	Raise the positioning apparatus and remove the temporary support material that temporarily fixed the extension pipe and the floor surface, while monitoring that the indicated value of the load cell does not exceed the allowable load.	Temporary support material can be removed	Good	
5	Use a crane to lower the monitoring tool from the top of the positioning tool along the inner surface of the extension pipe.	Monitoring tool and extension pipe do not interfere with each other.	Good	
6	Seat the monitoring tool camera box on the S/C surface.	Visually checking with a camera that the monitoring tool can be seated on the S/C surface.	Good	
7	Perform positioning by making fine adjustments while checking the gaps in each direction on the monitor image output from the camera of the monitoring tool.	Positioning operation is possible while monitoring with the camera of the monitoring tool.	See below	

No.7 Test results: Good
The positioning is performed to reduce the amount of gap while checking the four directions at every 90° on the monitor and using the align mark set in advance as a key. It was possible to reduce the amount of gap while making fine adjustments. This procedure was completed because the amount of gap could be adjusted to be as small as possible visually on the monitor.


Temporary fixing of extension pipe with temporary support material (No.0)


Installation of positioning tool (No.1)


Lowering of monitoring tool (No.5)


Seating the monitoring tool on the S/C surface (No.6)


Monitoring of extension pipe-S/C surface with monitoring tool (No.7)

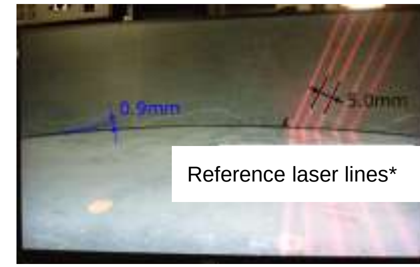
- Unit function test of positioning apparatus (Details and results) (2/2)

No.	Test details	Items to be verified (Criteria)	Test results	Remarks
8	(Verification of gap distribution by laser line) After positioning, confirm that the gap between the S/C surface and the lower end of the extension pipe is 5 mm or less by comparing the distance between the laser lines of the monitoring tool placed at 5 mm intervals on the monitor screen in eight directions.	It is possible to determine whether the gaps on the monitor screen are 5 mm or less by using the 5mm-interval laser lines as a reference.	Good	
9	Pull up the monitoring tool with a crane.	Monitoring tool and extension pipe do not interfere with each other.	Good	
10	Measure the gap between the S/C and the inner surface of the extension pipe in four directions with a clearance gauge.	Measured gap is 5 mm or less.	Good	
11	After fixing the lower end of the extension pipe to the S/C surface by temporary welding in four directions, insert a temporary support material between the extension pipe and the hole on the floor and temporarily fix it, and then use a crane to remove the positioning tool.	Positioning tool can be installed. (Check for interference with the extension pipe and support material)	Good	

Direction (°)	No.8 result (mm)	No.10 result (mm)	Criteria	Test results
0	0.8	0.6	■No.8 Gap of 5 mm or less can be determined from the monitor screen. ■No.10 Gap is 5 mm or less.	Good
45	0.3	-		
90	0.9	0.9		
135	1.5	-#		
180	1.5	1.4		
225	0.8	-		
270	0.7	0.7		
315	0.6	-		

Maximum gap is 1.8 mm in 135° direction

Condition of extension pipe - S/C surface after positioning (No.8)



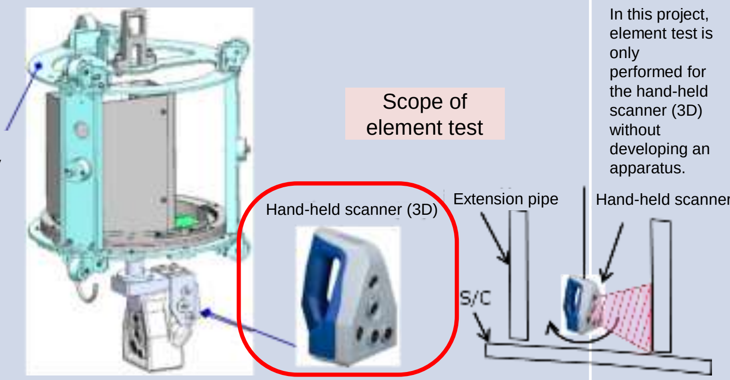
Verification status on the monitor screen of the monitoring tool: Near 90° (No.8)

*: Laser line intervals are measured in advance before the extension pipe is inserted.

- Summary
  - It was confirmed that the basic functions of positioning apparatus are satisfied.
  - It was confirmed that with the extension pipe positioning method, in which fine adjustments are repeated to make the gap smaller, using the align mark set in advance and visually checking the image from the monitoring tool camera, the gap between the S/C surface and extension pipe can be adjusted to 5 mm or less (test result is less than 2 mm).

- Matters reflecting a full-scale test based on the results of the unit function test
  - ➢ The following procedure includes in the procedures of full-scale test: If the gap in the extension pipe positioning is large based on the amount of deviation calculated from the hand-held scan results adjust the gap to 5 mm or less by visually checking the positioning using the image from the monitoring tool camera just like in the unit function test.

■ Specifications of gap measuring apparatus

Items	Specifications	Remarks
Configuration of apparatus		In this project, element test is only performed for the hand-held scanner (3D) without developing an apparatus.
Basic functions	(1) The hand-held scanner (3D) can be lowered to the specified position for installation, fixing, and recovery by remotely operating the carrier assembly. (2) The gap can be verified by shape measurement of the S/C surface and the entire circumference of the lower end of the extension pipe by means of a hand-held scanner (3D). (3) The throat thickness of the fillet weld can be verified by shape measurement of the S/C surface and the entire circumference of the lower end of the extension pipe by means of a hand-held scanner (3D) before and after welding. (4) The marking positions on the S/C surface and the inner surface of the extension pipe can be verified. (5) The accuracy of dimensional measurement by means of the hand-held scanner (3D) is ± 1 mm or less.	

- Specifications of hand-held scanner

Light source	LED (blue)
3D resolution (maximum)	0.1 mm
3D accuracy (maximum)	0.05 mm
Photographable range	200-300 mm
Photographing range (shortest distance) (height x width)	90 x 70 mm
Photographing range (longest distance) (height x width)	180 x 140 mm
Photographing range (angle) (height x width)	30 x 21 deg
Main unit dimensions (height x depth x width)	190 x 140 x 130 mm
Main unit weight	0.85 kg

■ Element test of gap measuring apparatus

- Purpose of the test

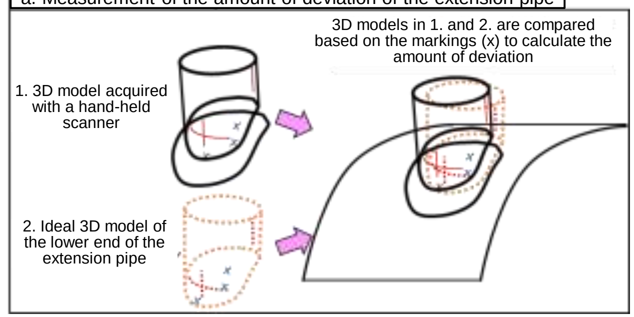
The gap measuring apparatus is an apparatus that remotely performs the following tasks while welding the S/C and extension pipe, from among the work for the establishment of the S/C water intake part structure:

a. Measurement of the amount of deviation of the extension pipe (Identification of the position and bearing of the lower end of the extension pipe before positioning)

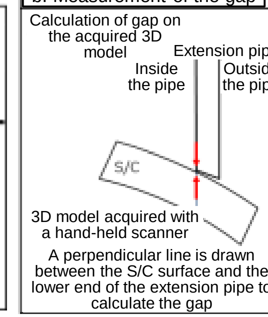
b. Measurement of the gap (Verification that the gap between the S/C surface and the lower end of the extension pipe before welding is at the tolerance value of 5 mm or less)

c. Weld dimensional testing (Verification that the weld throat thickness after welding has the required dimensions)

a. Measurement of the amount of deviation of the extension pipe



b. Measurement of the gap

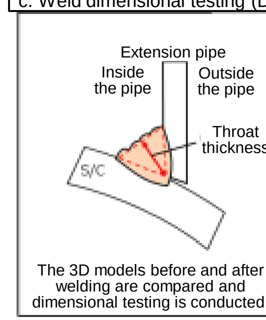


- Performance evaluation through element test

Since performance evaluation is carried out by acquiring a 3D model of the measurement point (between the lower end of the extension pipe and the S/C surface) using the hand-held scanner, which is the main component of the gap measuring apparatus, the following performance evaluation is carried out by means of element tests using the hand-held scanner alone:

1) Evaluation of measurement accuracy by manual scanning
2) Evaluation of photographing range by scanning with a rotating jig
3) Evaluation of marking
4) Evaluation of throat thickness

c. Weld dimensional testing (DT)



(Supplement) The hand-held scanner is an apparatus that builds a 3D model by processing the scanned image data at high speed, recognizing the geometric features of the object to be measured, automatically integrating the data, and superimposing the data to accurately capture the shape of the subject.

(2) Development and verification of element technology for accessing and connecting inside PCV

② Development and verification of element technology required for accessing and connecting inside S/C

i) Evaluation of measurement accuracy by manual scanning

[Purpose of the test]

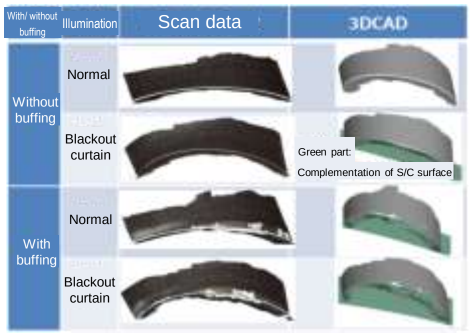
To manually scan a test specimen provided with a gap (4,5,6 mm) in advance and check the possibility of scanning based on the surface condition and verify the 3D model acquired from the scan data. In addition, to compare the gap measured on the 3D model acquired from the scan data with the gap measured with a straightedge.

[Test conditions] ・Shape of test specimen: S/C [saddle type], extension pipe [half cylinder]
・Surface condition of test specimen: With buffing, without buffing [2 conditions]
・Measurement position: 45°, 90°, 135° (3 directions)
・Illumination: Test specimen is covered with a blackout curtain (measurement with scanner lighting only), normal lighting (existing factory lighting) [2 conditions]

[Criteria]

a. The end of the lower end of the extension pipe simulation can be confirmed on the 3D model acquired from the scan data.
b. The S/C surface can be confirmed on the 3D model acquired from the scan data.
c. The gaps can be measured on the 3D model acquired from the scan data.
d. The difference between the 3D model acquired from the scan data and the measured values is ±1 mm or less.

[Test results]




Test specimen (Without buffing)


Test specimen (With buffing)

Surface condition	Illumination	Gap	Result a	Result b	Result c	Result d
Without buffing	Normal lighting	4 mm	Good	NG#1	NG#1	NG#2
		5 mm		Good	Good	Good
		6 mm		NG#1	NG#1	NG#2
	Blackout curtain	4 mm		Good	Good	Good
		5 mm		NG#1	NG#1	NG#2
		6 mm		Good	Good	Good
With buffing	Normal lighting	4 mm	NG#3	NG#3	-#3	-#3
		5 mm				
		6 mm				
	Blackout curtain	4 mm				
		5 mm				
		6 mm				

#1: There is a 3D model defect at 180° on the S/C surface.
#2: Peripheral data complements the shape determination of the defective part in the S/C model.
#3: Gap is not measured because there is a 3D model defect on the lower end of the extension pipe and the S/C surface, and the reliability is low.

[Conclusion] ・ In manual scanning, there is a defective part on the S/C surface (180°: trough side) without buffing, and there is a defective part in the 3D model over a wide area of the extension pipe and S/C surface with buffing.

➢ Handling full-scale test (Results will be reported in the full-scale test project)

・If the scan data of the S/C surface is missing, the peripheral data complements the shape determination.
・To avoid the effect of a glossy finish, avoid photographing immediately after buffing and shoot at an angle to the measurement point instead of the front.

ii) Evaluation of photographing range by scanning with a rotating jig

[Purpose of the test]

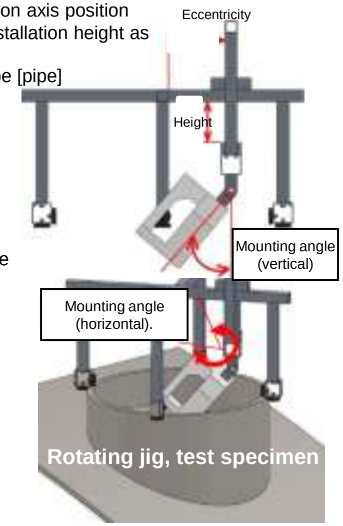
To use a rotating jig to manually rotate a test specimen provided with a gap (5 mm) in advance and scan the entire circumference, and confirm that the part to be measured is within the photographing range of the hand-held scanner, and to change the rotation axis position (eccentricity), scanner mounting angle (horizontal/ vertical), and scanner installation height as parameters.

[Test conditions] ・Shape of test specimen: S/C [saddle type], extension pipe [pipe]
・Surface condition of test specimen: Without buffing
・Illumination: Normal lighting (existing factory lighting)

[Test parameters] ・Rotation axis position (eccentricity)
・Hand-held scanner mounting angle
・Hand-held scanner installation height

[Criteria]

a. Parts to be measured (scanned) can be photographed when scanning with a rotating jig (3D model can be constructed.)
b. The difference between the gap value in the 3D model acquired from the scan data and the gap measurements from the clearance gauge is ±1 mm or less.

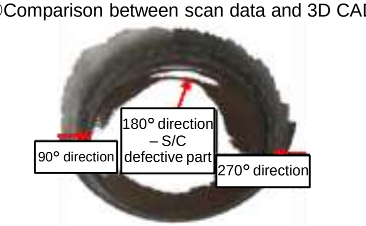


Rotating jig, test specimen

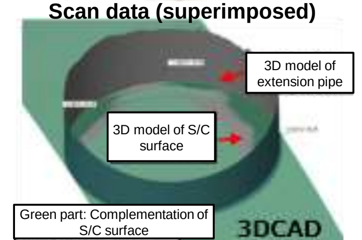
[Test results] a. Scan condition parameters and photographable range

	Height	Eccentricity	Mounting angle (horizontal)	Mounting angle (vertical)	Photographable range
1	144	30	50	0	280°~60°
2		80	50	25	270°~100°
3			50	45	0°~130°
4	180	80	50	45	240°~140°
5	200	80	50	45	240°~140°
6	230	80	50	45	50°~290°
7		100	20	50	110°~210°
8		130	20	50	120°~230°
9		150	20	50	120°~230°
10			20	60	130°~220°
11		205	20	60	130°~220°
12			0	55	140°~210°
13		80	30	50	90°~230°

①Comparison between scan data and 3D CAD



Scan data (superimposed)



b. Results of comparison of gap measurements

Direction (°)	① Gap value from 3D model (mm)	② Gap measurements (mm)	①-② (mm)	Result
0	3.0	4.0	-1.0	Good
90	2.7	4.7	-2.0	NG
180	2.8#	2.5	0.3	NG#
270	4.7	5.1	-0.4	Good

#: There is a 3D model defect on the S/C surface (180°), and the peripheral data complements the shape determination of the defective part.

[Conclusion] ・ In scanning with a rotating jig, since there is a defective part on the S/C surface (180°) without buffing (Same as (1)), and the 90° scan data for the lower end of the extension pipe is inadequate, the margin of error between the 3D model and the measured gap value is more than ±1 mm.

➢ Handling full-scale test (Results will be reported in the full-scale test project)

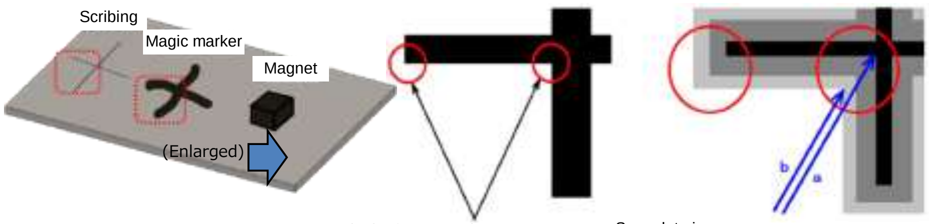
・If the scan data of the S/C surface is missing, the peripheral data complements the shape determination. (Same as (1))
・ If the scan data of the lower end of the extension pipe is missing, the position for the missing range is complemented with the 3D model acquired in advance.
・Further expand the scan conditions (mounting angle, position) for this test in order to collect sufficient scan data

iii) Evaluation of marking

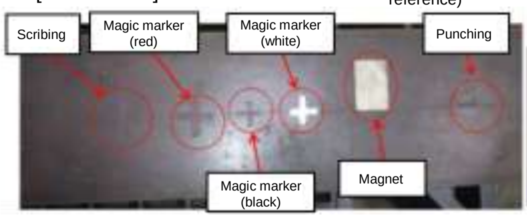
[Testing purpose]
To make markings on the flat plate and check the markings with the 3D model obtained from scan data.
Assuming the marking of the actual equipment, the types of the markings were used as the test parameter.
・Types of markings: scribing, magic marker (red, black, white), magnet, punching

[Testing conditions] ・Shape of specimen : Flat plate
・Simulated surface condition of S/C: Without buffing
・Illumination: Normal lighting (existing factory lighting)

[Criteria]
a. Can check the marking using the 3D model obtained from the scan data.
b. Accuracy as a result of blurring: The range (maximum / minimum width) difference with respect to another reference is within 1 mm.



[Test results]



Marked test


3D scan results

Marking method	Result a, b	Actual measurements (Reference)	3D model measurement a	3D model measurement b
Scribing	Good	87 mm	85.9 mm	86.3 mm
Magic marker red		122 mm	121.6 mm	122.6 mm
Magic marker black		154 mm	154.0 mm	154.4 mm
Magic marker white		184 mm	183.3 mm	183.9 mm
Magnet		227 mm	226.3 mm	226.6 mm
Punching		295 mm	293.7 mm	294.1 mm

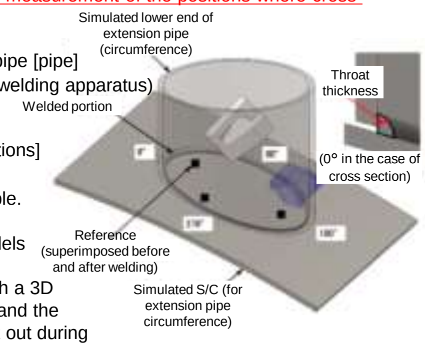
[Conclusion] ・The visibility of magnet or magic marker (especially white) was good, and the visibility of scribing line or punching was difficult as it was glossy and had few irregularities.
・There was no difference seen in accuracy due to blurring in each of the markings and the target values were satisfied.
➢ Response to full-scale tests: Use magnet or magic marker (white) that are easy for confirmation.

iv) Evaluating the throat thickness

[Purpose]
To superimpose the 3D models obtained from the scan data before and after welding on the test specimen used in the unit function test (STEP 3) of S/C joint welding apparatus, check the possibility of measuring the throat thickness, and compare with the actual throat thickness measurement of the positions where cross-sectional macro-observation were performed after welding.

[Testing conditions]
・Shape of test specimen : S/C [Saddle type], Extension pipe [pipe]
(Same test specimen as that used in unit function test of S/C joint welding apparatus)
・Surface condition of specimen : With buffing
・Illumination: Normal lighting (existing factory lighting)
・Amount of gap : 0 mm, 5 mm (1500 mm position) [2 conditions]

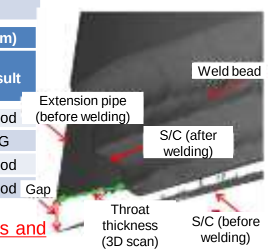
[Criteria]
a. Surface of the welded portion after polishing is photographable.
(Can build a 3D model)
b. Can measure the throat thickness by superimposing 3D models obtained from scan data before and after welding.
c. The margin of error, when the throat thickness measured with a 3D model obtained from the scan data before and after welding and the actual throat thickness measurement of the cross section cut out during cross-sectional macro-observation are compared, is ± 1 mm or less.



[Test results]

	Result a	Result b	Result c
Evaluation of throat thickness	Good	Good	NG

Direction	Throat thickness (Amount of gap: 0 mm)			Throat thickness (Amount of gap: 5 mm)		
	Model measurements	Actual measurements	Result	Model measurements	Actual measurements	Result
0°	19.9 mm	19 mm	Good	17.3 mm	18 mm	Good
90°	19.1 mm	19 mm	Good	15.3 mm	17 mm	NG
180°	20.0 mm	20 mm	Good	16.6 mm	17 mm	Good
270°	21.0 mm	20 mm	Good	18.2 mm	19 mm	Good



・With a throat thickness of 5 mm, the margin of error between the 3D model measurements and the actual measurements partially deviates from the decided value (within ± 1 mm).

(Cause)
It is presumed that the cause of this margin of error is that welding deformation is not taken into consideration by the 3D models before and after welding.
It is believed that the gap becomes narrower due to welding deformation. So, throat thickness before welding deformation (model measurement) tends to be smaller than that (actual measurement) after welding deformation.

(Measures) Not required
(It is difficult to estimate the extent of this welding deformation in advance and measure it from the inner surface of the pipe. However, it is believed that the gap becomes smaller due to welding deformation, and the throat thickness measurement by the 3D model is always conservative compared to the actual throat thickness, and can be used in DT.)

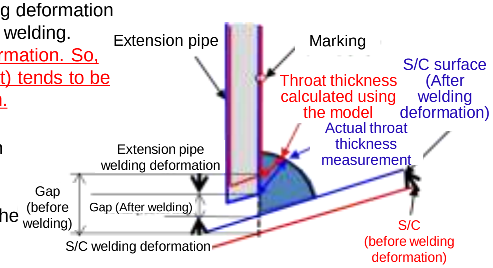


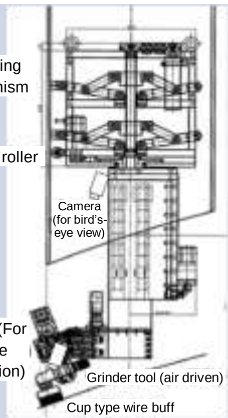
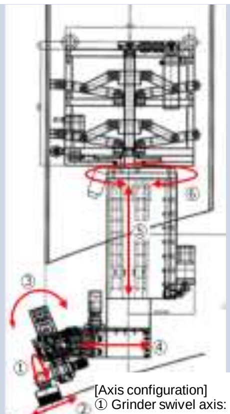
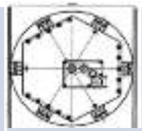
Image of throat thickness measurement using 3D scan with a gap of 5 mm

[Conclusion]
・Throat thickness can be measured by comparing 3D models before and after welding.
・With a test specimen having a gap of 5 mm, the effect of the gap becoming smaller due to welding deformation after welding cannot be taken into consideration, and the model value tends to be smaller than the actual measurement. However, as the results of throat thickness measurement are conservative, the current process will be continued.

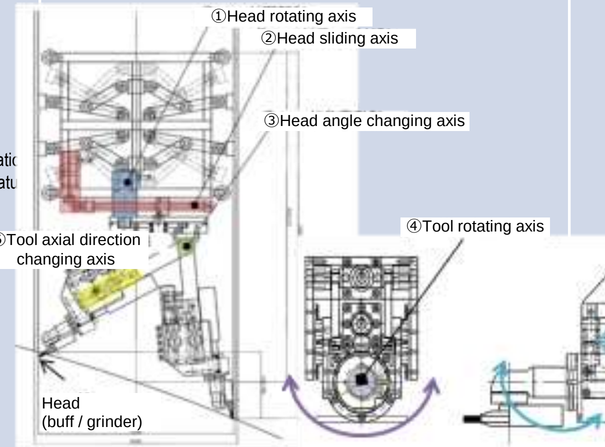
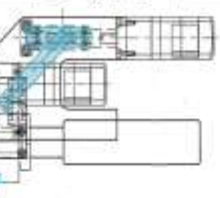
2) Development and verification of S/C surface polishing apparatus, weld bead treatment apparatus, S/C joint welding apparatus

■ Specifications of S/C surface polishing apparatus

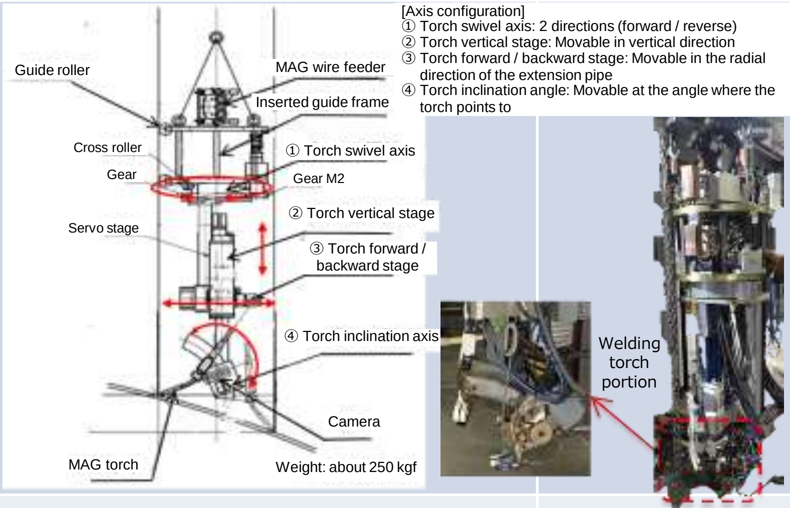
[Overview]
It is an apparatus that polishes the locations on the extension pipe and S/C surface planned to be welded by means of buffing, before welding the extension pipe (after peeling off the coating from the S/C surface) and removes the loose rust on the S/C surface.
With the S/C surface and extension pipe about 500 mm apart, the apparatus is fixed inside the inner surface of the extension pipe and used.

Items	Specifications	Remarks
Configuration of apparatus	 [Axis configuration] ① Grinder swivel axis: Swings in the rotational direction of the axis. ② Repeated forward / backward fine movement axis: Automatic forward / backward fine movement in the axial direction ③ Grinder swing axis: Swings in the radial direction. ④ Grinder forward / backward movement axis: Moves in the radial direction. ⑤ Grinder vertical movement axis: Moves vertically. ⑥ Unit swivel axis: Rotates in the circumferential direction.	 Clamping mechanism (6 locations)
Basic functions	(1) It removes the loose rust present on the S/C surface, from which the coating has been peeled off, before the installation of extension pipe. (2) The apparatus is lowered down to a predetermined location with a guide roller supporting the inner surface of the pipe and is fixed by means of the clamping mechanism. (3) The head position can be adjusted with respect to the S/C surface near the extension pipe installation location by means of the apparatus axis. (4) Using the grinder forward / backward movement axis, the grinder vertical movement axis and the unit swivel axis, the cup type wire buff is pressed against the surface to be processed and loose rust is removed. (5) The inclination can be adjusted using the grinder swivel axis and the swing of the grinder swing axis to make the buff touch the S/C surface evenly. (6) The S/C surface that is within the scope of treatment, can be observed using cameras and abnormal sounds can be checked with directional microphones.	

■ Specifications of weld bead treatment apparatus

Items	Specifications	Remarks
Configuratio of apparatu	[Axis configuration] ① Head rotating axis: 2 directions (forward / reverse) ② Head sliding axis: Extension pipe movable in the radial direction ③ Head angle changing axis: Movable angle at which the tool performs according to the S/C shape ④ Tool rotating axis: Tilts in the direction of the welding line so that the tool applies to the entire bead. ⑤ Tool angle changing axis: Rotates the tool vertically ⑥ Tool axial direction changing axis: Rotates the tool in the axial direction 	
Basic functions	(1) Slag removal and polishing with wheel type buff during and after welding* (2) Bead formation and grinding with a grinder (grinding stone) for the parts rejected in VT* (3) Chucking: The apparatus is inserted into the inner surface of the extension pipe with a guide roller and then fixed with the clamping mechanism. (4) Apparatus axis: The position of the head can be adjusted using the apparatus axis so that it comes in contact with the welded portion. (5) Control: The position aimed for can be adjusted manually. The head can be pressed with a constant force by the air cylinder. (6) Monitoring: Camera (1 or more), directional microphones ** (1 or more)	*: The head is replaced depending on the use of the apparatus such as for slag removal and polishing or bead formation and grinding. **: This functionality was added as a decision index for abnormal noise detection, execution management, etc.

■ Specifications of S/C joint welding apparatus

Item	Specifications	Remarks
Configuration of apparatus		
Basic functions	(1) Welding method: MAG (2) Control: Teaching: Wire touch, up to 30 points Welding speed / torch angle: Can be changed between teaching points (3) Chucking: Fixed to the inner surface of the extension pipe with the clamp mechanism. (4) Monitoring: Cameras (2 or more) directional microphones* (1 or more)	*: This functionality was added as a decision index for abnormal noise detection, execution management, etc.

■ Test flow

Welding element tests (preliminary tests)

- Manual — Step 1: Confirmation of welding conditions * (flat plate)
- Manual — Step 2: Confirmation of welding conditions * (cylinder)
- Simple automatic welding — Step 2.5: Confirmation of welding conditions * (flat plate)
- Simple automatic welding when S/C is fully filled with water — Confirm the impact of presence of water on the other side; Confirm the impact of water cooling and crack sensitivity

Reflect the test results appropriately in the design

- S/C joint welding apparatus, Weld bead treatment apparatus
  - Detailed design and prototype fabrication work of S/C joint welding apparatus
  - Detailed design and prototype fabrication work of weld bead treatment apparatus

Unit function tests (STEP 3)
Automatic welding using the S/C joint welding apparatus prototype

- Part 1: Adjusting the welding conditions obtained in the welding element tests (preliminary tests) — Adjusting the welding conditions obtained in the welding element tests (preliminary tests), on the prototype
- Part 2: Confirming the functions of the prototype, verifying the integrity of the welded portion — Welding confirmation tests using a combination of prototype apparatus

Full-scale test

* Welding conditions: Welding material, current, voltage, welding speed, welding direction, torch angle, stacking pattern, welding pre-treatment status, torch aiming location, wire protruding length

■ STEP1 Details and results of element tests

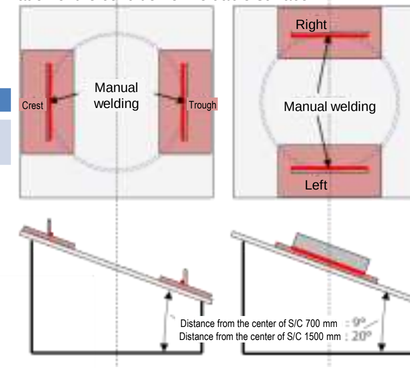
[Purpose] To confirm the following items using a manual welding test on a simple-shaped simulated test specimen made of flat plate.

- Optimal welding material
- Welding conditions (current, voltage, welding speed, welding direction, torch angle (advancing angle, receding angle), stacking pattern)
- Confirmation of the extent of polishing between passes (confirmation of the extent of slag removal through bead treatment using buff)
- Confirmation of the extent of welding pre-treatment on S/C surface (confirmation of the condition of weldable surface (extent of rusting)).

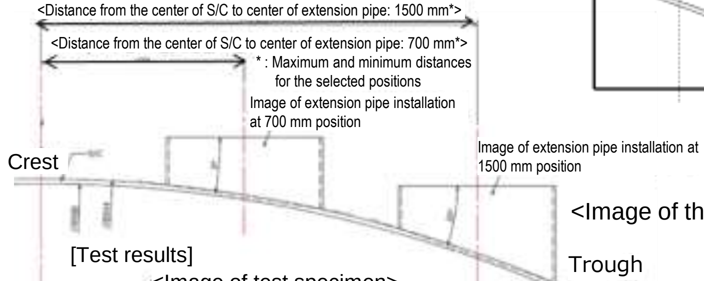
[Test details]

- Method of execution: **MAG manual welding** Fillet welding
- Welding pre-treatment: Manual wire buff

Test specimen	Shape	Thickness	Material	Gap
Simulated S/C	Flat plate	19 mm	SM490	0 mm
Simulated extension pipe	Flat plate	12 mm	SM490	



- The actual S/C inclination is simulated using the S/C angle simulation platform (flat plate) .
  The extension pipe is simulated in all the 4 directions (crest, trough, left, right) of the flat plate.
- The estimated distance from the center of S/C in the actual equipment: 700 mm, 1500 mm



<Image of the test specimen>

[Test results]

<Image of test specimen>

Items	Criteria	Results
VT	There shall be no cracks	Absence of cracks
DT	The predetermined throat thickness (10mm or more) should be met.	The predetermined values were ensured using cross-sectional macro.
(Reference confirmation) cross-sectional macro	Checking the shape of the penetration	There were gaps of 1mm or more at a few locations. (It is not a problem as DT can be performed even if the gaps are partially eliminated.)

[Results obtained from STEP 1 tests]

■ The following welding conditions were confirmed by manually welding the simple-shaped simulated test specimen.

- Method of welding: As volume inspection is not required and as there will only be the final level VT, MAG welding was selected and it was checked whether or not welding is possible.
- Welding Material: Flux cored wire generates a large amount of slag and it cannot be removed completely with a buff, so solid wire was selected.
- Basic welding conditions: Set the following general conditions and confirm that there is no problem.
  Current: nearly 250A, Voltage: about 30V, Welding speed, Welding direction: about 20 ~ 30 cm/min (up, down)
  Torch angle: 25° ~ 65° (1500 mm), 30° ~ 50° (700 mm)
- Stacking pattern: Although the design throat thickness of 10 mm was satisfied with 3 layers and 6 passes, it was decided to work with 3 layers and 8 passes in order to allow some margin.
- Extent of polishing between passes by buff: Compare wheel type and cup type buffs.
  As the anticipated welding location is in a confined space, a wheel type buff was selected considering the buff interference while polishing the bead.
- Extent of welding pre-treatment on S/C surface: It was confirmed that there is no problem with direct buffing of the black skinny (rust) surface of S/C simulated material.

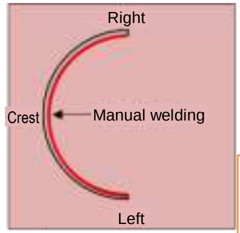
■ STEP2 Details and results of element tests

[Purpose] To confirm and verify the following items by manual welding test on actual equipment-shaped simulated test specimen based on the conditions of STEP1.
- ・Welding conditions
- ・ Confirmation of the extent of polishing between passes (confirmation of the extent of slag removal through bead treatment using buff)
- ・Confirmation of the extent of welding pre-treatment on S/C surface (confirmation of the condition of weldable surface (extent of rusting)).

[Test details]
- ・Method of execution: **MAG manual welding** Fillet welding
- ・Welding pre-treatment: Manual wire buff [Wheel type]
- ・ Number of passes: 3 layers 8 passes

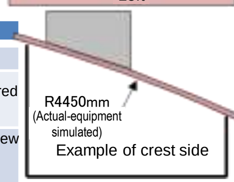
Test specimen	Shape	Thickness	Material	Gap
Simulated S/C	Saddle type	19 mm	SB450	0 mm
Simulated extension pipe	Semi-cylindrical	15.9 mm	SM490	

- ・The actual shape of S/C is simulated and half-split pipes are simulated in all the four directions (crest, trough, left, right)
- ・The estimated distance from the center of S/C in the actual equipment: 700 mm, 1500 mm



[Test results]

Items	Decision criteria	Results
VT	There shall be no cracks.	Absence of cracks
DT	The predetermined throat thickness (10 mm or more) and leg length (17 mm or more) should be met.	The predetermined values were ensured using cross-sectional macro.
(Reference confirmation) Cross-sectional macro	Checking the shape of the penetration	There were gaps of 2mm or less at a few locations. (It is not a problem as DT can be performed even if portions equivalent to the gaps are eliminated.



Example of crest side

[Results obtained from STEP 2 tests]
- It was confirmed that an actual equipment-shaped simulated test specimen can be manually welded using the conditions of STEP1.

〇1500 mm welding conditions
Current: Fixed to 270A， Welding speed: 17 ~ 26 cm/min (including upwards and downwards), Torch angle: 25° ~ 60°

〇700 mm welding conditions
Current: Fixed to 270A， Welding speed: 17 ~ 28cm/min (including upwards and downwards), Torch angle: 20° ~ 45°

■ STEP2.5 Details and results of element tests

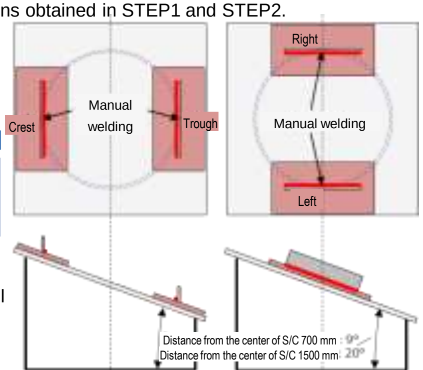
<Part 1>

[Purpose] To confirm and verify the integrity of the welded part through a simple automatic welding test on a simple-shaped simulated test specimen based on the conditions obtained in STEP1 and STEP2.

[Test details]
- ・Method of execution: **MAG simple automatic welding** Fillet welding
- ・Welding pre-treatment: Manual wire buff [Wheel type]
- ・Number of passes: 3 layers 8 passes

Test specimen	Shape	Thickness	Material	Gap
Simulated S/C	Flat plate	19 mm	SM490	0 mm
Simulated extension pipe	Flat plate	12 mm	SM490	

- ・ The actual S/C inclination is simulated using the S/C angle simulation platform (flat plate). The extension pipe of the platform (flat plate) is simulated in all the 4 directions (crest, trough, left, right).
- ・The estimated distance from the center of S/C in the actual equipment : 700 mm, 1500 mm



■ STEP2.5 Details and results of element tests (Continued...)

[Test results]

Items	Criteria	Results
VT	There shall be no cracks.	Absence of cracks
DT	The predetermined throat thickness (10 mm or more) and leg length (17 mm or more) should be met.	The predetermined values were ensured using cross-sectional macro.
(Reference confirmation) Cross-sectional macro	Checking the shape of penetration	No weld penetration defects

[Results obtained from STEP2.5 (Part 1) tests]
- It was confirmed that a simple-shaped simulated test specimen can be welded by simple automatic welding under the conditions of STEP1 and STEP2.
- It was projected that the actual equipment-shaped simulated test specimen can be welded using automatic welding.

The welding conditions for the unit function tests using a STEP 3 prototype were derived.

→ It was determined that the unit function tests can be performed using the STEP3 prototype.

Cross-sectional macro results
(E.g.) 1500 mm position (trough)

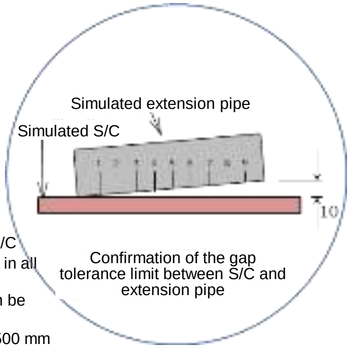
<Part 2>

[Purpose] To confirm the gap tolerance limit (The maximum gap limit with which S/C and extension pipe can be welded in 1 pass).

[Test details]
- ・Method of execution: **MAG simple automatic welding** Fillet welding
- ・Welding pre-treatment: Manual wire buff [Wheel type]
- ・Number of passes: 1 pass

Test specimen	Shape	Thickness	Material	Gap
Simulated S/C	Flat plate	19 mm	SM490	Refer to the figure
Simulated extension pipe	Flat plate	12 mm	SM490	

- ・With a preexisting gap, an actual S/C inclination is simulated using the S/C angle simulation platform (flat plate) and the extension pipe is simulated in all the four directions (crest, trough, left, right) of the flat plate.
- ・The maximum size of the gap with which the S/C and extension pipe can be welded is verified.
- ・The estimated distance from the center of S/C in the actual : 700 mm, 1500 mm



[Results obtained from STEP2.5 (Part 2) tests]
- It was confirmed that the gap tolerance limit value was 5 mm.

→ The obtained value is provided as a feedback as the allowable gap tolerance value for the positioning of S/C surface and extension pipe and is reflected in designs related to positioning accuracy.

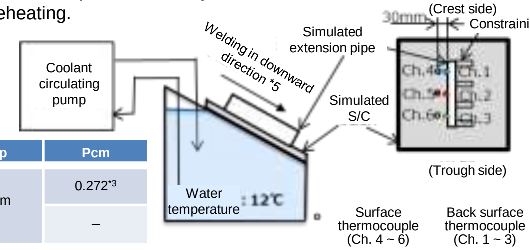
(2) Development and verification of element technology for accessing and connecting inside PCV
② Development and verification of element technology required for accessing and connecting inside S/C

■ Details and results of welding impact confirmation test with water on the other side

[Purpose]To confirm the impact of completely water filled state of S/C, due to the welding of extension pipe under STEP 2.5 (without water) conditions. As preheating is extremely difficult under on-site conditions such as high dose, confined spaces and remote operations, the goal is to confirm the welding conditions that can be executed without preheating.

[Test details]
- Method of execution: **MAG simple automatic welding**
  Fillet welding
- Welding pre-treatment: Manual wire buff
- Number of passes: 1 pass *1

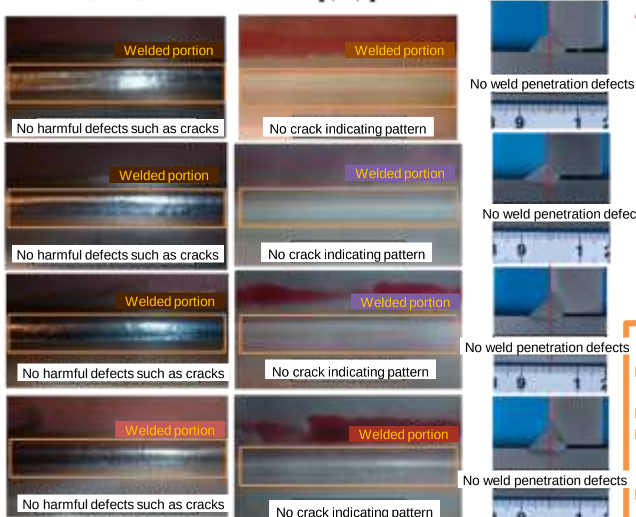
Test specimen	Shape	Thickness	Material	Gap	Pcm
Simulated S/C	Flat plate	17 mm	SB450	2 mm *2	0.272*3
Simulated extension pipe	Flat plate	12 mm	SM490		–



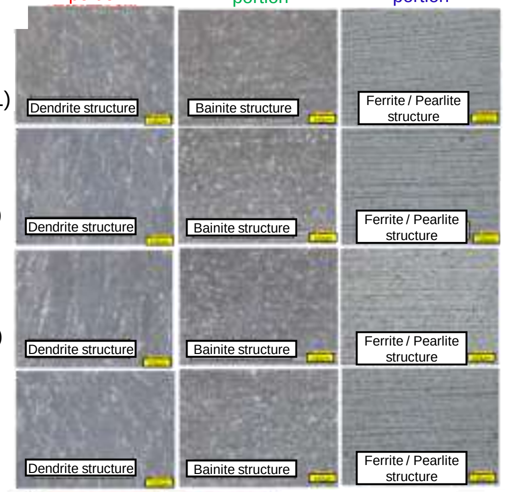
- Water temperature: 12 ℃*4
- Conditions such as current, welding speed: Conditions confirmed in the STEP2.5 element tests
- Filled with water (3 cases), no water (1 case)
- Actual S/C inclination is simulated using the S/C angle simulation platform (flat plate), and the flat plate is put up and welding is carried out. (Implemented by focusing on cases with conservative welding conditions)

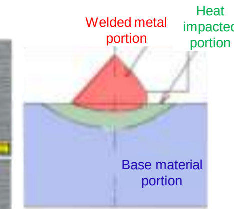
*1: Single pass is not expected to have a reheating effect compared to multi-layer filling, and it becomes hard and easily cracks at low temperature.
*2: Considering stress concentration at the root: JIS Z 3158 Y-groove weld cracking test method
*3: Use a plate (Pcm: 0.272) that covers the pcm (weld crack susceptibility composition) of actual S/C mill sheets in 1F – 1/3 , which are likely to get filled with water.
*4: Use the lowest value from among the actual measurements (Jan 1, 2019 ~ May 8, 2019) at the 1F – 1~3 sites
*5: In the downwards direction, the welding speed is faster than other welding directions and heat input is low, also, it is difficult for heat to enter the base material due to dripping from the pool.
*6: The slope is larger when compared with 700 mm, and the effect of the molten pool dripping during downward welding is large.

[Test results] 【VT】 【PT】 [Cross-sectional macro]



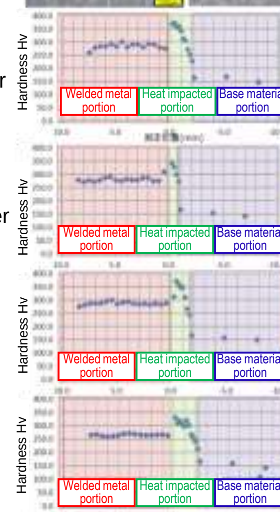
[Cross-sectional micro]



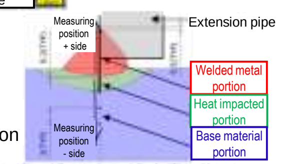


- There is no difference in the structure in all the regions
- The microstructures in the heat impacted region of the specimen full of water were bainite structures and were same as those in the specimen with no water. It does not become martensitic, which is generally seen during quenching, and the impact of water cooling is low.

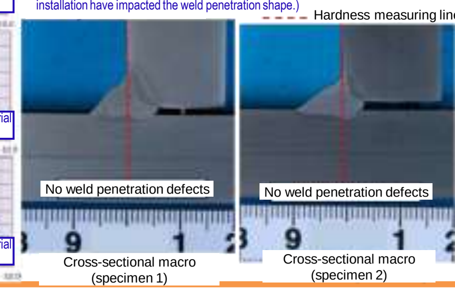
[Hardness measurement]



Hardness measuring position



- Although there is slight difference in hardness when full of water, the difference is not significant.
- It is believed that the difference in the tendency of specimen 1 (filled with water), and specimen 2 (filled with water) & specimen 3 (filled with water) is due to the difference in the penetration shape.
  (It is presumed that the variations in execution and the margin of error in apparatus installation have impacted the weld penetration shape.)



Cross-sectional macro (specimen 1) Cross-sectional macro (specimen 2)

[Results obtained from welding impact confirmation test with water on the other side]

- When the specimen was full of water, under the welding conditions of STEP 2.5 tests (no water state) it was confirmed that there were no cracks or weld penetration defects in the welded portion.
- Slight difference in hardness was seen during the hardness test with the specimen full of water, but the difference was not significant.
- The microstructures in the heat impacted region of the specimen full of water were bainite structures and were same as those in the specimen with no water. It is presumed that it does not become martensitic, which is generally seen during quenching, the impact of water cooling is low, and low temperature cracking does not occur when the specimen is full of water.
- → It was projected that welding is possible when S/C is filled with water under the same conditions as when there is no water in it.

■ Details and results of STEP3 unit function tests (related to welding apparatus and bead processing apparatus)

<Part 1>

[Purpose] To adjust the welding conditions obtained from the welding element test (preliminary test).
The welding conditions obtained from the preliminary tests conducted using simulated test specimens of actual equipment-shaped extension pipe and the S/C, are adjusted to be used in the prototype of S/C joint welding apparatus.

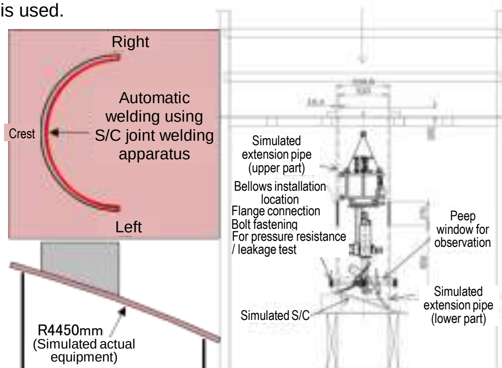
[Test details]

Test specimen	Shape	Thickness	Material	Gap
Simulated S/C	Saddle type	19 mm	SM490	5mm
Simulated extension pipe	Semi-cylindrical	15.9 mm	SM490	

- Method of execution: **MAG automatic welding** Fillet welding
  S/C joint welding apparatus (developed product) is used.
- Welding pre-treatment: Manual wire buff [Wheel type]
- Number of passes: 3 layers 8 passes
- Actual equipment-shaped S/C is simulated.

Half-split pipes are simulated in all the four directions (crest, trough, left, right).
- The estimated distance from the center of S/C in the actual equipment : 700 mm, 1500 mm
- Internal radius of simulated S/C: 4450 mm (equivalent to 1F-3)
- Distance from the flooring of R/B 1st floor to S/C: Not simulated

(A test to confirm the distance equivalent to 1F-3 to be conducted in the full-scale test)
- Environment (brightness / temperature / humidity): Not simulated
- The welding conditions* are adjusted as needed.
  *: Welding speed, torch angle, torch aimed position, conditional switching position (teaching position)



<Test specimen>

[Test results]

<Distance from center of S/C: 1500 mm>

<Distance from center of S/C: 700 mm>

- VT: There were no harmful defects such as cracks or undercuts, overlaps, craters, slag entanglements, pits in the final layer.
- DT: The conditions such as “throat thickness of 10 mm or more, leg length of 17 mm or more” were satisfied for the test specimens in all four directions.

- Cross-sectional macro: Although fusion defects due to weld penetration shape were noticed in the cross-sectional monitoring in the four directions, since the DT criteria is met even if the said parts are excluded, there is no problem.

<For 1500 mm> ① Fusion defects were seen on the left side (270°) of the 6th pass.

- Probable cause
  It has occurred while welding in the downward direction. It is presumed that, while welding in the downward direction, the molten pool has dripped and advanced in the welding direction ahead of the arc, which increased the distance from the surface of the molten metal to the base metal, because of which sufficient heat was not transferred to the base metal, resulting in fusion defects.
- Measures : Not required
  (Fusion defects can be eliminated by further increasing the welding speed during downward welding, reducing the amount of welding, and reducing the dripping of the molten pool. However, no measures are considered necessary as the DT criteria is satisfied even if the said parts are excluded.)

<For 700 mm> ① Fusion defects were seen on the crest side (0°) of the 6th pass.

- Probable cause
  It has occurred at the location where welding was started. It is presumed that at the location where MAG welding was started, the arc was not stable and heat concentration became difficult causing fusion defects. In addition, it is presumed that fusion defects occurred as the arc scattered outside the shielding gas range.
- Measures : Not required (Same as for 1500 mm)

■ Welding conditions obtained in STEP3 (Part 1) (1500 mm position)

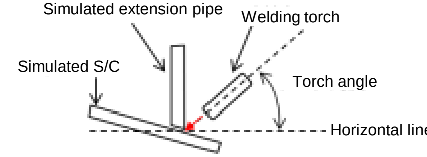
Method of execution: GMAW automatic welding Fillet welding
Treatment of welded portion: Wire buff (Wheel type)
Number of passes: 3 layers 8 passes

Target	Number of layers	Number of passes	Welding direction *1	Welding speed (cm / min)	Torch angle (°) *2	Torch aimed position *3 Aiming reference	X
山	1	1	-	25	45	1	0
	2	2	-	25	45	2	0
	2	3	-	25	45	3	0
	2	4	-	25	45	4	0
	3	5	-	25	45	5	0
	3	6	-	25	45	6	0
	3	7	-	25	45	7	0
	3	8	-	25	45	8	0
右	1	1	Downwards	30	60	1	0
	2	2	Upwards	20	60	2	0
	2	3	Downwards	30	60	3	0
	2	4	Upwards	20	45	4	0
	3	5	Downwards	30	60	5	0
	3	6	Upwards	20	50	6	0
	3	7	Downwards	30	60	7	0
	3	8	Upwards	20	45	8	0
谷	1	1	-	25	60	1	0
	2	2	-	25	60	2	3
	2	3	-	25	60	3	0
	2	4	-	25	50	4	0
	3	5	-	25	60	5	0
	3	6	-	25	60	6	0
	3	7	-	25	60	7	0
	3	8	-	25	45	8	0
左	1	1	上進	20	45	1	0
	2	2	下進	30	45	2	0
	2	3	上進	20	45	3	0
	2	4	下進	30	55	4	0
	3	5	上進	20	60	5	0
	3	6	下進	30	60	6	0
	3	7	上進	20	45	7	0
	3	8	下進	30	45	8	0

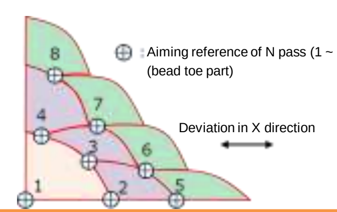
Text in red indicates the changes from STEP2.5 conditions.

Welding current: 270 A (fixed value), with pulse
Wire protrusion length: 15 mm
Welding speed [Refer to table on the left]: 20 cm/min ～30 cm/min
Torch angle [Refer to table on the left]: 45°～60°
Torch aimed position: Refer to image below

*1: Welding is repeated in forward and reverse direction for each pass.
*2: Torch angle indicates the angle between the welding aimed position of the welding torch and the horizontal line.



*3: Torch aimed position indicates the deviation from the aiming reference in the X direction.



[Results obtained from STEP3 (part 1) tests]
As a result of applying the STEP2.5 conditions, the spread of the bead was confirmed.
Therefore, with the purpose of improving the stability and reproducibility of the bead shape, STEP3 (part 1) was implemented by adding “torch angle” and partially modifying the “torch aimed position” in STEP2.5.

② Development and verification of element technology required for accessing and connecting inside S/C <Part 2>

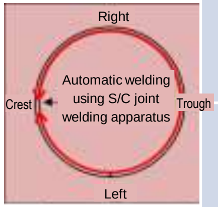
[Purpose] To confirm the functionality of the apparatus and verify the soundness of the welded portion.

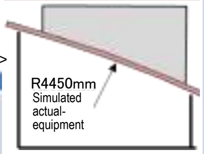
- The functionality of the apparatus is confirmed and the required joint performance is verified through a series of operations from apparatus installation / removal ~ welding work ~ up to bead treatment under conditions similar to the actual equipment by combining the prototypes of S/C joint welding apparatus and weld bead treatment apparatus, and it is reflected in the full-scale test procedure.
- The issues with the apparatus functionality are confirmed and the assumed risks are evaluated, and the issues in the apparatus for full-scale test are identified (to be corrected before the start of the test to the extent possible).

	Shape	Thickness	Material	Gap
Simulated S/C	Saddle type	19 mm	SM490	0 mm, 5 mm
Simulated extension pipe	Pipe	19.4 mm	SM490	

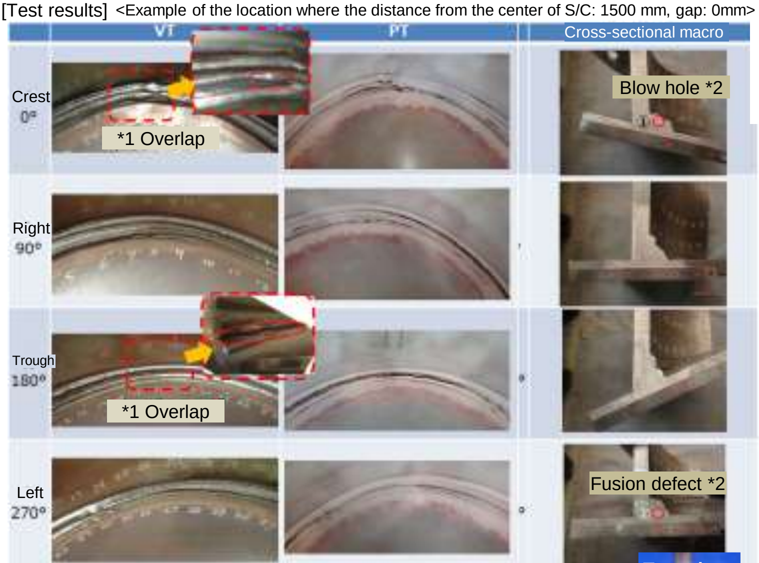
[Test details]

- Method of execution: **MAG automatic welding** Fillet welding
  S/C joint welding apparatus(developed product) is used.
- Treatment of welded portion: Wire buff (Wheel type)
  Weld bead treatment apparatus (developed product) is used.
- Number of passes: 3 layers 8 passes
- Simulated specimens of actual-equipment shaped S/C and pipe shaped extension pipe are created.
- The estimated distance from the center of S/C in the actual equipment:700 mm, 1500 mm
- Internal radius of simulated S/C: 4450 mm (Equivalent to 1F-3)
- Distance from the flooring of R/B 1st floor to S/C: Not simulated
  (A test to confirm the distance equivalent to 1F-3 to be conducted in the full-scale test)
- Environment (brightness / temperature / humidity): Not simulated
- The process of welding with S/C joint welding apparatus and then polishing the welded parts with bead treatment apparatus, is repeated.





[Test results] <Example of the location where the distance from the center of S/C: 1500 mm, gap: 0mm>



Joint tensile test		Tensile strength of base metal (N/mm²)	Width of test piece (mm)	Throat thickness (mm)	Tensile load (kN)	Tensile strength (N/mm²)	Efficiency of the joint
Crest	0°	547	33.6	19	189.8	297	0.54
Right	90°		33.1	19	176.0	280	0.51
Trough	180°		33.6	20	190.0	283	0.51
Left	270°		33.6	20	165.9	247	0.45

Here, σTJ: Tensile strength of joint = breaking load in tensile test / throat cross section (throat thickness*4 x width of test piece), σTB: Tensile strength of base metal = Tensile strength of base metal of test piece (mill sheet)

■ List of STEP3 (part 2) test results (Decision results) ○: Yes, ×: No

Distance from the center of S/C	Gap	Direction	VT	PT	DT	Cross-sectional macro	Joint tensile test	Pressure resistance test	Leakage test
1500 mm	0 mm	0°	○	○	○	Blow hole	–	–	–
		90°	×*1	○	○	No defects			
		180°	×*1	○	○	No defects			
		270°	○	○	○	Fusion defects			
	5 mm	0°	○	○	○	No defects	○	○	○
		90°	○	○	○	Fusion defects			
		180°	○	○	○	No defects			
		270°	○	○	○	fusion defects			
700 mm	0 mm	0°	○	○	○	Blow hole	–	–	–
		90°	○	○	○	No defects			
		180°	○	○	○	No defects			
		270°	○	○	○	No defects			
	5 mm	0°	○	○	○		○	–	–
		90°	○	○	○	No defects			
		180°	○	○	○	No defects			
		270°	○	○	○	No defects			

*1: Presence of harmful defect (no cracks, undercuts, craters, slag entanglements, pits) due to overlap at 0° and 180° on the 7th pass found during VT.

- Probable cause for overlap: It is presumed that the cause was that during the upward welding of the 1st, 3rd, 5th, and 7th passes in the clock-wise direction, the torch cable must have come in contact with the extension pipe and bent, because of which the wire must have bent upwards during welding and must have deviated from the aimed position during teaching.
- Measures: ・Improvement of cable management methods such as storing the torch cable inside the apparatus.
  ・Resetting the criteria for pass / fail of VT (E.g. Determined in combination with DT) (Leave it as an issue to be dealt by Engineering)

*2: Although blow holes and fusion defects were seen in the cross-sectional macro, since the DT criteria is met even if the said parts are excluded, there is no problem.

- Probable cause for blow hole: It has occurred at the location where welding was started. It is presumed that the arc was not stable at the location where MAG welding was started, got scattered outside the shielding gas range resulting in the generation of blow hole.
- Measures: Not Required (Considering the characteristics of MAG, blow hole is presumed to have occurred due to the disorder of the arc at the location where the welding was started. So, this can be solved by scraping the weld metal at the location where welding is started and starting the next pass from another location. However, as DT criteria is met even if the said parts are excluded, no measures are required.) The causes and countermeasures for fusion defects are the same as those for STEP (part 1) test.

<Criteria>

- VT: There shall be no harmful defects such as cracks or undercuts, overlaps, craters, slag entanglements, pits in the final layer.
- PT: Absence of cracks in the final layer
- DT: "Throat thickness of 10 mm or more, leg length of 17 mm or more" should be satisfied based on the cross-sectional macro for all four directions.
- Cross-sectional macro: The shape of the penetration should be checked through cross-sectional macro for all four directions.
- Pressure resistance test: Should withstand the test pressure of 110 kPa or more and should not get deformed excessively for 10 minutes or more.
- Leakage test: The test pressure should be 90 kPa or more and the pressure drop after 60 minutes should be 5 kPa or less.
- Joint tensile test *3: In addition to the strength of the welded joint, the joint efficiency of 0.35 should be satisfied.

*3: The actual value of joint efficiency is calculated based on the load-displacement curve from the tensile test and actual throat thickness measurement value: Joint efficiency η＝σTJ / σTB

* 4 Throat thickness is the average value of the measured values of two cross sections of the test specimen.

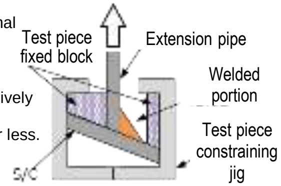


Image on joint tensile test

② Development and verification of element technology required for accessing and connecting inside S/C

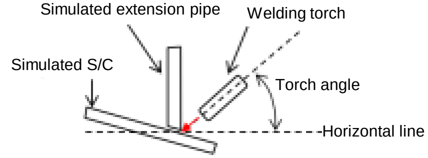
■ Following are the welding conditions applied in the full-scale test (distance from the center of S/C: 1500 mm) based on the STEP3 (part 1) test results.

Method of execution: GMAW automatic welding　Fillet welding
Treatment of welded portion: Wire buff (Wheel type)
Number of passes: 3 layers 8 passes

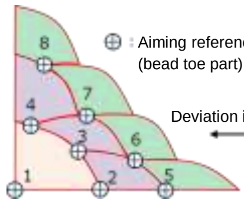
Welding current: 270 A (fixed value), with pulse
Wire protrusion length: 15 mm
Welding speed [Refer to table on the left]: 20 cm/min～30 cm/min
Torch angle [Refer to table on the left]: 45°～60°
Torch aimed position: Refer to image below

Target	Number of layers	Number of passes	Welding direction *1	Welding speed (cm / min)	Torch angle (°) *2	Torch aimed position *3	
						Aiming reference	X
Crest	1	1	-	25	45	1	0
	2	2	-	25	45	2	0
	2	3	-	25	45	3	0
	2	4	-	25	45	4	0
	3	5	-	25	45	5	0
	3	6	-	25	45	6	0
	3	7	-	25	45	7	0
	3	8	-	25	45	8	0
Right	1	1	Downwards	30	45	1	0
	2	2	Upwards	20	45	2	0
	2	3	Downwards	30	45	3	0
	2	4	Upwards	20	45	4	0
	3	5	Downwards	30	45	5	0
	3	6	Upwards	20	45	6	0
	3	7	Downwards	30	45	7	0
	3	8	Upwards	20	45	8	0
Trough	1	1	-	25	60	1	0
	2	2	-	25	60	2	0
	2	3	-	25	60	3	0
	2	4	-	25	45	4	0
	3	5	-	25	60	5	0
	3	6	-	25	60	6	0
	3	7	-	25	60	7	0
	3	8	-	25	45	8	0
Left	1	1	Upwards	20	45	1	0
	2	2	Downwards	30	45	2	0
	2	3	Upwards	20	45	3	0
	2	4	Downwards	30	45	4	0
	3	5	Upwards	20	45	5	0
	3	6	Downwards	30	45	6	0
	3	7	Upwards	20	45	7	0
	3	8	Downwards	30	45	8	0

*1: Welding is repeated in forward and reverse direction for each pass.
*2: Torch angle indicates the angle between the welding aimed position of the welding torch and the horizontal line



*3: Torch aimed position indicates the deviation from the aiming reference in the X direction.



Text in red indicates the changes from STEP3 (part 1) conditions.

■ Teaching position: Set a total of 24 teaching points (TP) for every 15°.


Camera image during teaching

・Manually remote control the welding torch using the camera screen on the welding device to match the welding aiming reference.
・Record the matching points on the device as teaching points.

[Results obtained from STEP3 (part 2) tests]
・The welding conditions for full-scale tests were set
・As a result of applying the STEP3 (part 1) conditions, the bead easily tends to become convex if the torch angle is set too high during upward / downward (right / left) movement under the 1500 mm condition. So, STEP3 (part 2) conditions were formed by changing the "torch angle" to be based on 45°, and partially changing the "torch aiming position" in STEP3 (part 1).

■ Details and results of STEP3 unit function tests (related to bead treatment apparatus)

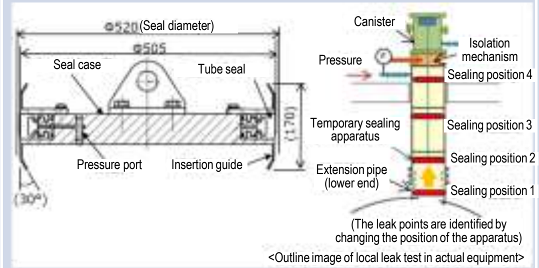
■ Weld bead formation using grinder on the parts rejected in VT

・Welding beads can be ground with a grinder, but the method for adjusting the shape of the weld beads cannot be established.

<Probable cause>
・The thickness of the grindstone is as thin as about 3 mm and it comes in contact with the weld bead only in the form of a line, thus making the adjustment of weld bead shape difficult.
<Measures>
・Change to a grindstone shape so that the entire plane can come in contact with the weld bead (leave it as an issue to be dealt by Engineering).

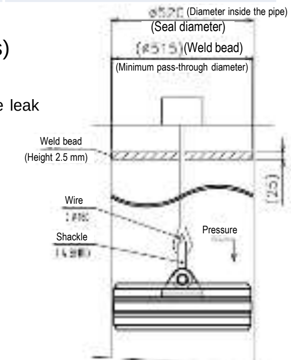
3) Development and verification of temporary sealing apparatus

■ Specifications of temporary sealing apparatus

Item	Specifications	Remarks
Configuration of apparatus		While in service, the pressure inside the extension pipe is monitored to check for leak occurrence tendency, and if a leak is suspected, the water intake operation is stopped, the intake facilities are recovered and then this apparatus is used for inspecting the extension pipe for leakage.
Basic functions	As level 2 inspection inside the extension pipe (intake part of S/C), the lower end of the extension pipe is closed with the temporary sealing apparatus and a local leak test (including the temporary storage container) of the S/C intake part is performed. If a leak is confirmed, leak location is identified by moving this apparatus step by step and narrowing down the pressurization range.	

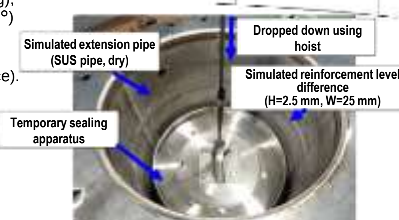
■ Element test of temporary sealing apparatus (details and results)

[Purpose]
To verify the following items pertaining to the temporary sealing apparatus used for the leak test in this element test.
(a) Dropping property of temporary sealing apparatus
(b) Sealing property under normal installation conditions
(Reference test) Sealing property during occurrence of mispositioning



(a) Test for confirming the dropping property of temporary sealing apparatus

[Test details]
✓ Test method: Temporary sealing apparatus is dropped down by a hoist and is made to pass through the simulated welding reinforcement level difference in the joint welded part of the simulated extension pipe.
✓ Test parameter: piping material (SUS steel, carbon steel with coating), presence of surface condensation, inclination of extension pipe (0, 1°)
✓ Testing conditions: Testing temperature -> room temperature
✓ Criteria: Able to move up and down smoothly inside the simulated extension pipe by only operating the hoist (without manual assistance).



[Test results]

No.	Test cases		Result
1	SUS pipe, absence of condensation	Inclination of extension pipe 0°	Good
2	SUS pipe, presence of condensation		Good
3	Carbon steel pipe (presence of coating), absence of condensation		Good
4	Carbon steel pipe (presence of coating), presence of condensation		Good
5	SUS pipe, absence of condensation	Inclination of extension pipe 1°	Good
6	SUS pipe, presence of condensation		Good
7	Carbon steel pipe (presence of coating), absence of condensation		Good
8	Carbon steel pipe (presence of coating), presence of condensation		Good

[Results obtained from this test]
Each of the factors (SUS / carbon steel, with or without coating, with or without condensation, inclination of extension pipe of about 1°) have very low impact on the dropping property of the apparatus.

(b) Test for confirming sealing property under normal installation conditions

[Test details]

✓ Testing method
- i) The temporary sealing apparatus is dropped down using a hoist.
- ii) The tube seal of the temporary sealing apparatus is pressurized to 0.10 to 0.15 MPaG. After pressurizing the tube seal, the valve (V4) on the pressurizing line is closed.
- iii) The inside of the extension pipe below the temporary sealing apparatus is depressurized to -10 kPaG.
- iv) After closing the depressurizing line valve (V1), the pressure and temperature history is recorded for 60 minutes.

✓ Test parameter: piping material (SUS steel, carbon steel with coating), presence of surface condensation

✓ Testing conditions: Test medium ->air, test temperature -> room temperature

✓ Criteria a. Structural stability: There shall be no significant mispositioning of temporary sealing apparatus during depressurization

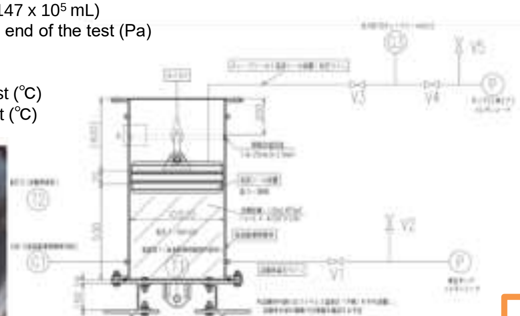
b. Sealing property: Leakage rate shall be 0.5 vol%/h or less (Note 1)

(Note 1) Leakage rate is calculated using the following formula by the method of "Calculation of leakage rate by atmospheric pressure comparison method" explained in JIS Z 4820 "Glove box sealing testing method". During the test, the temperature and atmospheric pressure (1.013×10^5Pa) are assumed to be constant.

Leakage amount: $Q = Ve \times (\Delta P / 1.013 \times 10^5) \times (3600/t)$ [mL/h]

Leakage rate: $q = (Q/Ve) \times 100$ [vol%/ h]

Here, Q : Leakage amount (mL/ h)
Ve: Equivalent internal capacity ($=1.147 \times 10^5$ mL)
ΔP: Pressure change at the start and end of the test (Pa)
t: Inspection time (sec)
q: Leakage rate (vol%/ h)
T_1: Temperature at the start of the test (℃)
T_2: Temperature at the end of the test (℃)



Leakage test status

[Test results]

No.	Test cases: Pipe material, presence of condensation	Inclination of the apparatus	a. Result	P1 at test start time [kPa]	P2 at test end time [kPa]	Pressure change at the end of the test ΔP [kPa]	T1 at test start time [℃]	T2 at test start time [℃]	Pressure change at the end of the test ΔT [K]	Leakage amount Q [ml/h]	Leakage rate q [vol%/h]	b. Result
1	SUS pipe, absence of condensation	About 0°	Good	-10.30	-10.00	0.30	12.0	13.0	1.0	339.7	0.296	Good
2	SUS pipe, presence of condensation		Good	-10.15	-9.90	0.25	15.5	16.3	0.8	283.1	0.247	Good
3	Carbon steel pipe (with coating), absence of condensation		Good	-10.25	-10.00	0.25	16.3	17.4	1.1	283.1	0.247	Good
4	Carbon steel pipe (with coating), presence of condensation		Good	-10.20	-10.10	0.10	17.6	18.4	0.8	113.2	0.099	Good

[Results obtained from this test]
In the sealing property confirmation test of the temporary sealing apparatus in its normal installation state (about 0°), there was no significant displacement of the temporary sealing apparatus in any of the cases due to decompression inside the extension pipe, and the leakage rate was 0.5 vol%/h or lower.
It was confirmed that sufficient structural stability and sealing property can be exhibited.

(Reference test) Test for confirming sealing property when there is rotational deviation

[Test details]

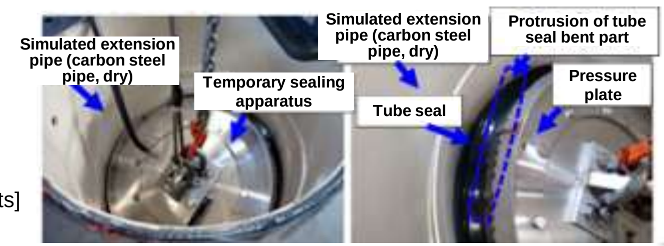
✓ Testing method
- i) The temporary sealing apparatus is dropped down by a hoist, it is held at an angle of about 15° with respect to the horizontal level, and the inclination of the temporary sealing apparatus from the horizontal level is measured by a digital spirit level.
- ii) The state said in i) is maintained and the tube seal of the temporary sealing apparatus is pressurized to 0.10 to 0.15 MPaG. After pressurizing the tube seal, the valve (V4) of the pressurizing line is closed and the inclination of the temporary sealing apparatus is measured again.
- iii) The inside of the extension pipe below the temporary sealing apparatus is depressurized to -10 kPaG.
- iv) After closing the depressurizing line valve (V1), the pressure and temperature history is recorded for 60 minutes.

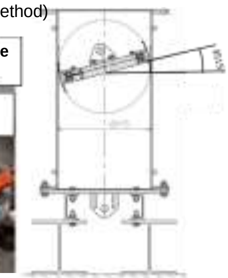
✓ Test parameter: ･Pipe material (SUS steel, carbon steel with coating), presence of surface condensation

✓ Testing conditions: Test medium ->air, test temperature -> room temperature

✓ Criteria (for reference) a. Structural stability: Confirmation for occurrence of significant mispositioning of temporary sealing apparatus during depressurization.

b. Sealing property: Calculation of leakage rate (Refer to test (b) Note 1 for calculation method)

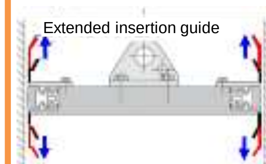




[Test results]

No.	Test cases: Pipe material, Presence or absence of condensation	Inclination of the apparatus	a. Result	P1 at test start time [kPa]	P2 at test end time [kPa]	Pressure change at the end of the test ΔP [kPa]	T1 at test start time [℃]	T2 at test start time [℃]	Pressure change at the end of the test ΔT [K]	Leakage amount Q [ml/h]	Leakage rate q [vol%/h]	b. Result
1	SUS pipe, absence of condensation	About 14.7°	Good	-10.20	-9.90	0.30	13.3	14.3	1.0	339.7	0.296	Good
2	SUS pipe, presence of condensation	About 14.8°	Good	-10.20	-10.00	0.20	16.4	17.0	0.6	226.5	0.197	Good
3	Carbon steel pipe (with coating), absence of condensation	About 4.7°	Good	-10.30	-10.20	0.10	17.6	18.1	0.5	113.2	0.099	Good
4	Carbon steel pipe (with coating), presence of condensation	About 2.4°	Good	-10.25	-10.20	0.05	18.3	18.6	0.3	56.6	0.049	Good

[Results obtained from this test]
When installed with a large rotational deviation, there was no significant difference in leakage performance in SUS pipes when compared to the normal installation state.
In carbon steel pipe with coating, when the tube seal is pressurized, the entire temporary seal slides and rotates greatly in the vertical direction, making sealing impossible.
→ For the actual equipment, it is desirable to take measures to prevent the rotation of the apparatus in consideration of the installation state with rotational deviation.
E.g.) Providing a rotation control mechanism in which the insertion guide in the temporary sealing apparatus is extended.

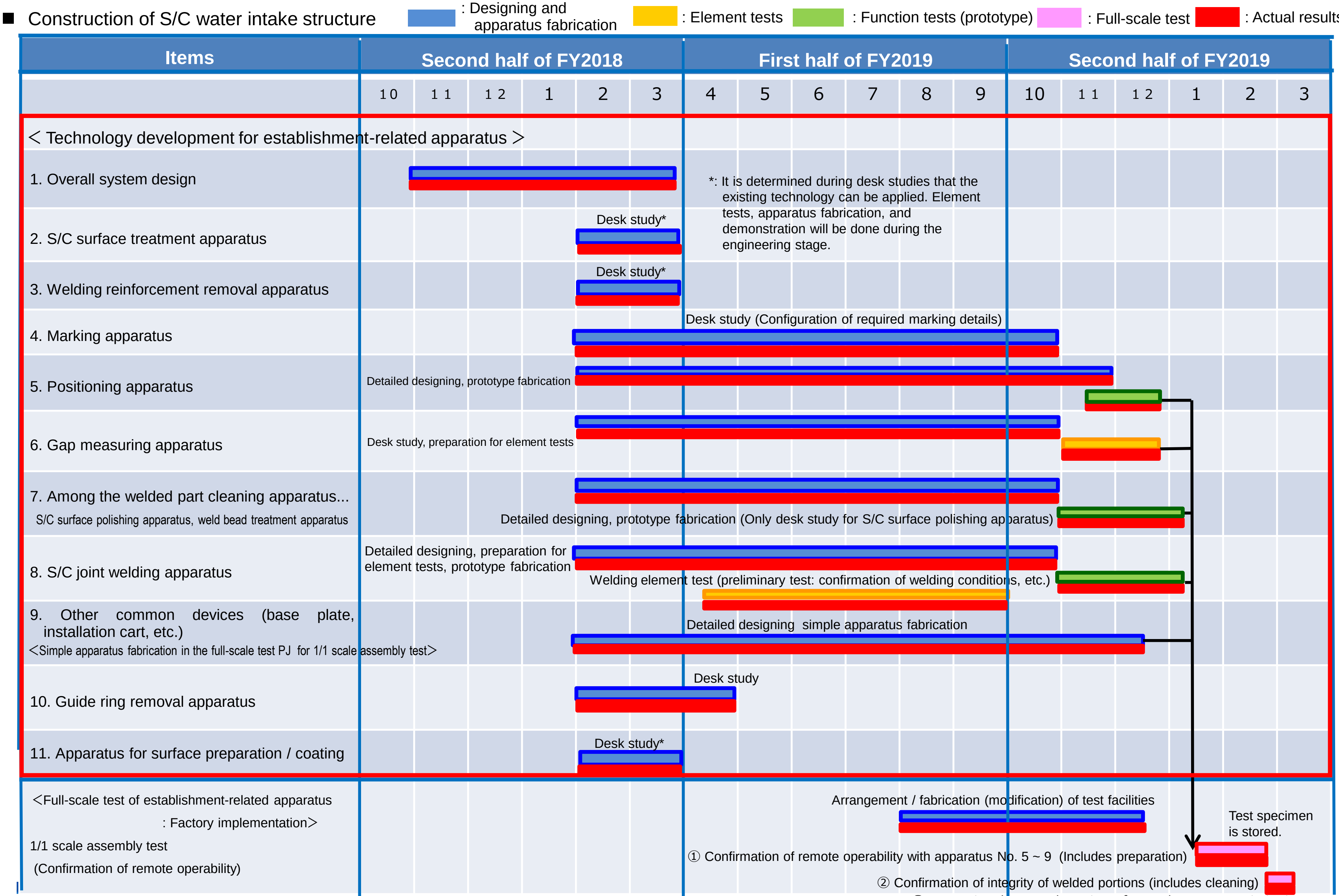


[Summary of the development of element technology required for accessing and connecting inside S/C]

- The specifications of each apparatus were clarified.
- The satisfaction of passing criteria of element tests and unit function tests of each apparatus was confirmed (tests are still in progress).
- The issues and solution policies were clearly specified (shown in 7.(2)).

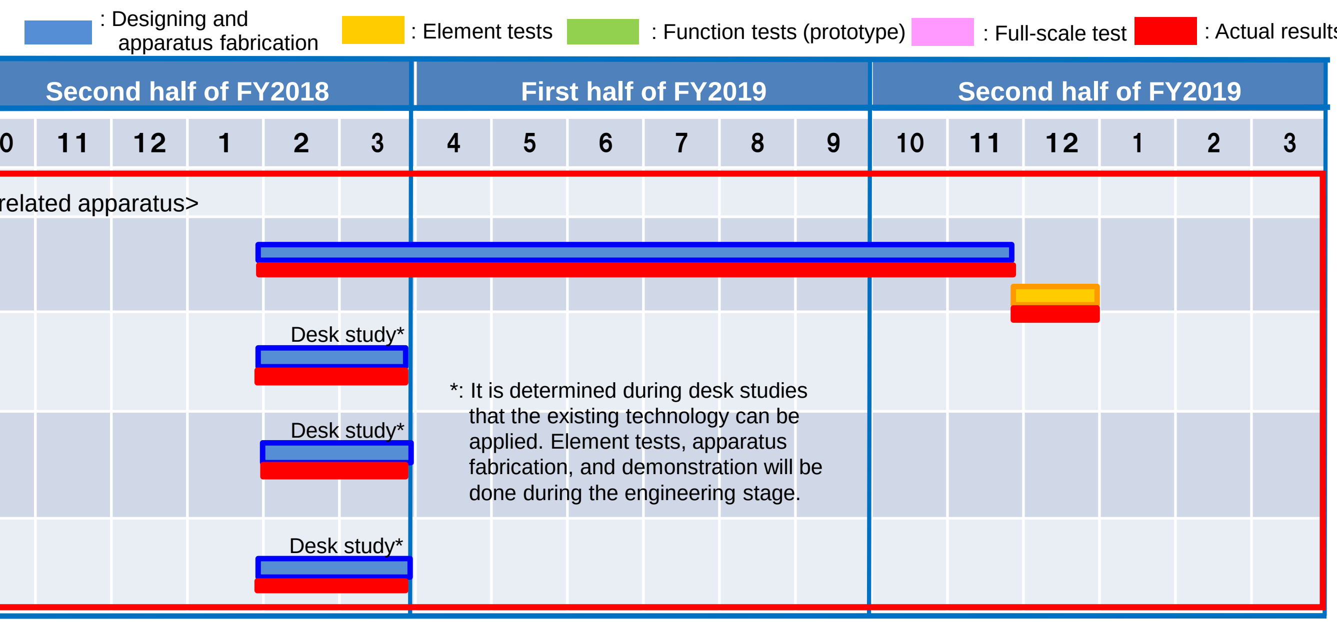
(2) Development and verification of element technology for accessing and connecting inside PCV
② Development and verification of element technology required for accessing and connecting inside S/C
4) Schedule for the development of technology for establishment of S/C water intake part

■ Construction of S/C water intake structure



4) Schedule for the development of technology for establishment of S/C water intake part

■ Inspection / repair of S/C water intake structure



7. Overall summary

(1) Level of achievement of initial target

① D/W water intake part (Target TRL at completion: Level 4)

② S/C water intake part (Target TRL at completion: Level 4)

(2) Issues and response policies

① D/W water intake part

② S/C water intake part

(1) Level of achievement of initial target

① D/W water intake part (Target TRL at completion: Level 4)

Criteria for determining goal achievement	Completed items Main issues	Achieved TRL level (Self evaluation)
Element tests pertaining to the technology for remotely operating the connection parts should be completed at the factory and the acceptance criteria of the element tests should be met. Or else, the issues to be resolved and the resolution policy should be clearly specified.	Element tests were conducted for the suspension and installation of the pump to the bottom of the D/W (pump pit), connection of pipes (hose), and the recovery of the pump for pump replacement through remote operations, and a feasible outlook was obtained. The main issues are summarized below. ・Monitoring method during operations (Camera, lighting arrangement, etc.) ・Hose feeding and lashing method ・Method of fixing the pipe to the utility stand ・Mispositioning between pipes ・Cable treatment* for various apparatus	4 (*3)

*: Has not reached the target TRL level

(1) Level of achievement of initial target

② S/C water intake part (Target TRL at completion: Level 4)

Criteria for determining goal achievement	Completed items Main issues	Achieved TRL level (Self evaluation)
Element tests pertaining to the technology for remotely operating the connection parts should be completed at the factory and the acceptance criteria of the element tests should be met. Or else, the issues to be resolved and the resolution policy should be clearly specified.	＜Gap measuring apparatus＞ ・The following passing criteria were met in the element test using only the hand-held scanner, which is the main component of the gap measuring apparatus. (*: partially not achieved) - The margin of error between the gap value measured using hand-held scanner and the actual measurement was ±1 mm or less.* (*Parts of S/C, extension pipe where data is missing) : In the case of a rotary scan using a manual or rotary jig - It is possible to confirm the markings with the 3D model obtained from the scan data. - The margin of error between the throat thickness value obtained by means of the 3D model obtained from the scan data before and after welding and the actual throat thickness measured by means of cross-sectional macro-observation was ± 1 mm or less* (* The values obtained from the model are more conservative than the actual measurement, and hence the current process will be continued.) ・The issues that must be resolved and the resolution policies were identified.	4 (*3)
	<Positioning apparatus> ・The following passing criteria were met in the unit function test of positioning apparatus. - The gap with the extension pipe can be adjusted to 5 mm or less. (Fine adjustments can be done by visually checking the image from monitoring tool camera mounted in 4 directions.)	4

(1) Level of achievement of initial target

② S/C water intake part (Target TRL at completion: Level 4)

Criteria for determining goal achievement	Completed items Main issues	Achieved TRL level (Self evaluation)
Element tests pertaining to the technology for remotely operating the connection parts should be completed at the factory and the acceptance criteria of the element tests should be met. Or else, the issues to be resolved and the resolution policy should be clearly specified. (Continued...)	＜S/C joint welding apparatus and bead treatment apparatus＞ ・The following passing criteria were met in a series of remotely operated unit function tests. (*: Partially not achieved) - Final level VT: There were no harmful defects* such as cracks or undercuts, overlaps, craters, slag entanglements, pits (*Presence of some overlaps) - DT of welded parts: Using cross-sectional macro it was confirmed that the predetermined throat thickness of 10 mm or more, and leg length of 17 mm or more was met. - Pressure resistance test: Withstood the test pressure of 110 kPa, and no excessive deformations were seen. - Leakage test: For the test pressure of 90 kPa, the pressure drop after 60 minutes was 5 kPa or less. - Joint tensile test: Joint efficiency was 0.35 or more ＜Reference confirmation＞ - Final level PT: Absence of cracks - Cross-sectional macro-observation: There were some fusion defects and blow holes in the weld penetration shape, but as the DT criteria is met even if the said parts are excluded, there is no problem. ・The issues that must be resolved and the resolution policies were identified.	4 (*3)

(1) Level of achievement of initial target

② S/C water intake part (Target TRL at completion: Level 4)

Criteria for determining goal achievement	Completed items Main issues	Achieved TRL level (Self evaluation)
Element tests pertaining to the technology for remotely inspecting access routes while in service at the time of establishment, should be completed at the factory and the acceptance criteria of the element tests should be met. Or else, the issues to be resolved and the resolution policy should be clearly specified.	＜Temporary sealing apparatus＞ ・The following passing criteria were met in the element test of temporary sealing apparatus. - Dropping property of the apparatus: Can move up and down smoothly inside the simulated extension pipe by only operating the hoist (without manual assistance). (When piping material: SUS, carbon steel with coating, presence or absence of condensation, and inclination of extension pipe: 0° or 1°) - Structural stability and Sealing property: There was no significant displacement of the apparatus when the apparatus was decompressed in its normal installation state, and leakage rate was 0.5 vol%/h or less. (When piping material: SUS, carbon steel with coating, presence or absence of condensation) - When the apparatus is inclined as during the reference tests, a part of it did not have structural stability and sealing property. (With SUS, it was possible. In the case of carbon steel with coating, presence or absence of condensation it was not possible) ・The issues that must be resolved and the resolution policies were identified.	4

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(1) Level of achievement of initial target

② S/C water intake part (Target TRL at completion: Level 4)

Criteria for determining goal achievement	Completed items Main issues	Achieved TRL level (Self evaluation)
Element tests pertaining to the technology for remotely carrying out maintenance of the connection parts while in service at the time of establishment, should be completed at the factory and the acceptance criteria of the element tests should be met. Or else, the issues to be resolved and the resolution policy should be clearly specified.	＜Bead treatment apparatus＞ ・The following passing criteria were satisfied in the following unit function tests. (*: Partially not achieved) - In the unit function test using bead treatment apparatus, it was possible to treat the weld bead at the base of the extension pipe with a grinder's grindstone. The method for adjusting the shape of the weld beads could not be established. * ・The issues that must be resolved and the resolution policies were identified.	4 (*3)

(2) Issues and response policies

① D/W water intake part

Legends for response policies
A: Verification required in full-scale
B: Can be verified by element test in factory
C: Requires adjustment / resolution in the engineering for execution

No.	Category	Issues and countermeasures	Response policies
1	Work monitoring	It is difficult to check the operations related to installation of pipe connecting jig to utility stand, pump recovery operation from the basement, etc. with the camera images. Review camera and lighting arrangements, such as attaching a camera to the tip of the work apparatus and checking the apparatus, to make the monitoring of each work easier.	C
2	Hose handling	When fixing the hose laid on the basement floor to the utility stand or when installing the hose on the hose drum during pump recovery, the hose gets pulled toward the basement floor by its own weight, making the connection of pipes and pump recovery difficult. Consider an apparatus that sends the hose onto the grating or temporary lashing methods.	C
3	Fixing of pipes	While fixing the pipe to the utility stand by inserting a nail into the groove on the stand side with a remote apparatus, it is difficult to confirm that the nail is inserted all the way inside. It is necessary to review the structure so that work can be done easily with a remote apparatus.	C
4	Fixing of pipes	While connecting the pipes, there was mispositioning between the pipes and hence the pipes could not be connected with the connection jig. Considering the application to the actual equipment, study the methods and procedure for centering the pipes.	C
5	Cable treatment	As there is no apparatus that remotely assists the cables of various apparatus, manual assistance was provided during this test. As apparatus and cables are crowded in a confined environment, study a remote treatment method. [Study in progress as part of the Further Increasing The Scale Of Retrieval PJ]	B

(2) Issues and response policies

Legends for response policies
A: Verification required in full-scale
B: Can be verified by element test in factory
C: Requires adjustment / resolution in the engineering for execution

② S/C water intake part

No.	Category	Issues and countermeasures	Response policies
1-1	Gap measuring apparatus	Establishment of measures against loss of S/C surface scan data → Complete shape determination by collecting data of nearby positions to compensate for the missing data. (To be reflected in full-scale test)	A*
1-2	Gap measuring apparatus	Establishment of measures against loss of scan data of extension pipe lower end →・Complete the positions of missing range using the pre-scanned 3D model. ・Further expand the scanning conditions (mounting angle, position). (To be reflected in full-scale test)	A*
1-3	Gap measuring apparatus	Establishment of measures against loss of scan data due to impact of glossiness →・ Photographing should be avoided immediately after buffing, and shall be done a few hours after the occurrence of loose rust. ・Instead of photographing from directly in front of the measurement point, it shall be done from an angle. (To be reflected in full-scale test)	A*

*: Verified during the Full-scale Test PJ

(2) Issues and response policies

Legends for response policies
A: Verification required in full-scale
B: Can be verified by element test in factory
C: Requires adjustment / resolution in the engineering for execution

② S/C water intake part

No.	Classification	Issues and countermeasures	Response policies
2-1	S/C joint welding apparatus	Establishment of measures against overlap (During welding, the torch cable and the extension pipe come in contact with each other causing the wire tip to bend upwards, causing overlap due to deviation from the aimed position during teaching.) →・Improve the cable management method, such as by storing the torch cable inside the apparatus (improvement in current apparatus). ・Reset the criteria for pass / fail of VT (E.g. Decide in combination with DT)	C
2-2	S/C joint welding apparatus	Establishment of repair welding methods for defective welds of each pass →・Set the criteria for deciding the necessity of repair. ・Study repairing methods, develop dedicated tools for execution (improvement in current apparatus).	C
2-3	S/C joint welding apparatus	Establishment of measures against condensation on the surface of welded parts → Eliminate condensation by feeding dry air inside the extension pipe before welding and by injecting shield gas in the S/C joint welding apparatus.	C
2-4	S/C joint welding apparatus	Establishment of a method for recovering the stuck wire → With the wire stuck, pull up the S/C joint welding apparatus, cut and pull out the wire, and then perform bead molding / repair welding of said parts (planned to be done partially by remote operations).	C
2-5	S/C joint welding apparatus	Currently, it is possible to get the results of VT of the welded part using the camera mounted on the S/C joint welding apparatus, but the image quality should be further improved for a clearer judgment. →・Change to a camera with auto-focus (improvement in current apparatus). ・Review and improve camera and lighting arrangement.	C
2-6	S/C joint welding apparatus	Measures against fume scattering during welding → During execution, install a closing lid on the top of the extension pipe + suction, etc.	C
2-7	S/C joint welding apparatus	Measures to reduce radiation exposure of workers during carrying-in, raising, lowering and removal operation of the apparatus → Based on full-scale test results, consider reducing the number of workers and time allotted for engineering, and try to move from manual operations to remote operations further.	A*, C

*: Verified during the full-scale test PJ

(2) Issues and response policies

② S/C water intake part

Legends for response policies
A: Verification required in full-scale
B: Can be verified by element test in factory
C: Requires adjustment / resolution in the engineering for execution

No.	Category	Issues and countermeasures	Response policies
3-1	Weld bead treatment apparatus	Establishment of methods for adjusting the shape of the weld bead using a grinder (grindstone) for the parts rejected in VT (The thickness of the grindstone is as thin as about 3 mm and it comes in contact with the weld beat only in the form of a line, thus making the adjustment of weld bead shape difficult.) → Change to a grindstone shape such that the entire plane can come in contact with the weld bead (improvement in current apparatus).	C
3-2	Weld bead treatment apparatus	Establishment of welding defect elimination and bead formation methods for each pass ・Study repairing methods, develop dedicated tools for execution (improvement in current apparatus).	C
3-3	Weld bead treatment apparatus	Establishment of measures against dust scattering caused by bead treatment → During execution, install a closing lid on the top of the extension pipe.	C
3-4	Weld bead treatment apparatus	Measures to reduce radiation exposure of workers during carrying-in, raising, lowering and removal operation of the apparatus → Based on full-scale test results, consider reducing the number of workers and time allotted for engineering, and try to move from manual operations to remote operations further.	A*, C
4-1	Temporary sealing apparatus	Prevention of apparatus rotation when the apparatus is installed with a rotational deviation. → Implementation of rotation control mechanism	C
5-1	On-site environment	Establishment of countermeasures (robustness) that can deal with unexpected circumstances resulting from insufficient information on actual equipment →・Establish drying procedures for condensation environment (Same as No.3-3) ・ Add a level adjustment mechanism to the base plate to accommodate the inclination of the flooring of R/B 1st floor. ・Study decontamination / measures against exposure in contaminated areas. .	C
5-2	Apparatus excluded from the scope of development under this PJ	Development and designing of apparatus excluded from the scope of development under this PJ → Engineering shall develop and design based on the issues and development items put together for each apparatus.	C
5-3	On-site survey	On-site survey required for promoting the development of apparatus excluded from the scope of development under this PJ → Develop and design apparatus taking into account specific interferences (especially interference removal apparatus).	C
5-4	Mobile S/C water intake cell	Development and designing of mobile S/C water intake cell → Share the trends of mobile cell technology development that is part of Further Increasing The Scale Of Retrieval PJ.	B,C

*: Verified during the Full-scale Test PJ

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