Investigation on Integrity of JMTR Concrete Structures, Cooling System and Utility Facilities

H. Ebisawa, K. Tobita, A. Fukasaku and M. Kaminaga

Neutron Irradiation and Testing Reactor Center,
Department of JMTR Operation,
Oarai Research and Development Center
Japan Atomic Energy Research Agency (JAEA)

JMTR Refurbishment Project

- The JMTR was constructed in order to perform irradiation tests for LWR fuels, materials and to produce radio isotopes. The construction of the JMTR was began 1965.

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Operation was stopped August 2006.

(*The JMTR was used for about 40 years.*)

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Future utilization of the JMTR was investigated.

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Re-operation from FY2011 was decided.

(*The JMTR will be utilized more than 20 years.*)

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Refurbishment of the JMTR was started from FY2007.

Purpose of the Aged-Investigation

- An investigation of aged components (aged-investigation) was performed at the beginning of 2007 as a part of the **JMTR refurbishment project**.

- The aged-investigation was performed in order to identify integrity of facilities and components to be used for re-operation of JMTR.

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- Based on the aged-investigation results, future **maintenance program** for each facility or component is to be **reconsidered**. If necessary, **repairing** or **replacement** of facilities or components is to be carried out.

Aged-Investigation

- **Following concrete structures and components were investigated in order to identify their integrity.**
  1. **JMTR reactor building**, Exhaust stack : Concrete
  2. Trench, canal, filter banks : Concrete
  3. Pressure vessel
  4. Diaphragm of the reactor pool
  5. UCL (Utility Cooling Loop) elevated water tank
  6. **Main heat exchangers of the primary cooling system**
  7. Surge tank, Purify water tank, Degas tank
  8. Secondary cooling system pipes, Cooling tower
  9. Canal expansion joint
  10. **Diesel generators (Emergency generators)**
- **In this presentation, the aged-investigation results of the JMTR reactor building, main heat exchangers and emergency generators are presented.**

Schedule for Aged-Investigation

Work schedule for the aged-investigation

No.	Item	FY 2006			FY 2007											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
1	JMTR reactor building															
2	Exhaust stack, Trench, canal, filter banks															
3	Pressure vessel															
4	Diaphragm of the reactor pool															
5	Elevated water tank of UCL															
6	Main heat exchangers															
7	Surge tank, Purify water tank, Degas tank															
8	Secondary cooling system pipes															
8'	Cooling tower															
9	Canal expansion joint															
10	Diesel generator (Emergency generator)															

JMTR Reactor Building (1/3)

➢ Outline of the investigation

Concrete structure of the JMTR reactor building was constructed from 1965 to 1967. At present, the JMTR reactor building has been used for more than **40 years** after completion of the building construction. The JMTR reactor building is to be used **more than 20 years** from now. Therefore, following items were investigated in order to clarify the integrity of the JMTR reactor building concrete.

➢ Investigated items

1. Visual inspection of concrete
   Crack, Rust fluid, Efflorescence, Float and Falling of masonry
2. Compression strength of concrete
3. Visual observation of reinforced bar corrosion
4. Chloride ion content in concrete
5. Carbonation depth of concrete

JMTR Reactor Building (2/3)

➢ Investigation results

1. Visual Inspection

   No damage was observed for the **outer wall**. On the other hand, small cracks (maximum gap size is 0.4 mm) , float of paint and falling of masonry were observed for a part of the **inner wall**.

2. Compression strength of concrete

   Compression strength of concrete was investigated for 16 samples. All the measured results of compression strength were greater than the design basis strength of 210 kgf/cm^2.

3. Visual observation of reinforced bar corrosion

   The point rust was caused on the surface of 7 samples of 16 samples. (Corrosion grade I) ➔ No problem

JMTR Reactor Building (3/3)

➢ Investigation results (Continue)

4. Chloride ion content in concrete

   Chloride ion content in concrete was kept below 0.2 kg/m^3 which is the criterion value of JASS 5N*, at the position of the reinforced bar.

   * Japanese Architectural Standard Specification JASS 5N Reinforced Concrete Work at Nuclear Power Plants .

5. Carbonation depth of concrete

   Carbonation of **the inner wall** didn't become worth because of protection effect by wall paint. On the other hand, carbonation of the outer wall became worth gradually, but the maximum measured carbonation depth was small enough against measured protection thickness of reinforced concrete (57 mm).

Main Heat Exchanger (1/2)

➢ Outline of the investigation

A detailed investigation was carried out for the main heat exchangers of the primary cooling system.

➢ Major specifications (3 Units)

Dimension : 11,390 mm H x 1,650 mmϕ
Tube material : SUS27TB (SUS304,18%Cr, 8%Ni)
Thickness of tube : 1.2 mm
Number of tubes : 1,152

➢ Investigated items

1. **Eddy current testing** for heat exchanger tubes
   Thinning of the heat exchanger tube was measured by the eddy current testing.
2. Thickness measurement of the main body
   Wall thickness of the heat exchanger main body was measured by an **ultrasonic thickness gauge**.
3. Visual observation using an endoscope
   According to the eddy current testing, visual observation was carried out with an **endoscope** for the heat exchanger tube that had been evaluated as the thinning of the thinning rate 20% or more. Surface condition and color change of the tube were checked.

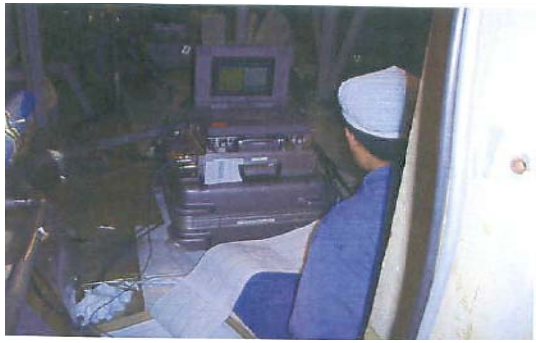
Main Heat Exchanger (2/2)

➢ Investigation results

1. **Eddy current testing** for heat exchanger tubes

   10 tubes in Unit No.1, 6 tubes in Unit No.2 and 7 tubes in Unit No.3 were evaluated to have the thinning rate 20% or more.

   Thinning was observed at the inner surface of the tube wall.



Eddy current testing for heat exchanger tubes

2. Thickness measurement of the main body

   All measured thickness were greater than required minimum thickness of 6 mm.

3. Visual observation using an endoscope

   Surface condition and color change of the tubes which had been evaluated as the thinning of the thinning rate 20% or more, were checked. No evidence of abnormal condition was observed. ➔ No problem

Thickness measurement by the ultrasonic thickness gauge

Diesel Generator (1/2)

➢ Outline of the investigation

To confirm the integrity of the diesel generator, the insulation diagnosis examination of the dynamo stator coil (high voltage) was carried out.

➢ Major specifications

Type: 3-phase brushless alternator,
Rated output 1,750 KVA, Voltage : 6,600 V,
Load current : 153A, Frequency: 50Hz

Diesel Generator No.2 (DG-2)

➢ Investigated items

1. The insulation resistance test

   The insulation resistance was measured by adding direct voltage between ground the alternator.

2. The dissipation factor test

   The voltage and the phase of leakage current were measured by adding alternating voltage between ground the alternator.

3. The alternating current test

   The voltage and the linearity of the leakage current were measured by adding alternating voltage between ground and the alternator.

4. The partial discharge test

   The amount of the partial electrical discharge generated at the coil was measured by adding alternating voltage between ground and the alternator.

Diesel Generator (2/2)

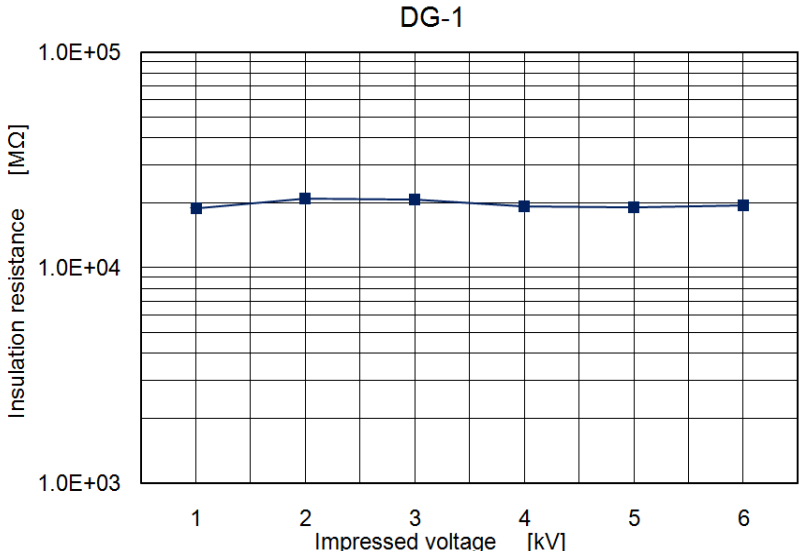
➢Investigation results

1. The insulation resistance test
   There was no surface leakage of current was measured(see figures). There is no deterioration of insulation resistance caused by moisture uptake.

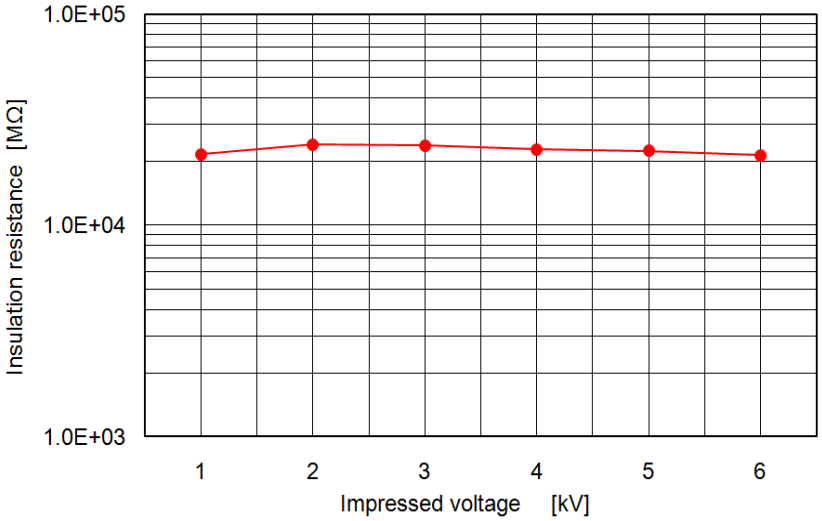
2. The dissipation factor test
   There was no evidence of the moisture uptake of the stator coil, the stain, changing in quality, flaking off. No void was generated.

3. The alternating current test
   There was no void caused by flaking off and the breakdown voltage was measured to be 6.6KV or more.

4. The partial discharge test
   There was no harmful partial discharge, and was no evidence of existing void.



Insulation resistance for DG-1



Insulation resistance for DG-2

Conclusion

- An aged-investigation was carried out for concrete structures, cooling systems and the utility facilities that will be continuously used in the future operation of the JMTR, at the beginning of a long-term shut-down period for the repairing or replacement work of the JMTR related facilities.
- As a result, it was confirmed that it was possible to use most of those facilities or components continuously. A small aged effect was found in a part of the equipment such as the secondary cooling system pipes linings, the secondary cooling towers, etc.
- Therefore, cracks of concrete and a part of the secondary cooling tower, etc., were repaired. The linings of the secondary cooling system pipes were replaced. Thus the long-term integrity of the concrete structures and the JMTR related facilities was established.
- “Facilities and components “ which are identified as having aged effects by the aged-investigation, will be maintained by the periodical maintenance activities based on the "Long-term maintenance plan" in the future.

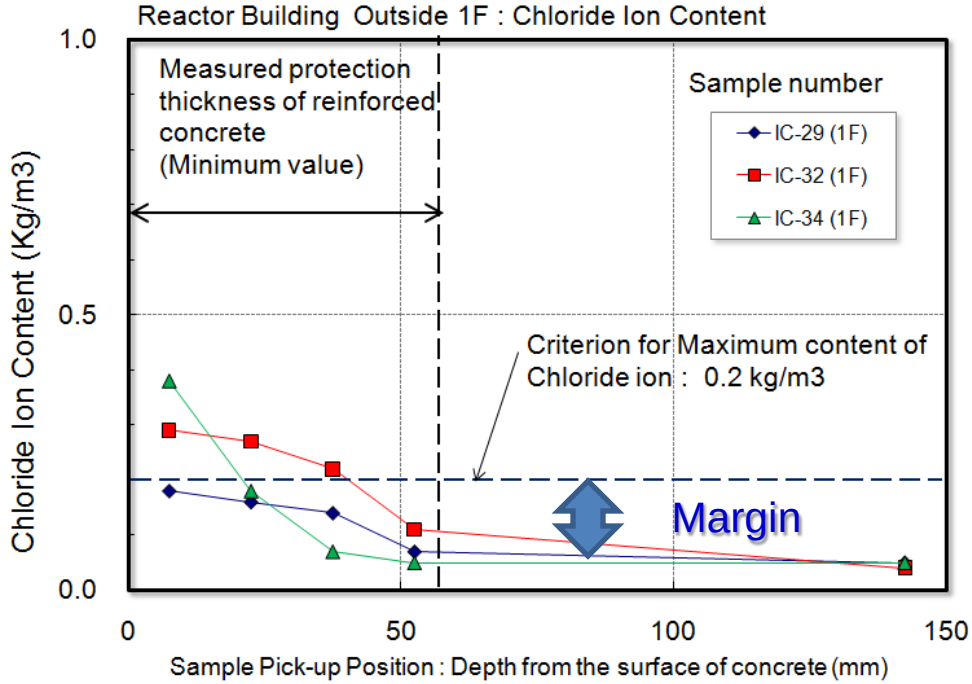
Appendix

Appendix. 1 JMTR Reactor Building - Chloride ion content in concrete

➢ Investigation results

➢ Chloride ion content in concrete

Chloride ion content in concrete was kept below 0.2 kg/m^3 which is the criterion value of JASS 5N*, at the position of the reinforced bar, even that of near the surface was greater than 0.2kg/m^3. Chloride ion content near the surface has been increased by accumulating the coming flying salinity.



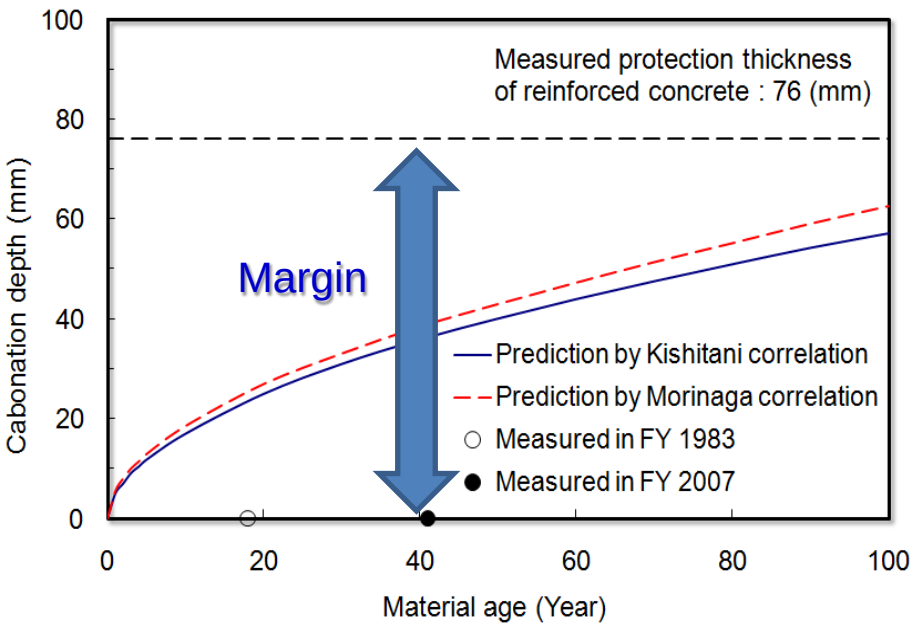
Chloride ion content distribution as a function of depth from the surface

* Japanese Architectural Standard Specification JASS 5N Reinforced Concrete Work at Nuclear Power Plants .

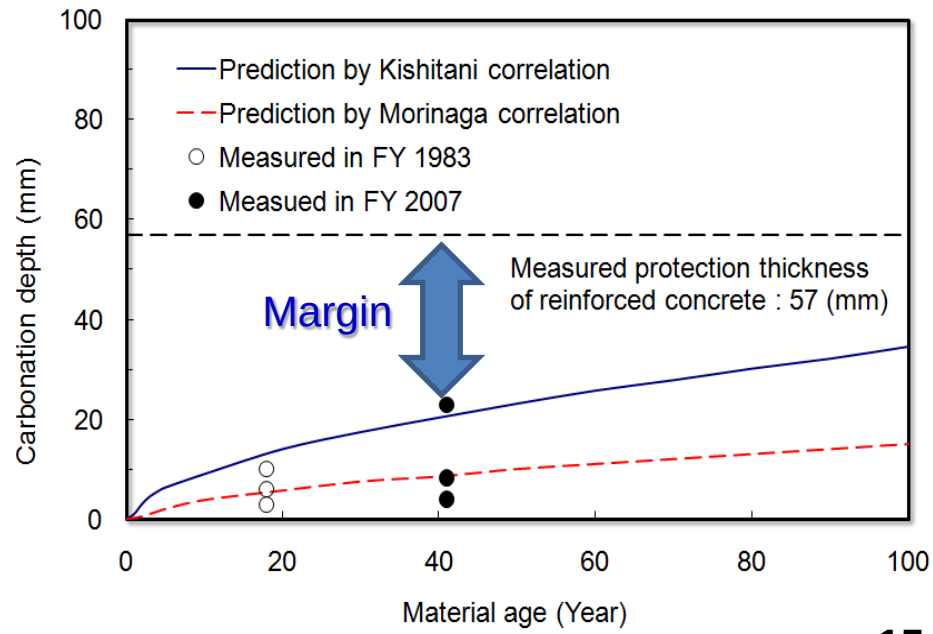
Appendix. 1 JMTR Reactor Building - Carbonation depth of concrete

- **Investigation results**
  - Carbonation depth of concrete

    Carbonation of **the inner wall** didn't become worth because of protection effect by wall paint. On the other hand, carbonation of the outer wall became worth gradually, but the maximum carbonation depth of 23mm was small enough against measured protection thickness of reinforced concrete (57 mm).



Carbonation depth of the inner wall



Carbonation depth of the outer wall

Appendix. 2 Reactor Vessel (1/2)

➢ Outline of the investigation

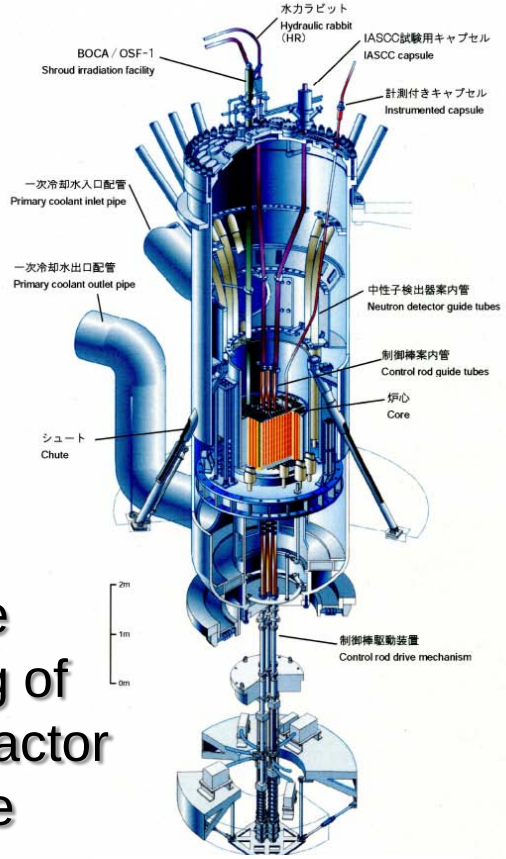
In order to use the reactor pressure vessel for long-term during the JMTR re-operation period, a visual investigation was carried out for the pressure vessel.

➢ Major specifications

Dimension : 95,000 mm H x 3,000 mmϕ
Material : SUS304L
Thickness : 34 mm

➢ Investigated items

- Visual observation using an underwater camera
  Presence of rust, harmful wound on surface of the pressure vessel inner wall, presence of loosening of the screws and bolts were investigated with a reactor pressure vessel external checking device with the underwater camera.

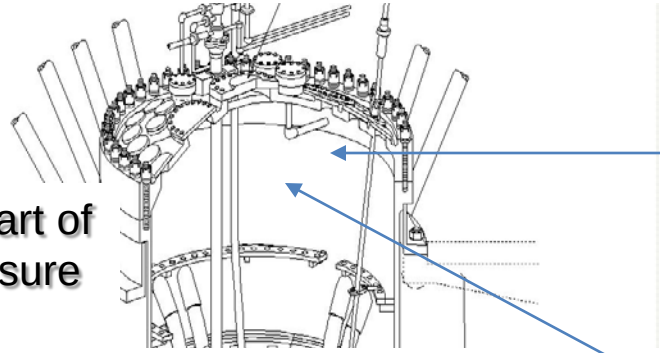


Pressure vessel

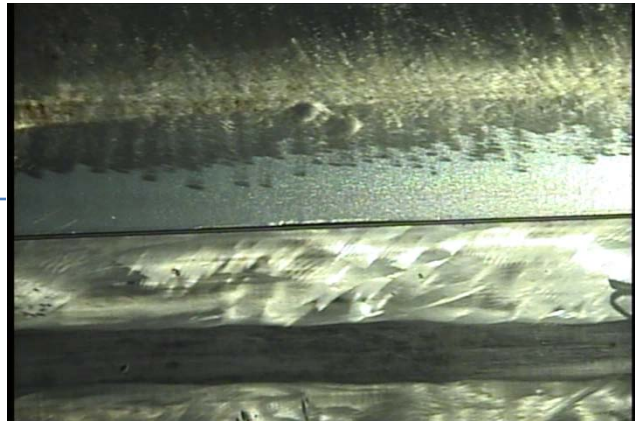
Appendix. 2 Reactor Vessel (2/2)

➢ Investigation results

- As a result of the visual observation, the harmful wound was not confirmed. Moreover, there was no loosening of the bolts and the screws. Negligible rust was observed near the upper part of the reactor pressure vessel.



Upper part of the Pressure vessel



- It is thought that the rust observed near the upper part of the reactor pressure vessel comes from the adhering iron etc. Because the upper part of the reactor pressure vessel will be exposed to the air during the reactor shut-down period in order to carry out necessary work for irradiation samples.

Appendix. 3 Diaphragm of Reactor Pool

- **Outline of the investigation**

  A diaphragm seal of the reactor pool was visually investigated in order to confirm its integrity by the inspection equipment with underwater camera. The diaphragm was located in the reactor pool bottom of about 10 m in depth and it was impossible to observe from the water surface.

- **Investigated items**
  - Visual observation using an underwater camera
    Presence of rust, harmful wound on surface of the diaphragm seal were investigated by the inspection equipment with underwater camera.

- **Investigated results**

  As a result of the visual observation, the harmful wound and rusts was not confirmed.

Surface of the diaphragm seal

Appendix. 4 Elevated water tank of UCL (1/2)

➢ Outline of the investigation

To confirm the integrity of the UCL(Utility Cooling Loop) elevated tank, UCL elevated water tank base bolts, the surrounding plate, and the base plate were investigated.

➢ Investigated items

1. Base bolts
   (1) Visual inspection
   Paints, surface condition after rust flakes off
   (2) Size measurement
   Confirmation of corrosion thinning ratio
2. Surrounding plate, Base plate
   (1) Visual inspection
   Paints, surface condition after rust flakes off
   (2) Magnetic particle testing
   Confirmation of welding joint
   (3) Size measurement
   Confirmation of corrosion thinning ratio

Appendix. 4 Elevated water tank of UCL (2/2)

➢Investigated results

1. Base bolts

(1) Visual inspection

There were flaking off and floating of the paints.

(2) Size measurement

There was one bolt that had the maximum thinning rate of 7.34mm (44.45mm→37.11mm) as a result of measuring 4 thinning bolts in 48 all bolts.

2. Surrounding plate, Base plate

(1) Visual inspection

There were flaking off and floating of the paints.

(2) Magnetic particle testing

There is no evidence of crack and false indication in the welding region.

(3) Size measurement

There was no remarkable thinning in other parts though there was thinning of 4.1mm (22.0mm→17.9mm) on a part of the base plate in the spot at maximum.

Removing paints and rusts from the investigation part

After repairing and paints

Appendix. 5 Surge tank, Purify water tank, Degas tank (1/2)

➢ Outline of the investigation

In the primary cooling system, there are a surge tank, a purify water tank and a degas tank. All these tanks will be used for during reoperation period. Therefore, an investigation was carried out for these tanks in order to identify their integrity.

➢ Investigated items

1. Visual inspection (Including inside structures)
2. Penetrant testing (PT) for welding region

Surge tank
3950 mm H x 1028 mm ϕ

Purify water tank
3160 mm H x 1486 mm ϕ

Degas tank
6200 mm H x 1566 mm ϕ

Appendix. 5 Surge tank, Purify water tank, Degas tank (2/2)

➢ Investigation results

1. Visual inspection (Including inside structures)
   There was no abnormal condition in the inside of all three tanks of the surge tank, the purify water tank and the degas tank.

2. Penetrant testing (PT) for welding region
   No false indication was found in the surge tank.

   False indications were observed in the welding lines of the purified water tank and the degas tank. But after grinding, no false indication was found in the re-inspection. Therefore, it was confirmed that they were not progressive defect. ➔ No problem

Appendix. 6 Secondary Cooling system - Main pipes (1/2)

➢ Outline of the investigation

The main pipes of the secondary cooling system are made of the ordinary steel, and inside of the pipes are covered by resin linings for protecting against rusts. Therefore, the lining check in the pipes was carried out in order to check the lining condition.

Secondary cooling system pipes 450A

➢ Investigated items

- Visual observation

(1) Observation objects

Linings of the secondary cooling pipes of 450A and 750A.

(2) Observation method

As for 750A pipes, the investigator entered in pipe and the lining was visually inspected by watching . As for 450A pipes, the fiberscope was used for the watching device.

Secondary cooling system pipes 750A

Appendix. 6 Secondary Cooling system - Main pipes (2/2)

➢ Investigation results

- As a result of the visual observation, the lining of the secondary cooling system pipes had swelling and cracks overall and the aged deterioration of the lining progressed.

  ➔ Repair of the lining has been carried out.

- There was no corrosion or thinning of the pipes.

Remarkable clacks

Swelling of lining

Appendix. 7 Secondary Cooling system - Cooling Tower (1/2)

➢ Outline of the investigation

Wooden structures of the cooling tower were investigated among the second cooling systems, and the integrity of the cooling tower was confirmed.

➢ Investigated items

- Visual observation

(1) Observation objects

- Tower exterior for 4 cells in the cooling tower (upper part, middle part, and lower part)

(2) Observation method

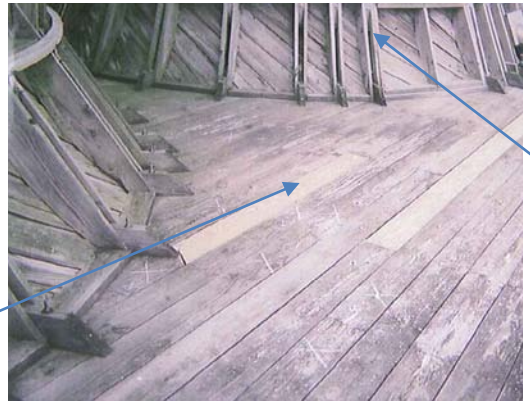
- Presence of damage, transformation, adhesion thing, and iron corrosion were observed visually.
- Presence of loosening of bolts, wood inside cracks were checked by wooden hammer.

JMTR secondary cooling system cooling tower (4 cells)

Appendix. 7 Secondary Cooling system - Cooling Tower (2/2)

➢ Investigation results

- As a result of the visual observation, partial internal decay and cracks caused by dryness were confirmed at the top deck, fan stacks, and deck joists, etc. It was confirmed that there were no remarkable corrosion or rust of bolts.



Fun stack

Top deck

Deck joist

Materials for the top deck, fan stacks, and deck joists were changed from wooden to FRP (reinforced plastic), and the repairing of these were carried out.

Fan stack made of FRP

Appendix. 8 Canal Expansion Joint (1/2)

➢ Outline of the investigation

The following checks and examinations were carried out in order to confirm integrity of the canal expansion joint which was located between No.2 and No.3 canal watertight gates.

➢ Investigated items

1. Visual observation
   The canal expansion joint was observed visually from out side.

2. Hardness examination
   The sample was extracted from a part of the canal expansion joint for the deterioration degree investigation of neoprene rubber, and the surface observation and the hardness examination were carried out.

Canal expansion joint

No.3 Canal watertight gate

No.2 canal watertight gate

Appendix. 8 Canal Expansion Joint (2/2)

➢ Investigated results

1. Visual observation

   Near the part of the waterline and underwater part, small swelling and cracks were observed in both east and west sides of the canal expansion joint. On the other hand, no abnormal condition was observed above the water surface part.

2. Hardness examination

   As a result of hardness examination, a hardness of the specimen was measured to be 77.6 (HAD). A normal hard rubber has a hardness of 60 to 90, therefore, it was confirmed that the measured value was in the range of normal condition.

   ⬇

   The hardness of the canal expansion joint will be checked periodically and based on the deterioration situation of the hard rubber, a replacement of the canal expansion joint will be considered.

Canal expansion joint