Demonstration Test Program for Long–term Dry Storage of PWR Spent Fuel

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Contents

1. Introduction

- ***Mutsu interim spent fuel storage facility in Japan*** is preparing for the maximum 50-year storage of spent fuels in dry metal casks for both transportation and storage.
- To reduce risk of exposure to workers and waste materials, the facility has no hot cell, and ***the spent fuels will be transported after the storage without opening the cask lid.***
- The Nuclear Safety Commission requested utilities to ***accumulate knowledge and experience on long-term integrity of spent fuels during dry storage to ensure safety of post-storage transportation.***

Lots of demonstrations & experiences in overseas

Lots of fuel cladding integrity investigations in Japan

Dry storage experiences of BWR fuel in Japan

Demonstration test program for long-term dry storage in domestic research facility to accumulate knowledge and experience on long-term integrity of PWR spent fuels during dry storage.

To make assurance doubly sure on safety of post-storage transportation.

2. Overview of Demonstration Test Program

Purpose:

To demonstrate integrity of PWR spent fuels in long-term dry storage prior to future post-storage transportation

Test Period:

Maximum 60 years from the beginning of demonstration test

Method:

Maximum 2 PWR spent fuels are stored in a test container whose environmental conditions are simulated those in actual casks.

Integrity of spend fuels is verified by analyzing gas sampled periodically from cavity of test container.

3. Organization of Demonstration Test Program

Utilities

- The Japan Atomic Power Company
- The Kansai Electric Power Co., Inc.
- Kyushu Electric power Co., Inc.

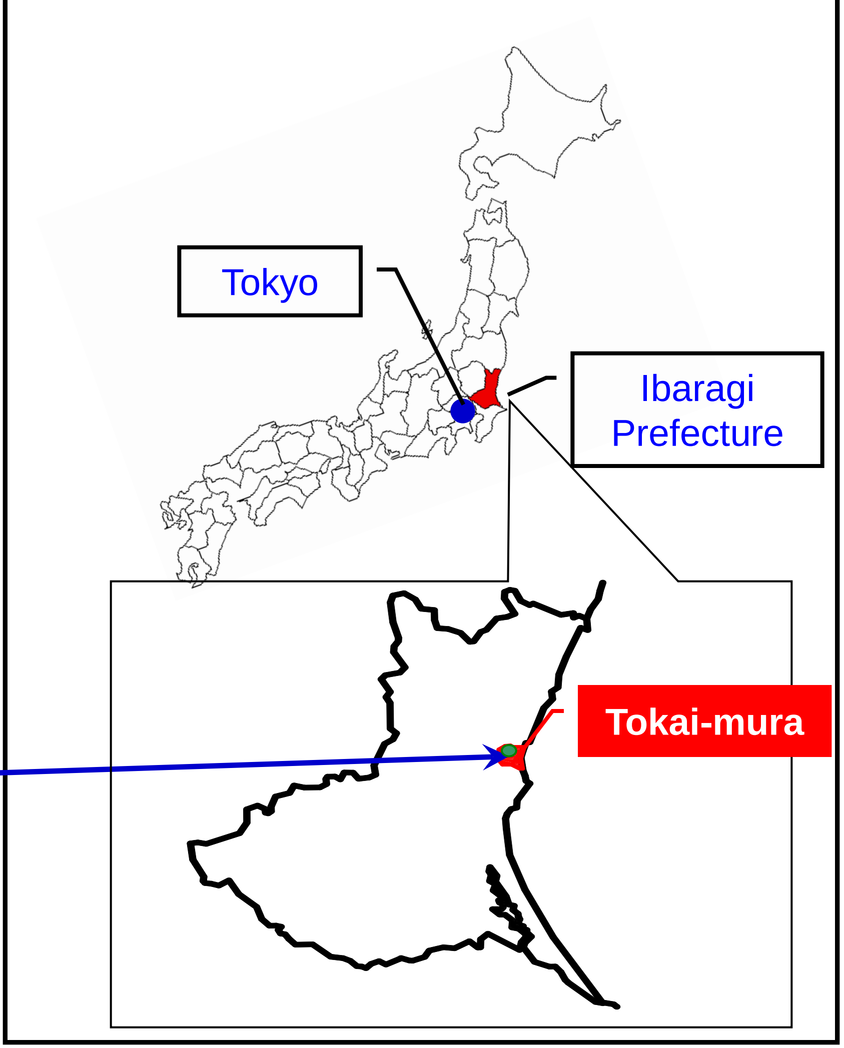
Contractor

- Mitsubishi Heavy Industries Ltd. (MHI)

Test Facility

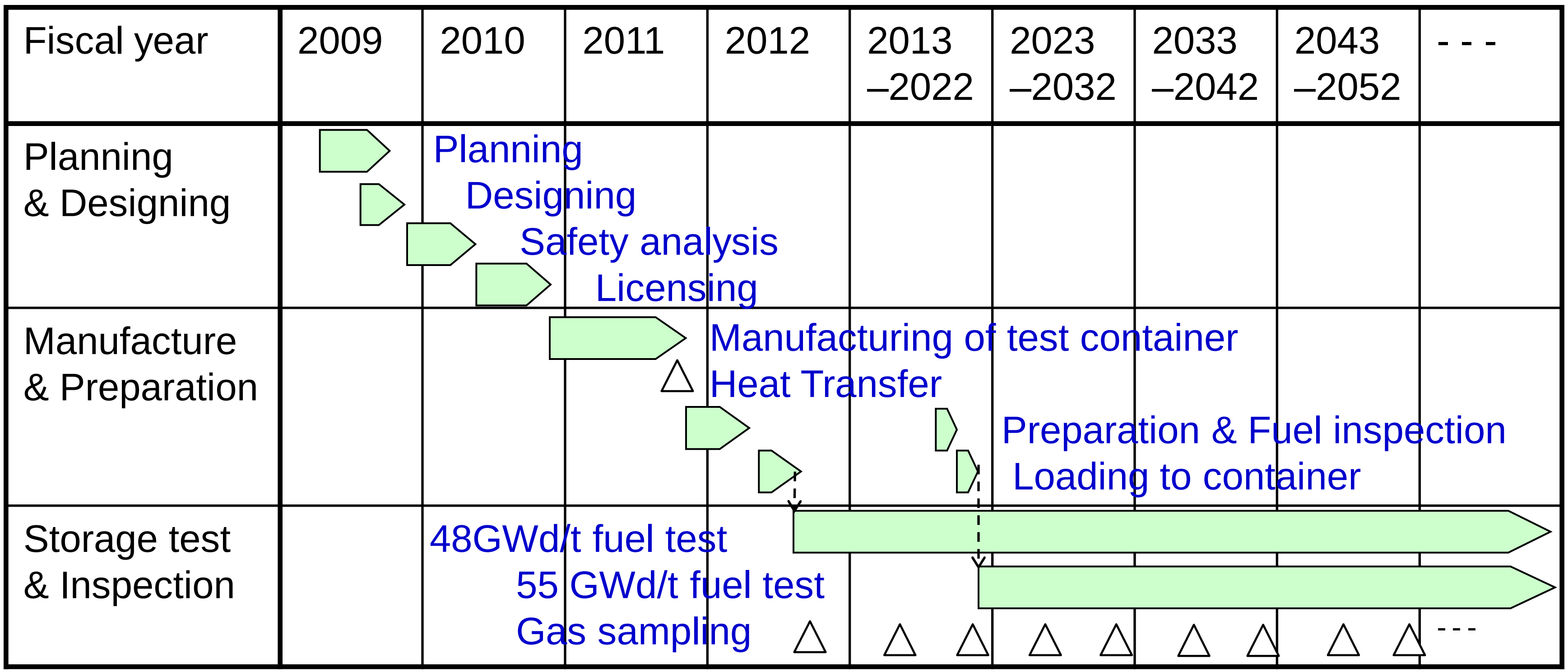
- Nuclear Development Corporation (NDC)

Location of the Test Facility



4. Planning Test Program (1)

～Major Time Schedule of Demonstration Test of PWR Fuel Storage～



4. Planning Test Program (2)

～Fuels used for Test～

- Max.2 spent fuels (48GWd/t and 55GWd/t) will be stored.
- 48GWd/t fuel : Some of the fuel rods were used for PIE test, and now it is stored in the pool of the hot laboratory at NDC.
- 55GWd/t fuel : spent fuels meeting the below assumption will be tested in the future.

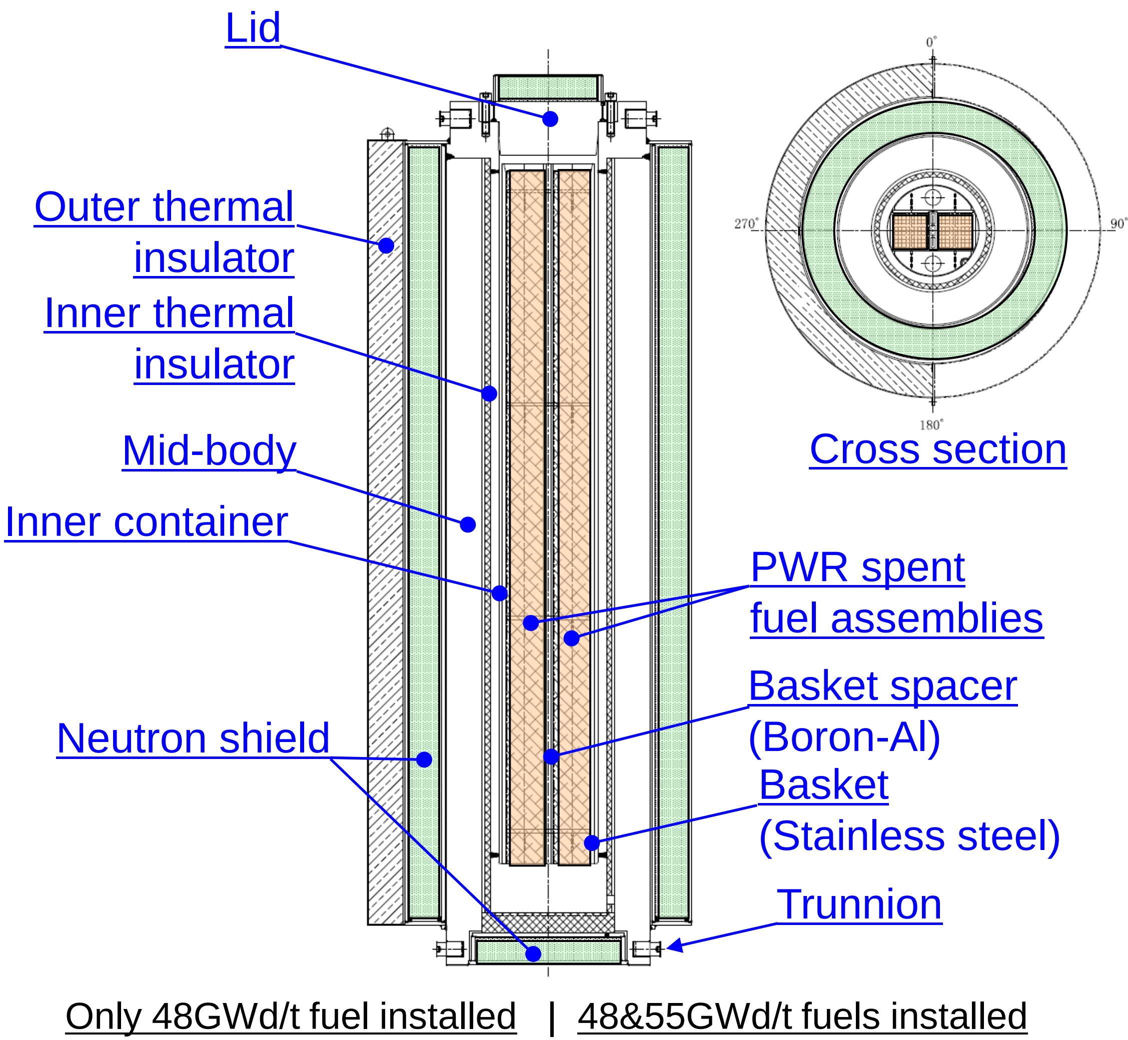
Fuels Assumed for Tests

	Type 17×17 48G Fuel	Type 17×17 55G Fuel
Burn-up (MWd/t)	42,800 (past record)	55,000 (assumption)
Cooling period	19 years (as of October, 2012)	≥10 years (as of October, 2022)
Cladding material	Zircalloy–4	MDA or ZIRLO
Remarks	15 empty fuel rods*	Non

*Fuel rods used in PIE are never used for long-term storage tests.

4. Planning Test Program (3)

～Outline of Test Container～



Outline

item	Description
Compo-nents	**- Lid** (Steel, Resin, Double metal gasket) **- Body** (Steel, insulator, Resin) **- Basket** (Steel, Boron-Al) **- Outer thermal insulator**
Size	**- Height :** Approx. 5.2m **- Outer diameter** Approx. 2.2m
Contents	**Max. 2 PWR spent fuels**

4. Planning Test Program (4)

～Verification Method of Fuel Integrity～

[48GWd/t fuel]

Inspection of fuel before storage test

– Visual inspection of fuel assembly

Loading to test container*

Start of Storage Test

under Dry Condition

10 years

* The following inspections of sampled cavity gas are to be carried out at the start of storage test after fuel loading;

– Kr-85 radioactivity analysis

– Gas composition analysis

[55GWd/t fuel]

Inspection of fuel before storage test

– Visual inspection of fuel assembly

Loading to test container*

Analysis and monitoring during storage test

– Kr-85 radioactivity analysis

– Gas composition analysis

– Monitoring of surface temperature of test container

– Monitoring of containment boundary pressure of test container

Increase of Kr-85 level

Pause of Test

Investigation of cause

End of Test

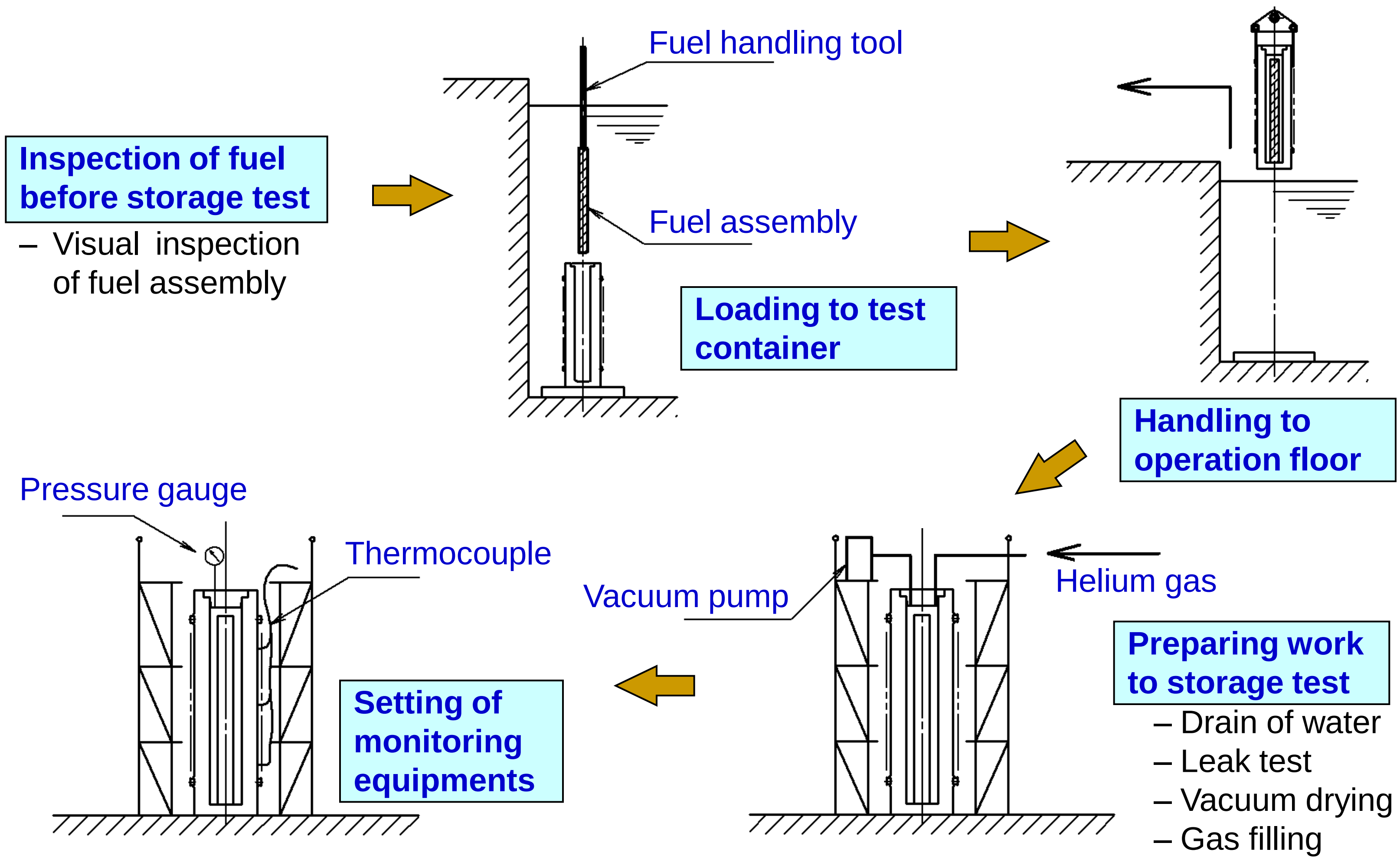
Inspection of fuel after storage test

– Visual inspection of fuel assembly

Flow Diagram of Test Program

4. Planning Test Program (5)

～Process of Fuel Handling and Test Container Installation～

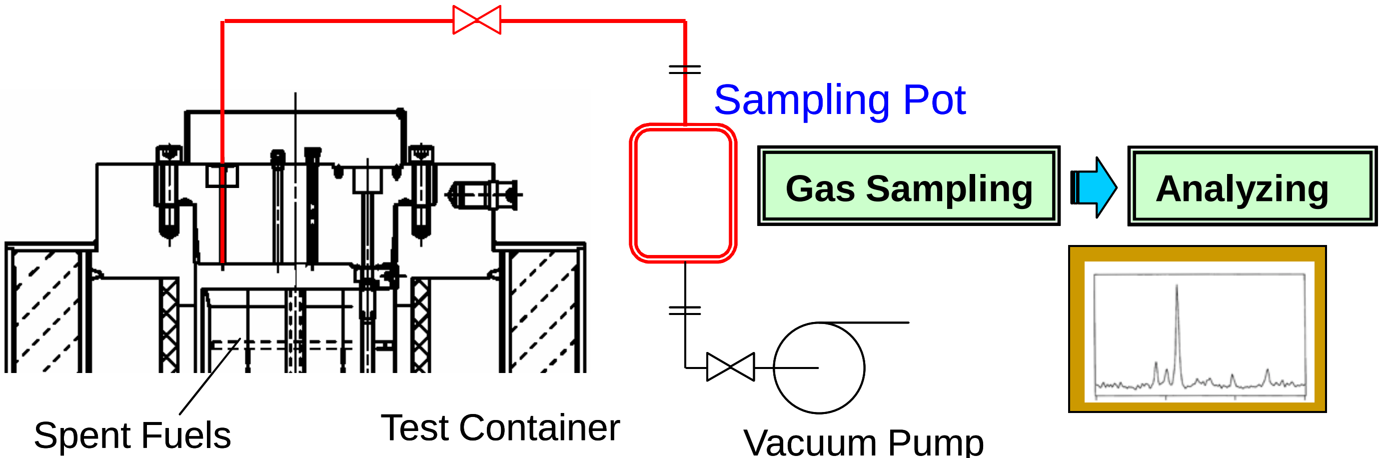


4. Planning Test Program (6)

～Confirmation during storage tests～

Gas sampling

- ***Confirmation for detecting fuel leakage***
- Inert gas sampled using a sampling pod
- Scheduled every 5 years
- ***Radioactive gas (Kr-85) analysis with a Ge detector***
- ***Gas components analysis with a mass spectrometer***



Temperature monitoring

- ***Estimating temperature history of fuel rods***
- Thermocouples are installed on the outer surface in the middle area.
- ***Temperature of the fuel rods is calculated by a previously-verified assessment tool by thermal performance test.***

4. Planning Test Program (7)

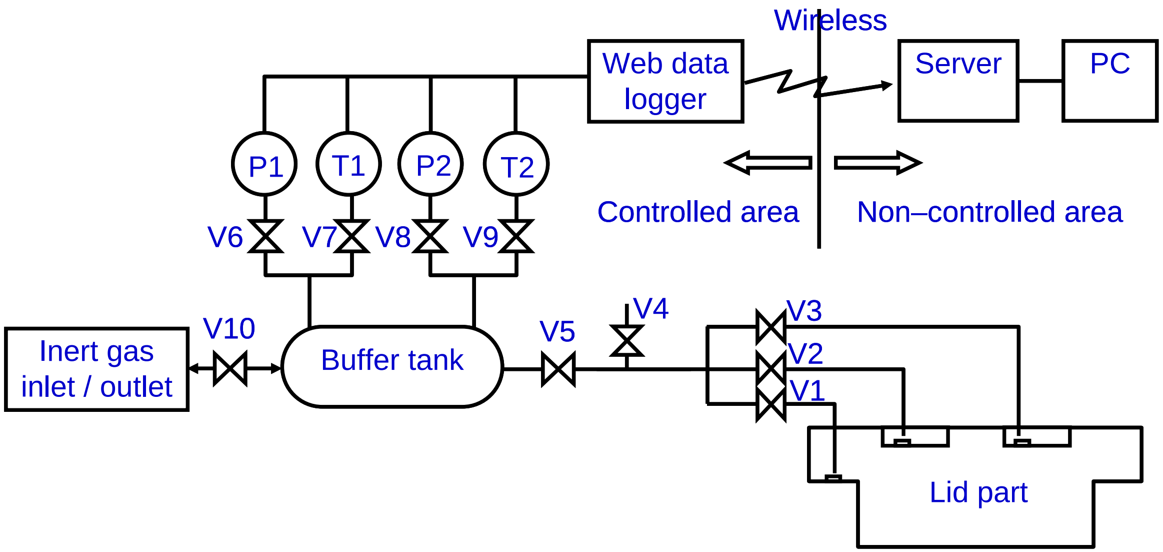
~Confirmation during storage tests (continued)~

Pressure monitoring

- Confirmation for maintenance of containment of the test container

- Monitoring of helium gas pressure at the lid boundary.

- Pressure gauges installed to buffer tank leading to gap of double metal gaskets.



Visual inspection

- Confirmation for no abnormality on the test container

- Visual inspection of surface of the test containment and its fixing condition.

5. Designing of Test Container (1)

～*Current Knowledge and Experience*～

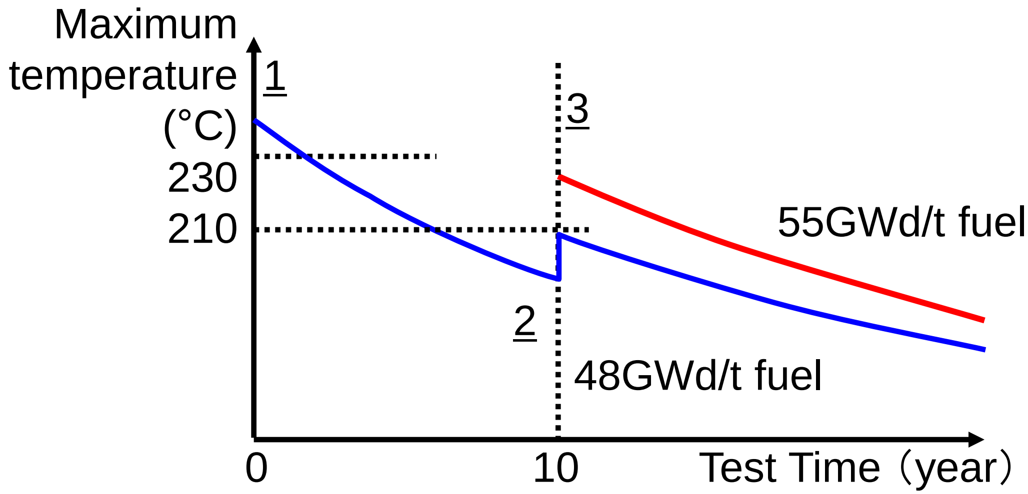
Evaluation of Degradation Events

Conditions to be considered	Technical Background	Actual Storage Condition	Target Test Conditions
Thermal degradation	No embitterment due to hydride reorientation, failure due to creep strain, recovery of irradiation hardening, or stress corrosion crack ***under 100MPa or less circumferential stress at 275℃***	***Around 230℃*** (Gradually decrease with decrease in decay heat)	***Around 230℃*** (Gradually decrease with decrease in decay heat)
Chemical degradation	Negligible oxidation/hydrogen absorption during storage (***inert gas atmosphere***) compared to that during in-core irradiation	***He gas atmosphere*** Moisture: 10% or less	***He gas atmosphere*** Moisture: 10% or less
Radiation degradation	Negligible neutron irradiation influence during storage Saturation of mechanical strength due to neutron irradiation at relatively ***low burn-up (around 5GWd/t)***	Burn-up of stored fuel: ***Maximum 47GWd/t***	Burn-up of contained fuel: ***5GWd/t or more***
Mechanical degradation	Maintenance of integrity under normal test conditions of transport (free drop) (***Acceleration :20 to 45G***)	During storage: static position During earthquakes: ***Acceleration of 1G***	During storage: static position During earthquakes: ***Acceleration of 1G***

5. Designing of Test Container (2)
～Simulated Environment of Actual Casks --- Temperature～

Target Value of Fuel Cladding Tube Max. Temperature at Beginning of Test (static state)

Fuel	Design Value of Actual Cask (at environmental temp.)	Planned Value of Storage Test (at environmental temp.)	Limit
48GWd/t	Up to 230°C (at 45°C)	Approx. 230°C (at 25°C)	≤ 275°C
55GWd/t	No assumption	Approx. 230°C (at 25°C)	≤ 250°C



Schematic drawing of Max. Temperature transition

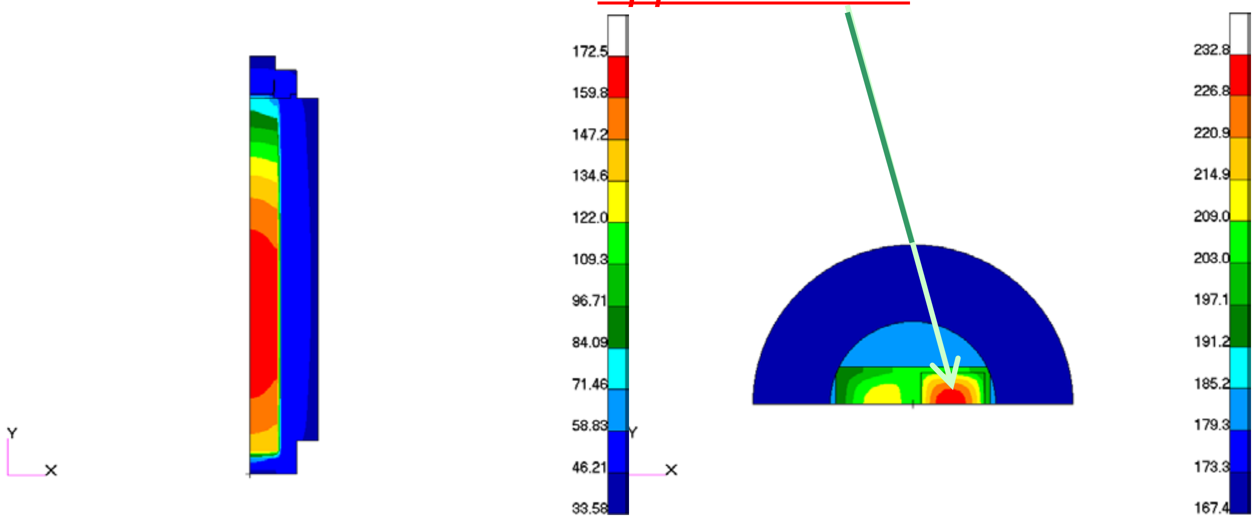
5. Designing of Test Container (3)

～*Simulated Environment of Actual Casks --- Temperature*～

Heat Load of Fuels in Test Container

	Beginning of Test	**Addition of 55G Fuel**
Content	48GWd/t fuel (cooling for 19 years)	**48GWd/t fuel (cooling for 29 years) & 55GWd/t fuel (cooling for 10 years)**
Heat Load	547 W	**1472 W (455+1017 W)**

- *Initial maximum temperature: Approx.* ***250℃*** *at 48GWd/t fuel*
  Approx. ***230℃*** *at 55GWd/t fuel*



Thermal Analyses of Test Container (during loading of 48&55GWd/t fuels)

5. Designing of Test Container (4)

～Simulated Environment of Actual Casks --- Test Atmosphere ～

- Test container is filled with ***helium gas*** having ***negative pressure as with actual dry cask cavity.***
- ***Vacuum drying operation*** is carried out before backfilling of helium gas.
- Amount of moisture is confirmed to be low.
- Residual moisture amount has ***little effect on aging degradation in terms of corrosion of cladding tubes and hydrogen absorption.***

5. Designing of Test Container (5)

～Safety Analysis of Test Container～

- The test container satisfies safety functions (Shielding , Sub-Criticality , Containment , Heat Transfer, Structure) during the storage test.
- Thermal stress , handling and some accident are considered in structural analysis of the test container.

Analysis	Calculating			Result	Criteria
Shielding	Maximum expected dose rates		lateral side	24.9μSv/h	≤ 25μSv/h
			top side	144μSv/h	≤ 250μSv/h
Criticality	Effective multiplication constant			0.92	≤ 0.95
Containment	Nuclide release rates keeping vacuum during the storage test			4.3×10^{-7} Pa・m^3/s	≥1.0×10^{-9} Pa・m^3/s
Heat Transfer	Temperature of fuel and container		48GWd/t fuel	～250°C	≤ 275°C
			55GWd/t fuel	～230°C	≤ 250°C
			Container surface	～50°C	≤ 85°C
Structure	Stress	Thermal stress	Sealing boundary	26MPa	≤ 180MPa(Sy)
		Handling	Upper Trunnion	571MPa	≤ 666MPa(Sy)
		0.5m Drop	Sealing boundary	55MPa	≤ 147MPa(Sy)
		Seismic	Lower Trunnion	167MPa	≤ 687MPa(Sy)

5. Designing of Test Container (6)

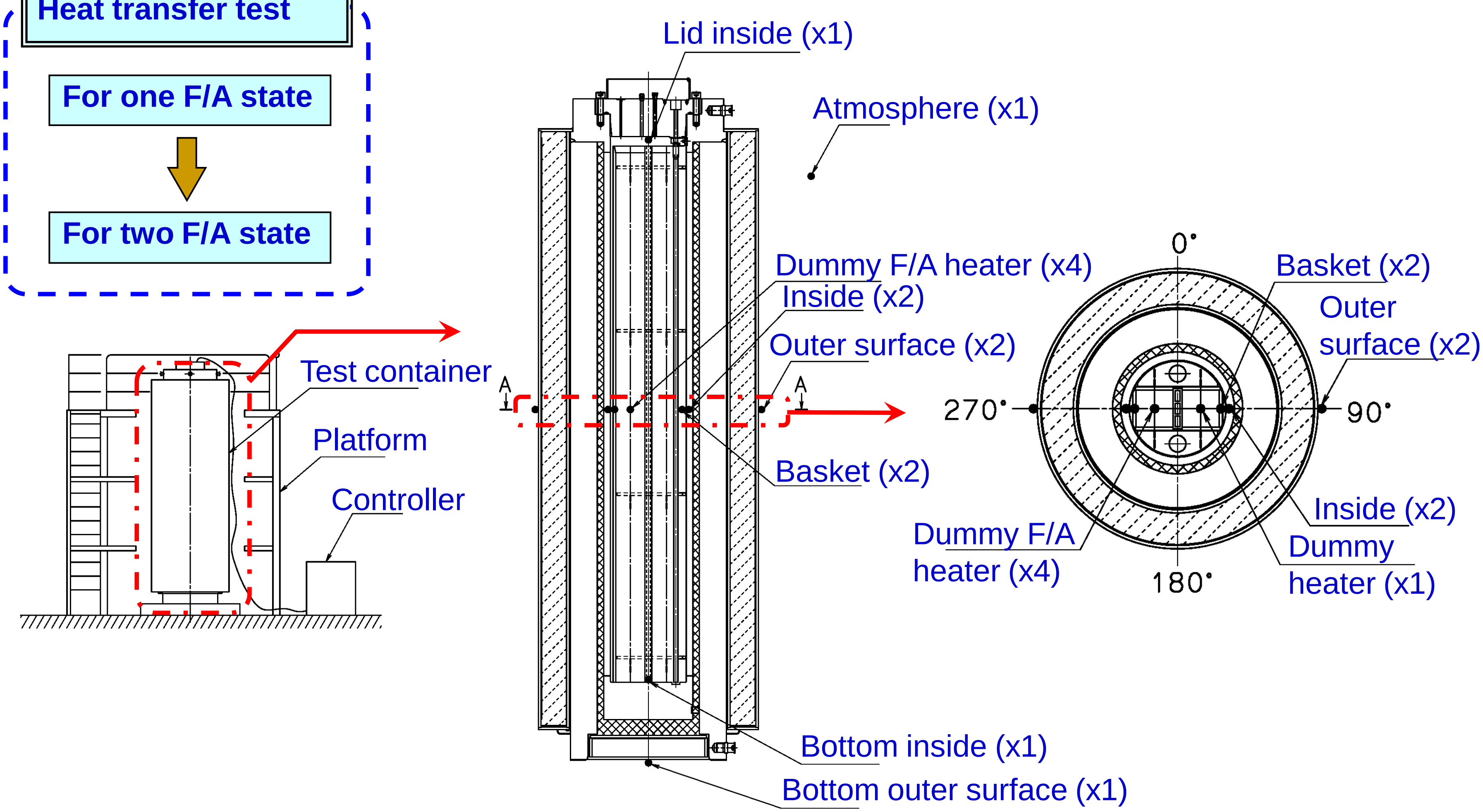
～Heat Transfer Test Plan of Test Container～

Heat transfer test

For one F/A state

↓

For two F/A state



6. Summary

- Some PWR utilities are planning to conduct a ***long-term storage test*** for maximum 60 years by placing PWR fuels in a test container which simulates temperature and internal gas of actual casks to accumulate ***knowledge and experience on long-term integrity of PWR spent fuels during dry storage***.

- The storage test plan such as ***test methods and inspection items, safety analyses and container design have been prepared***. In the future, licensing and manufacturing of the test container are planned, and the ***storage test of 48GWd/t fuel will start at late 2012***.

- ***Thermal design*** of the test container is important. Its ***temperature is controlled with thermal insulators*** and heat-transfer performance is confirmed by heat transfer tests at the completion of the container.

✓ Others ----- Japan Nuclear Energy Safety Organization (JNES) plans to participate in this test from a regulator's standpoint.