Locating Fuel Debris inside the Unit 2 Reactor Using a Muon Measurement Technology at Fukushima Daiichi Nuclear Power Station

July 28, 2016

TEPCO

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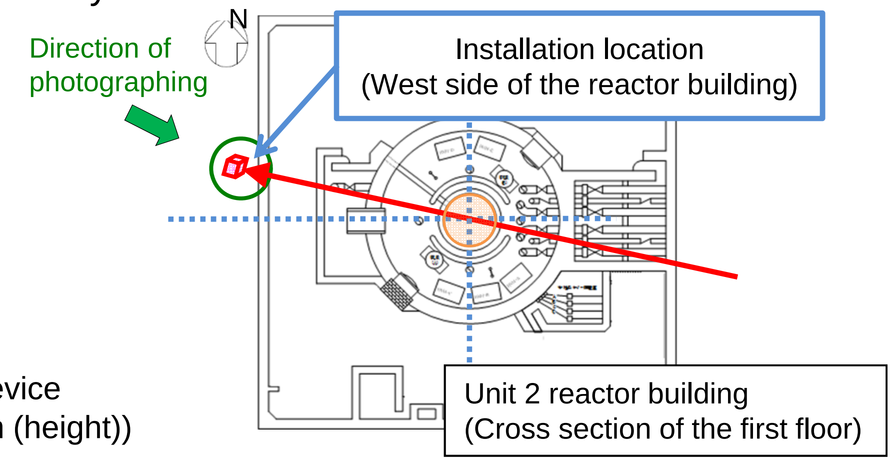
IRID

The contents of this document are what TEPCO carries out as a part of the project developed by the International Research Institute for Nuclear Decommissioning (IRID).

- A technology has been developed to detect fuel debris inside the reactor through the measurement of muon particles passing through it under the government project called “the Development of Technologies for the Detection of Fuel Debris inside Reactors.”

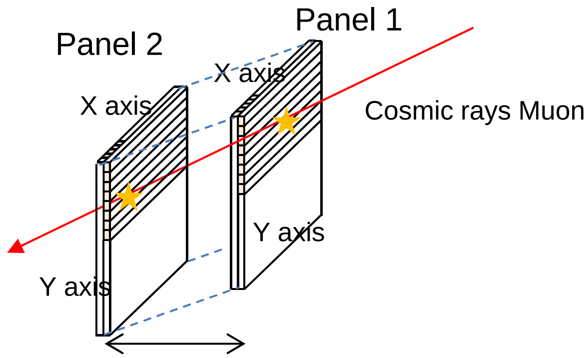
- From March to July 2016, measurement using the muon transmission method was carried out at Unit 2. This document reports the measurement and analysis results.

Installation of muon measurement device
(small-sized unit, approx. 1m✕1m✕1.3m (height))



Measurement principle of the muon transmission method (image)

Two panels (plastic scintillators) inside the muon measurement device detects incoming cosmic rays muon and calculate their trace on where they have pass through from the coordinates (X and Y axes) on the panels.



Measurement using the muon transmission method at Unit 2

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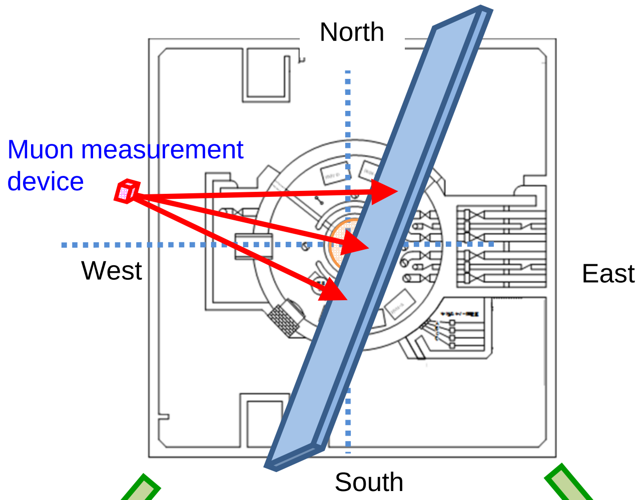
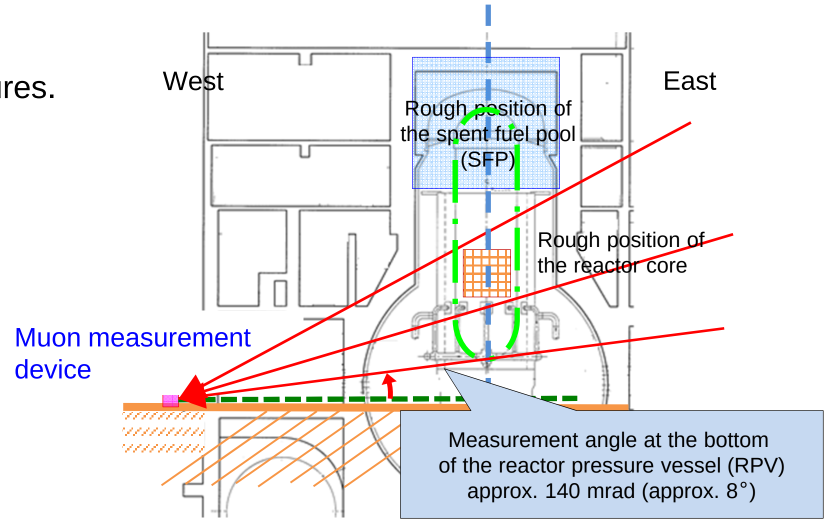
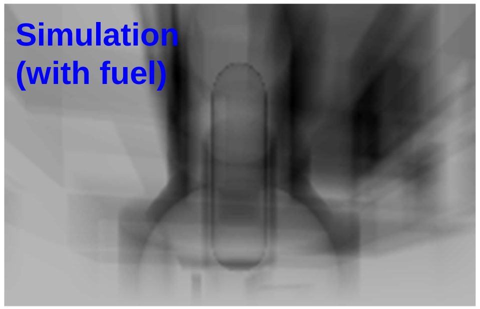
- By measuring muon particles which have passed through the Unit 2 reactor building, images of fuel debris in the reactor core or at the bottom of the reactor pressure vessel were captured like X-ray pictures.
  ⇒The image will be projected on the cross section of the reactor.



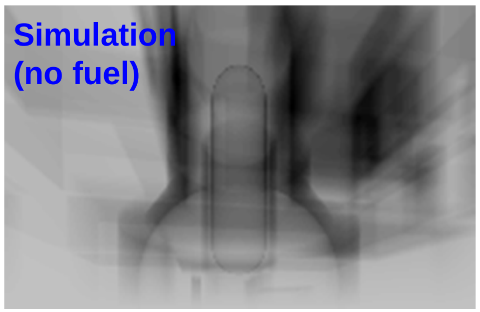


Measurement image of muon particles that pass through the reactor building (East-west cross section)

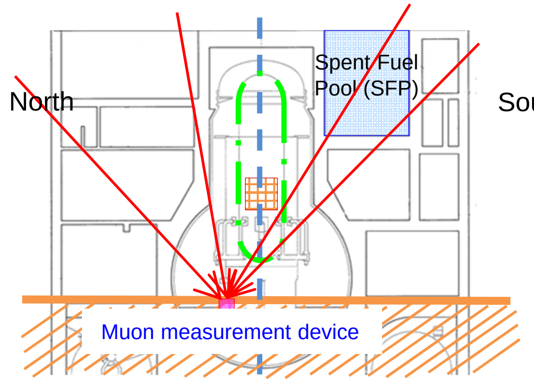
Projected images



<Conditions>
・Reactor core：Existence of fuel
・Bottom of RPV：Existence of fuel
・Inside SFP：Filled with water



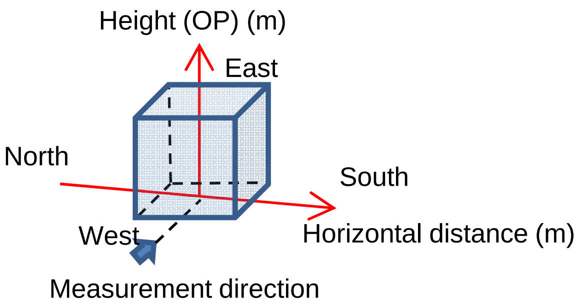
<Conditions>
・Reactor core：No existence of fuel
・Bottom of RPV：No existence of fuel
・Inside SFP：Filled with water

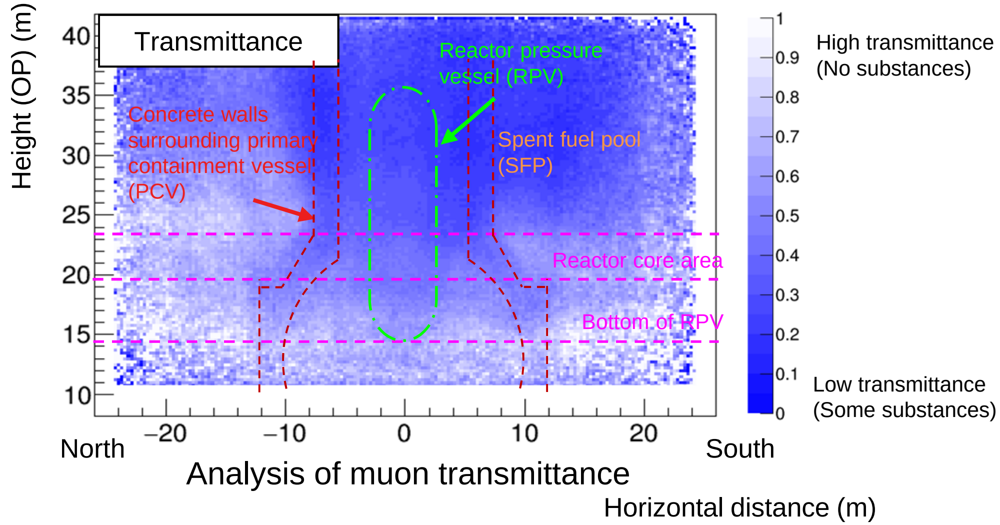


Measurement image of muon particles that pass through the reactor building (North-south cross section)

Measurement results at Unit 2 (muon transmittance and quantitative distribution)

(Measurement results as of July 22, 2016)



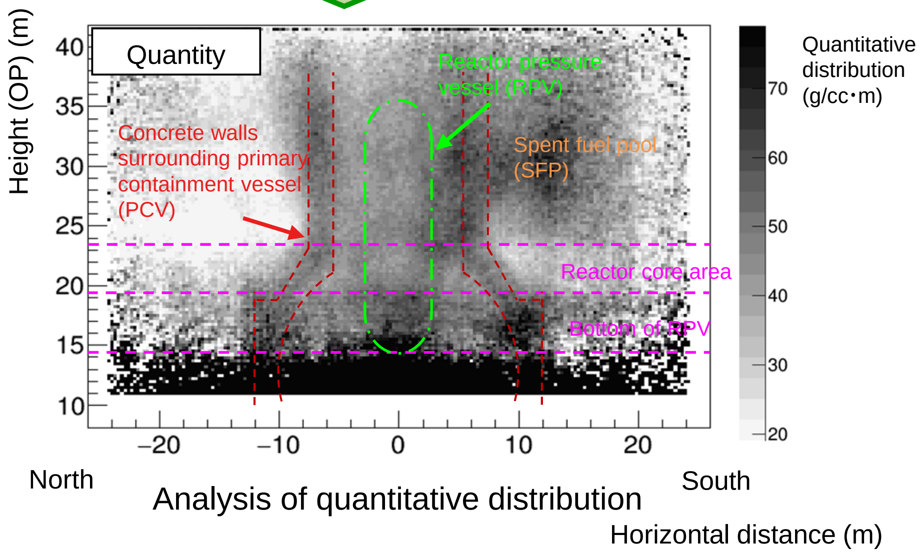


Analysis of muon transmittance

- Transmittance of muon particles that have passed through the reactor are calculated based on the number of particles measured by the device.
  - Shadows of structures such as concrete walls surrounding the primary containment vessel (PCV) and the spent fuel pool (SFP) were captured.

Quantitative distribution was analyzed from muon transmittance, considering the dependence on angles of muon transmittance based on the vertical difference in energy distribution of muon (the tendency that the color looks darker toward the upper part).

- Shadows of high density substances which are believed to be fuel debris were captured at the bottom of the reactor pressure vessel.



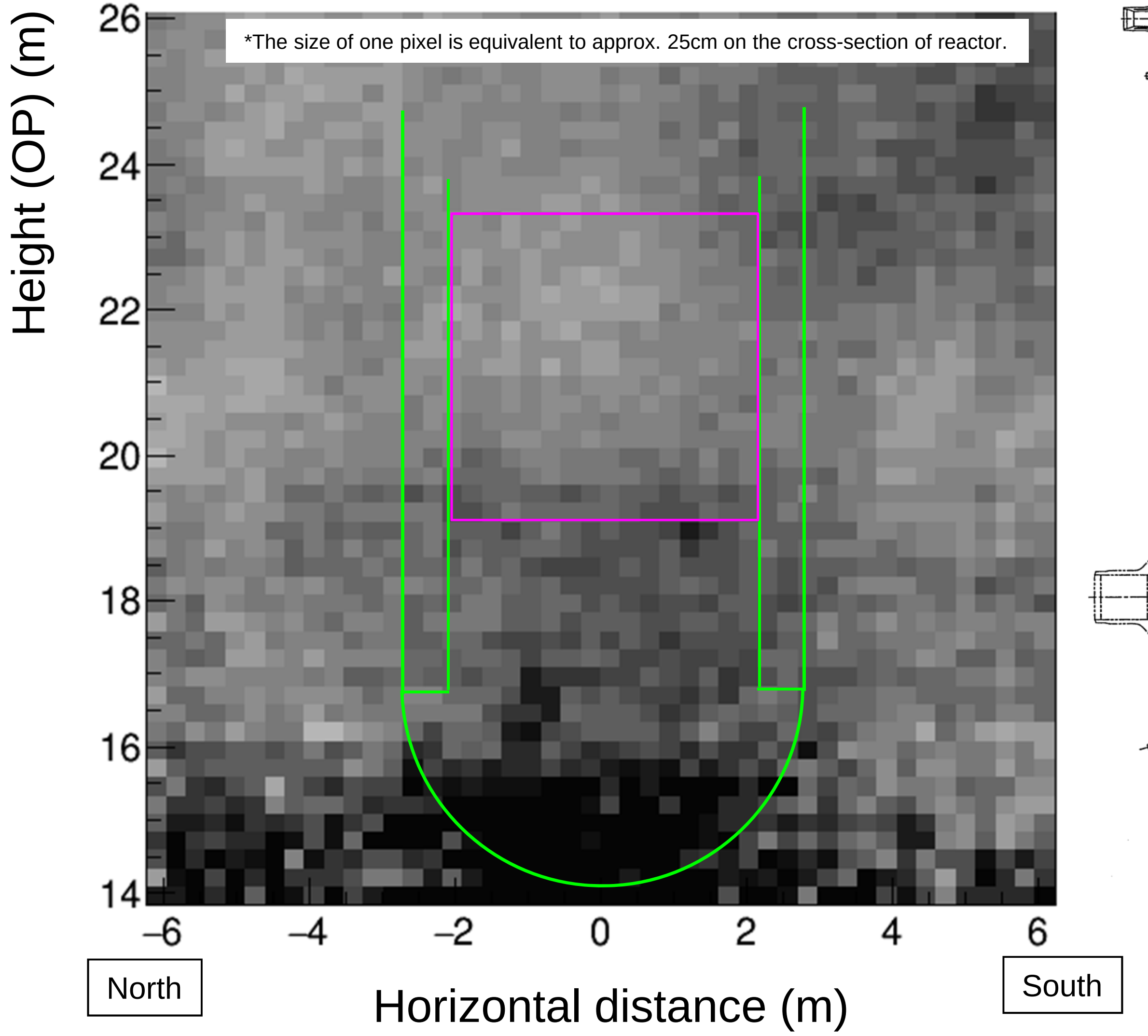
Analysis of quantitative distribution

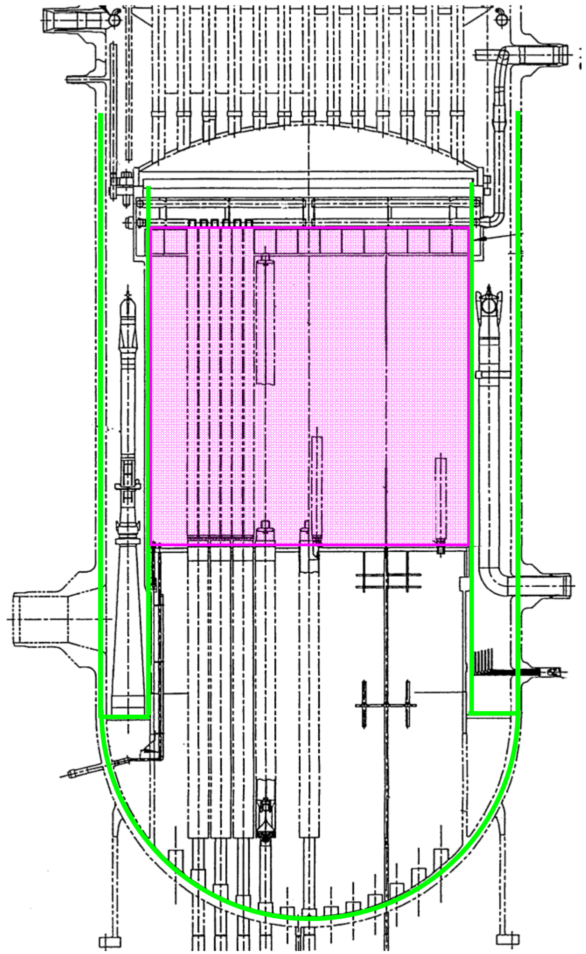
*Shadows of concrete walls surrounding around the primary containment vessel were captured at the same height as the bottom of the reactor pressure vessel (around OP14.3m), which can be considered as significant shadows.

Quantitative distribution inside the reactor pressure vessel (details of the lower part of the reactor pressure vessel)

(Measurement results as of July 22, 2016)

- Shadows of high density substances which are believed to be fuel debris were captured.

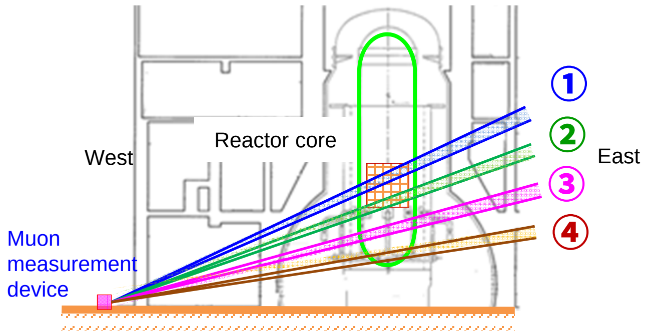


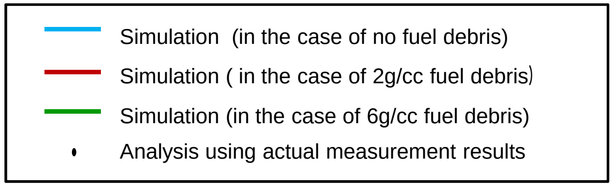


Structures at the lower part of the reactor pressure vessel

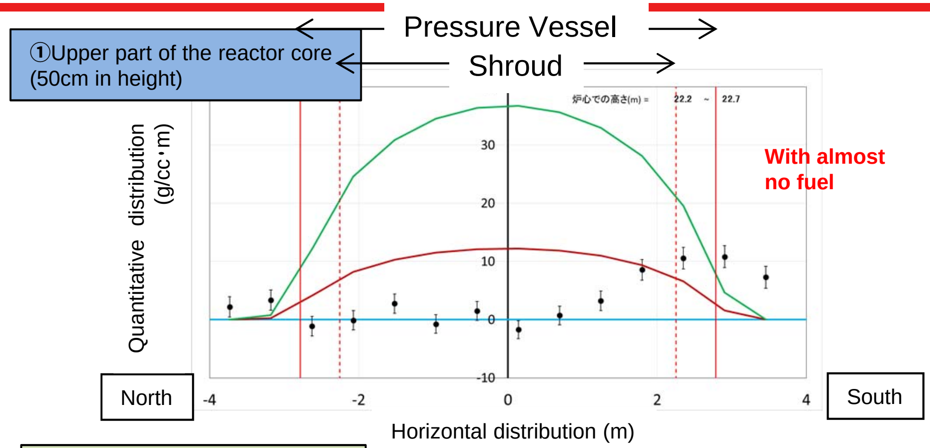
Quantitative distribution analysis inside the reactor pressure vessel using a statistical method

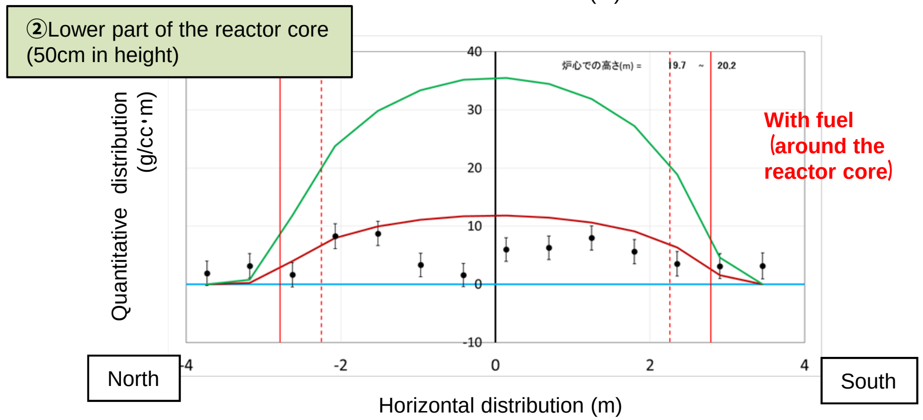
- Quantitative distribution inside the reactor pressure vessel was analyzed, comparing the simulations and the muon measurement results.

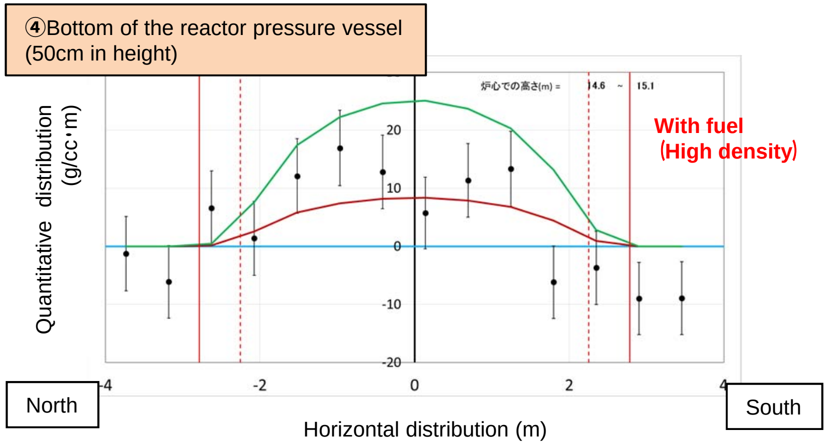


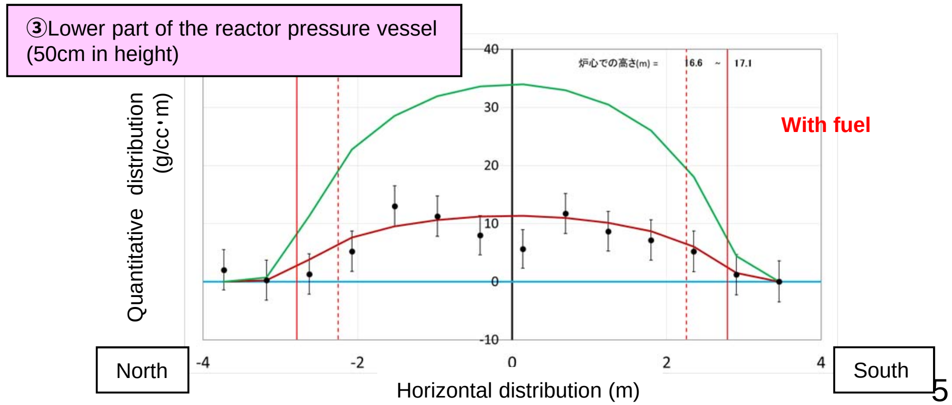


(Measurement results as of July 22, 2016)









Quantitative analysis of substances inside the reactor pressure vessel

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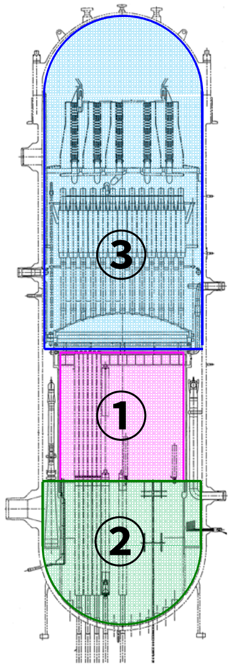
- Quantitative analysis of substances inside the reactor pressure vessel from the muon measurement results
  - From the two dimensional measurement results, the amout of substances inside the reactor pressure vessel were analyzed with the effects of the reactor building structures taking into account.



Quantitative analysis results

(Measurement results as of July 22, 2016)

	Analysis results (ton)		(Reference) Amount of substances before the accident* (ton)
① Reactor core (inside shroud)	Approx. 20-50	Uncertainty in this analysis for tens of tons	Approx. 160（Fuel assemblies） Approx. 15（Control rods）
② Bottom of reactor pressure vessel	Approx. 160		Approx. 35（Structures） No effects of water considered
Total（①+②）	Approx. 180-210		Approx. 210
(Reference) ③ Upper part of reactor pressure vessel	Approx. 70-100		Approx. 80（Structures）

- From the quantitative analysis results, most of the fuel debris is assumed to be at the bottom of the reactor pressure vessel.

*Design weights. Some structures are not taken into account for an simplified method. The analysis results are not precisely consistent with the design weights because the muon measurement is diagonally conducted in an angle of looking up the reactor pressure vessel.

Measurement results using the muon transmission method at Unit 2

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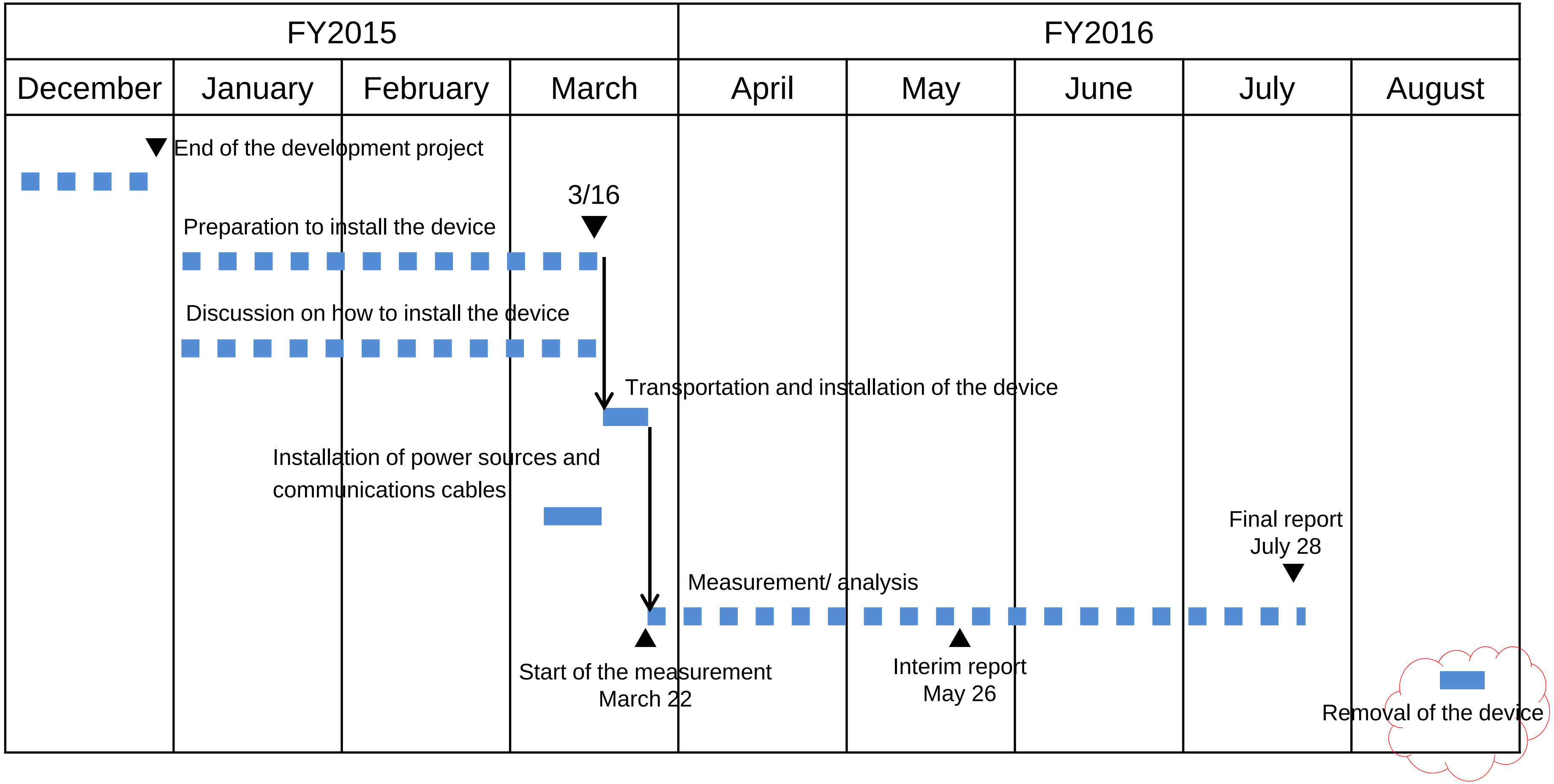
- In the measurement of muon particles through the use of the muon transmission method, shadows of major structures of the Unit 2 reactor were captured.
  - Shadows of concrete walls surrounding around the primary containment vessel were captured.
  - Shadows were captured in a position where the spent fuel pool is supposed to be.
  - Shadows of structures such as the walls and floors of the reactor building were captured.

- The analysis of the data obtained this time has indicated that high density substances which are believed to be fuel debris are at the bottom of the reactor pressure vessel.
  - From the quantitative analysis, most of the fuel debris is assumed to be at the bottom of the reactor pressure vessel

- Comparisons between the simulations and the muon measurement results have indicated that a small amount of high density substances which are believed to be fuel debris can also be at the lower part and around the reactor core.
  (However, some uncertainty remains in this analysis because the structures of the reactor building may affect the results.)

Rough schedule for the muon transmission method measurement at Unit 2



Removal work will be conducted after scheduling the use of the yard around Unit 2 with other work.