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Completion of the First ITER Toroidal Field Coil in Japan

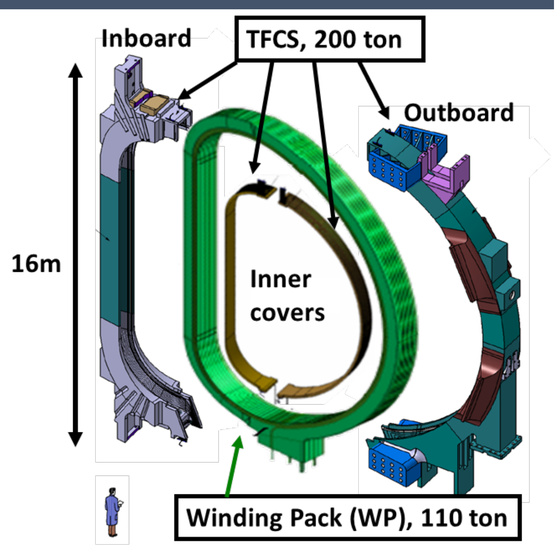
M. Nakamoto, T. Baba, Y. Kasai, K. Sakamoto, H. Shimane, T. Shimizu, K. Saito, M. Nakahira, N. Koizumi, M. Inoue*, E. Fujiwara*, T. Shichijo*, K. Kuno**, M. Yamane**, M. Hasegawa**, C. Luongo***

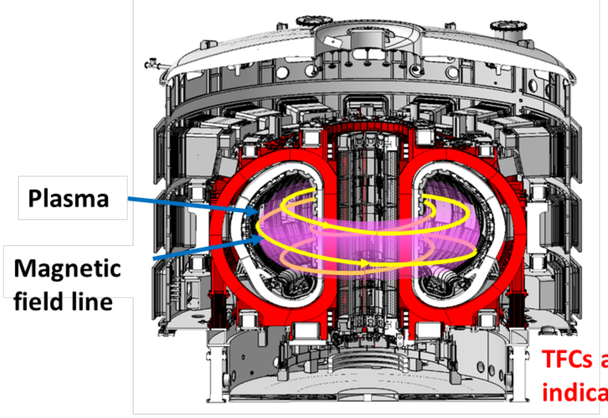
National Institutes for Quantum and Radiological Science and Technology
*Mitsubishi Heavy Industries, LTD.
**Mitsubishi Electric Corporation
***ITER Organization

Nakamoto.mio@qst.go.jp

INTRODUCTION

- 18 Toroidal Field Coils (TFC) in ITER
- TFC Specifications
  - Peak magnetic field: 11.8 T
  - Total magnetic energy: 41 GJ
  - Conductor material: Niobium Tin (Nb_3Sn), with application temperature ~ 4 K
  - TFCS material: SS316LN – ITER grade to maintain the structural integrity at 4 K, not easy to control welding deformation.





Function of 18 TFC: to generate precise circular magnetic field in a vacuum vessel

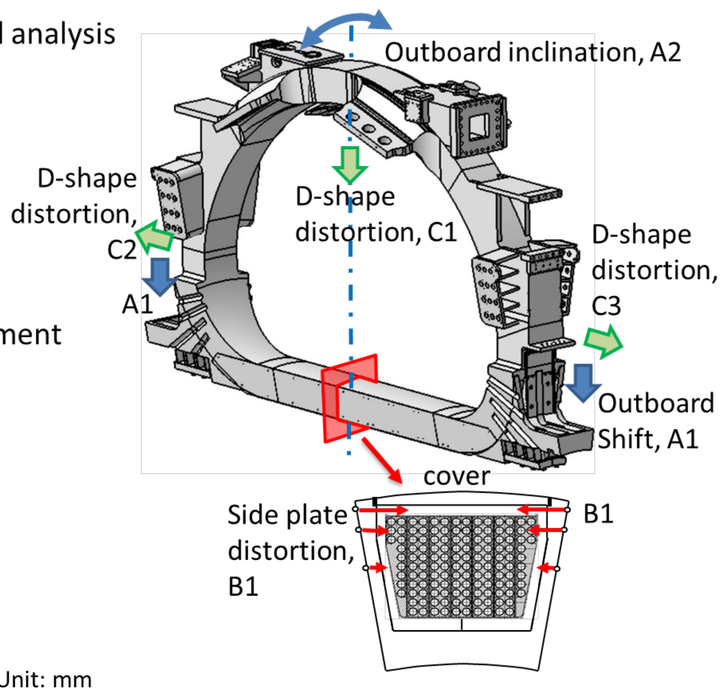
REQUIREMENTS/CHALLENGES

Challenges	Purpose	Requirements	Issues
(i) Interfaces	Assemblability	Sub-millimeter order tolerances	- Control of welding deformations
(ii) Gap	Integration of WP/TFCS	4 mm gap between WP-TFCS	- High-viscosity resin injection - Gap maintenance through welding
(iii) CCL	Magnetic property of each TFC	- Φ2.6 mm @ inboard - ±3.0 mm @ outboard	- Precise positioning of a WP - Traceability of a WP positions

(i) INTERFACE

Welding qualification trials Local analysis
↓ Inherent strain parameters
FEM analysis Global analysis
↓
Actual coil

Extra materials -> machined later
Laser tracker monitoring -> adjustment



Comparison of welding deformation

	Trial	FEM	1st coil
A1	8	5.6	6.9
A2	3.11	0	2.2
B1	4.4	4.0	5.0
C1	3.9	3.5	5.0
C2	3.6	2	1.8
C3	3.90	2	3.2

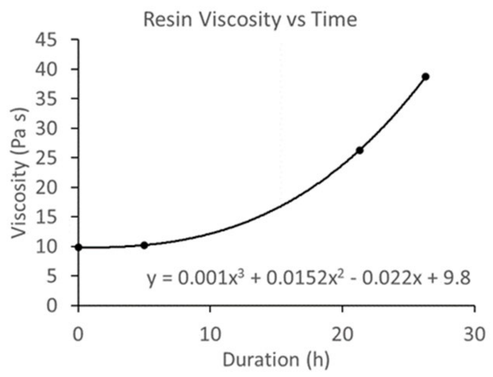
Unit: mm

- **Harmonization**:
  - **18 TFCs can be assembled** if all have the same shape
  - **Global remedial action** to accept the welding deformation
  - guided by IO

All the interfaces satisfied the severe tolerances.

(ii) GAP

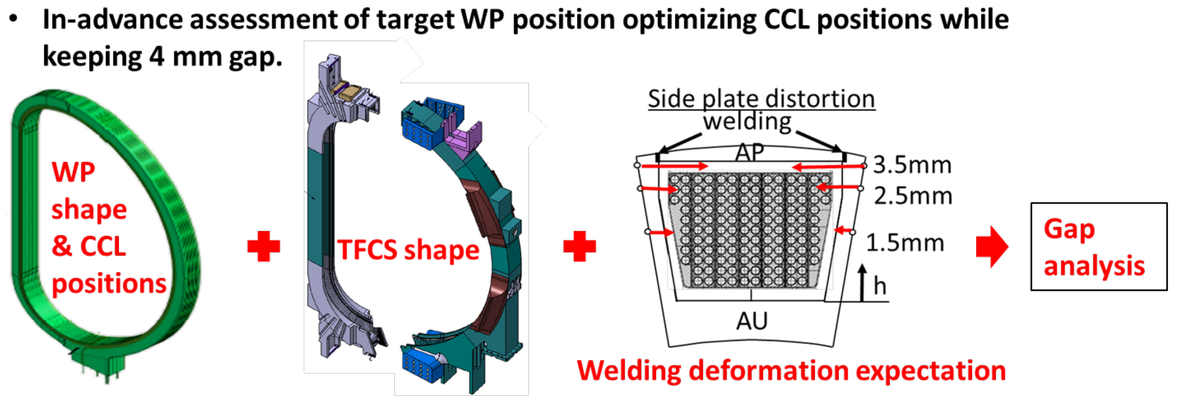
- Gap-filling:
  - **Structural integration** of WP & TFCS
  - **High viscosity resin**
  - **Fiberglass layer** on WPs
- **Vaccum pressure impregnation** to prevent void formation (0.2MPa pressurization).
- **Min. gap:** 4 mm to ensure the complete filling of gap with high viscosity resin.
- **Fresh resin at the resin front**: to minimize void formation & valves for higher resin injection holes were opened as the resin level reaches the hole positions.

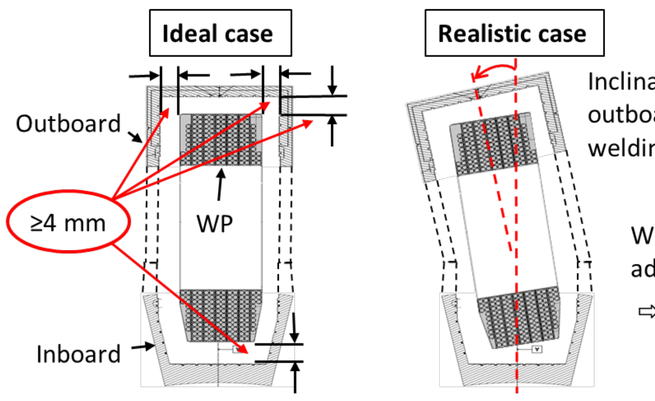


With proper measures, gap-filling procedure was verified for resin injection into 2 mm local gap (4 mm nominal).

(iii) CCL

- **In-advance assessment of target WP position optimizing CCL positions while keeping 4 mm gap.**





- **CCL traceability measurements** by laser tracker:
  - Frequent measurements ⇨ **minimize errors** during final machining
  - Repetitive measurements ⇨ **minimize uncertainties**

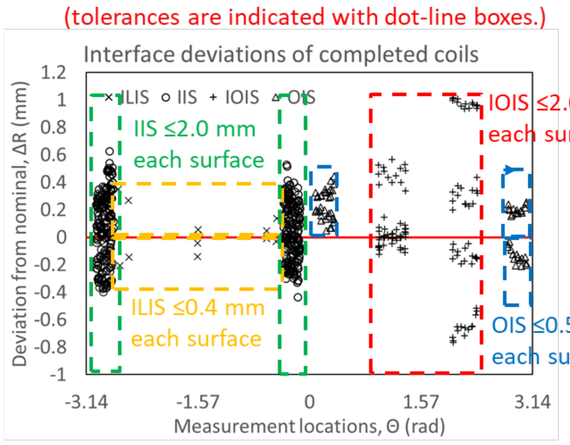
CCL deviations:
- **0.35 mm max. @ inboard**
- **1.46 mm max. @ outboard**

CCL requirements: satisfied!

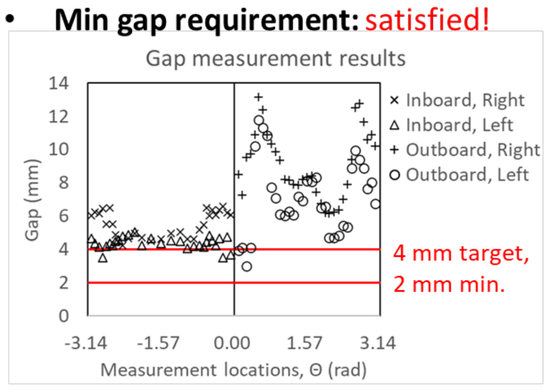
Laser tracker measurement

OUTCOME

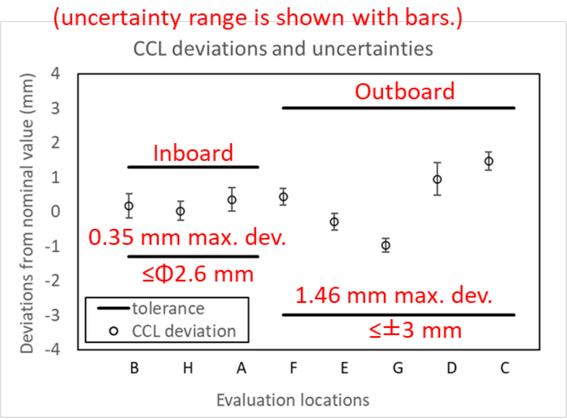
- **Interface requirement:** satisfied!
  (tolerances are indicated with dot-line boxes.)

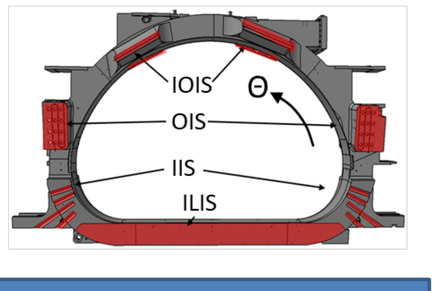


- **Min gap requirement:** satisfied!



- **CCL position requirement:** satisfied!
  (uncertainty range is shown with bars.)





For the 1st TFC,
- **Magnetic property: achieved!**
- **Assemblability: achieved!**

CONCLUSION