Status of ITER Thermal Shield Development

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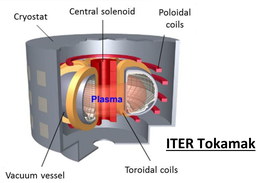
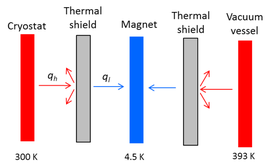
Abstract

Thermal shield (TS) will be installed in the ITER Tokamak to protect the superconducting magnet from thermal radiation from cryostat and vacuum vessel. The TS is cooled by 80 K helium supplied from cryoplant. The emissivity of TS surface must be maintained below 0.05 by bath-type silver electroplating. The TS is to be fully procured by Korea and it will be assembled in the ITER Tokamak by ITER organization. This poster describes the overall status of the ITER TS procurement: the manufacturing design and the current manufacturing status of vacuum vessel thermal shield (VVTS). Some mock-ups were fabricated and tested to validate the TS design and manufacturing: in-pit joint assembly, 3D shape bending method of long cooling tube. Prior to the manufacturing of the TS, full-scale prototype of VVTS 10 degree section was developed in order to assess the overall manufacturing procedure of the TS except silver coating. After the completion of manufacturing design, R&D and prototype fabrication, the VVTS manufacturing started in October 2014. The current status of VVTS manufacturing is shown in this poster.

1. Introduction



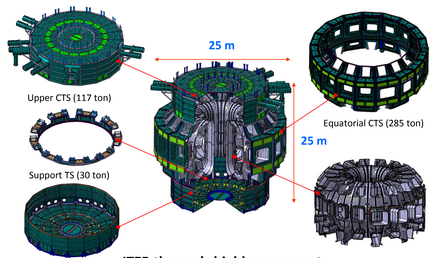
ITER Tokamak



ITER Thermal Shield location

◆ **Main parameters**

- Total weight: ~ 900 ton
- Total height: 25 m (~ 10 story building)
- Main material: SS304LN
- Cooling tube: OD 13.7x2.24t
- Thickness: 10 & 20 mm
- Emissivity : < 0.05 (silver coated)
- He coolant : 80 ~ 100 K, 1.8 Mpa
- Segment: 10 & 20 degree
- Assembly: bolted joints (~ 60000 ea)
- Surface area: 1920 m² (VVTS), 1990 m² (CTS/STS)
- Surface roughness: < Ra 0.24 μm

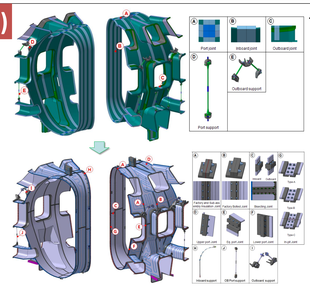


ITER thermal shield components

2. Design Finalization (1)

◆ **Final design of TS main components**

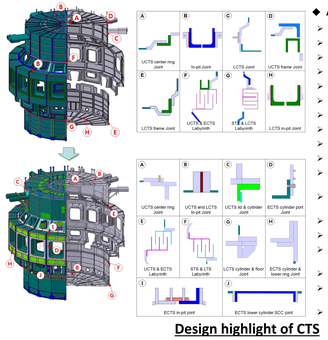
- The final design review was held in November 2011 and approved in Oct 2012.
- The final design and the supporting analysis were performed for the key components of the TS such as joint, panel, cooling tube, support, labyrinth and stopper.



Design highlight of VVTS

◆ **Additions and Changes**

- Welded flange→ Bolted flange
- Added Inboard support
- Added Lport central labyrinth
- Modified Uport lateral
- Added insulation stopper
- Divided inboard and outboard 2 part
- Added bisecting flange joint
- Modified outboard support
- Added inboard support
- Added cooling pipes
- Modified port flange(Bolt holes)
- Added stud flange
- Added In-pit joint with stud
- Modified 10deg. Segment flange
- Added hook cover
- Modified rucksack
- Modified lower central port flange(assembled to the STS)



Design highlight of CTS

◆ **Additions and Changes**

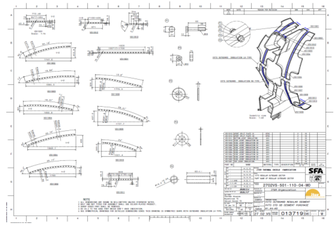
- Modified flange joint
- Added feedthru. supports
- Modified CTS main support
- Added maintenance hole
- Modified cooling pipes
- Added access gate
- Modified labyrinth
- Added labyrinth stopper
- Modified joint concept
- Added handing fixture
- Added screen(prevent direct shine through)
- Modified ECTS cylinder (welded → assembled type)
- Modified manifold penetration
- Divided ECTS lower cylinder
- Modified labyrinth due to assembly sequence
- Modified LCTS gate
- Modified magnet feeder labyrinth
- Divided Central ring 2 parts

- The VVTS and the CTS had been revised considering assembly, manufacturability and interface with other Tokamak components.
- Major changes for the VVTS are bolted in-pit joint, bisecting joint and hook cover.
- For the CTS, removable panels for maintenance purpose were added in the final design.

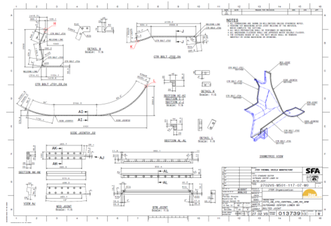
2. Design Finalization (2)

◆ **Manufacturing design of TS main components**

- TS CAD work was carried out by CATIA with ENOVIA system (PLM software of Dassault Systems), which is officially selected by ITER organization (IO).
- In order to create the 2D drawings of the TS, 3D models were converted from multi-body to multi-part in the ENOVIA. Minor model revisions were implemented to resolve model clashes and to reflect assemble feasibility.
- The three sorts of manufacturing drawings for the VVTS were developed: main assembly drawing, sub-assembly drawing and segment/part drawing.



Sub-assembly drawing

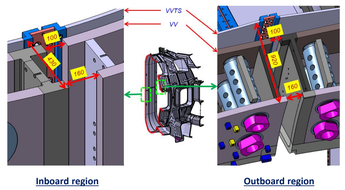


Segment/part drawing

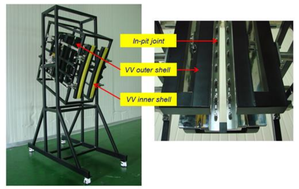
3. R&D Activities (1)

◆ **Assembly test of VVTS field joint**

- VVTS is located between the VV and the TFC.
- The field joint is far from the VV inside through narrow gap.
- Misalignment compensation: 3D reverse engineering of splice plate



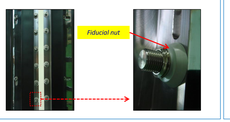
Assembly condition of VVTS field joint



Validation mock-up for VVTS in-pit joint

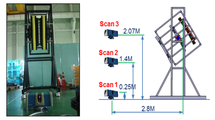
STEP 1: Assembling fiducial nuts for 3D scanning

- The matt finished fiducial nuts are assembled on the in-pit joint flange before 3D scanning to improve scan accuracy & quality.



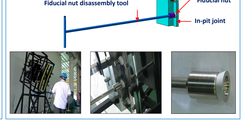
STEP 2: 3D scanning of in-pit joint

- The 3D scanning is performed with resolution 90 at three positions to minimize not scanned area and to improve scan accuracy.

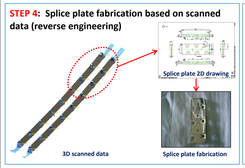


STEP 3: Disassembling fiducial nuts

- After 3D scanning, the fiducial nuts assembled on the in-pit joint are removed by following tool.



STEP 4: Splice plate fabrication based on scanned data (reverse engineering)

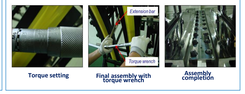


STEP 5: Assembling splice plates

- The splice plate handling tool is used to insert & assemble splice plates onto the in-pit joint.
- After assemble splice plate with the stud bolts, the nuts & washers are handled carefully and fastened by using nut & washer assembly tool.

STEP 6: Adjust torque of nuts

- After assemble nuts & washers to fix the splice plates, the torque of nuts are adjusted with the torque wrench.
- Extension bar is used to fasten the nuts.



Assembly procedure of VVTS field joint

3. R&D Activities (2)

◆ **Full-size Prototype Fabrication of VVTS 10 degree section**

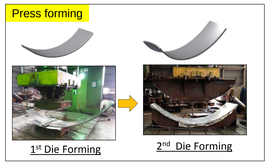
1. Buffing: Roughness ≤ Ra 0.24 μm

- 1st (before cutting) 2nd (before tube welding), 3rd (after assembly test)

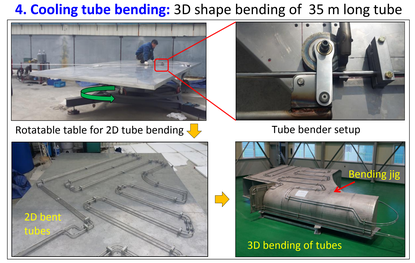
2. Cutting: Shell & flange cutting by water-jet

3. Shell Bending & Forming

- Press bending by press brake & press die forming by hydraulic press
- Thickness reduction: max 0.64 mm after bending, forming and buffing



4. Cooling tube bending: 3D shape bending of 35 m long tube



5. Shell/flange welding

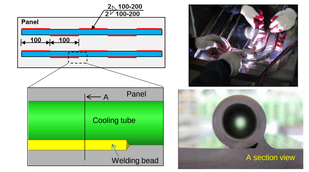
- Gas Tungsten Arc Welding (GTAW)
- Multi-pass welding
- Groove: X (shell to shell & flange to flange), K (shell to flange)

Inboard welding

Outboard +lower port welding

6. Cooling tube welding

- Gas Tungsten Arc Welding (GTAW)
- Staggered welding bead



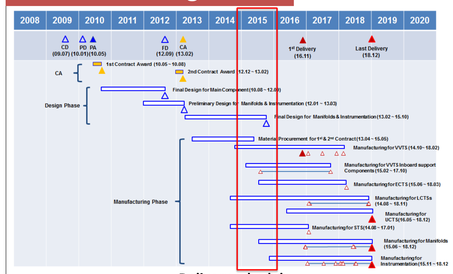
7. Final machining of flange by a plano miller

- Sector assembly needs tight tolerance (± 2 mm).

8. Final assembly & dimensional inspection

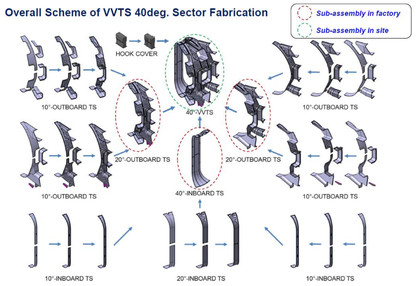
4. Manufacturing Status

◆ **Manufacturing of VVTS started in October 2014.**

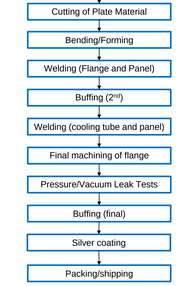


Delivery schedule

Overall Scheme of VVTS 40deg. Sector Fabrication



VVTS fabrication scheme



Manufacturing procedure

Plate buffing

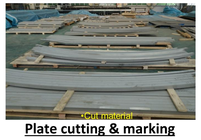
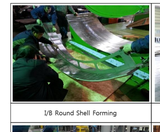
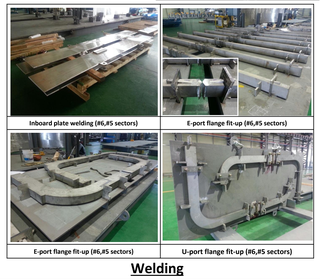


Plate cutting & marking



Bending & forming



Welding

5. Near-term plan

- Manifold & instrumentation final design approval (2015)
- Construction of silver coating facility (2015)
- Start of CTS & STS fabrication (2015)
- FAT of VVTS #6,#5 sectors (2016)

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