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# Recovery of ITER Sector Modules from Critical Issues

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## ABSTRACT

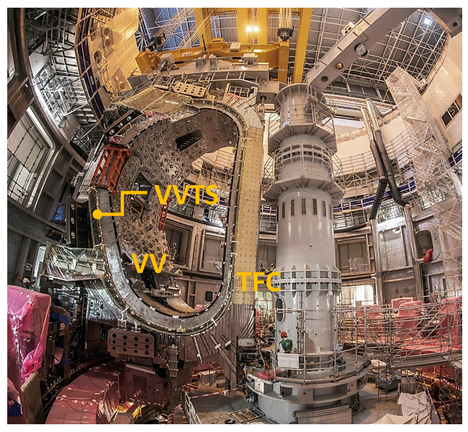

- This paper presents the critical issues identified in both the VVTS and VV, the recovery strategy, the repair process, and the lessons learned.
- In the VVTS, leakage was detected on the cooling pipes caused by SCC. VVTS was repaired to eliminate risk of corrosion cracking.
- In the VV, geometrical non-conformance on welding bevel for sector assembly was observed. VV was repaired through bevel build up and machining to comply with the VV sector welding requirement.


## BACKGROUND

- In May 2022, the assembly of the first Sector Module (SM) was completed, and it was successfully transferred to the pit.

However, it was decided to return the first SM to the SSAT and dismantle for repair due to critical non-conformance in the VVTS, confirmed in Sep. 2022.

It also was decided to carry out VV bevel repair outside the pit originally planned repair in the pit.

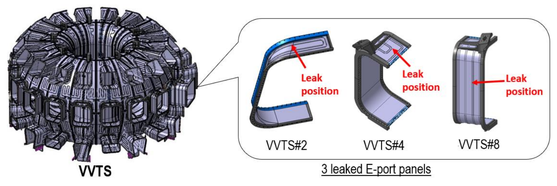



*ITER Sector Module in the pit*

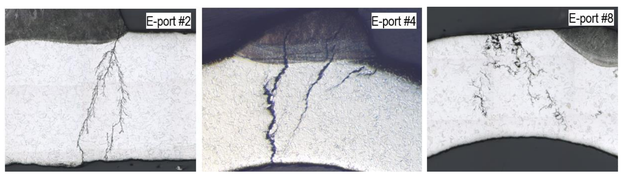
## VVTS – Critical Issue and Recovery

### SCC on TS pipes

- Intergranular crack observed by metallographic examination
- High contents of chloride detected on the pipe surface
  (chemicals from Ag coating process became trapped underneath of the pipe weld)
- Residual stress due to pipe bending and pipe welding



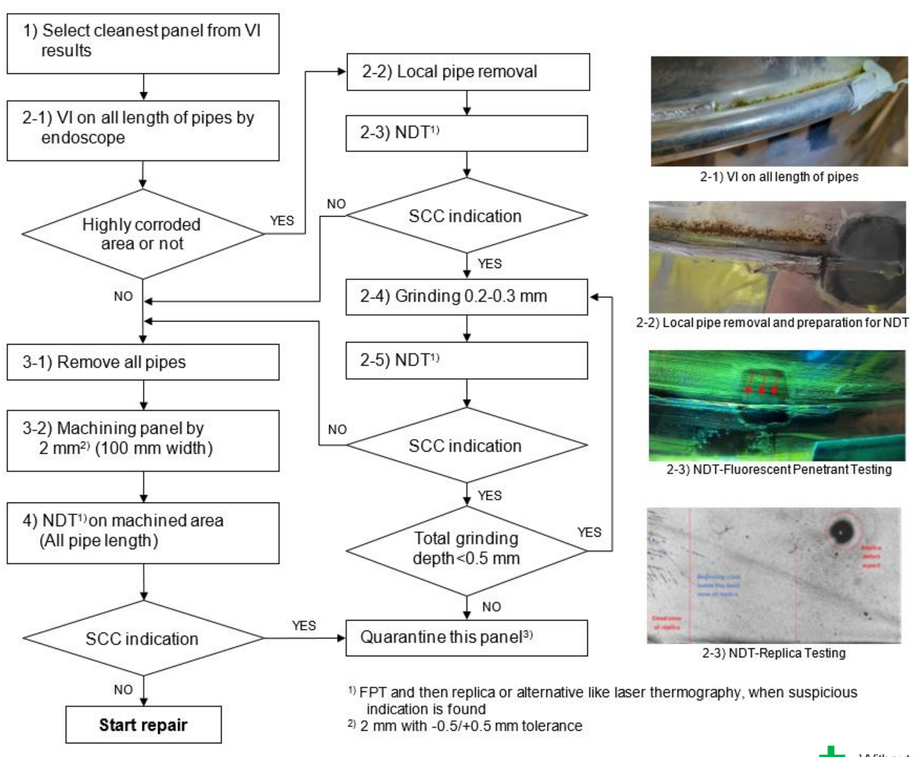

*3 leaked panels out of 500 TS panels*




*Pipe crack from leaked panels*

### Repair to eliminate risk of SCC and galvanic corrosion

- Presence of chloride and SCC crack
  → Systematic visual inspection / FPT, Targeted the pipe welded area
- Grinding can't guarantee perfect removal of chloride
  → Panel 2 mm thick layer in the vicinity of the pipes
- Potential risk of SCC and corrosion from long-term storage
  → Use of 316L grade pipe and ER317L Mn Mod filler
- Defects on Ag coating layer caused by exposure to high humidity conditions
  → Ag coating removal and surface buffing with Ra < 0.1 µm
  *Polished stainless steel (Ra< 0.2 µm) exhibit emissivity comparable to a silver-coated surface




*Repair process*



2-1) VI on all length of pipes



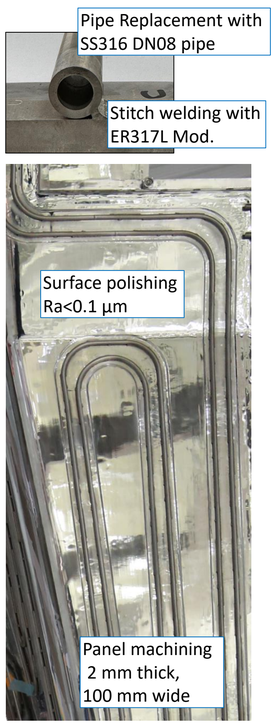
2-2) Local pipe removal and preparation for NDT



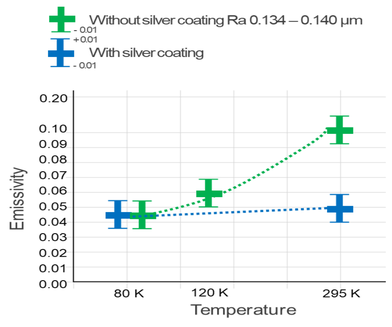
2-3) NDT-Fluorescent Penetrant Testing



2-3) NDT-Replica Testing




*VVTS outboard after repair*

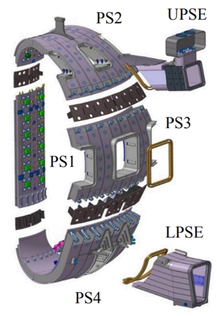



*Emissivity test result*

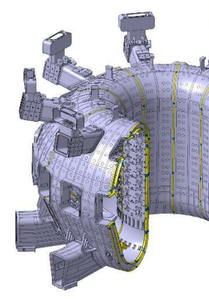
## VV – Critical Issue and Recovery

### Geometrical deviation on VV welding bevel

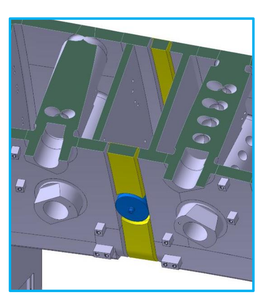
Toroidal welding shrinkage from manufacturing process causes radial/toroidal waviness, slope in bevel profile.



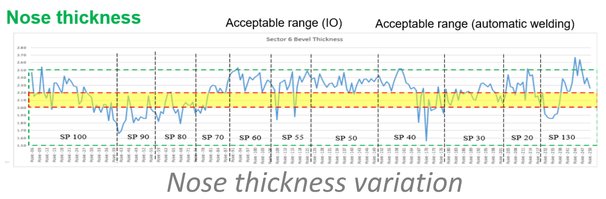

*VV segment*



*VV welding joint in the pit*




### Consequences of bevel dimensional deviations



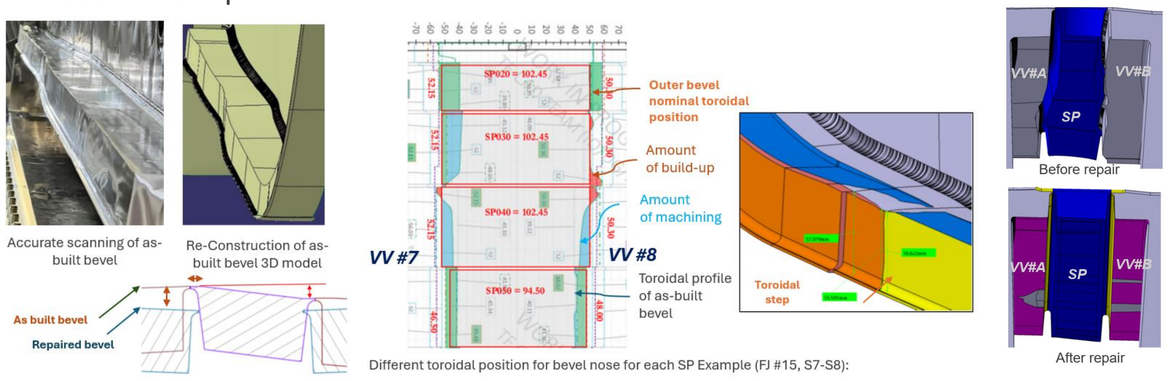

*Nose thickness variation*

- Difficulties to adapt the welding machine to trajectory changes / splice plate customization and alignment / welding machine operation
- Potential clash with welding machining and NDE tooling.

### Challenges and resolution

Feasibility of build-up in different welding positions / Need of significant level of build-up / Demonstration of mechanical properties of build-up / Dedicated UT qualification of the build-up area / Metrology validation of achieved tolerance
→ Demonstrated with specific qualification through dedicated representative build-up welding coupons in different positions for both manual tig and mechanized tig.

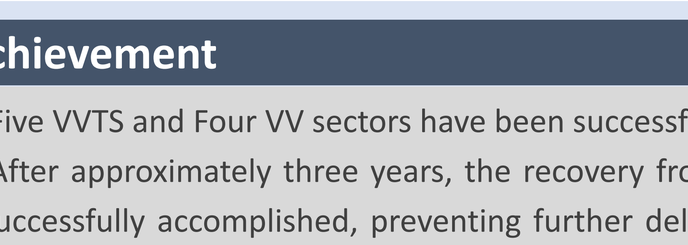
**Repair Strategy :** Optimized combination of build-up and machining
**Build-up**: to recover material in toroidal dir. (mostly outer bevel)
**Machining**: to remove excess of material in toroidal dir. (mostly inner shell) and to get final bevel shape
**Customized solution** for each Splice Plate adapted to each field joint.
**Development of metrology process** for identification, monitoring and validation of areas to be repaired




*Bevel repair process from as-built to repaired panel*

### Repair

**Build-up & NDE**: 3 different cases depending on level of material to be recovered
**Bevel machining & Metrology :** Portable milling machine - aligned to the Sector bevels by temporary metrology network / 3D scanning after final bevel machining to validate of achieved tolerances




*3 different cases of build up*

*Bevel Machining*

## Lesson Learned

- Silver coating on the pipe stitch welding should be avoided (by masking or similar way) due to potential risk of residual chlorides from the coating process. (VVTS)
- Polishing stainless steel can be considered a practicable alternative replacing Ag coating. (VVTS)
- Narrow gap welding required tight tolerance. Bevel machining shall be carried out at the last stage of manufacturing process. (VV)
- Key factors for success are: accurate analysis of as-built deviations, qualified welding & machining process, preliminary trials through dedicated mock-up, and skilled/experienced welders and operators. (VV)

## Achievement

- Five VVTS and Four VV sectors have been successfully repaired by mid of 2025.
- After approximately three years, the recovery from the critical problem has been successfully accomplished, preventing further delays by removing technical risk in the ITER project.