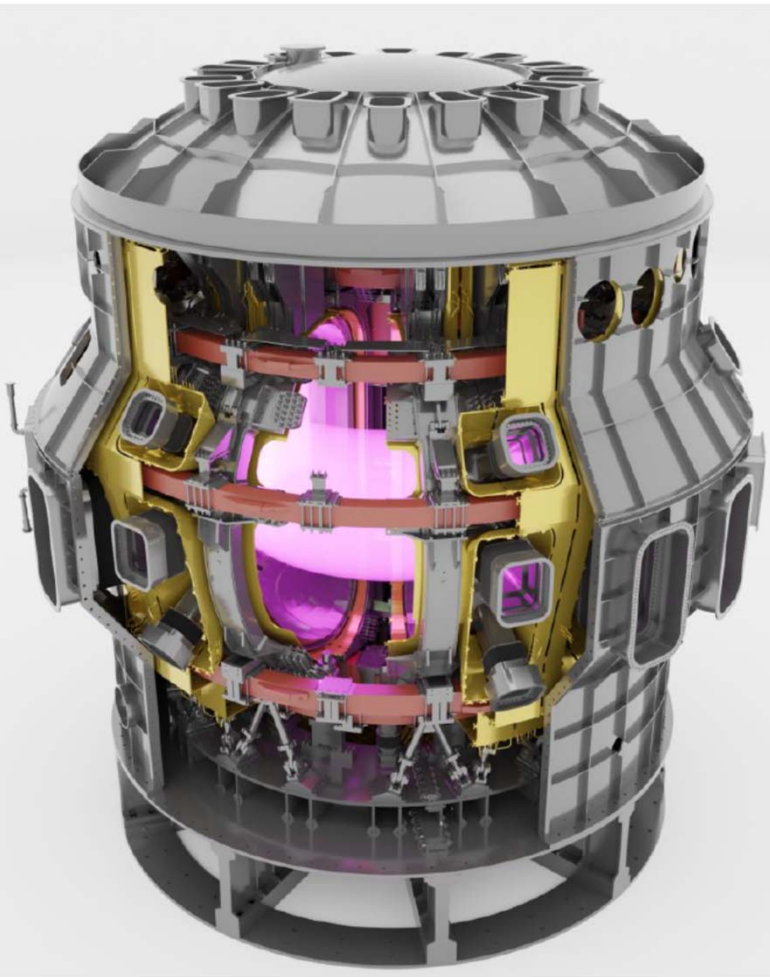
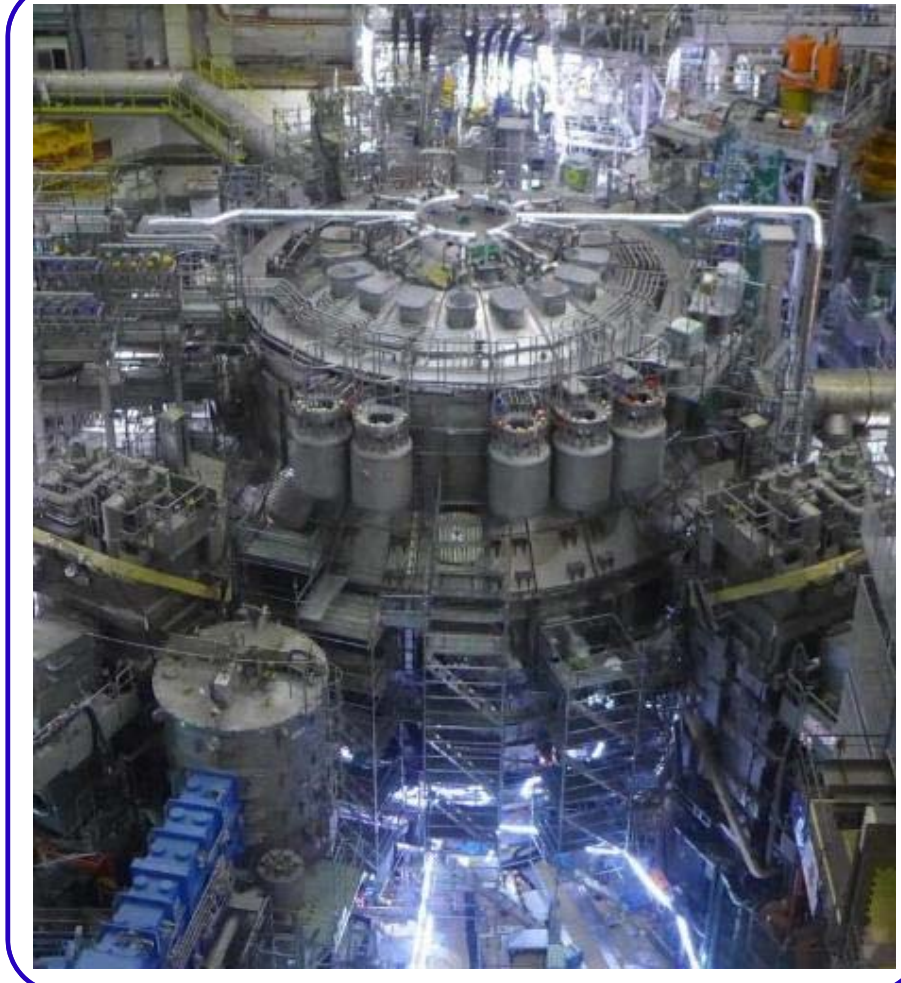


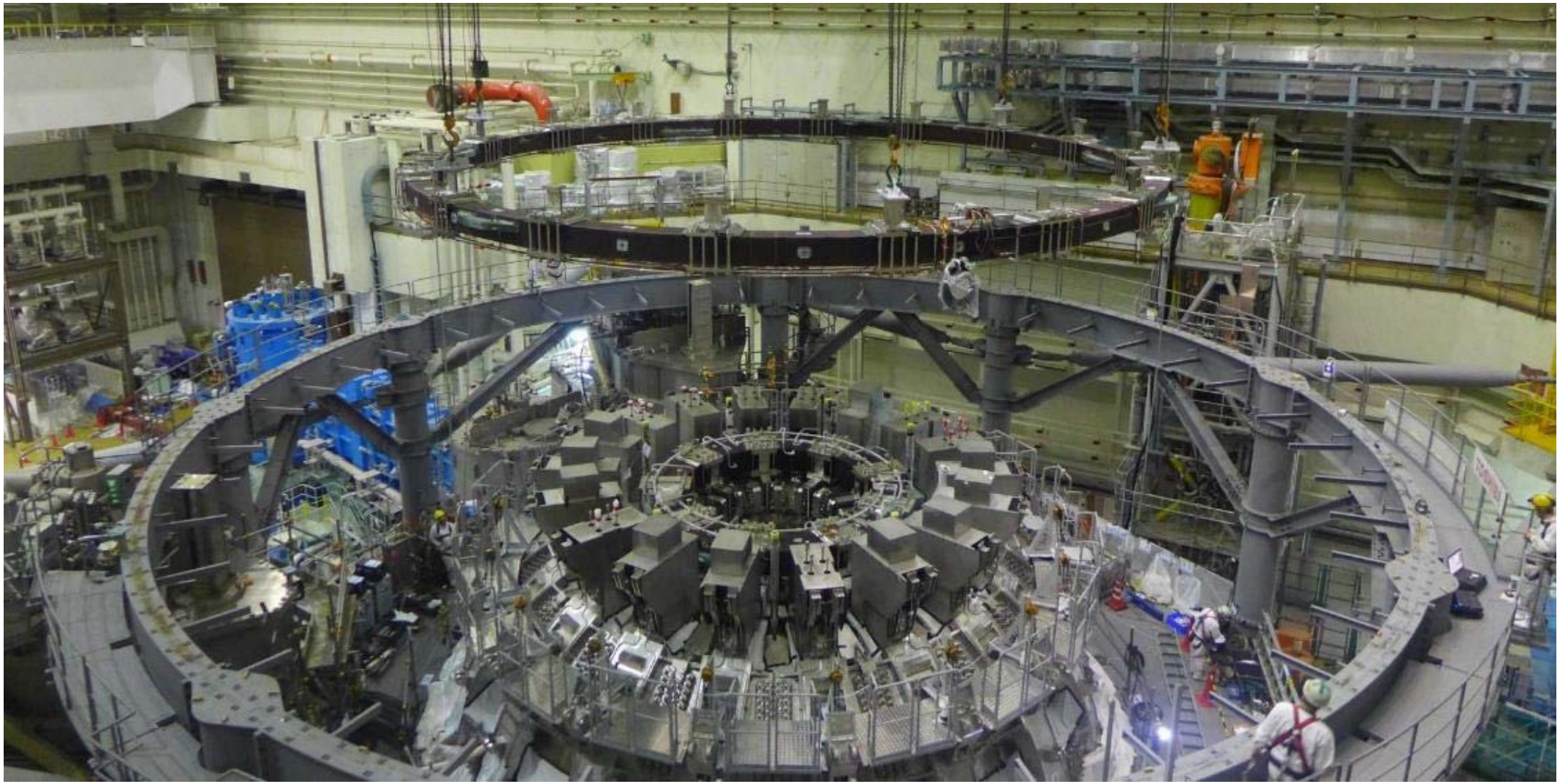
JT-60SA

Status Update
06 September 2022

Sam DAVIS

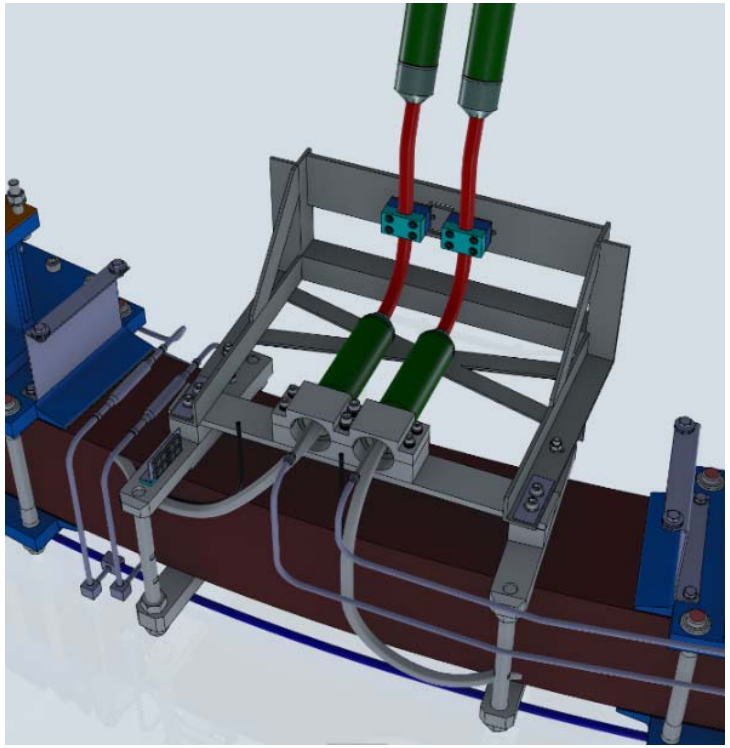


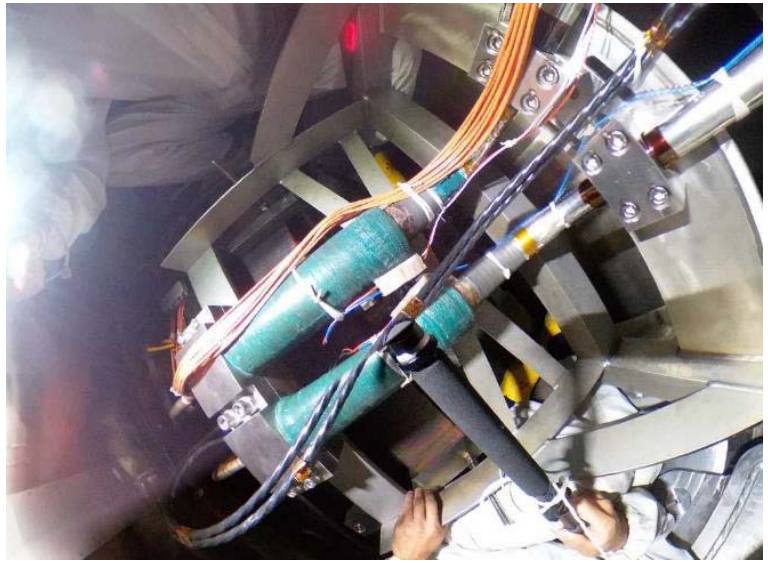
Background: EF1 arc

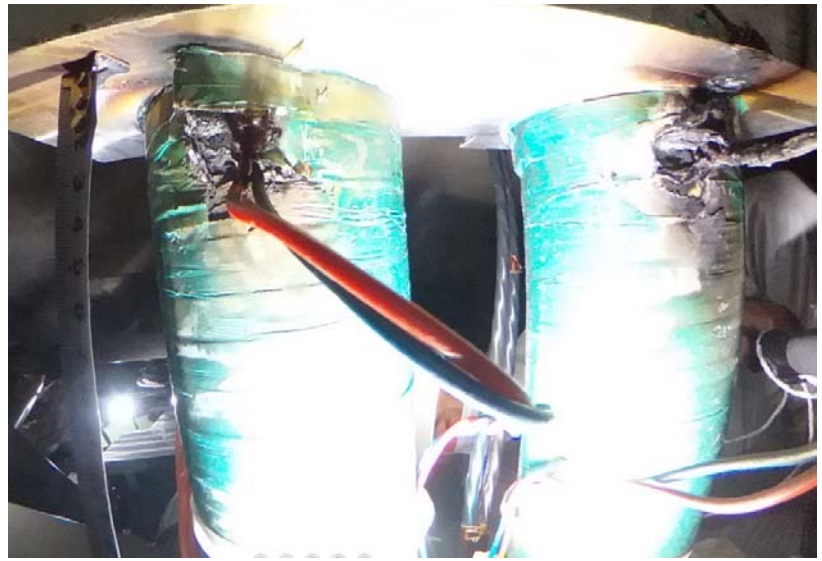


EF1 installation in 2018

EF1 terminal joints

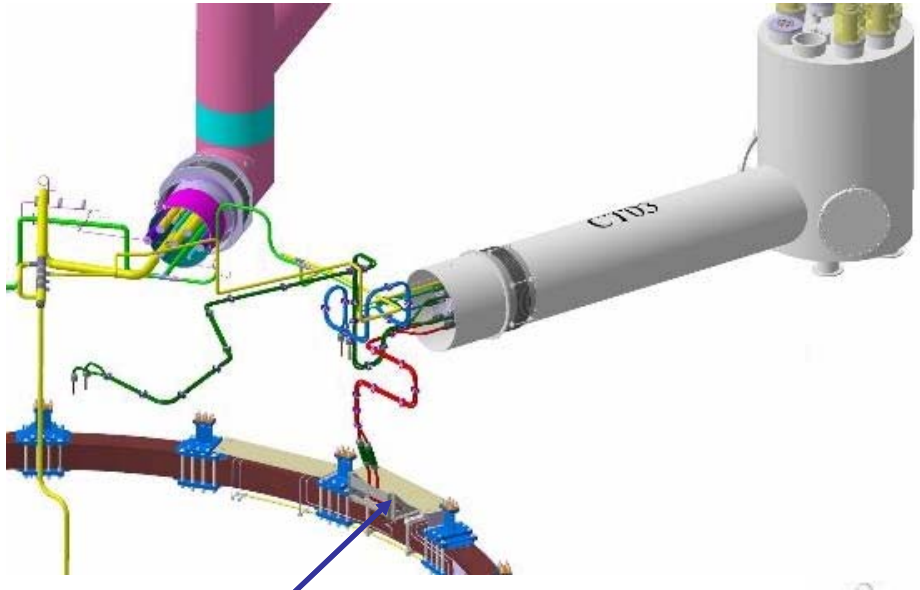






- Arc occurred between the EF 1 terminals on 09 March 2021 with 350 A in the coil
- Exact failure mechanism is still unknown since no degradation of cryostat vacuum was detected before the arc
- Target: Paschen-proof tokamak

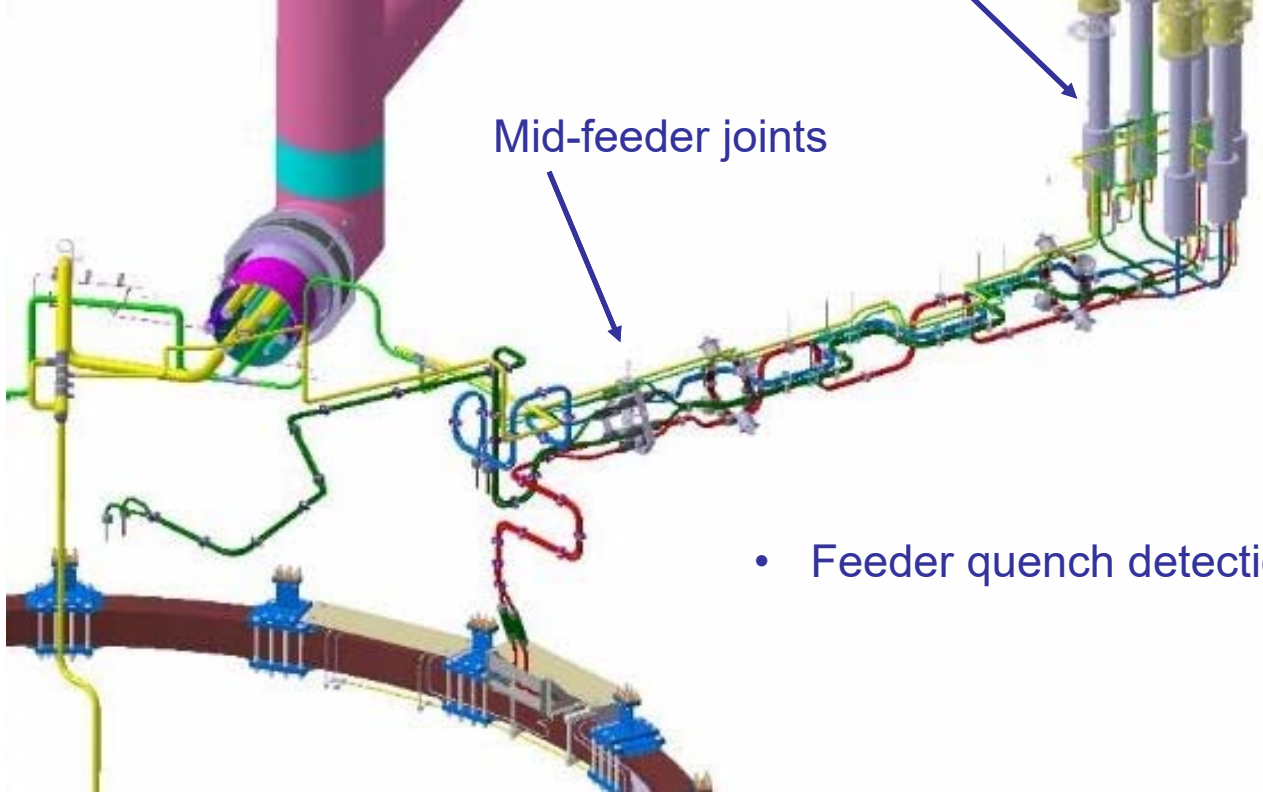
Areas reinforced



Coil terminal joints

HTS current leads

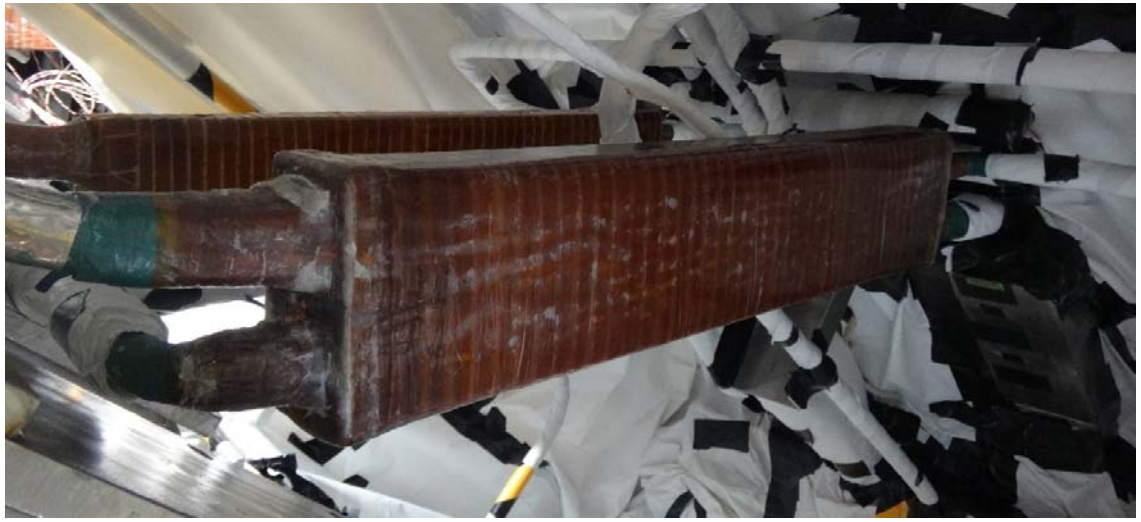
Mid-feeder joints

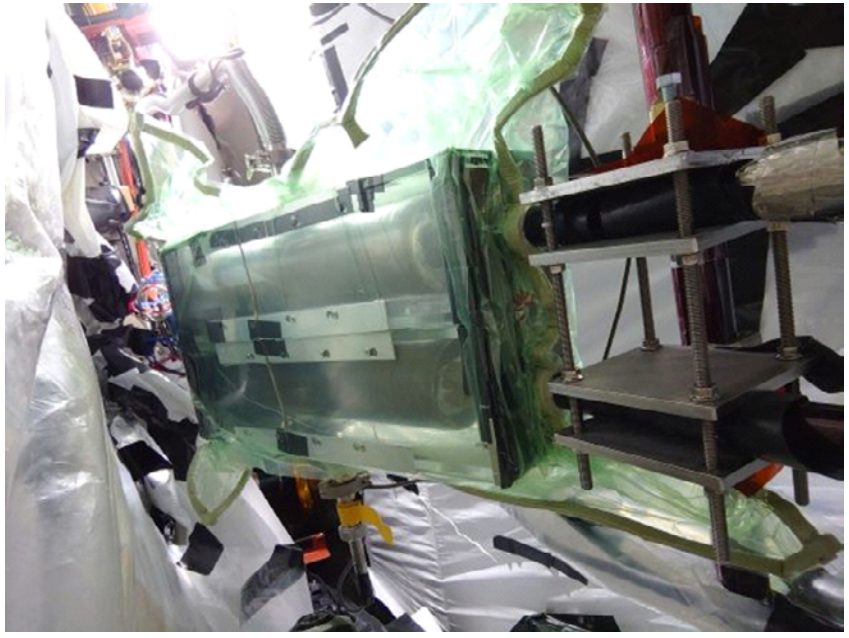


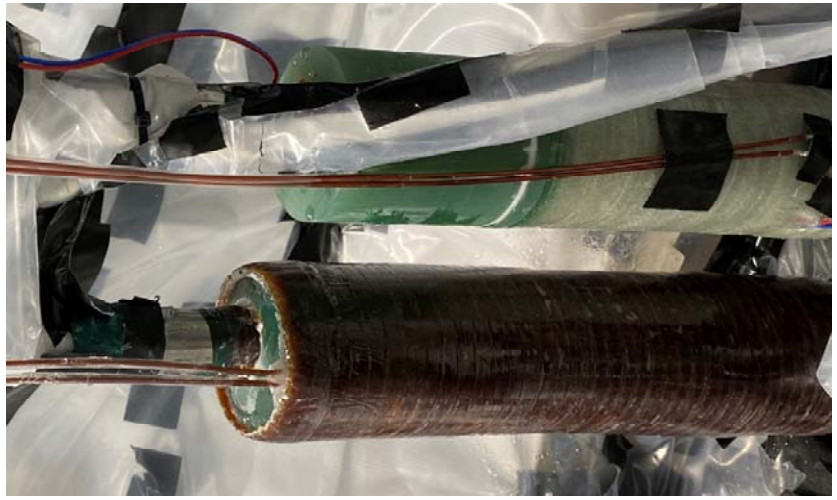
- Feeder quench detection (QD) wires

Completed insulation reinforcements (1)

- 84 joints and associated quench detection (QD) cable extractions
  - 36 TF terminal joints
  - 20 EF & CS terminal joints
  - 28 mid-feeder joints







Completed insulation reinforcements (2)

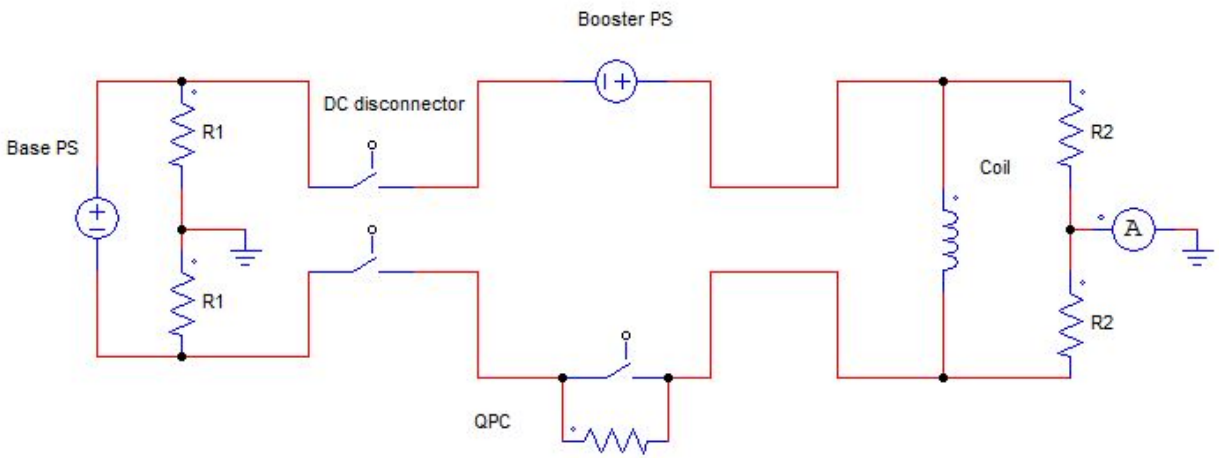
- “Complex geometry” near EF and CS terminals
  - 4-core wire extraction points
  - Conductor and pipe exits
  - … 30 customized solutions

- 26 current leads (4 locations each)
- Feeder quench detection wires replaced with individually screened cables
- One-off faults on TF 2 feeder and TF 15 tail

- All reinforced positions tested under local Paschen conditions (including numerous QD wire joints and feedthroughs)

Grounding point modifications

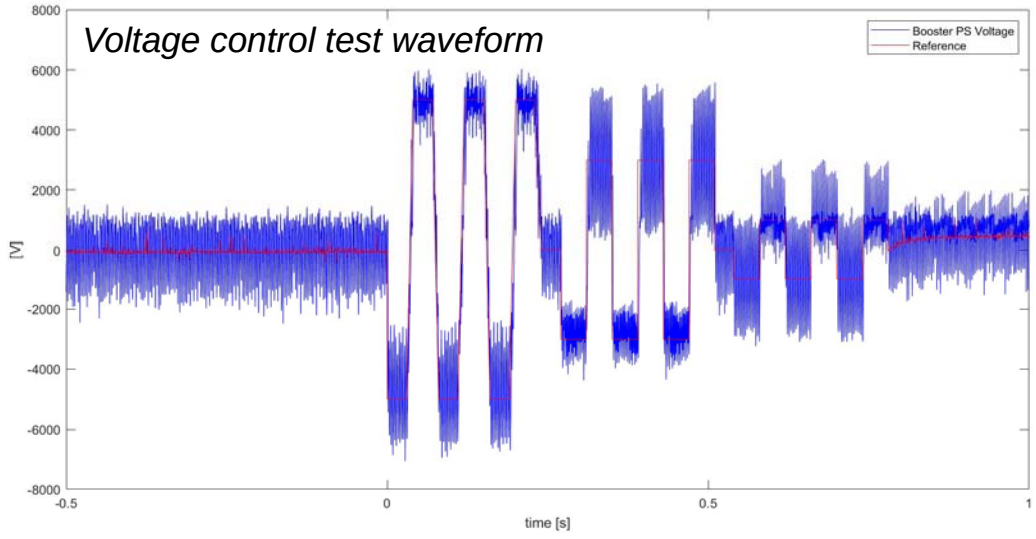
- Mid-point grounding has been implemented for the superconducting coils, effectively halving their potential versus ground during operation

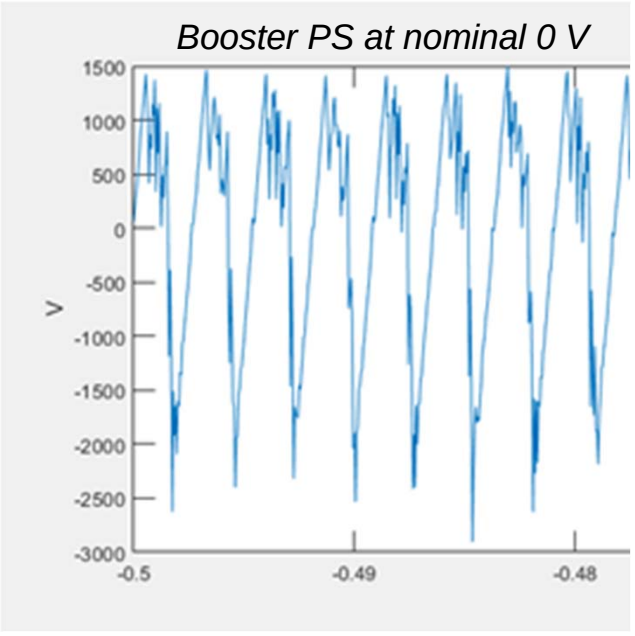


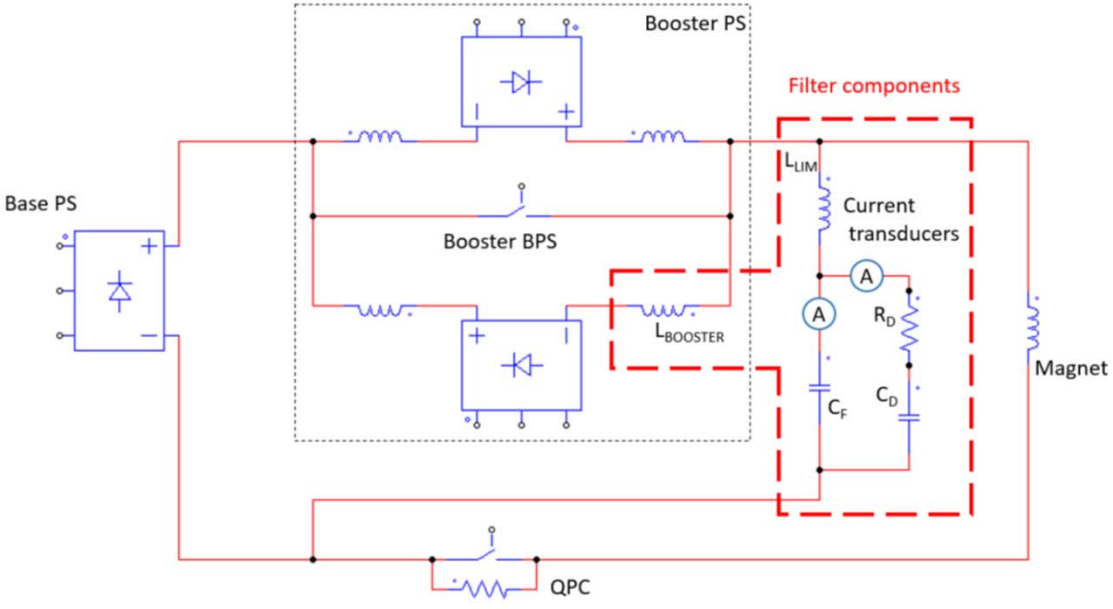
New "R2" grounding resistors under installation

Filters for booster power supplies

- Booster power supplies used on EF 1,2,5 and 6 are reused from JT-60U.
- Thyristor convertor technology results in very high voltage ripple



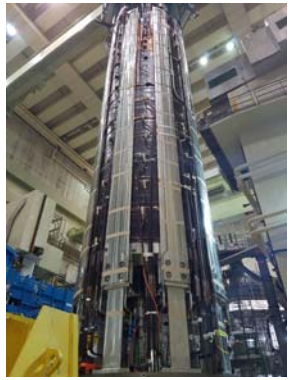




- Ripple may have been a contributing factor to EF1 arc; or at least increases applied voltage
- Filters will be fitted to the booster power supplies to reduce the ripple
- Booster power supplies will not be operated until filters are installed

Background to Global Pachen test

- With the exception of the central solenoid, until June 2022 it was expected that the Global Paschen test would confirm the integrity of the machine (or identify locations needing further work)
- In June 2022, further weaknesses were identified within the EF coils: pancake joints, tail exits and helium inlets
- Nevertheless it was thought that the Global Paschen test
  - could confirm the integrity of the TF circuits
  - may determine a voltage below which the PF coils could operate safely irrespective of any loss of cryostat vacuum
- The voltage required for operation is driven by plasma breakdown
- Before the Global Paschen test, all PF were tested at 15 kV and all TF at 3 kV in atmospheric air (i.e. 1e5 Pa)



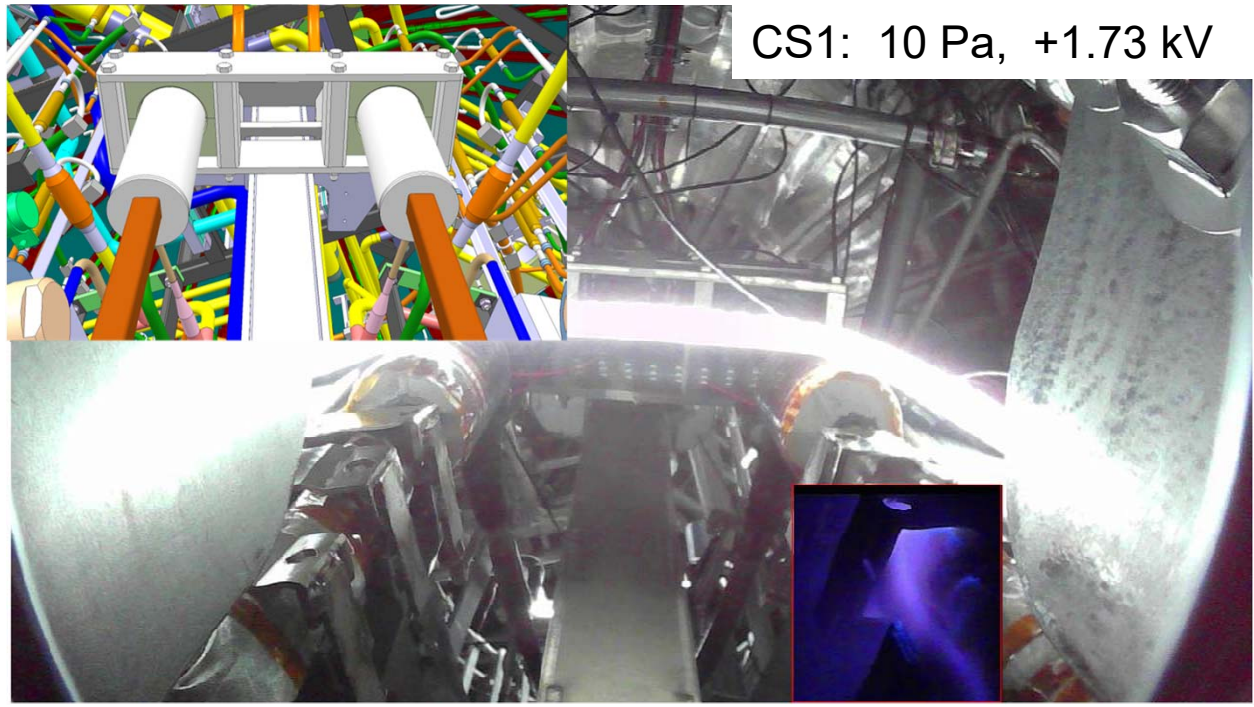
CS cannot be accessed for conventional repair in situ

EF pancake joints

EF He inlet

Outcomes

- In many cases, webcams (135) were able to detect visible breakdowns
  - Live observation / software post processing
  - Superposition of breakdowns on illuminated photos



- Some breakdown locations also indicated by
  - spark detectors
  - ΔV measurement using voltage taps of quench detection system

- Nevertheless, testing under Paschen conditions only reveals the weakest point in each circuit

- F4E / QST no longer consider it realistic to achieve a Paschen-proof tokamak

Next steps

If plan is endorsed by the European Commission & MEXT

JT-60SA
Advanced Superconducting Tokamak
BA-Satellite Tokamak Program

Procure booster PS filters

Fix CTB 1 vacuum leak

Perform HV testing in high vacuum

Inspect coils, especially TF 2-7 & TF 14-1

Enhance interlocks on cryostat vacuum

Reinforce priority points of insulation (scope TBD)

Install & commission filters

Evacuate, cool down cryostat and bake vacuum vessel

Integrated commissioning may restart in early 2023

Coil energization

Conclusions

- It is no longer considered realistic to make the JT-60SA tokamak Paschen proof
- Nevertheless the magnets must hold their operating voltage in their operating state, i.e. under high vacuum
- Some further repairs to magnet insulation are unavoidable
- This will be performed while filters are procured for the booster power supplies of EF 1, 2, 5 & 6
- Integrated Commissioning may restart early in 2023
- In the meantime, preparation for the two-year enhancement period M&E1 continues
- After that high powered operation is planned for 2025